THE KUWAIT OIL FIRES:

AIR QUALITY DATA AND REPORTS



THE GULF PROGRAM OFFICE - N.O.A.A.
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The Kuwait Oil Fires: Air Quality Data and Reports

Gulf Program Office Office of the Chief Scientist National Oceanic and Atmospheric Administration

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FOREWORD

The reports in this collection are a cross section of the international research effort on the atmospheric effects of the Kuwait oil fires. All of the research has been undertaken since February 1991, when over 600 oil wells in Kuwait were ignited by Iraqi forces. Although some of the selections are final reports by government agencies, others are still in draft form. Many of the selections are sets of unpublished statistical tables that summarize the results of laboratory analysis of smoke plume and ambient air samples. Articles already published in the scientific literature are not included.

The Gulf Program Office of the National Oceanic and Atmospheric Administration (NOAA) has helped coordinate the US research effort on atmospheric aspects of the oil fires in Kuwait. This collection is an extension of that effort, and is in keeping with NOAA's commitment to ensuring that all data are shared with all concerned parties. The Office thanks all those who have forwarded copies of their reports and unpublished data for inclusion in this collection.

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- "Report of the WMO Meetings of Experts on the Atmospheric Part of the Joint UN Response to the Kuwait Oilfield Fires," World Meteorological Organization, Geneva, Switzerland, April 27-30 1991.
- 2. "Gulf Regional Air Monitoring Plan (GRAMP)," Andrew E. Bond, Environmental Protection Agency, Research Triangle Park, North Carolina, 3 April 1991.
- 3. "Kuwait Oil Fires: Interagency Interim Report," Environmental Protection Agency, Washington, DC, 3 April 1991.
- 4. "UN Interagency Action Plan on the Kuwait Oil Fires," presented by World Meteorological Organization at the Workshop on the Management and Analysis of Data Relating to the Kuwait Oil Fires, National Center of Atmospheric Research (NCAR) 22-24 July, 1991.
- 5. "Statement by Miss Margaret J. Anstee, Director-General, United Nations Office at Vienna, and Personal Representative of the Secretary-General to Coordinate United Nations Efforts to Counter the Impact of the Burning Oil Wells and Other Environmental Consequences of the Gulf Conflict in Kuwait and in the Region," [Presented to the Second Committee, United Nations General Assembly, 19 November 1991]

OVERVIEWS, ASSESSMENTS

- 6. "Preliminary Scientific Report Kuwait Oil Fires,"[NCAR and University of Washington flight team debriefing in Bahrain], John Robinson, Gulf Program Office, NOAA, Washington, DC, June 1991.
- 7. "An Updated Briefing on the Kuwaiti Oil Fire Smoke Experiment (KOFSE)," Lawrence F. Radke, National Center for Atmospheric Research (NCAR), and Peter V. Hobbs, University of Washington, July 1991.
- 8. "Statement by Dr. Abdulrahman A. Al Awadi, Chairman of Emergency Committee, Environment Protection Council (EPC), of Kuwait, to the Second Committee, United Nations General Assembly, 20 November 1991."

KUWAIT OIL FIRE STATUS

- 9. "Kuwait Oil Well Fires Updated," Joseph P. Riva, Jr., <u>CRS Report for Congress</u>, 91-313 SPR, Congressional Research Service, Library of Congress, Washington, DC, 8 May 1991.
- 10. "Kuwait Oil Fire Extinguishing Chronology," Gulf Program Office, National Oceanic and Atmospheric Administration (NOAA), Washington, DC, 19 November 1991.

AIRCRAFT MONITORING DATA AND INFORMATION

Meteorological Office Mission

- 11. "Summary of the GULFEX Flights, 23rd 31st March 1991," M.A. Gibbs, D.W. Johnson, C.G. Kilsby, D.S. McKenna, Meteorological Research Flight, Meteorological Office, Farnborough, England, May 1991.
- 12. "Observations in March 1991 of the Oil Smoke Plume from Kuwait by the UK Meteorological Office C-130 Aircraft: Preliminary Report" Meteorological Research Flight, Meteorological Office, Farnborough, England, June 1991.
- 13. "Airborne Observations of the Physical and Chemical Characteristics of the Kuwait Oil Smoke Plume," D.W. Johnson, C.G. Kilsby, D.S. McKenna, R.W. Saunders, G.J. Jenkins, F.B. Smith, J.S. Foot, Meteorological Office, Farnborough and Bracknell, England, September 1991.

National Center for Atmospheric Research (NCAR) Mission

- 14. "Aircraft Research Instrumentation, Electra N308D," [also includes raw data from flight legs], NCAR, Boulder, Colorado, 6 May 1991.
 - 15. "NCAR Scientists Release Preliminary Results from Kuwait Oil Fires Study." Press Release, National Center for Atmospheric Research, Boulder, Colorado, 24 June 1991.
 - 16. Abstracts of papers submitted to the American Geophysical Union for presentation at December 1991 meeting in San Francisco, California and at the January 1992 Ocean Sciences meeting in New Orleans, Louisiana.

University of Washington Mission

- 17. "Carbon Budget Data," Department of Atmospheric Sciences, University of Washington, Seattle, Washington, 14 August 1991.
- 18. "Canister Samples (Partial Results)," Department of Atmospheric Sciences, University of Washington, Seattle, Washington, 14 August 1991.

- 19. "Summary of 'Grab Bag' Chemical Samples Obtained by University of Washington in the Kuwait Oil Fire Study (16 May 12 June 1991)," Department of Atmospheric Sciences, University of Washington, Seattle, Washington, 14 August 1991.
- 20. "Kuwait Filter Data," Department of Atmospheric Sciences, University of Washington, Seattle, Washington, 14 August 1991.
- 21. Abstracts of papers submitted to the American Geophysical Union for presentation at the December 1991 meeting in San Francisco, California.

Department of Energy Mission

22. "Bahrain Debriefing of DOE Monitoring Team, August 20, 1991,"
Barbara Bailey, Gulf Program Office, NOAA, Washington, DC, 20
August 1991.

NASA/EPA Helicopter Mission

- 23. "Overview of the EPA/NASA In Plume and Ground Level Measurements Made in Kuwait July 28 to August 8, 1991," Robert K. Stevens and Joseph P. Pinto, Environmental Protection Agency (EPA), Research Triangle Park, North Carolina, 10 September 1991.
- 24. "Kuwait Oil Fires: Helicopter Operations," Wesley R. Cofer III, NASA-Langley Research Center, Hampton, Virginia, 16 October 1991.
- 25. "Kuwait Oil Fires: NASA/EPA Near-Field Helicopter Source Characterizations," Wesley R. Cofer III, NASA-Langley Research Center, Hampton, Virginia, 27 September 1991.
- 26. "NASA Kuwait Helicopter Operations: Kuwait Oil Fires," Wesley R. Cofer III, NASA-Langley, Hampton, Virginia, 1 October 1991.

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SURFACE MONITORING DATA AND INFORMATION

- A. Measurement Campaign of the Regional Mobile Laboratory for Measurement of Air Quality in Kuwait, 27 March to 4 April 1991, Final Report. Philippe Lameloise, Gerard Thibaut, R. Masse, J. Lafuma, A. Person, M. Pasquereau, AIRPARIF, Paris, France, 27 May 1991.
- B. "Analysis of Smoke Samples From Oil Well Fires in Kuwait," George W. Mulholland, Bruce A. Benner, Robert A. Fletcher, Eric Steel, Stephen A. Wise, Willie E. May, Daniel Madrzykowski, David Evans, Report of Test FR 3985, National Institute of Standards and Testing [NIST], Gaithersburg, Maryland, 20 June 1991.
- C. "Air Quality Monitoring in Kuwait: First NILU Mission, 5-12 June 1991," B. Sivertsen, T.C. Berg, <u>NILU RR:6/91</u>, Norsk Institut for Luftforskning, Lillestrom, Norway, June 1991.
- D. "Air Quality Measurements at Nordmedunit, Umm Qasr, Iraq," B. Sivertsen, <u>NILU TR:6/91</u>, Norsk Institut for Luftforskning, Lillestrom, Norway, July 1991
- E. "Ambient Air Monitoring Data: Dammam," (Draft), [Data for April, May 1991] Meteorology and Environmental Protection Administration [MEPA], Jeddah, Saudi Arabia, August 1991.
- F. "Ambient Air Monitoring Data: Kuwait," (Draft), [Data for April, May, June 1991] Meteorology and Environmental Protection Administration, Jeddah, Saudi Arabia, August 1991.
- G. "Khafji," addendum to "Ambient Air Monitoring Data: Dammam," (Draft), [Data for 07 to 11 September 1991] Meteorology and Environmental Protection Administration, Jeddah, Saudi Arabia, August 1991.
- H. "Draft Report on Kuwait PAH Analysis," Charles B. Henry, Jr., Louisiana State University, Baton Rouge, Louisiana, 24 September 1991.
- I. "Rainfall Samples Hydrocarbon Analyses: Analytical Data Reporting Forms," Wayne C. Curry, Surface Water Department, Ministry of Water Resources, Sultanate of Oman; Ruwi, Oman, 9 November 1991.

HEALTH ASSESSMENTS

- J. "Assessment of Effects on Human Health from Kuwaiti Oil Field Fires," D. Engi, Sandia National Laboratories, Albuquerque, New Mexico, March 1991.
- K. "Status Report of Public Health in Kuwait as of March 21, 1991," John S. Andrews, Jr., Agency for Toxic Substances and Disease Registry, United States Public Health Service, Department of Health and Human Services, Atlanta, Georgia.
- L. "Emergency Health Plan of Action, Kuwait," (Working Document), Ministry of Public Health, Kuwait and World Health Organization, Ministry of Public Health, Safat, Kuwait, 3 April 1991.
- M. "Plan of Action for Protecting Public Health," Frank E. Young, Coordinator, Kuwait Working Party of the United States Public Health Service, Department of Health and Human Services, Washington, DC, 31 May 1991.
- N. "Emergency Room Surveillance—Kuwait City," US Public Health Service, Department of Health and Human Services, Washington, DC, 10 June 1991.
- O. "Harvard School of Public Health: Kuwait Air Sampling Survey, April 24 to May 11, 1991," Department of Environmental Health, Harvard University School of Public Health, Cambridge, Massachusetts, August 1991.
- P. "The Kuwait Oil Fires: Presentation Abstracts and Speaker Biographies," [Harvard Conference materials], Harvard University School of Public Health and the Center for Middle Eastern Studies, Cambridge, Massachusetts, August 1991.
- Q. "Air Pollution from the Kuwait Oil Fires: Report of the Official Mission on the Environmental and Health Effects of the Oil Fires," Environment Agency, Tokyo, Japan, August 1991.
- R. "Impact of Oil Well Fires on Air Quality in the Urban Areas of Kuwait, Part I: Pollution by Particulates Less Than 10 Microns, and Part II: Pollution by Noxious Gases," Moustafa El Desouky and Mahmood Y. Abdulraheem, Environment Protection Department, Ministry of Public Health, Safat, Kuwait, August 1991.

T. "Health Advisory for Kuwait and Saudi Arabia," Centers for Disease Control, Atlanta, Georgia, 8 October 1991.

DATA MANAGEMENT

- U. "Workshop Review: Management of Data Collected in GRAMP (Gulf Region Atmospheric Measurement Program)," Darrel Baumgardner and Richard Friesen, NCAR/TN-363+PROC, National Center for Atmospheric Research, Boulder, Colorado, August 1991.
- V. "Status of Kuwait Data Archive Project," Darrel Baumgardner and Richard Friesen, National Center for Atmospheric Research, Boulder, Colorado, 14 October 1991.

SOURCES OF INFORMATION

W. Sources

WORLD METEOROLOGICAL ORGANIZATION

REPORT OF THE

WMO MEETING OF EXPERTS ON THE ATMOSPHERIC PART OF THE

JOINT U.N. RESPONSE TO THE KUWAIT OILFIELD FIRES

Geneva, 27-30 April 1991



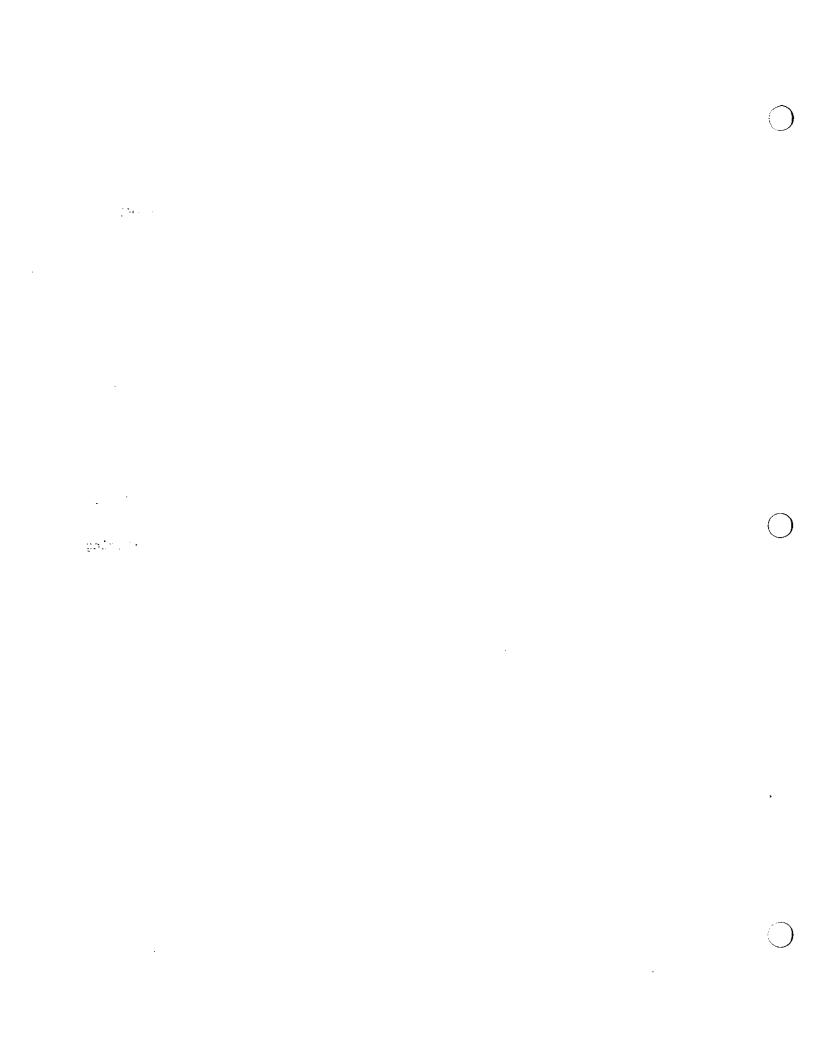


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ΙX U.S.S.R. Aircraft Monitoring Programme for the Gulf

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XI. An Aircraft Monitoring Strategy The world is facing a unique, man-caused environmental pollution on an order never before experienced. The 500 or more burning oil wells in the Kuwaiti oilfields and the oil released on land and in the Gulf represent unprecedented threat to the environment and possible severe short—as well as long-term damage to the health and ambient conditions of humans and animals. The oil release began in January 1991 and the oilfield fires began in late February. It is estimated that extinguishing the oilfield fires will take about two years and that the effects of the oil spills will last a similarly long time.

This report represents the views of a group of experts, originating from 14 countries, brought together by the World Meteorological Organization, on how to access the effects and coordinate an international response for the atmospheric part of the joint U.N. response to the Kuwait oilfield fires, as a component of the joint U.N. Inter-Agency Action Plan (March 1991). A list of participating organizations and contact persons is summarized in Appendix I. The WMO Meeting of Experts report addresses:

- (a) the need for augmenting surface, upper-air including aircraft, and satellite monitoring of meteorological and air quality variables (especially of trace gases and particles);
- (b) the data and information flow, both operational and special, from real-time, delayed, and research sources;
- (c) relevant meteorological and air pollution numerical models for local, regional, and global predictions.

The atmospheric part of the response to the Kuwait oilfield fires is based largely on existing structures of the WMO including the World Weather Watch and the Global Atmosphere Watch. The World Weather Watch, which includes meteorological surface, upper-air and satellite data and a global network for exchange of data and information, will need augmentation especially near the source and where observing stations are not functioning. The Global Atmosphere Watch, which is a system for measuring the chemical composition and physical characteristics of the atmosphere, must be enhanced in the region of the fires and fully activated and augmented in downwind areas. The improvements to the WWW and the GAW can be assisted by dedicated contributions by interested Members.

Health problems could result from gases such as sulfur dioxide, sulfuric acid, hydrogen sulfides, carbon monoxide, nitrogen oxides; from suspended particles containing partially burned hydrocarbons and metals; and from carcinogens such as benzo-a-pyrene. The extent and severity of potential health impacts are the concerns of the World Health Organization which has its own special needs for air quality data specifically related to population areas. The WHO air quality measurements will be coordinated with the WMO monitoring activity.

As for the effects of the fires thus far, the local atmospheric radiation balance has been disturbed, but no global effect has been detected. Although, at present, the effect of the fires on the southwest monsoon is unknown, the actual difference is expected to be difficult to distinguish from natural fluctuations. Global precipitation patterns are not expected to be impacted by the fires, but regionally, incidences of precipitation containing pollutants, including oil and soot scavenged from the fire plume, and highly acidic rain have occurred. Near the source, the lower level winds vary throughout the year (most recently coming from the north), but the upper winds which effect global distribution of the plume are generally from the west throughout the year. Increased concentrations of soot particles are being detected in Global Atmosphere Watch monitoring sites as far away as Mauna Loa observatory.

Several numerical models have produced predictions of the location and concentration of various pollutants from the fires on local, regional and global scales. Nevertheless, without proper data on source characteristics and the meteorological environment, and without data to evaluate the model predictions, it is not possible to select any specific model or set of models suitable to provide routine predictions or accurate long-term assessments. Modellers made known their data needs for monitoring and were encouraged to continue their modelling activities until such time as comparisons are possible to determine which models are more appropriate for operational purposes. Modellers were asked to continue their work including development and improvement of models specifically to address the fires problem. WMO was asked to assist with arranging for timely transmission of model results to the region as soon as proper communications can be established.

The U.K. presented the preliminary results from their recent aircraft flights in the region. The U.S.S.R. also presented aircraft data collected 2-3000 km downwind. Germany, the U.S.A., and the U.S.S.R. presented plans for aircraft monitoring flights in the region. Other countries (e.g. Canada) have aircraft programmes under consideration. The meeting identified the most important aircraft data requirements and urged WMO to co-ordinate among the measurement flights in order to establish a sequence of monitoring flights covering the next several months, with some overlap for intercomparison purposes. The WMO also was asked to assist with logistical support for the aircraft programmes including developing focal points and in-country contacts, and also to assist with data and information flow.

A number of governments and groups of scientists are ready to assist in carrying out additional measurements programmes and to help develop forecasting capabilities. However, no individual group or country is in a position to plan, organize and coordinate such actions. The meeting strongly recommended that, as part of the international efforts, the WMO establish a coordination office for atmospheric monitoring and modelling in Geneva as soon as possible and consider the need to have WMO experts join the U.N. Interagency Coordination Office in Kuwait City which opened on 26 April 1991. There, an operational data and a modelling center to support the atmospheric and environment efforts contributing also to health-related studies, could be included. Since WMO activities will require funding, which is not provided in

the regular budget, countries were encouraged to contribute directly to a WMO Trust Fund for these purposes. Depending on the availability of funding, the WMO was asked to establish an operational data and modelling centre to support the atmospheric and environment efforts which would contribute also to health-related studies.

The most immediate needs for atmospheric monitoring include the re-establishment of Kuwait's surface and upper-air meteorological stations; the placement of mobile air monitoring stations, especially air chemistry measurements, at locations near the source and in population centres; enhancement of downwind meteorological and air chemistry observations including special observations important for modelling, such as carbon soot, atmospheric transparency, and components of the radiation balance. Of special importance is the continuation of monitoring activities along with the expected changes in the meteorological regimes and of the characteristics of the source.

WMO was asked to convene several task groups and expert meetings over the next few months (i) to consider further implementation of monitoring (immediate area, regional, global), (ii) to examine modelling efforts, thus far, and related data needs, (iii) to compare aircraft data and coordinate further programmes, if needed, and (iv) to evaluate overall results and recommend further actions.

The meeting noted both the Gulf Regional Air Monitoring Programme that was presented by experts from Saudi Arabia and the Work Plan for the Rehabilitation of an Environmental Monitoring Programme for Kuwait that was made available to the meeting by the Secretary-General of WMO by the courtesy of the Environmental Protection Council of Kuwait. These two plans, which have many common elements, will serve as basis for WMO coordination activities in the immediate area of the fires while the programme in the downwind region is being developed.

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- OPENING OF MEETING, ELECTION OF CHAIRMEN AND APPROVAL OF THE AGENDA
- 1.1 The meeting was opened on Saturday, 27 April 1991 at 09:30 a.m. by the Secretary-General of the World Meteorological Organization,
 Professor G.O.P. Obasi, who welcomed the participants and thanked them for responding upon such short notice (for list of participants see Appendix II). He expressed WMO's appreciation to the Governments who made possible the attendance of their experts, noting the concern felt by governments and scientists over the serious environmental problems confronting the Gulf region.
- 1.2 Professor Obasi stated that, within the U.N. system, the WMO is charged with the responsibilities for providing the authoritative scientific information and advice on the condition and behaviour of the global atmosphere and the climate, and the factors affecting them. Accordingly, WMO has convened this meeting with the aim of developing a project to monitor and assess the atmospheric pollution resulting from the Gulf fires. This action is carried out in the context of the joint U.N. Inter-Agency Action Plan for response to the consequences of the fires.
- 1.3 Professor Obasi emphasized that the main task of this meeting is to consider and make proposals for, the rehabilitation and enhancement of the monitoring systems in the region, for modelling and assessing, both on the short— and long—term basis, the severity of the pollution within and downwind from the region. He asked the meeting to recommend establishing predictive capabilities on a semi-operational basis for estimating the adverse effects of the fires in the Gulf region and other parts of the globe. In conclusion, Professor Obasi said that WMO stands ready to provide the forum to coordinate this effort.
- 1.4 The meeting unanimously elected Dr. F.B. Smith (U.K.) and Mr. B.B. Hicks (U.S.A.) as co-chairmen. The provisional agenda (Appendix III) was adopted with the understanding that it could be amended as necessary during the meeting.
- 2. INTRODUCTION TO THE PROBLEM

2.1 <u>International Involvement</u>

2.1.1 Dr. R. Bojkov, Chief of the Environment Division in the WMO Research and Development Programme Department informed the meeting that apart from its operational system - the World Weather Watch (WWW) - which provides for real-time, world-wide monitoring of standardized meteorological parameters and data communication, the WMO has also the Global Atmosphere Watch (GAW) system which is a potential source of continuous information on the chemical composition and physical characteristics of the atmosphere necessary for detecting changes in the atmosphere. He then explained that the UN Inter-Agency Action Plan on the Kuwait oil fires has identified four main areas of concern and that WMO was the lead agency to develop the atmospheric component. WMO is willing to assist coordination for its implementation which will include:

- air and precipitation sampling in the immediate vicinity of the fires and in downwind regions up to 3-5000 km;
- rehabilitation and enhancement of the meteorological networks of the WWW and GAW, including provision of equipment and training;
- establishment of near real time data collection necessary for modelling of air pollution dispersion and deposition;
- scientific assessments of the atmospheric effect of pollution updated periodically to serve as advice to decision makers.
- 2.1.2 Dr. Bojkov further informed the meeting that although there are a number of GAW stations in the Red Sea region and further downwind in Pakistan, India, the southern U.S.S.R. and western China reporting ozone data, only incidentally precipitation chemistry or atmospheric turbidity is reported. Therefore, there is an urgent need to reactivate, augment and extend GAW stations in the affected region in order to monitor anomalous tropospheric chemistry and physical characteristics. The cooperation with potentially affected countries and timely contributions by interested Members would be essential.
- 2.1.3 Finally, Dr. Bojkov asked the experts to identify ways to provide answers to the following questions:
 - What is the composition and amount of gaseous and particles by-products being produced from the burning oil wells?
 - What is the magnitude of the exposure to toxic substances in the Gulf region in relation to human health risks?
 - What are the expected effects in areas more remote from the source as regards additional air pollution and deposition?
 - Are there any global effects to be expected and what would be the magnitude and duration?
- Mr. S. Mildner, Director of Basic Systems in the WMO World Weather Watch Department provided an overview of the existing WWW operational structures in the Middle East. The WWW has about 180 surface observing stations and about 40 upper air stations in the countries concerned (See Figure 1). Recent monitoring at WMO shows that the data regularly available from these stations for international exchange varies between 0% and 90%. Meteorological satellites, both geostationary (METEOSAT 4 and 5) and polar-orbiting (NOAA 10 and 11), are providing regular coverage . He noted that Jeddah (Saudi Arabia) has the role of the Regional Telecommunications Hub (RTH) and maintains high capacity links to various major meteorological centres. It also functions as a Regional Specialized Meteorological Centre (RSMC) providing analysis and forecast products on a regular basis. Jeddah RSMC might also be used for establishing a specialized environmental data base and the exchange of relevant products for the Kuwaiti oilfield fires emergency. He also noted that the WWW offers the infrastructure needed for the successful implementation of data flow for the emergency response to this environmental disaster.

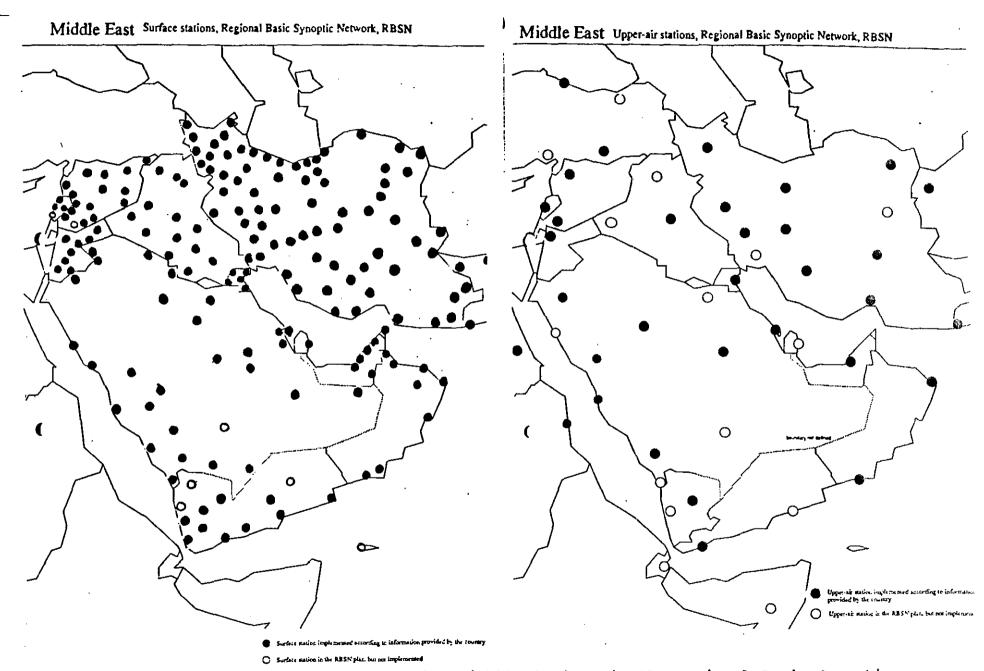
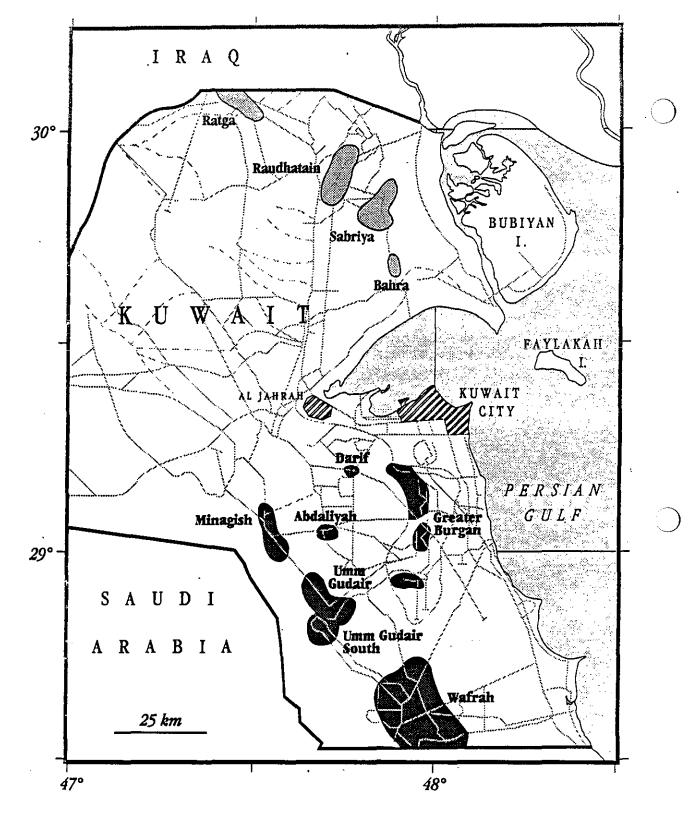


Fig. 1. Locations of surface (left) and upper air (right) stations in the Regional Basic Synoptic Network of the WMO World Weather Watch.

- 2.1.5 Mr. G. Ozolins from the World Health Organization discussed the activities and plans of WHO with respect to air quality monitoring needed for responding to the health needs of Kuwait. A WHO air quality specialist, Dr. D. Mage, was recently in Kuwait, assisting the Kuwaiti Ministry of Public Health and the Environment Protection Council in preparing a Workplan for the Rehabilitation of an Environmental Monitoring Programme for Kuwait. The Secretary General of the Environment Protection Council (Kuwait) sent the Workplan by telefax to the Secretary-General of WMO and this was made available to the meeting (see Appendix IV).
- 2.1.6 The representative from the Commission of the European Communities (CEC), Dr. A. Ghazi, informed the meeting that CEC has already allocated several million ECUs as funds dealing with different aspects of pollution in the Gulf. He pledged close cooperation between the CEC programme and the WMO and WHO efforts.
- 2.1.7 Dr. C.C. Wallen, representing the United Nations Environment Programme, announced that UNEP had been instrumental in establishing the U.N. Interagency Office in Kuwait City which was opened on 26 April 1991.
- 2.1.8 The Saudi Arabia Monitoring Action Plan covering the Gulf regional air monitoring programme (Appendix V) was presented by experts from Saudi Arabia. The programme was developed in consultation with other countries and represents the basis for work currently underway in part of the affected region.
- Dr. R. Sartorius, the representative of the German Federal Environmental Agency informed the meeting that an action was prepared to send a mobile container for monitoring air pollutants to Kuwait City. The Federal Government is ready to integrate this project into the internationally coordinated action by WMO as a contribution of Germany. Any suggestions and proposals are welcome and will be thoroughly considered. The German Government has been informed that there is an urgent demand by the Kuwaiti authorities to have these measurement devices available as soon as possible. Providing that this meeting supports this initiative and that the WMO as the international organization involved agrees, Germany would expedite shipment in the beginning of May. Another project having a more bilateral character, consists of an airplane measuring programme to investigate the extension, behaviour and chemical composition of the (visible and invisible) plume of the burning oil wells. Coordination with other airplane measurements would be very useful in order to achieve mutual supplementation and comparability of results. Furthermore, groundbased mobile measurements are planned in Iran.
- 2.1.10 The Kuwaiti representative, Mr. M. Behbehani, said that the situation in Kuwait at the present time is desperate and remedial action is urgent. He noted that the international aspects to the problem and the need for international cooperation to address it. Mr. Behbehani pledged the cooperation of the Government of Kuwait to a coordinated monitoring and modelling effort which would benefit both local and regional population.



Oilfields of Kuwait



Oilfield



Oilfield with H2S gas production

2.2 Local Effects: The Human Health Concern

- 2.2.1 The focus of this meeting was on the meteorological factors that influence the fires and the plume from them, not on the health effects or their causes. Nevertheless, considerable time was spent on discussion of matters related to exposure and human health, largely to help the audience of meteorologists gain an improved understanding of the severe problems presently confronting the Kuwaiti population. Other meetings and other organizations are addressing the health impact issue more directly.
- 2.2.2 The meeting was informed that about 500 oil wells are currently burning in Kuwait, consuming approximately three to five million barrels of crude oil and 70 million cubic meters of associated gases daily. The fires originate in seven oilfields, located both north and south of Kuwait City (see Figure 2). Based on measurements to date and the known composition of Kuwaiti crude oil, emissions from the burning wells will include airborne particles, carbon dioxide, sulfur dioxide formed from the combustion of hydrogen sulfide, and oxides of nitrogen, as well as considerable quantities of water vapour. Incomplete combustion products include hydrogen sulfide, carbon monoxide, polycyclic aromatic hydrocarbons (PAHs) and other volatile organic hydrocarbons, and heavy metals. Other secondary pollutants will include ozone and acidic aerosols, such as sulfuric acid.
- 2.2.3 The urgent question faced by the countries in the Gulf region, and in particular by Kuwait, is the extent and severity of potential health impacts on their populations. Informed answers must be obtained so that the affected countries can act to protect their populations and plan for future health needs. A concerted, coordinated effort on the part of experts in (i) air monitoring (ii) local, regional, and global scale modelling (iii) atmospheric chemistry and (iv) health and risk assessment will be necessary.
- 2.2.4 Emissions from the oilfield fires have the potential of causing both acute and chronic health effects, although there is considerable uncertainty as to the magnitude of the risk. Prolonged exposure to lower concentration levels of soot and chemical components of the plume may decrease lung function, and increase the incidence of chronic bronchitis and lung cancer. Special health concern is focused on individuals working close to the fires, pregnant women, children, the elderly, and those with pre-existing respiratory and cardiac diseases.
- 2.2.5 A U.S.A. Inter-Agency scientific team obtained some limited real-time data in Kuwait and in Saudi Arabia on the smoke emissions. The sampling did not reveal the existence of high concentrations at ground level of sulfur dioxide or hydrogen sulfide close to the burning wells. Also, no large-scale acute human health impacts have yet been observed although reports of respiratory difficulties among local population are increasingly frequent. It was stressed that the report of the findings, however, were only preliminary and that considerable follow-up will be necessary to evaluate definitely the nature and magnitude of the human health, ecological, and atmospheric effects of the smoke problem.

- 2.2.6 The pollutants of primary concern to people are likely to be particles and sulfur dioxide. According to the U.S.A. preliminary measurements, hydrogen sulfide concentrations have been found to be very low, thus far, as were PAHs attached to particles, and volatile organic compounds. Not surprisingly, a wide variability of the measurements was noted according to distance from the source and wind direction. The extremes of the Total Suspended Particulates (TSP) measurements range from a low of $10~\mu\text{g/m}^3$ at the U.S.A. Embassy in Kuwait City on a day when the wind was out of the north, to a high of $5400~\mu\text{g/m}^3$ within a plume in the Al Maqwa oilfield. It should be emphasized that the space and time sampling of the measurements is insufficient and their results should be viewed and interpreted with great caution.
- 2.2.7 Physicians in Kuwait feel that they are observing exacerbation of asthma and non-reversible chronic obstructive lung disease. Furthermore, they perceive an increase in complaints of upper airway irritation and eye irritation sometimes associated with conjunctivitis (inflammation of the eye). All of these phemonena appear to be treatable by standard medical practice.

2.3 Regional-scale Effects

- 2.3.1 The local meteorological conditions over the past two months have tended to transport the smoke plume in the atmospheric boundary layer toward the southeast, with periodic excursions toward the northeast. At altitudes above 600 m, the pollutants were transported mainly eastward. In the region, March through July are relatively windy months; there are on average 30 days of very strong winds from the northwest in this period. Frequent sandstorms are expected to rapidly ventilate the smoke in the immediate surroundings of the fires and to spread the pollutants further downwind. As summer advances, solar-induced convective mixing will increase the maximum height of the plume into the upper half of the troposphere, perhaps to above 7 km which is not yet experienced. It is in these situations that the stage will be set for extensive long-distance transport of the plume in the middle and possibly upper troposphere, with associated long-range effects. In August to October, the incidence of strong winds should drop sharply, and local conditions may worsen.
- 2.3.2 Upper-level winds tend to be more consistently from the southwest and west causing a marked vertical wind shear which has had, as seen from satellite photos, and will continue to have a profound effect on plume behaviour.

2.4 Global Effects

2.4.1 The experts felt that, although "self-lofting" may occur (due to the heating of the particles in the plume by solar radiation), the top of the plume should not often rise above 5 km. Large convective cells in the summer could easily transport material into the upper half of the troposphere. However, this would rarely happen. It was felt that there is little fear of a stratospheric injection of plume pollutants, as would be required for severe global environmental effects.

- 2.4.2 In the troposphere, the pollutants should have a residence time from ten to perhaps as many as 20 days (depending on the prevailing meteorology). This is enough time for the pollutants to be distributed widely over the Northern Hemisphere. Thus, the pollutants are expected to be detected at great distances, although their effects on the temperature or precipitation distribution will likely be small and difficult to distinguish from natural variability.
- 2.4.3 While the above arguments rule out major effects on the global radiation balance, reduced surface temperatures by low degrees C under the plume have indeed been observed at localities near the fires themselves.
- 2.4.4 The reported "black rain" or "black snow," precipitation falling from clouds affected by the plume, are due to pollutants scavenged from the plume, including oil and soot. It remains to be seen how frequently such events will occur and, therefore, there is a necessity for a rapid expansion of of Global Atmosphere Watch measurements of carbon soot content precipitation chemistry, SO_2 and surface ozone from the area of the Red Sea through the Gulf, downwind (eastward) as far as Iran, Pakistan, northern India, Afghanistan, the U.S.S.R. and western China.
- 2.4.5 It is projected that soot deposition over the snow covered mountains of the Himalayas and northward may cause some faster melting in the spring season (March-May). The projected slight increase in the temperature contrast with the Indian Ocean might somewhat intensify the monsoon rain (as in an anomalous year); however, the natural variability is so large that the detection of a significant change would be difficult.

THE SOURCE

3.1 <u>Meteorology</u>

- 3.1.1 Near-source exposure regimes will be dominated by local meteorological factors, such as the presence of a land-sea breeze circulation and the strength of any drainage flow from higher elevations inland. In addition, the local wind velocity will be affected considerably by the presence of the fires themselves. Forecasts of periods of high concentration must take such factors into account. Figure 3 defines the generic source term in the broader context of local, regional and global meteorological perspectives and the need for local warning/alerting and forecasting systems.
- 3.1.2 The area is generally arid with rainfall varying from 50-500 mm/year (Kuwait has about 115 mm/year). Most of this rain falls from November to May, with the summer months being particularly dry. Somewhat further afield, and especially over much of the Indian sub-continent, the annual rainfall is dominated by the summer monsoons. The shift in rainfall pattern will be reflected in shifts in the deposition pattern of the fire-plume's constituents.

3.2 Output

3.2.1 Current estimates of the amount of oil burning vary from 3 to 5 Mbl/day. Combustion product formation is highly dependent on fuel characteristics which vary across the Kuwaiti oilfields, fire size, and fire dynamics. In particular, soot is often in the form of complex agglomerates. The products will include a spectrum of particles sizes and types, sulfur dioxide, carbon monoxide, carbon dioxide, polycyclic aromatic hydrocarbons (PAHs), volatile hydrocarbons and heavy metals including vanadium. Hydrogen sulfide will also be present, but will be rapidly oxidized to sulfur dioxide if the plume is burning.

3.3 Combustion Products

3.3.1 Preliminary results in the near-field have shown peak concentrations as follows (see also Appendix VI):

SO₂ : 2 ppm (instrument detection limit of 1 ppm)

H₂S : 42 ppb (close to a pool of oil)

VOC : 2.5 ppm

Particulates : 5.4 mg/m³ (during plume touchdown in the Al Maqwa

oilfield)

Long-term averages of SO_2 and particulate matter - "fumées noires" (FN) were measured by the mobile air monitoring laboratory of AIRPARIF, Paris, France. SO_2 was recorded at $500~\mu g/m^3$ for 8- and 12-hour measuring periods with peaks ranging up to $2900~\mu g/m^3$. FN reached $700~\mu g/m^3$ for a 6-hour average and the maximum hourly average was $1600~\mu g/m^3$. The Kuwait Oil Company also measured an 18-hour average of $5000~\mu g/m^3$ of SO_2 at Ahmadi Hospital (See Appendix IV, Section 2.2).

While somewhat further away in Saudi Arabia, high levels observed were 600 $\mu g/m^3$ for SO_2 and 300 $\mu g/m^3$ for TSP.

3.3.2 P. Foster (France) carried out various simulations of oil burning for different O_2 /oil ratios to simulate incomplete burning. Previous analyses of the exhaust gases where done for CO_2 , NO_3 , NO_4 , SO_2 and PAH. Interactions with aerosols can be studied using a special smog chamber.

3.4 Particle Size Distribution

3.4.1 Particulate aerosols resulting from oil fires, in addition to gases, pose a health problem to exposed populations. Particles with small aerodynamic sizes (on the order of one micron) penetrate deeper into the human respiratory system than do larger particles. Combustion processes can produce a large number of small particles and thus the size distribution of airborne particles in addition to the total suspended mass, must be characterized to determine the level of health threat. Chemical reactions, particles scavenging, agglomeration, and deposition are a function of the particles size distribution.

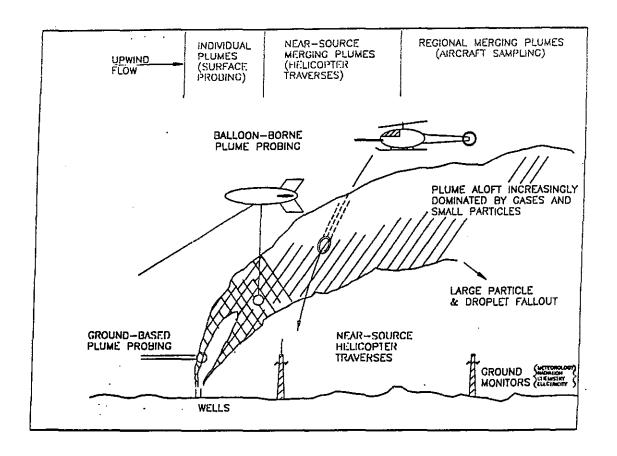
- 3.4.2 Soot particles formed from the source have irregular shapes and their size distribution depends upon the oil fuel composition and resulting temperature of combustion. In order to determine the evaluation and fate of the resulting pollution, size and composition distribution of the aerosols at the source and along the plume paths must be measured and modelled.
- 3.4.3 There are a large number of scientific particles measurement capabilities which can determine the quantity of Total Suspended Particles (TSP), Particle Mass below 10 microns (PM_{10}) and the quantity of the varying chemical composition and mass across the spectrum of particle sizes (using a so-called diffusion battery). Such measurements, when compared with upstream values, are invaluable for analysis and modelling of source processes and plume evolution.

3.5 Heat Output

3.5.1 As the emitted oil burns, heat is released into the environment. The resulting heat is responsible for the initial buoyancy driven plume rise although additional rise or fall may occur due to the absorption of solar radiation (self-lofting), and the effect of fire-induced wind circulations. Super or aggregate plumes result from the contributions of many smaller fires. While combustion temperatures can be modelled from fuel composition and mixing approximations, these models are not accurate enough and uncertainty surrounds such calculations. Combustion, temperature and plume rise measurements can be made by remote and in situ techniques.

3.6 Near-source Monitoring

- 3.6.1 Figure 3 defines a framework for source term measurements from individual well fires and total oilfield including the gaseous and particulate emissions into individual plumes which subsequently merge into the super plumes.
- 3.6.2 The near-source measurements needed for establishing credible assessments, models, or forecasts include the following:
 - collection of background air samples for particle and gas analysis, both at ground level and at plume levels,
 - characterization of the Kuwait crude oil in terms of its chemical composition and its product when burned in the conditions of the fires.
 - characterization of soot both organic and black carbon from an appropriate range of combustion conditions, including geometrical and optical properties, and
 - a survey of burning wells in which each well is classified by the character of its fire (to be updated periodically as the fires are extinguished).



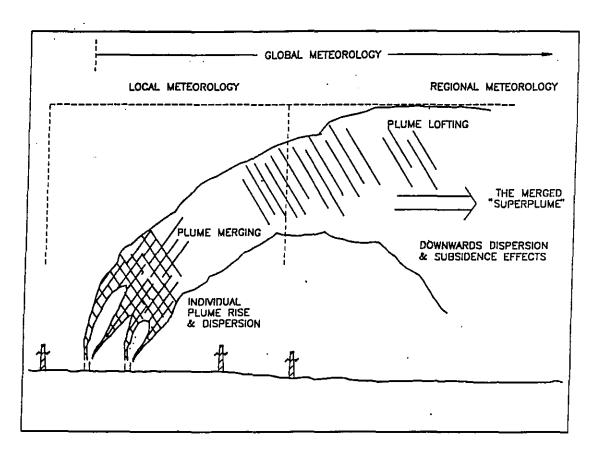


Fig. 3. (top) A sampling of the various levels of experimental activity, necessary to provide data to test components of models; (bottom) A schematic representation showing the different scales associated with the individual plumes from separate well-fires.

These data then can be used to:

- estimate fuel flows,
- estimate heat release rates of individual burning wells and of total oilfields,
- estimate detailed well smoke, gaseous and particulate emissions,
- coordinate emission estimates resulting from the above source analyses and from measurements within the super plumes, using aircraft and surface-based instrumentation,
- develop local induced flow field models in combination with ground data for local warning system forecasts, and
- develop super plume effective source prediction model to provide input to regional and global models.
- 3.6.3 Near the source, the effect on population centres and sensitive ecosystems on land and in the Gulf waters will be influenced by local meteorological conditions the presence of strong vertical mixing, subsidence due to local effects (for example the presence of a closed circulation due to land—sea differences) or subsidence due to large—scale synoptic conditions. None of these conditions can be accurately forecast without extensive information on local wind fields, primarily in the region between the sources and the impact areas of concern. Such wind field information can be provided by an array of meteorological instruments and by a numerical model that is designed to account for the local surface variability and is verified against data.
- 4 REVIEW OF PRESENT MONITORING AND ESTIMATED EFFECTS OF THE FIRES

4.1 Structure of the Plume

- 4.1.1 Where they exist, data on the composition of the source oil taken prior to the fires need to be made available to the modellers. Other data on flows rates, heat, smoke, gas or particulate emissions are not available. Consequently modellers have based their calculations on either assumed values for source term parameters or literature values derived from other, presumably similar cases. This makes modelling the Kuwaiti plume very uncertain.
- 4.1.2 Photographs of the burning wells, show a variety of conditions: some wells have high pressure jet flames shooting straight up, others appear to be a combination of tilted jets with or without substantial surrounding burning pools of oil on the ground; some wells are spewing out large quantities of thick black smoke, other have whitish plumes that look more like steam than burning oil. The meeting was informed that with the creation of a local heat-island, a distinct inflow of near surface air has been observed within the lower 150 to 300 m above ground level. At times that inflow wind was estimated to be 5 to 15 m/s.

4.2 Current Meteorological and Air Sampling Surface Monitoring

- 4.2.1 Surface monitoring programmes are critical to any evaluation of potential health impacts of the pollutants generated by the Kuwaiti oilfield fires. Concentrations of these pollutants are governed by emissions and by a wide range of meteorological variables. Surface based and upper air meteorological measurements are essential and currently missing in Kuwait. Therefore, an improved knowledge of the local and regional meteorological regime is urgently required.
- 4.2.2 Saudi Arabia has a long-standing monitoring capability which is presently being enhanced to provide more information related to questions about potential human health effects (see Appendix VI).
- 4.2.3 There are at present only two operational air quality stations. In Kuwait City, however, these currently do not measure soot or other particles fractions likely to be of concern to health physicists. The locations and coverage of samples are inadequate to cover what is needed for assessment of the environmental damage and the impact on health.
- 4.2.4 The reports on Kuwaiti and French measurements of SO_2 (5000 $\mu g/m^3$) are alarming and exceed the WHO standards. Measurements done in Saudi Arabia show maximum levels of SO_2 (6000 $\mu g/m^3$, TSP (3000 $\mu g/m^3$), and PAH when within the plume. Already topsoil (0-5 cm) analyses show higher nickel and vanadium concentrations than lower soil layers (15-25 cm).
- 4.2.5 On the regional scale, outside Saudi Arabia and Kuwait, no data are available as yet. At WMO GAW global baseline stations no significant atmospheric disturbances have been reported yet, but if trends or anomalies in e.g. atmospheric turbidity would be detected, it is expected that immediate reports will be available.

4.3 <u>Aircraft Measurements</u>

4.3.1 Observations, taken in late March/early April 1991 by the U.K. aircraft, are still being analyzed (See Appendix VII). However, preliminary results at a height of 2000 m, at a distance of 100 km downwind of the fires, indicate peak values as follows:

SO ₂	NO _×	PM ₁₀	Ozone	Sunlight	Plume-	Plume- base
(ppb)	(ppb)	(cm ⁻³)	(ppb)		(km)	(km)
1000	50	30,000	Reduced levels except at at plume-top (80 ppb)	Reduced to essentially zero	3-4	1-1.5

At 1000 km downwind, PM10 counts reduced to 1,000 per cc.

4.3.2 The results taken by the U.S.S.R. aircraft at distances more than 2000 km from the fires in the region of the Caucasus and the Crimea at a height of 1500-3000 m indicate soot values of 0.12-0.32 $\mu g/m^3$ amd a benzo-a-pyrene concentration of 0.02-0.16 ng/m^3

- 4.3.3 The U.S.A. presented a national plan (summarized in Appendix VIII) for research aircraft flights involving several agencies which is about to be implemented in the Gulf region. The existence of plans in various stages of development for activities in the region (for example, Germany and U.S.S.R.) was noted by the experts. The interested parties were urged to coordinate their plans and flights with the existing Kuwaiti and Saudi Arabian plans through the use of the recommended WMO coordination mechanism for this project.
- 4.3.4 The U.S.S.R. proposed an aircraft campaign in order to determine the geographical distribution of the combustion on the regional scale over a range up to 3000 km from the source. Details of the plan are given in the Appendix IX).

4.4 Satellite Observations

4.4.1 Satellites and the space shuttle observations clearly show the Kuwait oilfield fire signatures and downwind gas/aerosol plumes spreading out and merging over hundreds of kilometers. Conventional meteorological, LANDSAT, SPOT, and other satellites provide a range of spectral and areal resolutions which can be used to identify well and surface fires as well as track the plumes. Image processing and analysis of satellite data is proceeding to quantify the character and extent of plume coverage and will provide a means of verifying predictions. In addition, future satellites and shuttle missions should be considered for new observational tasks.

5. USE OF MODELS TO ASSESS CONTINUING EFFECTS

The meeting heard presentations on the results of several modelling efforts already performed based on the available data and information. A review of the models presented is given in Appendix X.

5.1 Near-field Models

- 5.1.1 At the present time, near-field results depend on data from limited information about the source, local meteorology, and atmospheric composition characteristics. Photographs from the oilfields show significant variations in plumes from nearby fires.
- 5.1.2 Relatively brief attention was given to the problem of near-field modelling, regardless of the recognized importance of this topic. In practice, the purpose of near-field modelling is largely to warn of the likelihood of occasions of unusually high exposures, for which application it is not necessary to have detailed information on emission rates. However, if it is desired to forecast actual exposure regimes as well as their likelihood of occurrence, then detailed source data are required. For proper prediction of downwind concentrations, it is necessary to have reliable input data on the following parameters:

- a. Source emission rates with time for individual wells and their locations;
- Heat release for each fire and combustion efficiency;
- c. Chemical composition of gases and particles;
- d. Oil-water mixing ratio;
- e. Exit velocity and exit temperature;
- f. Effective diameter of the ruptured pipe;
- g. Effective plume rise;
- h. Variation of transport layer depth with time;
- i. Wind-field data at various locations;
- j. Stability conditions in time and space.
- 5.1.3 Dr. U. Schumann presented results from a non-hydrostatic three-dimensional mesoscale model. The heat release from burning 1.3 Mbl/day of oil within an area of 10 km x 10 km causes a fire-wind of about 10 m/s inward and upward. This wind carries the soot from the fire upward up to the level of increasing tropospheric stratification (about 3 km). The plume penetrates about 500 m into the stable troposphere but is then transported downwind with the mean wind which was about 7.5 m/s at that level. The soot concentration is of the order of 1 mg/kg within a layer from 2 to 3 km in altitude. Satellite observations of 24 February 1991 confirmed that the plume stays below about 3 kms.
- 5.1.4 The King Fahd University attempted to apply "RAM" near-field software package in order to estimate concentration of pollutants within 100-150km radius from the burning oil wells. This model when applied in the Gulf area showed high concentrations of pollutants on 1-hour time scale, atmospheric chemistry development on an 8-hourly time-scale and wet and dry deposition processes (also see Appendix VI).

5.2 Medium- and Long-range Models

- 5.2.1 Operational models, both Eulerian and Lagrangian exist for simulating dispersion on medium-range scales. They simulate transport, dispersion, wet and dry deposition. Urban and regional scale air pollution models which treat the atmospheric chemistry, wet and dry deposition processes are available for application in the Gulf region. Use of models on this scale is hampered by lack of meteorological and pollution concentration observations, particularly precipitation fields.
- 5.2.2 Some models concentrate on climatological aspects of the problem on this scale. Other models attempt to give fields (short period or long-term) of concentration; dosage and deposition; as well as statistics of episodes of highly acidic rain. For their verification, there is an acute need of atmospheric composition and precipitation measurements in the downwind regions.
- 5.2.3 The Air Resources Laboratory (ARL) of National Oceanic and Atmospheric Administration (NOAA) produces operational forecasts of trajectories in the 850-700 mb height range for 36 to 72 hours. These forecasts can be produced routinely for use in assessments of the movement of emissions from the Kuwaiti

- oilfield fires. Trajectories are integrated from NOAA meteorological forecast and analysis products. The NOAA "ATDL" model has been prepared for operation in the Gulf region and beyond, and can give operationally daily information as well as estimates of climatology.
- 5.2.4 Both the Lawrence Livermore National Laboratory (LLNL) and the Dutch National Meteorological Service (KNMI) are able to produce operationally and routinely patterns of air pollution dispersion in the region. Due to the uncertainty of the source term and the meteorological input data, these patterns have a highly qualitative nature.
- 5.2.5 More detailed mesoscale meteorological models such as the "Pielke" model have also been applied to the oilfield fires. The model has been used to assess the likelihood of land-sea breeze effects as they might influence the transport of the plume. NOAA is already supporting and will continue to support operations in the larger Kuwait area with its modelling tools.

5.3 Global Models

- 5.3.1 Only a few general circulation models modified to cope with pollutant transfer are available. They have been used to assess the large-scale increase in atmospheric dust load and the impact this may have on the strength of the Indian monsoon, on "black snow", and the effect of this on overall albedo.
- 5.3.2 J.P. Blanchet informed the meeting on some preliminary results obtained with the Canadian Atmospheric Environment Service Climate Centre model (see Appendix X).
- 5.3.3 Dr. H. Graf from the Max Planck Institute for Meteorology showed results of similar calculations and announced that the investigations will be published in "Nature" (30 May 1991) (see also Appendix X for a summary).
- 5.3.4 Dr. J. Penner from the Lawrence Livermore National Laboratory presented results (Appendix X) from the application of the LLNL global climate/chemistry model.
 - Preliminary results from these modelling activities are summarized 5.3.5 here. They showed that the soot, estimated to be fully two-thirds of the total world-wide emissions, will certainly have regional implications for climate, but its global consequences are projected to be negligible although they need to be further investigated. As it is known, the smoke could either warm the climate or cool it, depending on its altitude in the atmosphere and on whether it is thermally coupled or decoupled from the surface. Enhancements to existing Global Atmosphere Watch stations throughout the region and downwind on the order of 3000 to 5000 km should be pursued in order to quantify the amount and spread of the soot as well as the changes in radiation parameters and atmospheric composition. It has been estimated that the total mass release of fine particles (less that 2.5 microns) from the burning oilfields will be on the order of 18×10^{12} g/y, which is similar or in excess of the annual world-wide emissions of such particles through car exhausts. After one year, the emissions of carbon soot from the fires will double the present concentration of these particles in the global atmosphere. For more detailed results of these studies is referred to Appendix X.

RECOMMENDATIONS

'6.1 General

- 6.1.1 The experts agreed that plans for activities in relation to the atmospheric environmental effects of the Kuwait oil fires should focus on:
 - a. the fires themselves their dynamics and products,
 - the plumes their dispersion and trajectories and their chemistry,
 - improvement of the meteorological and atmospheric composition monitoring,
 - deposition and effects, such as those related to acid rain and other chronic environmental impacts,
 - e. effects on weather, especially concerning the monsoon, and
 - f. effects on climate, including the effect on the global radiation balance.
 - g. the provision of effective daily risk assessments to the Kuwaiti authorities to help minimize the impact of the pollution on local centres of population.
- 6.1.2 The Workplan for the Rehabilitation of an Environmental Monitoring Programme for Kuwait (Appendix IV) was noted by the meeting. In this respect, the meeting also recommended that close cooperation be established between the monitoring activities of WHO and those of WMO.
- 6.1.3 The Gulf Regional Air Monitoring Programme (Appendix V) was also endorsed by the meeting, with the following suggestions:
 - a. The possibility that evaporating light fraction from oil spills could contribute to the dosage of noxious pollutants experienced in major population centres was noted.
 - b. The plan focuses on PM₁₀ monitoring. The WMO experts group suggest an additional central monitoring station where many air pollutant components are measured as well as the standard PM₁₀.
 - c. Surface ozone measurements were suggested for key monitoring stations, with SO_2 at the source, in order to provide data related to possible synèrgistic reactions.
 - d. Black carbon measurements in both air and precipitation are desirable at key locations. There is a need to analyze total carbon aerosols since black carbon is likely to constitute a minor fraction of the carbonaceous material.

- e. Some monitoring sites near the coast are suggested in order to assess deposition fluxes to the water surface and possible accumulation and effects in marine organisms.
- f. An emphasis on the source term is needed. Presently, estimates vary across a range of more than a factor of two on amounts of oil consumed per day and a factor of ten on chemical and particulate emissions per unit of oil consumed.
- g. The extension of the plan to wider areas and the global scale was deemed desirable.
- h. Measurements of optical depth of the atmosphere are needed, with a few sites arranged around the sources, a few others distributed globally.
- i. Up to 3-4000 km downwind, the GAW/BAPMON (Background Air Pollution Monitoring Network) precipitation collection protocols should be expanded to include measurements of Ni, V, and soot, as well as of the normal chemical species including pH of the samples. Collections should be weekly. New stations should be set up in the immediate as well as downwind region, to augment the existing GAW/BAPMON stations.
- j. In addition, a major GAW baseline background monitoring station should be set up in the southwest part of Saudi Arabia at 3000 m above msl (Abha region) as soon as possible. This station is essential to the air monitoring part of this project.
- 6.1.4 The meeting suggested that in order to assist in determining the chronic exposure to SO_2 , diffusion batteries might be used. These are entirely passive devices and large numbers of them can be deployed. Only one central analysis facility would be required. Exposure times for the batteries could be on the order of a few days to a week in duration. In addition to using the batteries in populated areas, arrays of batteries could be used over a larger area to assist in determining the ground level concentration field of SO_2 for comparison with the numerical model predictions of the long-term average concentrations of SO_2 .
- 6.1.5 For an assessment of the acute effects of Total Suspended Particles (TSP) on human health, a continuous method would be preferred. The meeting suggested using quartz microbalances which can provide a "continuous" TSP signal. This can then be used directly with the continuous measurements of SO_2 concentrations. In addition to the improvement to human exposure estimates, such measurements can be used to help in assessing the flux of particles from the source. The ratio of TSP to SO_2 would be obtained on a continuous basis and it is probably easier to estimate the H_2S and SO_2 source strengths than it is to make estimates of the particles source. It is essential that scanning electron microscope images be taken to reveal partial morphology.

- 6.1.6 The meeting noted that measurement programmes should continue for at least two years after the last fires are extinguished, to show the complete recovery of the atmospheric environment to its unperturbed state.
- 6.1.7 In view of the Kuwait Workplan, the Saudi Arabian Programme and subsequent discussion as summarized above, the meeting strongly recommended that an international project be organized under the leadership of WMO, in close cooperation with WHO and UNEP, with the following components:
 - a. Establish, in cooperation with the meteorological services of countries in the region, a network of upper-air and surface meteorological and background air pollution stations to provide data required for analysis, forecasts, and advisory purposes, and to provide input for transport and dispersion models;
 - b. Establish a network of surface layer wind and other meteorological observations required near the source of the fires, including relevant air chemistry;
 - c. Establish and/or augment existing GAW network of surface meteorological stations on a regional scale including the solar radiation measurements (diffuse, global and optical depth), precipitation chemistry, and essential atmospheric composition measurements (eg. SO_z, soot, surface ozone);
 - d. Undertake a co-ordinated programme of aircraft measurements and develop a coordination mechanism for aircraft operations and other experimental activities (e.g., tethered balloon operations);
 - e. Promote the expansion of on-going air monitoring programme within the Global Atmosphere Watch on a global scale;
 - f. Develop formats and procedures to facilitate the international exchange of data ensuring that these data required in real time are exchanged through the WMO/WWW mechanisms;
 - g. Arrange for operational forecasting capabilities and international exchange of forecast information using model output on all scales including determination of the source term, the prediction of the plume, and the long-range transport of the pollutants. The objective will be to predict high concentrations, deposition and optical characteristics in space, time, and content;
 - h. Promote observational and analysis activities to test the validity of models on all scales;
 - i. Provide required atmospheric data and analysis to support WHO programmes for human health assessment activities; and
 - j. Arrange for workshops and expert meetings as required for comparison of measurements and assessing progress.

- 6.1.8 The meeting recommended that the WMO provide the interface between the various national efforts participating in this project and also provide a focus for proposals by all groups seeking to participate.
- 6.1.9 The meeting noted that the activities envisaged above would require substantial funds which are not available under the regular WMO budget. In addition to the work of the WMO constituent bodies and their working groups, a considerable amount would have to be covered by external funds and assistance in kind. This might include support for field operations, provision of instruments, expert missions, central analysis laboratory, as well as the establishment of a central coordinating office (providing logistic support) and a coordinating body involving the Organization and interested countries.
- 6.1.10 Based on availability of funds, WMO will seek to organize a centre for data acquisition, archiving, and regional environmental assessment in the Gulf region which will facilitate the archival of all observed data within the existing system of the World Data Centres.
- 6.1.11 Based on availability of funds, WMO will seek to organize a centre for observations and operational support in Kuwait City in conjunction with WHO activities and with the U.N. Inter-Agency Action Plan. This centre would also provide in-country logistic support for aircraft studies and other field activities.
- 6.1.12 Based on availability of funds, the meeting recommended that an operational modelling centre be established for support of health efforts, environmental efforts, and real-time operational support of measurements and tactical decisions.

6.2 Aircraft Monitoring Strategy

- 6.2.1 The meeting recommended that, where possible, aircraft should give priority to the measurement of source strength and characterization of soot, the wind and concentration field in near to medium distances (up to 200 kms), the evolution of plume chemistry at long distances downwind (greater than 200 kms) and the temporal variation of source strength, as above, as fires are put out.
- 6.2.2 Since for determination of the amount of soot released per time unit, the mass-flux is required, it was therefore recommended to measure (i) the mean wind field by aircraft and sondes, (ii) the extent and relative concentration field within the total plume, (iii) in-situ measurements of soot concentration at approximately the same time and at least one flight level within the plume, (iv) total sulfur concentration by probes and (v) increase in water vapour within the plume. Considered flight patterns were: vertical profiles near the source (30 to 80 km) and along the main plume axis at distances from 30 km to 300 km and, in addition vertical cross-sections at large distances from the sources (up to 1000 km).

- 6.2.3 The meeting considered the following items as important for immediate consideration:
 - a. The WMO aircraft coordinator should contact UNEP and appropriate officials within Kuwait immediately to coordinate establishment within Kuwait of a focal point for coordination and logistical support of personnel and projects involved in the implementation of the aircraft operations,
 - b. Funding for provision of logistical support for field projects, especially aspects of the aircraft programme, must be provided to WMO by participants either directly or through the U.N. Interagency Fund (through UNEP),
 - c. All data collected by parties to this programme, particularly in the region, should be made available to all parties through WMO, in a timely manner, in view of the multiple uses for the data and the urgency of the matter,
 - d. A very high priority needs to be placed on the re-establishment of capabilities in Kuwait for collection of source and local meteorological data,
 - e. In view of the continuing critical importance of accurate source term data, it is essential that efforts be implemented immediately and provision be made for continuing updates and dissemination of data.
- 6.2.4 The coordination of aircraft flights should proceed as follows:
 - A sequence of aircraft flights should be made covering each month with some overlap, where possible, for intercomparison of measurements,
 - b. WMO should assist in arranging the coordination of aircraft activities through national focal points,
 - c. WMO should assist aircraft teams to obtain access to national air space in the region,
 - d. Local support for aircraft teams in the Gulf area is essential,
 - Assistance is needed in providing aircraft teams with model forecasts for flight campaigns,
 - f. The WMO should assist in the distribution of flight data. Wide distribution of flight data will assist in the planning of subsequent aircraft activities and provide test data for model evaluation.

- g. The WMO should assist, within the next few months, in the organization of at least one workshop to compare and discuss aircraft results,
- h. The experts noted that the U.K., U.S.A. and German airplane measuring programmes were bilateral in character. While recognizing the need for urgent measurements, the meeting urged these programmes and future aircraft monitoring programmes to be structured under the framework of the WMO project.

(More details on the aircraft monitoring strategy are given in Appendix XI)

6.3 Surface Monitoring Strategy

- 6.3.1 The meeting listed the following important considerations in developing a coordinated monitoring strategy:
 - a. Dispersion of the plumes including upper and lower heights, and lateral spreading,
 - b. Particle size spectrum of soot,
 - c. Upward and downward short-wave and long-wave radiation fluxes in order to estimate the heating rate within the plume and the cooling below the plume,
 - d. Turbulence generated by solar radiation heating within the plume which should be observable by pilot reports and measureable by turbulence probes (the turbulent motions on the order of much less that 10 Hz are important),
 - e. Particle sedimentation measurements at various distances from source.
 - f. Observations of the deposition of soot by precipitation,
 - g. Boundary conditions for microscale/mesoscale modelling (including horizontal wind-field, vertical temperature-profile, vertical humidity-profile, accurate information on distribution and intensity of the single fire sources, cloud cover, background concentrations of ozone, nitrogen oxides, sulfur, etc., up to altitudes well above the plume),
 - h. Air-chemistry measurements including surface ozone, NO, NO_x , particles, sulfate, nitrate, etc. These measurements would be essential in determining detrimental interactions between existing air pollutants (chlorinated pesticides) and the soot component of the oil fire plumes.
 - Surface albedo, atmospheric transparency, components of radiation balance.

6.3.2 There is an urgent need for a small meeting of experts on atmospheric monitoring to determine the most desirable measurements as a factor of distance from the fires (immediate, regional, global) and to recommend specific actions for WMO to take for implementation, funding, and expert missions to make these data available.

6.4 Modelling Strategy

- 6.4.1 The meeting recommended the following strategy for the modelling community:
 - a. Emergency response and hazard assessment models should be used immediately to provide information on possible health implications and close and downwind guidance for necessary measurements,
 - b. Regional and global models must be tested using the available enhanced data which must be archived and made available,
 - c. WMO should designate a task force of modelling experts to meet shortly to examine results of modelling and data gathering efforts in order to determine how to use these in the larger scale models and to plan for later aircraft intercomparisons and comparisons with other data, and
 - d. Research efforts should be made to improve these models and to transfer advanced technology into operational and assessment models (the task force may be used to coordinate this technology transfer).
- 6.4.2 The meeting concluded that the models discussed in Appendix X have important capabilities for multiple situations. However, for improved specific application, research efforts are still needed for regional atmospheric modelling in the areas of transport and diffusion, terrain influences, surface boundary layer parameterization, air-land-sea interaction, oil fire impacts, radiation balance, chemical reactions, deposition, model formulation, solution technology, and coupled verification and development measures. Appendix X also contains a detailed list of modelling recommendations endorsed by the meeting.
- 6.4.3 For source-term characterization, a phased approach will be necessary to include:
 - a. conducting preliminary exploratory studies of the feasibility of characterizing individual fire plumes, their heat release, and their combustion products,
 - conducting full scale programmes including both dynamic and chemical aspects,

- c. establishing a micrometeorological network to provide local wind field data and to verify local flow field models, and
- d. implement multi-fire local flow field models.

6.5 Data Collection, Assessment, and Management

- 6.5.1 Near field data from Kuwait should be routinely collected and analyzed in Kuwait City and made available to the authorities concerned. The WMO office on site in cooperation with these authorities would also serve to provide local background wind field data for field studies as well as to effect exchanges of data and analyses with aircraft and modellers.
- 6.5.2 The collection of data and exchange of information on an international scale would be organized by WMO in accordance with agreed WWW procedures using WWW structures, where appropriate. In particular, use would be made of the GTS as far as possible for the real-time exchange of data and products and of the capabilities of the Regional Specialized Meteorological Centre (RSMC) and Regional Telecommunication Hub (RTH) in Jeddah to provide data base services.
- 6.5.3 Relevant data collected downwind and globally should be copied to the RSMC in Jeddah in addition to their normal submission procedures to the World Data Centres.

7. REPORT AND CLOSURE OF THE MEETING

- 7.1 The Co-chairmen thanked the experts for their hard work and active participation during the past four days. They noted that despite the short time available for preparation and the short meeting time which included a weekend, a number of important steps had already been taken.
- 7.2 The meeting reviewed the main parts of the draft report and the Chairmen promised to assist the WMO Secretariat to produce the final report in the shortest time possible so that it could be used to meet the urgent needs in Kuwait and the entire affected region by WMO, by WHO, by other international agencies, and by countries involved with further contributions, coordination, and planning.
- 7.3 The Kuwaiti representative thanked the chairmen and the experts for their efforts. He reiterated the urgency of the current situation and appealed to interested countries to make timely contributions and thus facilitate WMO's effort to proceed with implementation of the meeting recommendations as quickly as possible.
- 7.4 The meeting was declared closed at 3:00 PM on Tuesday, 30 April 1991.

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INTERNATIONAL ORGANIZATIONS INVOLVED IN THE UN INTER-AGENCY PLAN OF ACTION IN THE ROPME REGION

Organization	<u>Contact Person</u>	<u>Fax number</u>
IAEA, Monaco	Mr. Laurence Mee	(33 93) 257346
IMO, London	Mr. David Edwards	(44 71) 587 3210
IOC (UNESCO), Paris	Mr. Chidi Ibe	(33 1) 40 56 93 16
UNDP, Geneva	Mr. Thierry Delbreuve	(41 22) 798 75 24
UNDP, New York	Dr. Mohamed Nour	(1 212) 906 54 87
FAQ, Rome	Director General	(39 6) 57976500
		(39 6) 504 3463
UNDRO, Geneva	Mr. T. Noda	(41 22) 733 56 23
UNEP, Paris	Dr. J. David Thwaites	(33 1) 40 58 88 74
	Mr. Robert Young	
UNEP, Athens	Mr. Ljubomir Jeftic	(301) 7291160
UNEP, Geneva	Mr. Ole Hebin	(41 22) 43 88 62
UNEP, Geneva	Ms. Heera Laurijssen	(41 22) 733 26 73
WMO, Geneva	Dr. Rumen Bojkov	(41 22) 734 23 26
WHO, Geneva	Mr. G. Ozolins	(41 22) 791 07 46
WHO, Alexandria, Egypt	Or. H. Sheikh	(20 3) 48 38 916
IUCN, Gland, Switzerland	Mr. Danny Elder	(41 22) 64 29 26
•	Mr. Andrew-Price	,
WWF, Gland, Switzerland	Ms. Nicole King Volcy	(41 22) 64 58 29
UNCED, Conches, Switzerland	Ms. Alicia Barcena	(41 22) 789 35 36
Ministry of Housing, Netherlands	Or. P. Vellinga	(31 70) 317 4449
Minister of Health, Bahrain	H.E. Jawad Al-Arrayed	(973) 252569
Delft Hydraulics, Netherlands	Mr. E. van Beek	(31 15) 619 674
UN, ESCAP, Bangkok	Mr. K.F. Jalal	(66 2) 282 9602

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WMO MEETING OF EXPERTS ON THE ATMOSPHERIC PART OF THE JOINT U.N. RESPONSE TO THE KUWAIT OILFIELD FIRES

(Geneva, 27-30 April 1991)

LIST OF PARTICIPANTS (alphabetical by last name)

Mr. Mohammed Salah Al Sahafi Meteorology and Environmental Protection Agency (MEPA) P.O. Box 6649 JEDDAH 21452 Saudi Arabia

Telephone: (2) 65 12 312, 65 10 368,

67 10 439, 67 13 238

601 236 ARSAD SJ Telex: Telefax: (2) 651-1424, 651-3640

Dr. Abdulmuhsen A. Al-Sunaid Group Leader Air and Marine Sciences Unit Environmental Engineering Division Process and Control Systems Dept. Saudi ARAMCO DHAHRAN Saudi Arabia Telephone: +966-3-876-6153

Telex: Telefax:

Dr. Elliot Atlas Atmospheric Chemistry Division National Center for Atmospheric Research Box 3000 BOULDER, Colorado 80307

Telephone: +1 303 497-1425-direct, +1 303 497-1000-switchbd

Telex:

+1 303 497-1400 Telefax:

Dr. Howard Baum NIST Fellow Building and Fire Research Laboratory, NIST GAITHERSBURG, MD 20899 U.S.A. Telephone: +1 301 975-6668

Telex:

Telefax: +1 301 975-4052

Dr. Ali Al Thowaini

Meteorology and Environmental Protection Agency (MEPA)

P.O. Box 1358 JEDDAH 21431 Saudi Arabia

Telephone: (2) 65 12 312, 67 10 448,

67 10 439, 67 13 238 601 236 ARSAD SJ

Telex: Telefax: (2) 651-1424

Dr. Ibrahim A. Alam Manager Environmental Protection Program Research Institute King Fahd University of Petroleum and Minerals

DHAHRAN Saudi Arabia

Telephone: +966-3-860-3233 801913 KFUPMISJ Telex: Telefax: +966-3-860-3220

Dr. Arthur Bass TASC 55 Walkers Brook Drive READING, MA 01867 U.S.A.

Telephone: +1 617 942-2000

Telex:

Telefax: +1 617 942-7100

Mr. Darrel Baumgardner Scientist

National Center for Atmospheric Research (NCAR)

Box 3000

BOULDER, Colorado 80307

U.S.A.

Telephone: +1 303 497-1054

Telex:

Telefax: +1 303 497-1092 Dr. Manaf Behbehani Department of Zoology Faculty of Science University of Kuwait P.O. Box 5969 SAFAT

Kuwait

Telephone: 4830420

Telex: Telefax:

Dr. J.P. Blanchet Atmospheric Environment Service 4905 Dufferin Street DOWNSVIEW Ontario M3H 5T4 Canada

Telephone: +1 416 739-4414 Telex: 06-964 582

Telefax: +1 416 739-4521

Mr. Andrew E. Bond Research and Monitoring Evaluation Branch

Atmospheric Research and Exposure Assessment Laboratory, MD-76 US Environmental Protection Agency RESEARCH TRIANGLE PARK, NC 27711 U.S.A.

Telephone: +1 919 541-4329

Telex:

Telefax: +1 919 541-4609

Dr. Gregory Carmichael Max-Planck-Institut Für Chemie Abtlg. Chemie der Atmosphäre Postfach 3060 6500 MAINZ Federal Republic of Germany

Telephone: +49 6131 30 5464
Telex: 4 187 647 mpch d
Telefax: +49 6131 30 54 36

Dr. Christian Belin
Europoll
2, rue Amorteaux
78730 ST-ARNOULT-EN-Y.
France

Telephone: +33 1 30 41 21 45

Telex:

Telefax: +33 1 30 59 32 20

Mr. F. Bompay
Direction de la Météorologie
Nationale
Service Central d'Exploitation
de la Météorologie
2. avenue Rapp
75340 PARIS Cédex
France

Telephone: +33 1 45 56 71 46 .

Telex:

Telefax: +33 1 45 56 71 28

Ms. Helen Cachier Centre des Faibles Radioactivites CNRS-CEA

B.P. 1 91198 GIF-SUR-YVETTE Cédex France

Telephone: +33 1 69 82 35 48

Telex:

Telefax: +33 1 69 82 35 68

Mr. Gordon Cartwright 33 avenue du Budé 1202 GENEVA Switzerland Telephone: +41 22 733 6846

Telex: Telefax: Cdr. Francesca Cava Office of the Undersecretary for Oceans & Atmosphere (NOAA) Herbert Hoover Bldg., Room 5128 14th & Constitution Avenue WASHINGTON, D.C. 20230 U.S.A.

Telephone: +1 202 377-3436

Telex:

Telefax: +1 202 408-9678

Dr. Ruth A. Etzel Center for Environmental Health and Injury Control Centers for Disease Control ATLANTA, GA 30333

Telephone: +1 404 488-4682

Telex:

Telefax: +1 404 488-4308

Mr. Danny Foster NOAA NWS - OM32 International Activities Division 1325 East-West Highway SILVER SPRING, MD 20910 · U.S.A.

Telephone: +1 301 427-7784 248376 OBSW UR, Telex: 197683 KWBC UT

Telefax: +1 301 589-1321

Dr. Timothy R. Gerrity Chief, Dosimetry Section Health Effects Research Laboratory US Environmental Protection Agency RESEARCH TRIANGLE PARK, NC 27711 Telephone: +1 919 966-6206 Telex:

Telefax: +1 919 966-6212

Dr. Robert R.P. Chase TASC 55 Walkers Brook Drive READING, MA 01867 U.S.A.

Telephone: +1 617 942-2000

Telex:

Telefax: +1 617 942-7100

Prof. Panayotis Foster Université J.F. Grenoble 1 rue F. Raoult 38000 GRENOBLE France

Telephone: +76 87 26 16 or

+76 87 39 88

Telex:

Telefax: +76 85 06 62

Dr. Claus Frohlich World Radiation Center Physikalisch-Meteorologisches Observatorium Dorfstrasse 33 Postfach 173 7260 DAVOS-DORF Switzerland Telephone: +0 81 46 21 31

Telex: 74732 pmod ch Telefax: +0 81 46 21 34

Dr. Anver Ghazi Coordinator, Space Applications Joint Research Centre Commission of the European Communities 200, rue de la Loi 1049 BRUSSELS Belgium

Telephone: +322 235-8445 Telex: 21877 COMEU Telefax: +322 235-0146 Mr. H. Graf
Max-Planck-Institut für
Meteorologie
Bundesstrasse 55
2000 HAMBURG 13
Federal Republic of Germany
Telephone: +49 40 411 73 307
Telex: 211 092 mpime d
Telefax: +49 40 411 73 298

Dr. Bruce Hicks

NOAA - Air Resources Laboratory
(R/E/AR)

SSMCII, Rm. 9358

1325 East West Highway

SILVER SPRING, MD 20910

U.S.A.

Telephone: +1 301 427-7684

Telex:

Telefax: +1 301 427-8119

Dr. Ingo Jacobsen
Deutscher Wetterdienst Zentralamt
Frankfurterstrasse 135
Postfach 100465
W-6050 OFFENBACH
Federal Republic of Germany
Telephone: +49 69 806 2729
Telex:
Telefax: +49 69 806 2673

Dr. Tim Johnson
Max-Planck-Institut Füer Chemie
Abt. Chemie der Atmosphäere
Postfach 3060
6500 MAINZ
Federal Republic of Germany
Telephone: +49 6131 305 495
Telex: 4 187 647 mpch d
Telefax: +49 6131 305 388

Dr. Jerome L. Heffter
Air Resources Laboratory
National Oceanic and Atmospheric
Administration
1325 East West Highway
SILVER SPRING, MD 20910
U.S.A.
Telephone: +1 301 427-7684
Telex:

Telefax: +1 301 427-8119

Dr. Tahir Husain
Research Engineer - I
Research Institute
King Fahd University of Petroleum
and Minerals
DHAHRAN
Saudi Arabia
Telephone: +966-3-860-3227
Telex: 801913 KFUPMISJ
Telefax: +966-3-860-3220

Dr. H.J. Jakobs
Universität zu Köln
Institut für Geophysik und
Meteorologie
Projekt-EURAD
Salierring 48
D-5000 KOLN 1
Federal Republic of Germany
Telephone: +49 221 21 29 95
Telex: 8 882 279 cosm d
Telefax: +49 221 23 62 89

Mr. Tony Jover
Director, Information Mgmt. Staff
Chemical Emergency Preparedness
and Prevention Office, (OS-120)
US Environmental Protection Agency
401 M Street, S.W.
WASHINGTON, D.C. 20460
U.S.A.
Telephone: +1 202 245-3850 or 382-2387
Telex:

Telefax: +1 202 252-0154

Dr. G. Lambert Centre des Faibles Radioactivites CNRS-CEA B.P. 1 91198 GIF-SUR-YVETTE Cédex France Telephone: +33 1 69 82 35 41

Telex:

Telefax: +33 1 69 82 35 68

Dr. A.R. Marsh National Power Technology & Environmental Centre Kelvin Avenue GB-LEATHERHEAD/Surrey KT22 7SE United Kingdom Telephone: +44 372 374488 ex. 2298

917338 Telex:

Telefax: +44 372 374488 manual

Dr. Ron E. Meyers U.S. Army Atmospheric Sciences Lab. SLCAS-BA-M WHITE SANDS MISSILE RANGE, NM 88002-5501 U.S.A.

Telephone: +1 505 678-4037

Telex:

Telefax: +1 505 678-4393

Prof. Igor M. Nazarov Institute of Global Climate and Ecology 20B Glebovskaya Street MOSCOW 107258 U.S.S.R.

Telephone: +7 095 160 0831 Telex: 411914 ZEMLA Telefax: +7 095 160 5847

Mr. Saad Mahlafi Meteorology and Environmental Protection Agency (MEPA) P.O. Box 1358 JEDDAH 21431 Saudi Arabia

Telephone: (2) 65 12 312, 67 10 448,

67 10 439, 67 13 238

601 236 ARSAD SJ Telex: Telefax: (2) 651-1424

Mr. M. Martin-Bouyer Université de Savoie Service Chimie B.P. 1104 73011 CHAMBERY Cédex France

Telephone: Telex:

Telefax: +33 79 75 85 14

Dr. Tsuguo Mizoguchi National Institute for Environmental Studies Japan Environment Agency 16-2, Onogawa TSUKUBA 305

Japan

Telephone: +81 298 51-6111

Telex:

Telefax: +81 298 51-4732

Dr. W. Pendergrass

NOAA - Air Resources Laboratory NOAA/ATDD

456 S. Illinois Ave.

P.O. Box 2456

OAK RIDGE, TN 37830

U.S.A.

Telephone: +1 615 576-6234

Telex:

Telefax: +1 615 576-2222

Dr. Joyce Penner
Atmospheric and Geophysical
Sciences Division
Lawrence Livermore National Lab.
P.O. Box 808, L-262
LIVERMORE, CA 94550
U.S.A.

Telephone: +1 415 422-4140

Telex:

Telefax: +1 415 422-5844

Dr. F. Roesler
DLR; Flight Dept.
8031 OBERFAFFENHOFEN
Federal Republic of Germany
Telephone: +49 8153 28542
Telex: 526435 (dvlop)
Telefax: +49 8153 281346 or

+49 8153 28243

Dr. U. Schumann
DLR; Institut f. Physik der
Atmosphäre
8031 OBERPFAFFENHOFEN
Federal Republic of Germany
Telephone: +49 8153 28520
Telex: 526435 (dvlop)
Telefax: +49 8153 281346 or
+49 8153 28243

Dr. Jack E. Snell
Deputy Director, Bldg. & Fire
Research Laboratory, NIST
Room B-216, Bldg. 226
GAITHERSBURG, MD 20899
U.S.A.

Telephone: +1 301 975-6850

Telex:

Telefax: +1 301 975-4032

Mr. John Robinson
NOAA
Herbert Hoover Bldg., Room 5128
14th & Constitution Avenue
WASHINGTON, D.C. 20230
U.S.A.
Telephone: +1 202 377-3436
Telex:
Telefax: +1 202 408-9674

Dr. Rolf Sartorius Umweltbundesamt Bismarckplatz 1 1000 BERLIN 33 Federal Republic of Germany Telephone: +30 8903 2511 Telex: Telefax: +30 8903 2285

Dr. F.B. Smith
Meteorological Office
London Road
BRACKNELL
Berkshire, RG12 2SZ
United Kingdom
Telephone: +44 344 420242 ext. 6250
Telex:
Telefax: +44 344 856 909 or 861 197

Dr. Thomas Sullivan
Atmospheric and Geophysical
Sciences Division
Lawrence Livermore National Lab.
P.O. Box 808, L-262
LIVERMORE, CA 94551
U.S.A.
Telephone: +1 415 422-1838

Telefax: +1 415 422-5924

Telex:

Dr. Yu. S. Tsaturov
Deputy Chairman
USSR State Committee for
Hydrometeorology
12 Pavlik Morozov Street
123376 MOSCOW D-376
U.S.S.R.

Telephone: 252 24 29 Telex: 411117 RUMS SU

Telefax:

Dr. Marty Yerg
NCPD
1825 Connecticut Ave., NW,
Suite 518
WASHINGTON, D.C.
U.S.A.
Telephone: +1 202 673-5360
Telex:

Telefax: +1 202 673-5355

UNEP

Dr. C.C. Wallen
UNEP/GEMS Consultant
c/o World Meteorological
Organization (WMO)
Case postale No. 2300
CH-1211 GENEVE 2
Switzerland

Telephone: +41 22 730 84 69 Telex: 414199A OMM CH Telefax: +41 22 734 23 26

World Health Organization (WHO)

Mr. G. Ozolins
Manager, Prevention of
Environmental Pollution
Division of Environmental Health
World Health Organization (WHO)
av. Appia 20
1211 GENEVA 27
Switzerland

Telephone: +41 22 791 37 91

Telex: 415416

Telefax: +41 22 791 07 46

Mr. Ge-H.L. Verver
Royal Netherlands Meteorological
Institute (KNMI)
P.O. Box 201
3730 AE DE BILT
Netherlands
Telephone: +31 30 20 69 11
Telex: 47096 NL

Telefax: +31 30 21 04 07

Dr. David Mage Consultant World Health Organization (WHO) CH-1211 GENEVA 27 Switzerland Telephone: +41 22 791 37 29 Telex:

World Meteorological Organization (WMO)

Mr. T. Azab

Dr. R.D. Bojkov

Mr. F. Delsol

Mr. S. Mildner

Dr. J. Rasmussen

Dr. H. van Dop

Technical Cooperation Department Environment Division

Research & Development Department

Basic Systems

World Weather Watch Department

Environment Division

World Meteorological Organization (WMO) Case postale No. 2300 CH-1211 GENEVE 2

Switzerland

Telephone: +41 22 730 81 11 Telex: 414199A OMM CH

Telefax:

+41 22 734 23 26

APPENDIX III

WMO MEETING OF EXPERTS ON THE ATMOSPHERIC PART OF THE JOINT U.N. RESPONSE TO THE KUWAIT OLLFIELD FIRES

(Geneva, 27-30 April 1991)

AGENDA

- 1. OPENING OF THE MEETING, ELECTION OF CHAIRMEN AND APPROVAL OF THE AGENDA
- 2. INTRODUCTION TO THE PROBLEM
- 3. THE SOURCE
- 4. REVIEW OF PRESENT MONITORING AND ESTIMATED EFFECTS OF THE FIRES
- 5. USE OF MODELS TO ASSESS CONTINUING EFFECTS
- 6. RECOMMENDATIONS
- 7. REPORT AND CLOSURE OF THE MEETING

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مجنلس حتماية البيئ

ENVIRONMENT PROTECTION COUNCIL



Reference FPC/90/1600 Date 26 APRIL 1991 Dr. Obasi Secretary General W M O

Dear Sir:

Thank you and the World Meteorological Organization for hosting this meeting and for your kind invitation to attend. We are very sorry we could not come because of the short notice and the unavailability of flights from Kuwait.

Attached please find a copy of a plan for the rehabilitation of the environmental monitoring facilities of Kuwait. The plan was discussed with Dr. David Mage of the World Health Organization (WHO) who kindly agreed to present it in our behalf and express our points of view. We regret that he will not be able to return to Geneva until Sunday 28 April 1991. Many other experts, some of them attending this meeting, have first hand information of the situation in Kuwait. If Dr. Will Pendergraf (NOAA) and Mr. Andy Bond (US EPA) are attending they can explain to you how desperate our situation is and how much help we need.

I would like to take this opportunity to thank WMO and all the organizations represented at the meeting for their interest and desire to help us. Many organizations and governments have already provided help. The French Ministry of the Environment helped with the air pollution measurements and the US EPA provided us some badly needed equipment and promised more. Many other organizations showed real concern and willingness to help, which we would like to acknowledge.

Thank you again for your kind assistance.

I female sincerely yours,

Secretary General,

Environment Protection Council (KUWAIT)

Director General, Environmental Protection Department

Attachment: Plan for Rehabilitation Environmental Manitoring

cc: Dr. Hiroshi Nakajima, Director General WHO Attention Dr. D. Tarantola, ERO and Dr. W. Kreisel, EHE Kuwait Mission to the United Nations, Geneva

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WORK PLAN FOR THE REHABILITATION OF AN ENVIRONMENTAL MONITORING PROGRAMME FOR KUWAIT

A. AIR POLLUTION MONITORING

1. Background

- 1.1 The air pollution problem coming from the burning of approximately 6 million barrels per day of crude oil plus natural gas from the oilfields is probably the most serious incident of this kind ever recorded. This burning began in earnest on 22 February 1991 and many people have been exposed to the resulting fumes since then. The environmental impact of crude oil smoke is probably unique and previous experience with coal smoke or diesel particulates is not going to help very much. To our knowledge there is no information on the composition and toxicity of the chemicals being emitted and no computer models are available to handle the complex plume behaviour from the burning oilfields.
- 1.2 The urban area in Kuwait extends as an inverted L. The short limb runs from east to west along the coast of the Gulf of Kuwait. The longer limb extends north to south down towards Saudi Arabia (see Figure 2).
- 1.3 The oilfields on fire are to the southeast and to the northwest of Kuwait City. The coastal strip will be mostly affected by the oilfields to the south. These oilfields are quite close to the coastal strip and extend for almost 80 km on its periphery.
- 1.4 The meteorological department is not operating at the time, as all equipment was looted and the facilities destroyed. Based on the previous records (1957-1982), during the period April-June the synoptic wind is mostly north or northwest. In the absence of the oil fire heat island effects the wind would be blowing from the southeast for 18% of the time. Further day and night differences were recorded and land and sea breeze data had to be taken into account for the coastal area when the wind speed is low. Ground based inversions were generally prevalent at night when the sky was clear and radiation from the surface unobstructed.
- 1.5 The existing pattern of the surface wind is now probably significantly different from what it was before the oil fires. The burning wells are creating strong "heat islands" and strong incoming winds towards the fires are reported at the periphery of the fields no matter what the direction of the prevailing wind in the upper air might be.
- 1.6 The monitoring facilities for air quality included three fixed stations measuring the principle pollutants and meteorology. Four high volume samplers and several dustfall buckets were available. Two of the stations are operating now but the third station is being cannibalized and used up as spare parts to keep the other two stations operating.

2.1 Air Quality Data

Air quality measurements have been made by several agencies during the first two months of this oil fire crisis. Preliminary data show that peak levels of SO_2 are exceeding WHO guidelines with an increase in mortality among elderly and chronically ill people when accompanied by an equal

concentration of (coal) smoke type particulate matter. Because the crude oil smoke particles have a different chemical composition, their relative toxicity compared to coal smoke particles is an unknown. For example, to our knowledge, the rate of catalytic conversion of SO_2 to H_2SO_4 on the surface of these oil smoke particles has not been measured. These plumes are so opaque over the EPD monitoring stations that incident solar radiation is being reduced to one-tenth of the normal values measured on the same dates in the past.

2.2 Measurements of SO₂

2.2.1 The government of France, through the Department of Police, Paris, kindly provided the services of a mobile air monitoring laboratory to EPD in late March and early April 1991. Measurements made on SO_2 at several locations in Kuwait found concentrations of SO_2 reaching high levels.

High values of 470 $\mu g/m^3$ for a 12-hour average, with a maximum five-minute value of 2900 $\mu g/m^3$ and a 3-second peak of 3400 $\mu g/m^3$ were obtained. During this period of peak pollution the thermometer recorded a significant rise of temperature indicating the touchdown of direct plume. These data were measured during the evening from 3 to 4 April 1991 at the English school at the 5th ring road of Kuwait City.

On 3 April 1991 at the 7th ring road nearer to the oilfield fires an 8-hour average of 500 $\mu g/m^3$ was measured with a maximum 5-minute average of 1200 $\mu g/m^3$ and a 3-second peak of 1450 $\mu g/m^3$ with no accompanying fluctations of temperature.

- 2.2.2 The government of the U.S.A. through the courtesy of EPA provided measurements of SO_2 made at several locations in Kuwait from instantaneous and 20-minute grab samples. Although the measurement technique used had a high limit of detection, their results on SO_2 in the Kuwait area indicated a range of instantaneous values up 0 to 1 ppm (2860 $\mu g/m^3$) at the U.S. Embassy and up to 0.2 ppm SO_2 (Summa data) in the oilfields directly in the plumes. The U.S. Air Team report states "the SO_2 levels of 1 2 ppm should be used with caution".
- 2.2.3 The Kuwait Oil Company medical facility of Ahmadi Hospital has recorded SO_2 by the H_2O_2 bubbler method. On 22 April 1991 an 18-hour average of 1.65 ppm (4700 $\mu\text{g/mg}^3$) was measured during a period of direct fumigation from the Ahmadi oilfield plumes which produced a blackout. During this period a Professor of environmental studies reported that stinging droplets of oil fell on his skin and that two of his female students fainted while out taking part in a survey of symptoms in the neighborhood.
- 2.2.4 The Kuwait MOPH/EPD has also measured 24-hour average SO_2 by the H_2O_2 bubbler method at 4 hospitals in Kuwait City since 13 March 1991. Maximum daily SO_2 levels of 200 to 250 μ g/m³ have been measured.
- 2.3 Comparison to WHO Guidelines for SO₂ and Particulate

WHO has recommended that susceptible individuals be protected from 10-minute peak values of 1000 $\mu g/m^3$ of SO_2 by use of a safety factor of 2 resulting in a guideline value of 500 $\mu g/m^3$. This value is consistent with a one-hour value of 350 $\mu g/m^3$ under typical urban air pollution conditions which was therefore chosen as the 1-hour average guideline value.

For longer term 24-hour averages of SO₂ exposures combined with particles arising from urban sources such as coal, fuel oil and gasoline combustion, the health effects associated with these combinations are shown in Table 1. It is necessary to note again that the chemistry of the particulate phase resulting from the Kuwait crude oil fires can vary between the oilfields as some are sweet (low S) and others are sour (high S) and both will be different from the winter urban particle mix on which Table 1 is based.

WHO does not provide guidelines for exposures based on carcinogenicity since no safe threshold may exist. Until the organic constituents of the plumes are measured and understood prudence requires avoiding unnecessary outdoor exposures during blackout periods.

2.4 Potential for Health Effects from the Oil Fire Plumes

The measurements described above and their relationship to the WHO guidelines indicate that a serious air pollution situation exists for the people residing in Kuwait. At the present time, the combination of synoptic meteorology, the heat island effect and the emission source distribution has lead to rapidly fluctuating positions of maximal impact of the oil fire plumes. Measurements at fixed station locations show the presence of high concentrations for short periods of time (6 to 18 hours), after which the plume cloud appears to shift to another location where measurements are not available and the concentrations decrease at the station.

At the present time, it is impossible to predict accurately what the seasonal changes in weather patterns will do to the oil fire plumes. As the pressure in the oilfields decreases and oil fires are extinguished the thermal plume rise and heat island effect will become smaller and much higher ground levels of SO_2 and PM_{10} can be expected nearer to the population centres. In the event of atmospheric stagnation the SO_2 and PM_{10} concentrations could build up to the levels shown in Table 1 which would constitute an acute air pollution emergency.

It is therefore necessary that an air quality monitoring system capable of measuring the overall spatial pollution distribution and meteorological variables be developed to provide real time information and predictive capabilities so that public health authorities can issue warnings and take protective actions to protect the people living in Kuwait.

The sections that follow describe the components of the overall plan that the MOPH/EPD sees as necessary to put in place. There is a need for funding, supplies, equipment, personnel, consultants and advisors to help the MOPH and EPD in this period of need until our country can stand on its own as it did before the war. It is hoped that this outline will show areas of need so that the international community can provide assistance to Kuwait that is an element of our plan and not a duplication or superfluous effort.

Air Quality Monitoring

The system was designed to look after the air quality resulting from traffic, industry and power plants. Of course the problem of the pollution from the burning oil wells was not anticipated or accounted for so major changes may need to be introduced to the system to get them in line with the existing (or future) plume directions and impact locations. Examination of the SO_2 data from the fixed stations shows significantly lower concentrations than measured by the mobile lab and grab samples taken nearer to the plume axes.

1.

A number of facilities including three mobile stations were looted and other equipment was badly damaged. This loss of equipment combined with the loss of technical personnel and the existing magnitude of the new air pollution sources makes it imperative for the complete system to be expanded and updated as soon as possible.

The following sections describe the integrated elements that will be required for an air quality monitoring system that is proposed by the EPD for managing the overall programme:

3.1 Fixed Monitoring Station Requirements

The area to the west of Kuwait City, Jahra (150,000 before the crisis) is not covered in the existing system now. The area is rural but it is now in the plume shadow of the northern fields. No monitoring stations are now in the area to the south near the border with Saudi Arabia. Information from this area will help estimate the transboundary flux. A means for transmitting the information directly to the central computer in the EPC is needed. An alarm system should be installed to alert us if and when the levels of pollutants exceed our warning levels (still to be established by EPD). The computer capabilities should be upgraded and special software developed for this system.

3.2 Mobile Air Monitoring Laboratories

All the mobile laboratories were taken away to Iraq. At least two vans provided with pollutant analyzers and meteorology sensors are needed. The wind direction in the vicinity of the oilfields is changing very rapidly and vans are needed to measure the levels up and down the wind axes and to trace the plumes. The system could determine the probable contribution of the different sources. The vans are intended to be used in the field and a power supply (220 V/50 Hz) would provide the necessary flexibility.

The Federal Republic of Germany has kindly promised to provide one van to the EPD and the People's Republic of China has offered the services of a similar van and crew, if transportation and crew expenses can be provided. A mobile gas chromatograph would be a very valuable complement to this system.

3.3 Monitoring for Particulate Matter

The U.S.A. EPA has kindly loaned us 9 portable PM₁₀ samplers. The equipment will be installed at sites to be agreed on. Three fixed PM₁₀ monitors are available now (2 provided by U.S. EPA) and will be installed at the fixed stations. The filter papers will be weighed and extracted locally. Certain heavy metals will be looked for in an attempt at "finger printing" and the composition of the hydrocarbon fractions will be determined by the HPLC and GCMS in the EPC laboratory.

3.4 Personal and Indoor/Outdoor Monitoring

Because people will spend most of their time indoors, preferentially in air conditioned homes especially during times of plume impact and blackout, their exposures may not be accurately characterized by ambient air quality data. It is therefore necessary to run some personal monitoring of exposures to SO_2 and PM_{10} in areas of expected maximal concentrations in order to evaluate exposures and protection factors. For certain volunteer subjects

 SO_2 and PM_{10} will also be monitored both indoors and outdoors to measure the protection factors for the various types of homes and activity diaries will be kept. Equipment required will be passive personal exposure monitors (PEMS) for SO_2 and pump/cyclone cartridge combinations for particles. Personal samplers for PAH such as those designed by ORNL can be used to get the vapour phase PAH exposures. (See section 4.2 for discussion of the HEAL project this will be a part of).

3.5 Meteorology Network

The only available (non-military) data now for meteorology and modelling are those provided by the two EPC fixed stations in the built up areas. No predictive capabilities are available from the Kuwait weather service which was destroyed during the war. The U.S. NOAA was kind enough to provide a system of 15 weather stations together with transmitter/receiver capabilities that can operate remotely using solar powered batteries. This will cover the problem of the surface data. However, upper air data are not available and they are needed for tracing the large scale plume transport. The alarm system will require this information. A doppler sodar system with 3 km range is needed to replace the one destroyed.

3.6 Quality Assurance

Some grave decisions may need to be based on the information generated by this system and the quality of the data must be looked into critically. There are many protocols available and the appropriate ones should be selected. The U.S. EPA has promised QA/QC help in extracting and analyzing the PM10 filters. Before the war EPD used to run duplicate samples with Kuwait University and Kuwait Institute of Scientific Research (KISR). Now this must be done through other institutions abroad. The IAEA marine laboratory (ILMR) in Monaco was used as a reference lab before the war and contacts will be established through the UN coordinated plan to reinstate this service.

3.7 Laboratory Requirements

The EPD laboratory will need the ability to measure the inorganic and organic gas phase constituents which are sampled in special studies using Summa containers or equivalent. The particulate fractions to be collected will need to be weighted, extracted and analyzed in Kuwait in order to minimize turn around time and reduce the possibility of sample loss or transformation during transport. Microbalances and extraction equipment are required for weighing and sample preparation. The equipment for analytical procedures, GCFID, GCMS and HPLC are available in Kuwait but new standards for the crude oil combustion constituents and spare parts are required.

The toxicology testing of collected fractions of the particle mix and semi-volatiles (PUF) will be performed by the Harvard School of Public Health and another laboratory (perhaps at EPA) and will be needed for an independent verification or QA/QC control.

3.8 Repair Facility

In order to assure continuous operation of equipment a repair facility with modern test kits and diagnostic tools is required. An inventory of spare parts most likely to fail must be established and communications arranged with

suppliers so that expensive units not stocked can be supplied immediately on demand. Although it is planned to have a spare one of each type of monitoring instrument in the repair/calibration facility the ability to immediately repair equipment is needed. The EPD repair facility was looted and a list of equipment required will be made available for donor support.

3.9 · Data Base Management

The most urgent requirement is for real time data transmission from remote stations to the central location for emergency warning capabilities. There will be a continuous flow of data into the data base from monitoring stations, meteorlogical stations, chemistry laboratories and other participating institutes (e.g. QC results). A data base manager will have to organize sample identification, tracking, storage and retrieval and arrange priorities for special reports to MOPH along with routine processing.

3.10 Coordination Centre (CC)

The MOPH/EPD will provide a project director (PD) who will be responsible for overall management of the entire programme. The PD will establish priorities and maintain oversight of all activities. The coordinating centre will hold a daily briefing in the morning to review the forecast for daily pollution and weather, to review the previous 24-hour conditions and to discuss non-routine projects such as special studies. There will be 24 hour per day coverage at the coordination centre so emergencies during nighttime and holidays are responded to, and to provide communications to and from other time zones where collaborators are located. The CC will also have a finance/budget officer to keep track of spending and maintain records of the expenditures.

3.11 Data Analysis and Interpretation

In the short-term the inflow of data on air quality and meteorology needs to be analyzed with the aid of predictive models that can reliably forecast where pollution maxima will occur in the next 6 to 24 hours. Summary reports on pollution extent and possible health impacts (e.g. relation to WHO guidelines) need to be prepared on a fixed schedule. These data reports will need to be interfaced with the health monitoring project (see section 4 below).

3.12 Logistics

A basic need for any complex international project is for logistical support. There will be a need for planning and coordination of transport/vehicles, ordering of parts, supplies and consumables, keeping a secure storeroom and inventory, plus typewriters, fax, computers, phones, copiers to keep operational. There will be a need to organize visas, tickets, customs clearances, mail, shipments, etc.

3.13 Public Relations (PR)

A PR officer (PRO) should be assigned as the contact point to keep the news media informed of progress and of the general situation. The PRO would arrange for visits and tours by government officials and others, and would handle press releases.

3.14 Public Awareness (PA)

The PA officer (PAO) would be the official contact to the media and emergency authorities to provide forecasts of critical situations on a daily basis. The PAO would also be responsible for discussing the health implications of the situation in consultation with the medical specialists assigned by MOPH.

4. Requirements for the Study of Health Impacts

The impact on the health of the people residing close to the oil plume sources is causing due concern. A large proportion of the population is still outside the country and needs assurance that the situation is quite safe and that predictive and preventive measures are planned in case the situation changes. The question of the need to evacuate certain areas was discussed and although the need didn't arise, and it is hoped that it will not, public health is our first concern and all precautions must be taken to assure that appropriate measures are in place.

4.1 Health Status of Populations

The short term impact mostly related to particulates and SO_2 (and to a lesser extent NO_2 and O_3) are of immediate concern. An epidemiological study showing the health status of people in relation to the environment and the various factors that influence their exposure and resulting test outcomes is needed. Until the carcinogenic potential of the oil smoke plume is established, the longer term possible effects will have to take second priority. The investigation should address the selection of a representative random sample and/or specially targeted populations, designing questionnaires for the local conditions, clinical examinations, pulmonary function tests, the taking of blood, urine and sputum samples and other investigations.

The following sections address the other elements that must be considered in the design of the appropriate health studies for our population.

4.2 Personal Exposures

In June 1990 before the present disaster, Kuwait joined the WHO/UNEP Global Environment Monitoring System (GEMS) Human Exposure Assessment Locations (HEAL) programme. Exposure to particulates was suggested as a priority because of the wind blown dust problem. Even before the war, Kuwait had the highest TSP levels reported to the GEMS/Air system and now the particulates due to the oil fire plumes will be added to them. In addition, the wind blown dust will now probably have a high organic content adhering to it from the crude oil residues contaminating the top soil.

The U.S.A. EPA has offered to provide the needed technical support for this aspect of the study if funding can be provided. Personal exposures to SO_2 may be added to the particulate studies. A stratified random sample of the population living in different areas of Kuwait with different age groups would be selected as part of the health study.

The HEAL protocols used for the exposure portion of this health study could provide better knowledge about the short term (SO_2) and long term (PAH) exposure risks of the populations of the subjects under study so that their total exposures to PAHs from possibly contaminated food or water can be considered, if they are found to be significant in relation to the air route exposures.

Assistance will be required for the food sampling and analysis portion of this study. Because of the possible dermal exposures from the droplets of oil falling out of the plume clouds, some measures of the effects of these droplets on total exposure will need to included.

4.3 Quality Assurance

A quality assurance (QA) protocol needs to be established to cover each type of measurement in the studies. There needs to be duplicate sampling and replicate analyses on measurements of exposure variables, biological media and physiological data. Questionnaire and diary response need to be validated and the digitized responses should be checked. A QA officer needs to be appointed with responsibility for carrying out the QA protocol.

4.4 Data Management

There will need to be a person assigned to manage and coordinate the data flow. There will be physiological and exposure data to be associated with each subject along with their medical history, questionnaire and diary responses. General medical records (admissions) from hospitals and clinics need to be entered.

4.5 Coordination Centre (CC)

The project manager (PM) from MOPH should be established at the CC where overall direction for the project can be maintained. The PM would maintain oversight of all project aspects and hold regular meetings with medical, exposure, data and record retrieval staff. The CC would handle all international contacts and interface with the air quality monitoring project director on a regular basis.

4.6 Data Analysis

The data sets obtained in this study need to be examined on a continuing basis. Whereas a classical epidemiology study might analyze these data after the fact, in this case it may be possible to discover health effects associated with the oil smoke now so that prophylaxis can be considered and susceptible groups can be identified and warned. Epidemiologists will need to screen these data for early warning signs in susceptible populations. When the oil fires are extinguished and air quality returns to the previous regime dominated by wind blown dust, the analyses of the overall effects can be performed. However, the wind blown dust may then have a high residual oil component bound to it which could present another problem. Population data will need to be gathered so that the denominator can be estimated for use in incidence rate computations.

4.7 Hospital records:

The national recording system was interrupted on the second of August 1990. The data of the previous years could be retrieved and used as background for comparative studies. The recording at Ahmadi hospital started from the first of April 1991 and some data will be available soon. The records from the local clinics and regional polyclinics are more difficult to use and they may not be of the needed quality. Some polyclinics could be selected and the physicians in charge asked to start the recording of their diagnoses for a predetermined period. This will give an overall bird's-eye view of the situation and the expenses and labor involved would be within the existing limitations.

4.8 Logistics

With many institutions participating in the investigation, a local group with the MOH or EPC should be appointed and given the task of looking after the visas, travel, accommodations, transport, mail, etc. This is usually done as a matter of routine by EPD, but with the present situation, a special group would be given that responsibility.

4.9 Emergency Response and Warning

Special risk groups (elderly, asthmatics, bronchitics, etc.) may need prior warning of the worsening air quality conditions. The hospital emergency rooms at the general hospital should be alerted to the situation of the possibility of the plume impacting their catchment areas. The hospitals should prepare their own protocols for handling the inflow of cases that are suffering due to the air pollution episode.

4.10 Long Term Follow Up Studies

There should be consideration for the development of a tracking system for long term follow up studies of the exposed populations. Records that show development of pulmonary conditions, cancer incidence and other disease data will need to be established, pending the results of toxicity and mutagenicity testing.

B. Water Quality Monitoring

5.1 Drinking Water Supplies

The programme for monitoring the drinking water quality was completely interrupted by the occupation. Basic water quality parameters will be overlooked for the time being. Analyses of the residual chlorine shows very low concentrations owing to the stagnation of the water in the reservoirs. Samples for bacteriological examinations will be collected from the residential areas on a weekly basis. Positive faecal coliform will be reported to the Ministry of Electricity and Water (MEW) for examination of the network for possible sewage intrusion. Examination for bacteriophages for indication of viral contamination will be resumed after the technical staff is recruited.

The programme needs the following support:

- a) Four (4) total and faecal coliform field testing kits (about 120 samples per month will be analyzed)
- b) Four (4) chlorine test kits
- c) Two (2) digital pH meters
- 5.2 Coastal and Marine Environmental Monitoring

The Kuwait Gulf has been exposed to the biggest oil slick in history. However, in the past it was chronically impacted, and a monitoring programme was established many years ago. The EPD had a large research vessel and several speed boats for taking samples. The vessels were lost during the occupation and the sampling programme was suspended.

Samples of the surface film, water, sediment and biota will be collected for PAH and trace metal analyses (Ni, V, Hg, Pb) in order to determine the impact of the oil well spills and oil fire fallout on the marine environment. Sulfated PAH species may be used to differentiate between the two possible sources. Baseline data on trace metals and PAHs are available through the EPC national monitoring programme records as well as through the ROPME regional monitoring projects, carried out in cooperation with the IAEA Monaco ILMR laboratory.

Such a study should be a part of an ecological assessment of the marine environment with the objective of assessing the impact of the war activities, oil spills, well fires and the presence of mines on the marine environment, with special emphasis on sensitive populations and systems (i.e. coral reefs, oyster beds, tidal flats, marine turtles, mammals and birds). The impact on avoidance of mined areas on fishing activities and fishery resources could also be incorporated in such a study.

The equipment needed for running the programme includes the following items:

- a) Two (2) four-man inflatable rubber boats and engines (Zodiac)
- b) Two (2) sediment grab samplers (Vanweer)
- c) Three (3) sets of diving equipment (Scuba)
- d) Two (2) sea water quality analyzers (salinity range 10 50 ppt, temperature 0 - 45°C)
- e) Two (2) hand held low speed current meters with recorders
- f) One (1) meteorological station (wind speed and direction, temperature and humidity, solar radiation and atmospheric pressure)
- One (1) 100 foot shallow draft research vessel (cruising speed to 14 knots, accommodations for 3 crew and 4 researchers, navigational and positional fixing aides, echosounder, sea bed profile scanner, current meter, temperature probes 0 to 40°C, salinity probes up to 50 ppt, DO, turbidity, water samplers for water quality, trace metals and bacteriology, PC, refrigerators and freezers).
- C. Soil, Flora and Fauna Monitoring Needs
- 6.1 The desert flora of Kuwait used to suffer from overgrazing, off-road vehicles and quarrying. Now they are facing new problems. The military vehicles with their treads probably caused greater harm to the soil surface than the passenger cars. Abandoned mine fields are a threat that will take years to eliminate by clearance, if this can ever truly be completely accomplished. The disturbance to the top soil by mine sweeping operations will last for decades.

In the vicinity of the burning oilfields, the chemical properties of the soil and its capacity to retain water have probably changed due to its contamination by oil. Vegetation is suffering from the deposition of soot and the intensive heat generated by the fires. All the trees and shrubs in the city of Kuwait were not irrigated during the period of occupation. Water is not yet available in sufficient quantity to allow normal watering. The dry hot summer months are coming, and it is not known whether our plants and trees will survive.

Little is known about the effects of the war on wildlife. Sheep, goats and camels grazing in the areas impacted by the burning wells have turned black from the falling drops of oil and have started to lose their fur and die. Many birds observed flying through the plumes are overcome by heat and fumes and fall to the ground. Many other birds have died as a result of the oil pollution when they landed in the oil pools (mistaken for water) caused by the freely gushing wells.

The home gardens were a rest place for migrating birds, and the lack of water has destroyed this habitat. The farms at Abdally and Wafra to the northwest and south of Kuwait City have been destroyed and abandoned which will add to the suffering of the domestic and migrating birds.

6.2 Monitoring Needs

The needs to assess the impact on the top soil would include an aerial survey to determine the magnitude of the top soil damage and the extent of the mine fields in coordination with the military authorities. A survey of the vegetative cover and wildlife should be organized. The background information on the prewar conditions is available from surveys sponsored by the EPC. FAO and non-governmental organizations can provide advice on replanting of new species, rehabilitation of the soil and the combat of desertification.

D. Environmental Awareness Campaign

7.1 The problems of water supply, waste and sanitation, air pollution, and the presence of mines and other unexploded ordinance should be the focus for a vigorous public awareness campaign. The production of posters, booklets, TV short films and radio messages by medical staff, military officers, and religious leaders should be started immediately. A special short weekly or biweekly TV programme on public safety should be centered around interviews with specialists on mines, mine field clearance operations, and mine victim treatment specialists from the casualty wards to impress upon the population the seriousness of this impending danger.

7.2 Equipment Needs

- a) Two (2) video cameras compatible with the national system
- b) Two (2) video sets
- c) Two (2) portable tape recorders
- d) Film (100 hours)

TABLE I. SUMMARY OF HEALTH EFFECTS KNOWN TO BE ASSOCIATED WITH WINTER TYPE SMOG - LEVELS OF 24-HOUR AVERAGE CONCENTRATIONS OF AIR-POLLUTANT MIXTURES CONTAINING SO₂ AND FARTICULATE MATTER ABOVE WHICH SPECIFIC ACUTE EFFECTS ON HUMAN HEALTH ARE EXPECTED ON THE BASIS OF OBSERVATIONS MADE IN EPIDEMIOLOGICAL STUDIES

SO ₂	Particles (μg/m³)	Health effects	Overall classification of effects
200	200 (gravimetric)	Small, transient decrements in lung function (FVC, FEV ₁) in children and adults, which may last for 2-4 weeks. The magnitude of the effect is in the order of 2-4% of the group mean.	Moderate
250	250 (black smoke)	Increase in respiratory morbidity among susceptible adults (chronic bronchitis) and possibly children.	Moderate
500	500 (black smoke)	Increase in mortality among elderly and chronically ill people.	Severe

Note: Effects on human health are thought to become severe at levels of 400 $\mu g/m^3$ for both sulfur dioxide and particulate matter.

مصلحة الأرصاد وحماية البيئة



METEOROLOGY & ENVIRONMENTAL PROTECTION ADMINISTRATION

(MEPA)

Saudi Arabia Monitoring Programme

Action Plan

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SAUDI ARABIA AIR MONITORING PROGRAMME ACTION PLAN

GULF REGIONAL AIR MONITORING PROGRAMME

1. INTRODUCTION

The U.S. Interagency Air Monitoring Team is working with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA) to develop an air monitoring plan for the Gulf region that will provide information to assess the impact of the fires in Saudi Arabia. This plan is being discussed and developed with the King Fahd University of Petroleum and Minerals/Research Institute (K.F.U.P.M./R.I./R.I.) in Dhahran, the Cooperation Council for the Arab States of the Gulf (GCC), and the Saudi Arabian Oil Company (ARAMCO). The plan is being developed at the request of Dr. Tawfiq, Vice President of the Saudi Arabian MEPA. Meetings have been held with officials from all of the above mentioned organizations.

1.1 Approach

The Team is gathering information on the existing air monitoring networks in the region operated by MEPA, Saudi ARAMCO, Kuwait, Bahrain, and the Royal Commission of Jubayl and Yunbo. The spatial distribution of the existing network in the Region is being reviewed as to the location of sites, the air pollutants and meteorological variables that are monitored at each of these sites and the quality of existing data. That review is to determine if the existing network needs to be expanded in terms of the air pollutants and meteorological variables monitored and additional air monitoring stations to determine the impact from the oil fires. The capabilities of the existing agencies and governments to deal with a more complete network is also being investigated.

1.2 Objectives of Air Monitoring in the Gulf Region

Air monitoring data is needed for the following reasons:

a. To provide an Early Warning Health Advisory System for the Gulf Region to respond to the air pollution resulting from the Kuwaiti oil fires. The proposed Early Warning System could be based on an adaptation of the U.S. Air Quality Index, the Pollutant Standards Index (PSI), which can be modified to use Saudi air quality standards. The index would provide for health advisories to the affected populations so they can minimize their exposure to high pollution levels.

- b. To track the air pollution from the Kuwaiti oilfield fires over time to assess the potential long term health and ecological effects. The air monitoring network proposal being developed is being coordinated with a parallel effort to develop a health monitoring information system.
- c. To collect samples of airborne particles to perform toxicity testing and dose response assessment utilizing in-vivo animal models.
- d. To facilitate evaluations of models which are use to predict the local and regional scale behaviour of the oilfield emissions. Data from the expanded GULF REGIONAL AIR MONITORING NETWORK of ambient air quality and meteorological data will be important for those evaluations.

BACKGROUND

There are currently 516 oils wells burning in Kuwait, consuming approximately five million barrels of crude oil and 70 million m³ of associated gases daily. The fires originate in seven oilfields (Figure 1), located both north and south of the Kuwait City airport. The fires may represent one of the greatest manmade environmental disasters in recorded history.

Based on the composition of Kuwaiti crude oil, emissions from the burning wells are likely to include airborne particles, sulfur dioxide formed from the combustion of hydrogen sulfide, and oxides of nitrogen. Incomplete combustion products include hydrogen sulfide, carbon monoxide, polycyclic aromatic and other volatile organic hydrocarbons, and heavy metals. Other pollutants, including ozone and acid aerosols, such as sulfuric acid, would be formed secondarily in the atmosphere.

Meteorological conditions over the past two months have tended to transport the smoke plume toward the southeast, with periodic excursions toward the northeast. March through July are relatively windy months; there are normally 30 days of very strong winds from the northwest in this period, which produce sandstorms and rapidly ventilate the smoke. August to October, the incidence of strong winds should drop sharply, and local conditions will likely worsen.

As summer advances, solar induced convective mixing will increase the maximum height or pollutants to levels not yet experienced, perhaps to above 6 km. It is in these situations that the stage will be set for long-distance transport of the plume in the upper atmosphere, with associated long-range effects.

Emissions from the well fires have the potential of causing both acute and chronic health effects, although there is considerable uncertainty as to the magnitude of the risk. Thermal damage and poisoning from the chemical components of the plume are the two major mechanisms of acute pulmonary injury. Prolonged exposure to lower concentration levels of smoke may decrease lung function, and increase the incidence of chronic bronchitis and lung cancer. Special health concern is focussed on individuals working close to the fires, pregnant women, children, the elderly, and those with pre-existing respiratory and cardiac diseases.

The U.S. interagency scientific team has been conducting a reconnaissance survey of the fire plumes and their effects in Kuwait and Saudi Arabia since 10 March 1991. The Team obtained limited real-time data on the smoke emissions, assessed the existing air pollution monitoring infrastructure in the region, and conducted a number of interviews with health officials to evaluate the extent of acute respiratory problems related to smoke exposure. While only a cursory assessment is possible at this point, some data obtained by the Team were encouraging. Large-scale acute human health impacts, for example, have not been observed. Nor did limited sampling reveal the existence of high concentrations of sulfur dioxide or hydrogen sulfide close to the burning wells. The Team has stressed, however, that their observations represent only a preliminary assessment and that considerable follow-up will be necessary to definitely evaluate the nature and magnitude of the human health, ecological, and atmospheric effects of the smoke problem.

2.1 Preliminary Investigation of the Existing Monitoring Networks

The air quality monitoring sites listed in Table 1 have been identified for each of the Gulf nations that could contribute monitoring information within the sphere of influence of airborne effluents from the Kuwait oil fires.

Based upon our review of the existing networks, the principal pollutants which are missing are in the Saudi network and in the present Kuwaiti network are PM10, which represents particulate matter with particles less than 10 microns in diameter, polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOC). With respect to PM10, these are the particles which are most likely to penetrate deeply into the lung. It should be noted that Kuwait has collected particulate data using an Anderson Cascade Impactor, with limited size distributions below seven microns within a TSP sample. Because of the importance of this particular pollutant and the large amount of TSP resulting from the oil fires, the Team is recommending that special efforts be initiated to gather PM10 data and if possible to determine its constituents - trace metals and hydrocarbons. The PM10 data collection effort should be supplemented with the collections of PAH samples and if possible, grab samples for VOC analysis.

An ongoing effort is being conducted to examine the analytical laboratory support for air monitoring in Kuwait, MEPA, King Fahd U.P.M., and Saudi ARAMCO. The Kuwaiti laboratory capability to analyze air and TSP samples has been left largely intact. As of 27 March 1991, two of the three continuous monitoring stations have been activated and are collecting data. The remaining site has its continuous sampling equipment however, like the analytical laboratory, is without electrical power. There is no projected date for power at these locations. The analytical laboratory has had experience with polyurethane foam (PUF) extractions for PAH measurements (PS-1 sampler) and has done pesticide extraction and analysis research. The most critical need for the laboratory is obviously power to provide the basis of future support to the sampling plan. Additional training must be provided with documented procedures for these new sampling and analytical procedures. and lastly they are in need of a complete set of standards to support instrument calibrations for their existing continuous monitors and the new proposed technologies. Quality control and quality assurance samples and support for the network should be developed within the available laboratories but, should be supplemented from an external source.

TABLE I - The Distribution of Air Pollutant and Meteorological Monitoring Sites by Gulf Nation

Nation	Organization	Number of Air and Meteorological Sites
SAUDI ARABIA	MEPA	3 fixed sites - meteorology and air pollution at different locations of the same city 1 mobile site - meteorology and air pollution 1 fixed meteorology site
	Saudi ARAMCO	8 air quality sites with meteorology 6 additional meteorology sites
	Royal Commission for Jubayl & Yunbo	
KUWAIT		3 sites with continuous monitors (2 with power, 1 without power). 4 sites with Anderson samplers, high vols. and dustfall buckets. (no power) 1 additional TSP site (no power) 6 additional dustfall sites 4 temporary SO ₂ bubbler sites located at 4 hospitals (some power)
BAHRAIN		2 sites
QATAR		3 mobile monitoring sites
IRAN		unknown
IRAQ		unknown

The analytical laboratory at King Fahd U.P.M. has recently been provided the above procedures to permit a self assessment of their equipment availability to conduct these detailed analyses. Currently, the K.F.U.P.M. is conducting experiments on PAH's analysis of high volume filters as a first step in this programme. K.F.U.P.M. has not had any experience with PUF, VOC canister analysis, or PM₁₀ sampling and analysis. They can expand their current analytical capability to provide support to the proposed network.

The analytical laboratory of Saudi ARAMCO as with MEPA has had no experience in collecting and analyzing PM_{10} samples, PUF, and canister samples for VOC speciation and PAHs.

In summary, the current level of technical competence within all of the facilities visited, MEPA, King Fahd U.P.M., Saudi ARAMCO, and Kuwait, indicates that upon the procurement of additional equipment, standards, and training, they all could support the sampling and analysis required for this programme.

A substantial number of meteorological measurement sites exist within the eastern province of Saudi Arabia and the nations of the Gulf Region. Most of those sites are along the shoreline of the Gulf. ARAMCO operates 14 sites with meteorological data. Eight of those sites have collocated air quality measurements. Three of those sites are over the Gulf waters on platforms or on an island. MEPA (Saudi Arabia) has five sites with collocated air quality measurements. In addition, there are surface observations collected at many of the airports throughout the Kingdom. Surface meteorological data are being collected at other Gulf region locations. Their locations may be identified through the WMO publications. Previously, there were other surface measurement sites within Kuwait but their operational status remain unknown at this time.

Two upper air balloon sounding sites are operating within Saudi Arabia. One site is at Dhahran and the other is about 115 miles to the southwest of Kuwait City at Al Qaysumah. Twice daily soundings are collected at those locations, at 0000 and 1200 GMT. Prior to the war in Kuwait, twice daily upper air soundings were made at the Kuwait International Airport. The resumption of those soundings could be of substantial benefit to describing the airflow across the areas of Kuwaiti oil fires.

2.2 <u>Meteorological Observations</u>

The following summarizations are based upon first hand observations of the smoke plumes and fires. Those observations were made during overflights and during vehicle traverses both within the oilfields and along roads outside of the burning oilfields.

For any given day, the prevailing large-scale meteorological pattern will be the main driving feature which determines where the smoke plumes will be located and how dense they will be.

Individual smoke plumes appear to act in manners typical of buoyant plumes from ground level sources or plumes from short chimneys. Plume rise, the development of a bent-over plume geometry, etc., seem to apply to the individual well-head fires; some have jets of fire and others are nearly surface based burnings of the more combustible fractions of crude oil spread across the ground in the vicinity of the well. Most of the fire plumes rise to between 150 to 300 feet above ground level before becoming mostly bent over, although some plumes have a significant amount of smoke remaining within a few hundred feet of the ground.

Collectively, as groups of multiple fires within oilfields with a high density of burning wells (particularly Greater Burgan), they assert a meteorological influence of their own. It is suggested that the grouping of fires with a horizontal diameter of 25 to 40 km provides enough of an intense "heat-island" that significant additional vertical rise of the smoke occurs inside the area. That additional plume rise lifts smoke to elevations often 1000, 1200, to 1500 m above ground within the initial few miles downwind. Eventually, portions of the smoke rise even more, with multiple layers often forming at heights up to 2400, 2700, 3600, to 3900 m. Between such layers and at the tops of layers many tens of miles downwind, a generally diffuse and homogenous zone of smoke has been observed. The eventual smoke height limits are bounded by the regional vertical temperature structure and synoptic weather characteristics. Information reviewed to date suggest that those maximum heights are mostly 2400 to 3600 m within the initial 150 to 300 km downwind from the Kuwaiti oilfield fires.

With the creation of a local heat-island, a distinct inflow of near surface air has been observed within the initial 500 to 1000 feet above ground level. At times, that inflow of wind is estimated to be 5 to 15 m/s in strength. Smoke plumes at the peripheral bounds of the burn area tend to slant inward toward the centre of the burning field instead of pointing downwind with direction of the expected ambient wind.

Local variations in daily wind flow, along with the fire-storm like winds, are likely to produce preferred locations and times of day at which more concentrated smoke plume exposures reach ground level. Prevailing winds are from the northwest throughout the year. During the daytime a sea breeze can be expected to develop at the Gulf shoreline and progress inland as the day progresses. That inflow of air can readily clear out the smoke plumes and yield substantially cleaner air at ground level on the Gulf side. Along the leading edge of the sea breeze front there likely may be a zone of extended and elevated exposures to fire effluent. That zone may well extend down the shoreline from Kuwait City some 100 km. The area of greatest susceptibility appears to be to the southeast of fires in the Al Ahmadi oilfield (part of the greater Burgan field).

2.3 Data Base Management

In addition to evaluating the existing air monitoring networks, the Team made an initial review of existing data systems to handle the air monitoring data. The previous meteorological, air quality, and visual observations of the oilfield fire plumes should be archived, along with data to be obtained during the period of on-going Kuwaiti fires. A dedicated facility for the performance of that archiving does not appear to exist. The data management task is likely to be a sizeable task and extend a period of a year and more.

Some of the general functional needs of the data management system include the following. The data which will need to be assembled into the data base will likely come from many different sources and exist in diverse formats and media. One role of the data base management activity will be to assemble all information into a common, uniform structure. The second and equally important part of the data archiving is the provision of a uniform and consistent mechanism for the retrieval of data by participating agencies. The degree to which that data base is well formulated, will significantly affect the efforts of users of the data as they attempt to study and interpret the measurements.

A number of possible methods exist for the set-up of a computerized data base. Commercial software and hardware of various degrees and complexity and cost exist which would satisfy the data management needs. Before the choices of system software and hardware are made, the functionality of the overall system and the manners in which users work with the data sets should be considered. For example, it may be required that the data base be a "relational" data base. Other sources of software that might be used to handle a large volume of data would be the U.S. Environmental Agency's (USEPA) Aerometric Information and Retrieval System. That system can handle hourly data and has considerable software available to both summarize and analyze the ambient air data.

MEPA has asked the Team to recommend the type of computer and associated software needed to manage the data collected in order to implement the monitoring plan. For now, it is more appropriate to defer specific recommendations. A number of general performance characteristics may be stated but specific details should be formulated in conjunction with data base specialists at a later date.

3. RECOMMENDATIONS

While preliminary, the Team believes that the following recommendations should be implemented based on our initial data gathering exercise. A general objective is listed as a recommended goal and below that objective are listed several needed items or activities to facilitate the achievement of the overall goal.

Objective 1

Provide a framework for an early warning advisory capability for areas expected to be impacted by effluents from Kuwaiti oilfield fires.

Needs:

- Meteorological data observations and forecasts;
- Visual observations from key receptor areas;
- Review existing monitoring data;
- d. Calculate smoke trajectories and concentrations.

Objective 2

Provide a cursory wide-area indication of the distribution and composition of the Kuwaiti oilfield fire effluents.

Needs:

- a. Establish 15 to 20 PM₁₀ monitoring locations using portable monitors:
- b. Train personnel in the operation of the portable PM₁₀ monitors and develop the analytical support capability within Saudi Arabia and Kuwait;
- c. Define the PM₁₀ to TSP ratios;
- d. Define the composition of the plume by XRF analysis for metals, and GC-MS analysis for limited organic identification;
- e. Establish a central media preparation and analysis location;
- f. Define the baseline contribution of the ambient aerosol from the surrounding desert.

Objective 3

Characterize the aerial smoke plume.

Needs:

- a. Collect by fixed or rotary winged aircraft many of the same plume measurement's recommended for the ground monitoring array;
- b. Correct descriptions of the width and vertical extent of the smoke plume at several downwind distances;
- c. Characterize the regional background by samples outside of the smoke plumes.

Objective 4

Develop a more complete profile of the smoke plume constituents

Needs:

- a. Procure equipment for a limited number of comprehensive air quality monitoring stations to collect: TSP, PM_{10} , organic, and inorganic constituents;
- b. Establish a limited number of comprehensive air quality monitoring stations to collect: TSP, PM₁₀, organic, and inorganic constituents. These should be collocated with the continuous monitors wherever possible;
- c. Train individuals to operate and maintain the sampling instrumentation in support of the monitoring programme;
- d. Procure the necessary analytical laboratory equipment required for analyses of the samples collected under this objective;
- e. Train laboratory personnel in the preparation of the sampling media, QA/QC procedures required and the subsequent sample analytical procedures.

Objective 5

Determine the need for expansion of the monitoring network to a wider regional coverage.

Needs:

- a. Review the data developed from the limited network;
- b. Assess the current and projected status of control of the oilfield fires and emissions;
- c. Review the population health survey statistics;
- d. Review the suitability of the sampling strategy, and modify where needed;
- e. Expand the limited network as the situation requires, data analysis indicates an additional need for data.

Many of the same considerations listed for air quality above also apply to meteorological considerations.

<u>Objective 6</u>

Provide a meteorological data stream to facilitate the modelling and prediction of areas expected to be impacted by effluents from Kuwaiti oilfield fires.

Needs:

- Upper air balloon sounding data representative of the Kuwaiti oilfield fire area and Gulf region plume transport;
- b. Supplemental surface based measurements of wind speed and direction, temperature, moisture content of the air (dew point, relative humidity, etc.), solar radiation, atmospheric pressure, precipitation.

Objective 7

Provide a meteorological data set to investigate the areas of climate modifications occurring due to effluents from Kuwaiti oilfield fires.

Needs:

- a. Supplemental surface based measurements diffuse and direct solar radiation;
- b. Special collections of precipitation throughout the region to examine the pH and chemistry of the rains;
- c. Aircraft soundings and profiles of smoke, winds and temperatures, air quality related measurements of plume compositions and concentrations representative of the Kuwaiti oilfield fire area and Gulf region transported plumes.

4. PHASED AIR MONITORING PLAN

This section of the report discusses a prioritized plan of stepwise incremental actions for the phased implementation of the recommendations discussed above. Five phases for implementing the plan follow.

4.1 Phase 1. Provide a Framework for an Early Warning Advisory

In order to accomplish this task, the following action items need to be initiated or incorporated into the task framework.

- Gather daily weather forecasts to predict meteorological conditions which would effect pollution potential in both Saudi Arabia and Kuwait;
- 2. Use visual observations from key receptor sites to determine possible pollution levels:
- 3. Gather existing air monitoring data from fixed and mobile sites operated by MEPA, Saudi ARAMCO, and the governments of Kuwait and Bahrain to develop a data base of existing data;
- Establish a daily briefing for representatives of the many entities concerned with behaviours and fate of the aerial effluents from the oilfield fires in Kuwait;
- 5. Develop a daily map depiction of the aerial distribution of the smoke plumes across the region using satellite imagery, for each day since initiation of the oilfield fires;
- 6. Issue a daily general statement about the expected behaviour(s) of the oil fire plumes. Areas of potentially adverse conditions could be treated as locations for which advisories would be issued;

- 7. Provide forecast meteorological conditions across the region for the next 2 to 3 day period, including the expected location(s) of the smoke;
- 8. Obtain data from the MEPA network throughout the eastern province;
- 9. Direct the crews of the SLAR aircraft (USCG Falcon Jet) to continue on a regular basis the present visual observation and mapped notations concerning the horizontal extent of the smoke plumes and the estimations of altitudes of layer bases and tops;
- 10. The above information could be compiled initially in hard copy form. Later it should be stored on electronic media in a way that an existing PC data management system could readily incorporate it.

4.2 Phase 2. Establish a PM₁₀ Monitoring Network Using Portable PM₁₀ Monitors

Working in conjunction with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA), the proposed plan has been developed to collect information on PM_{10} , which represents particulate matter with particles less than 10 microns in diameter. At the present time there is no PM_{10} monitoring in the Gulf region.

OBJECTIVES

The objectives for this effort are as follows:

- Determine the magnitude or the health threat to residents of population centres and field-based military personnel impacted by the oilfield fires and typical sources (windblown desert soils);
- Establish a scientifically based capability to alert these affected populations prior to the onset of the potential health threats from real-time measurements;
- 3) Establish a technical basis for executing predictive air quality dispersion models which simulate the oil well fire emissions, background sources, and consequent impacts over space and time;
- 4) Establish a regional network of PM₁₀ stations using a consistent monitoring methodology across the countries of Saudi Arabia, Kuwait, and Baḥrain;
- 5) Train personnel to operate and analyze the media produced by the network from each of the participating countries;

6) Develop a regional data base and encourage the sharing of data developed from the network with all participants;

The above objectives convert the foregoing goals into discrete actions:

- Determine the spatial temporal frequency, and severity of the impact to the resident populations and military centres affected through the application of saturation sampling techniques with portable PM₁₀ samplers;
- Establish the correlation of real-time surrogate monitoring data to data generated from direct sampling methods through the collocation and simultaneous operation of both methods over time;
- 3) Where possible use impact data collected from samplers as an input to the dispersion model, run the model "backwards" to develop a better estimate of the emission rates of the fires and produce a higher level of confidence in the predictive modelling results;
- 4) Obtain from the literature and/or develop from source sampling analysis chemical profiles of all major pollutant sources in order to:
- a) Identify those contaminants that pose the greatest health concerns and to develop an estimate of acceptable ambient levels (AALs) prior to the conduct of field work,
- b) identify the chemical "signature" of the major contaminants and other tracers characteristic of the primary sources,
- enable apportionment of these contaminants and other tracers compounds from a simple total mass concentration measured by the ambient samples, and
- d) attempt to relate these levels in turn to the surrogate real-time monitoring methods for use in issuing timely health risk alerts;
- 5) Ensure that the data generated by the network are of a demonstrably high quality (precision & accuracy), completeness, representativeness, and comparability.

APPROACH

Conduct a PM_{10} saturation sampling study to determine the temporal and spatial features of the impact of the oil well fires and attempt to reconcile the data with existing model estimates. PM_{10} mass concentrations would be available within 24-48 hours following sampling. No on-site meteorological, gas, or aerosol monitoring or chemical analysis is required (chemistry could be attempted later on the preserved media). One or more portable nephelometers would be collocated at several sampling sites to develop correlations between manual and continuous (real-time) methods for alert advisories.

A total of 15-20 portable PM_{10} samplers equipped with quartz filters would be run simultaneously on a daily basis or "triggered" (impact forecast) basis throughout the study area. Network design would involve a "nested" approach to address the objectives:

- samplers sited at background locations (not impacted) by the smoke plume and samplers in populated areas;
- 2) samplers in populated areas impacted by smoke.

Samplers could be "ganged" (2 or more) and programmed to run consecutively at individual sites if filter clogging problems occur because of high loading. Further, multiple samplers could be collocated at certain sites to collect fine particles (less than 2.5 microns) and coarse particles (2.5-10 microns) on teflon sample filters (facilitating XRF elemental analysis). One of the 10-12 sampling sites would be equipped with duplicate samplers in an effort to develop sampling precision estimates.

This comprehensive programme will yield the following:

- short turnaround PM₁₀ concentrations;
- 2) gross estimates of the fire-specific contributions to total mass could be derived by subtracting background concentrations from the impact site concentrations;
- applying assumptions on the source profiles to pollutant loading attributable to the well fires, estimates of individual target compound loadings could be computed and a comparison to AALs made;
- 4) correlations factors can be determined between real-time surrogate methods and manual methods, and
- 5) impacted sampling media would be available for subsequent intensive chemical analysis in an attempt to reconcile assumed source signatures and extracts can be used to perform any other analytical tests (mutagenicity). Special precautions may be needed to preserve the sample integrity during storage and transfer.

<u>Limitations</u>: potentially, no on-site meteorological data to calculate emissions rates, no on-site chemistry (unless developed) to confirm critical assumptions, and no concurrent gas or acid aerosol measurements to evaluate or correlate with the particulate data.

Resources: 1-2 professionals, 1 field technician per site, if it must be operated individually (actual number contingent upon the network logistics and potential "clogging" implications), portable PM_{10} saturation samplers, portable nephelometers, lap-top computer, microbalance, expendables and sundry support gear.

In summary, this approach is PM_{10} mass data- and assumption-rich which must be reconciled with a poor and broad pollutant characterization.

SAMPLING AND ANALYTICAL METHODS

The alternate approaches identified above involve the use of a variety of sampling and analytical methods summarized below:

Portable PM10 Saturation Samplers

- segregate and capture of filter, particles of 10 micron size (respirable particles) and smaller;
- battery-operated, lightweight, rugged, inexpensive, small, and quiet;
- easily deployed and operated;
- programmable timer for unattended on and off;
- rechargeable battery packs;
- continuous operation up to 30 hours on a single charge;
- precise and accurate;
- low detection limit of approximately 5 μg/m³
- sustained operation under high particulate loadings, e.g. 1000 µg/m³ or more;
- electronic sample flow regulation;
- electronic sample flow totalizer;
- low flow shutoff/warning;
- can accept a variety of other pollutant sampling media (e.g. PUF, DNPH, charcoal, denuders, etc.) or take whole air samples (Tedlar bags) with little or no modification.

Portable Nephelometers

- many of the same attributes of the PM₁₀ saturation sampler;
- battery operated;
- effectively measure particles of 1 micron diameter or smaller;
- continuous reading, storing five minute averages;
- rechargeable;
- continuous operation from 24-48 hours on a single battery charge;
- internal storage for up to nine days of sampling data;
- data download to a portable lap-top computer through RS232 serial port;
- operationally equivalent to standard nephelometers.

Microbalance

- five to six place balance;
- rugged, transportable while precise and accurate.

Field XRF Unit

- similar MQLS with in-situ laboratory units;
- rugged.

Support Gear

calibration and audit gear, tools and diagnostic equipment, etc.

PROPOSED NETWORK DESIGN

The recommendation for siting of the portable PM_{10} samplers is predicated on providing a large area of coverage for developing a better estimate of the areas impacted by the plume, a cross-sampling of population and troop centres, and to provide the opportunity to transfer this technology to Saudi Arabia, Kuwait, and Bahrain.

SAUDI ARABIA

- collocated site at K.F.U.P.M. (2 sites);
- two sites in Riyadh (1 U.S. Embassy & I MEPA location);
- one site collocated with one of the Royal Commission for Jubayl and Yunbo sites;
- one site Saudi ARAMCO at Tanajib;
- one site MEPA at Khafji.

Total of seven (7) sites.

KUWAIT

- three sites (3) located at the two operational continuous monitoring sites within Kuwait City (one site collocated);
- one site at Camp Freedom;
- One site U.S. Embassy;
- One site Al-Ahmadi (Kuwait Oil Company Hospital).

Total of six (6) sites.

CENTCOM

two sites at selected troop locations.

Total of two (2) sites.

BAHRAIN

one site to be determined.

Total of one (1) site.

A total of sixteen samplers are committed to field sampling with the remainder as spares or as changes to the sampling plan dictate.

DATA MANAGEMENT

The data base created by this special PM_{10} network could be stored and analyzed using existing PC software.

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4.3 Phase 3. Characterize the Aerial Plume.

This phase should follow closely with Phase 2, in order to characterize the 3-dimensional nature of the smoke plumes from the fires in Kuwaiti oilfields. To achieve that goal, many of the same plume measurements collected by the existing and proposed ground level measurement locations should be provided by the aerial sampling platform. Obviously, the longer time integrated samples (e.g., 24 hour total values, averages, etc.) cannot be reproduced by aircraft borne devices. Short-term and across plume integrated measurement descriptions may be obtained to characterize the spatial extent and details of actual constituents of the elevated portions of the oil fire plumes.

The aerial sampling activities may be separated into measurements which address the three general zones of plume characteristics, from a meteorological sense. Those zones are the 1) close—in zone, 2) intermediate or transition zone and 3) extended or distant zone. Measurements very near the wellhead are difficult to impossible to obtain due to excessive heat and great levels of turbulence. Measurements at intermediate distances will be difficult and many locations within the clustered groups of burning wells may be unsafe for aerial traverses due to the extremely dense smoke and hidden turbulent plumes. Measurements at the longer distances, a few miles downwind of the last burning wells, should be possible. Measurements from a few to several hundred miles downwind of the fire area should be feasible. Within that distance range the approximate concentrations, plume dimensions, and estimated mass flux in the downwind directions may be approximated. The aerial sampling strategies should concentrate on the obtaining of those types of information.

4.4 Phase 4. Develop a Complete Profile of the Smoke Plume Constituents.

Obtain additional equipment to expand existing continuous monitoring high priority sites in Kuwait and Saudi Arabia

The survey conducted by the Team during Phase 1 of this plan indicated that within the region, respirable particulate sampling technology, aerosol and total particulate sampling and analysis for volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), and PAHs were either not available or insufficient to properly characterize the effects of the oil well fires on the population centres and the troop concentrations within the region.

This phase of the plan proposes to bring into the region several new technologies and to train personnel within the region to operate samplers, to condition, and analyze the several new media necessary to support this expanded network. The objective of this process is to develop a stand-along capability within each participating country for aerosol and particulate monitoring which will support the Gulf regional air quality characterization and index plan outlined in Phase V.

During this phase of the plan the Team proposes to expand the continuous air and meteorological monitoring currently being conducted within the region at six sites. These sites are recommended based on the need to jointly develop the sampling and analytical capability within the region to ensure that it becomes self-sufficient and sustainable. The particular technologies outlined below are not currently operated within the region nor are the analytical procedures required to support them currently being utilized. However, the Phase I survey indicates that with sufficient training, additional equipment, and some experience with actual field samples the transfer should be relatively smooth.

Initially, the Team's recommendation of six strategically placed sites along the axis of the area of greatest impact by the oil well fire plume will generate sufficient samples for the required training, while also providing critical data not currently being collected by the existing networks or available through the portable PM₁₀ network proposed in Phase II. As this data base develops it can be used to better define the constituents of the plume and thus permit a more accurate assessment of the potential long-term health risk.

The equipment listed below should be collocated with the full compliment of continuous air and meteorological monitors described in Phase V at these six proposed sites. A brief description of the equipment is provided below:

- TSP High Volume Sampler used to collect a 24-hour sample of the total suspended particles, operated nominally at 50 CFM, and typically uses 8x10 inch glass fiber or quartz filter media;
- PM10 High Volume Sampler used to collect a 24-hour sample of the 10 micron and smaller sized fraction of the TSP sample collected by the TSP sampler above, sampler is typically operated at 40 CFM, and utilizes an 8x10 inch Quartz or teflon filter media. Note: glass fiber media should not be used if there is concern for a known sulfate artifact formation problem;
- PM₁₀ Manual Dichotomous Sampler used to collect a 24-hour sample of the 10 micron particle size fraction of the TSP, sampler operates at 16.7 liters/minute, and utilizes two (2) 37 mm diameter Teflon filters to collect a fractionated sample with a cut point of 0-2.5 micron (fine fraction) and 2.5 10 micron (coarse fraction);
- VOC Canister Sampler used to collect up to a 24-hour integrated whole air sample in six-liter evacuated stainless steel canisters, interior walls are passivated to minimize sample degradation, samples volume can be regulated by either limiting the volume to ambient pressure or pumping in addition sample to

an approximate volume of 16 liters, these samples can be used for the determination of total hydrocarbons or analyzed for specific hydrocarbons, multiple analysis are available from a single pressurized canister sample. Note: An extensive canister cleanup process is required prior to the collection of additional air samples;

- Polyurethane Foam (PUF) Low Volume Sampler used to collect 24-hour aerosol samples utilizing small AC or battery operated pumps at flow rates less than five liters per minute on relatively small glass cartridges containing a PUF plug, these samples can be extracted and analyzed for PAHs, or other SVOCs. Note: Both the glass cartridge and PUF plug require an extensive cleanup procedure prior to re-use;
- Optional Tenex/Charcoal/XAD-2 tubes these media can be used with same type of low volume pumps described above to collect additional samples for further definition of the constituents of the plume for SVOCs.

Organic compounds will be present in all three phase distributions (particle bound, SVOC, and VOC) and each phase will have to be sampled and then a determination will have made as to importance of each.

The particle bound phase can be collected for extractible organic analysis from both quartz, teflon impregnated glass fiber filters, or teflon.

The SVOC phase can be collected on PUF and within the canister. The VOC phase can be collected with canisters and charcoal tubes. Employment of Tenex and XAD-2 sampling tubes in conjunction with PUF, charcoal tubes, and canisters in an overlapping sampling matrix, can be used to confirm of the presence or absence of compounds which could be missed by a less complex sampling matrix.

PROPOSED LOCATIONS FOR THE INITIAL SIX EXPANDED SITES

The Team recommends that the six locations follow the general axis of plume drift from Kuwait City south into Saudi Arabia. It is further suggested that the operation of these sites be divided amongst the key network managers within the two countries: Kuwait, MEPA, and Saudi ARAMCO. This division of responsibility supports the philosophy to jointly develop both the sampling and analytical capability within all three entities.

Kuwaiti Locations

The Team recommends that two (2) of the sites be located at the existing operational continuous monitoring stations located in Kuwait City. A third site should be established in Al-Ahmadi at the Kuwaiti Oil Company Hospital. This location is situated within 300 - 400 m of several burning wells and is adjacent to the closest residential area associated with any of the oilfields.

Saudia Arabian Locations

The Team recommends that a site be established at King Fahd University of Petroleum and Miners (K.F.U.P.M.) in Dhahran, one site to be collocated with Saudi ARAMCO site in Tanajib and the last site should be established by MEPA in Khafji.

Phase 5. Develop Regional Air Monitoring Network to Track the Impact of the Kuwaiti Oil Fires on the Gulf Region.

This phase of the proposal will be developed in series of stages. The network is directed at long term fixed site monitoring, which will collect a battery of both air quality and meteorological data that would satisfy the objectives identified in this report. Particular attention will be given to providing an early warning system advising the effected public on what cautionary steps should be taken to minimize the impact of air pollution on health. It is proposed that the early warning system will be modelled after the air quality index used in the U.S.A.. The second focus will be directed at tracking the air pollution problem over time to be used in determining both long term health and ecological impacts due to the Kuwaiti oil fires. The data base will provide information to develop key policy decisions which could minimize the possible health and ecological impacts.

RECOMMENDED MEASUREMENT PARAMETERS AT EACH SITE

The basic plan is for each site within the regional monitoring network to consist of the same types of measurement devices. Deviations for that general consistency will be addressed on an individual basis. Two general categories of information are proposed for every location. Data measurement are grouped into either meteorological or air quality categories.

a. Meteorological variables

The nominal set of meteorological measurements to be collected at each site are the following:

Wind speed and direction (at 10 m);
Temperature;
Moisture content of the air;
Dew point, relative humidity, or wet bulb;
Solar radiation;
Precipitation (saved for chemical analyses, pH, etc.).

b. Air quality variables

The nominal set of air quality measurements to be collected at each site are the following. Two general categories of collection needs exist. The first set of needs relate to the onset of episodic levels of airborne concentrations. In those situations a need may be developing for an early warning advisory for downwind population centres. The second set of needs relate to the need to monitor for longer term, more subtle risks.

Episodio	:/EARLY WARNING measurements	Longer term monitoring
PM ₁₀ TSP	(continuous)	Acid aerosols VOCs
SO ₂	(continuous)	Aldehydes
О3	(continuous)	BaP, other PAHs
NOx, NO	(continuous)	Trace elements
CO	(continuous)	Fine particles
H_2S	(continuous)	

c. Health Monitoring Survey

Air monitoring data collected through the proposed air monitoring network will provide basis for interpreting the results of health surveys of the populations and ecosystems potentially effected by the effluents from the oil fires in Kuwait. The kinds of health data that could be collected include:

TABLE 2 - Location of existing air meteorology monitoring stations

NATION	ORGANIZATION	LOCATION	STAGE OF PLEMENTATION
SAUDI ARABIA	MEPA	Damman	1
		Hofuf	2
		Tanagib (Mobile Site)	ī
		Riyadh	1 .
	Saudi ARAMCO	Udhailiyah	3
		Shedgum	3 .
	•	Abqaiq	3
		Dhahran	2
	•	Tartut	2
		Rahimah	2
		Juaymah	1
		Tanajib	1
		Safaniyah Oilfield (met. only)	`3
		Marjan Oilfield (met. only)	3
		Abusafahs Field (met. only	
	The Royal Commission for Jubyayl and Yunbo	Cluster of 5 stations in Jubyayl	1
KUWAIT		Mansoria	
NUWALT		mansoria Rabia	1
			1
		Rega	1
QATAR		3 mobile units, unknown locations	2

Health questionnaires;
Blood samples;
Urine samples;
Hair samples;
In-vivo animal studies;
Forced expiratory volumes;
Other morbidity parameters.

Distribution of Proposed and Existing Air Monitoring Sites

Table 2 lists the location of the existing and proposed air monitoring sites, while Table 3 lists the locations of the proposed air monitoring sites. In order to complete the network in an orderly manner, it is proposed that the network be developed in several stages. The first order of business would be to upgrade key existing monitoring locations so that there exist a full complement of air and meteorological monitoring equipment, as well as add new critical air monitoring sites (Stage 1). The second stage would be to establish those sites that would satisfy the minimum requirements for tracking the plume caused by the oil fire and to provide an early warning system for Saudi Arabia, Kuwait, and Bahrain (Stage 2). The third and final stage would be to complete the final network following a review of the quality and quantity of findings to date (Stage 3).

5. SUMMARY

The initial measurements made by the Team suggest that there is not an imminent threat from SO_2 and H_2S to the urban populations, while short-term measurements of particles are frequently high. Historically, this region has high particulate levels due to wind blown dust. The particulate measurements that were collected by the Team reflect total particles, as opposed to respirable particles, that is PM_{10} . There has not been a principal focus in the Region on total particles, PM_{10} , and organics up to now. Therefore, the Team developed the five phased monitoring plan with an emphasis on better understanding particulates and the aerosol organics associated with the oil fires in Kuwait. Particulates and organics could be a source of concern for both health and ecological effects.

The air monitoring proposals presented in this report represent the Team's collective judgement on what needs to be done. Those judgements are based upon an on-site evaluation of the situation in Kuwait, discussions with officials from the Saudi Arabian MEPA, Kuwait, Saudi ARAMCO, and the King Fahd University of Petroleum and Minerals. Needless to say more work is needed regarding data management, statistical design, data analysis and quality assurance. Because of the complexity and immediacy of this problem, an extended time commitment will be needed on the part of all Gulf nation agencies to achieve the objectives outlined here.

TABLE 3 - Location of proposed air meteorology monitoring stations

NATION	ORGANIZATION	LOCATION	STAGE OF IMPLEMENTATION
SAUDI ARABIA	MEPA	Awiyah	3
		Shumlul	2
		Sarrar	2
	•	Nuayriyah	2
		Lisafah	3
		Hafar al Batin	1
		28°6' N	2
	-	47°51' E	
•	•	28°30' N	1
		48°1' E	
		28°55' N	1
		47°32' E	
		29°7' N	1
•		46°39' E	
KUWAIT		Mina Saud	1
		U.S. Embassy	1
		Al Ahmadi (Hospital)	1
		International Airport	1
		29°23' N	2
		46°55' E	
		29°50' N	2
		47°15' E	
		30°4' N	2
		47°42' E	
		29°33' N	2
		47°50' E	
BAHRAIN		Mina Manama	2
		Bahrain University	2
QATAR	•	Doha	3
UNITED ARAB		Abu Dhabi	3
emirates		Dubai	3
NAMC		Muscat	3

ENVIRONMENTAL IMPACT OF OIL BURNING IN THE KUWAITI OILFIELDS - A PRELIMINARY EVALUATION

Prepared by

The Research Institute
King Fahd University of Petroleum and Minerals
Dhahran, Saudi Arabia

and

Meteorology and Environmental Protection Administration Jeddah, Saudi Arabia

For Presentation

at the

EXPERT MEETING ON THE ATMOSPHERIC PART OF THE EMERGENCY RESPONSE TO THE KUWAIT OILFIELD FIRES THE WORLD METEOROLOGICAL ORGANIZATION (Geneva, 27-30 April 1991)

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SUMMARY

It was reported in the second week of February 1991 that about 200 oil wells were put on fire in Wafra, Umm Gudair, Minagesh Burgan, and Romeilla oil fields in Kuwait. These numbers increased to above 600 by February 24 with the addition of more wells on fire in Raudhatain, Sabriya, and a large area of Burgan oil-fields. It is estimated that approximately 2.5 million barrels of crude oil and 35 million cubic meters of associated gases are on fire emitting approximately 20,000 tons of sulfur dioxide (SO₂), 1500 tons of particulates, 250 tons of carbon monoxide (CO) and 500 tons of oxides of nitrogen (NOx) to the atmosphere on daily basis. In addition to these, tons of toxic metals and carcinogenic elements are also being released into the atmosphere.

The above pollutants in high concentration may cause serious health problems. So far the measured concentration of these pollutants in major cities in Saudi Arabia have been found within the permissible limits as recommended by MEPA. However, simulation study shows very high concentration of these pollutants, particularly SO₂ in Kuwait City, Mina al Saud, Mina al Ahmadi, and Bubayan and Faylakah islands. Depending upon wind direction and wind speed, high concentration of SO₂ has been estimated few times in cities such as Khafji, Safaniyah, and Basrah. Since it may take several months to extinguish these wells, it is important to understand the impact of these pollutants on human health.

In order to assess the environmental impact of burning of oil wells, both modelling and monitoring programs have been initiated by the Research Institute at King Fahd University of Petroleum and Minerals (KFUPM/RI). The Institute, in addition to its own monitoring program, has also been compiling ambient air pollution data from various sources such as Saudi ARAMCO, Royal Commission for Jubail and Yanbu, and the Meteorology and Environmental Protection Administration (MEPA).

This report summarizes various activities being conducted by KFUPM/RI in collaboration with the Meteorology and Environmental Protection Administration (MEPA), US Air Team, Ministry of Health, and Saudi Arabian American Oil Company (ARAMCO).

INTRODUCTION

Burning wells in Kuwait are producing large amount of gases such as sulfur dioxide, carbon monoxide, hydrogen sulfide, carbon dioxide, and oxides of nitrogen as well as particulates containing partially burned hydrocarbons and metals, all of which have a potential for affecting human health and vegetation growth. Particularly harmful gases are sulfur dioxide and the nitrogen oxides. Photochemical reactions between the nitrogen oxides and hydrocarbons produce oxidants of secondary pollutants which may also affect vegetation.

The chronic effects of the air pollutants increase the death rate among the elderly and chronically ill people. The moderate effects may cause increase of prevalence of eyes and respiratory irritation. Epidemiological data suggests an association between increased concentration of SO₂ and particulate matters. Sulfur dioxide, being a very soluble gas, is absorbed in the nose and upper airway while breathing which, in turn, produces increased airway resistance in the lung. High doses of SO₂ i. e. 2 to 5 ppm (5200 to 13,000 micrgram/cum) may cause severe impairment of lung functions. In some cases, a healthy person without any previous history of asthma may develop a moderately severe attack of the disease. Chronic cough and mucus secretion may result from repeated exposures.

Of several oxides of nitrogen present in the ambient air, only two are known to affect human health. These are nitric oxide and nitrogen dioxide. These oxides, if transferred across the lung-blood barrier, can produce inactive forms of hemoglobin. It is estimated that eye and nasal irritation will develop after exposure to about 15 ppm nitrogen dioxide and pulmonary discomfort will commence after brief exposure to 25 ppm.

Upon entering the respiratory system, carbon monoxide (CO) combines in the lung with hemoglobin in the bloodstream to form carboxyhemoglobin (COHb). This reduces the capability of hemoglobin to carry oxygen to the body tissue.

Sulfur dioxide concentration above 0.5 ppm for a maximum exposure time of three hours may cause visible injury in most temperate crops. Atmospheric sulfur dioxide

can enter leaves and can be absorbed by the roots. Prolonged exposure to high concentrations of sulfur dioxide can be lethal to some plants depending upon a variety of environmental conditions. Oil burning in Kuwait may cause an increase in atmospheric acidity. Photo-oxidation of sulfur dioxide is enhanced by the presence of moisture and results in the formation of sulfuric acid. Similarly nitrogen oxides may also contribute to acid rain. Should burning of the oil wells in Kuwait continues unabated for some time, adverse impacts on regional vegetation may occur.

Oil burning will release metals in the smoke. High concentrations of some of these metals, such as nickel and vanadium, are toxic to both plants and animals. The availability of toxic elements to crop plant may increase due to acidification of the soils through acid rain.

The release of huge amount of toxic gases and other oil hydrocarbon compounds into the atmosphere as a result of burning of the Kuwaiti oil wells, may result an adverse health hazard if the level of polynuclear aromatic compounds (PAHs) in the atmosphere increases. These compounds have both mutagenic and carcinogenic properties.

This paper summarizes various monitoring and modeling activities to assess the impact of the pollutants due to burning of well in the Kuwait oil fields.

REMOTE SENSING APPLICATION IN IDENTIFYING BURNING OIL WELLS

The image processing facilities at KFUPM/RI has been used in identifying the locations and number of burning oil wells in the Kuwaiti oil fields. Among the various oil fields, the Burgan is the largest one with more than 600 wells. The average daily production rate of each well is approximately 4,000 barrels. The National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (A VHRR) computer compatible tapes were received from NOAA/NESDIS, USA. These tapes were digitally processed at the Image Processing Center using the thermal infrared band 3 which is designed to record intense heat sources such as volcances and fires.

The fire at Greater Burgan increased slightly by January 29, 1991. On February 4, 1991, number of fires in Kuwait increased while on February 7, 1991, the fires at the Greater Burgan and Umm Gudair oil fields increased substantially. Fires reached peak on February 24 Landsat TM band 6 of February 23, 1991 showed more than 300 wells on fire in the Greater Burgan field.

Based on the information through satellite imagery processing and other sources, the number of wells on fire in different oil fields with their capacities were estimated about 600. Their locations, capacities, and distributions are listed in Table 1. Using US EPA emission factors for crude oil and associated gases (Ref. 1), the total emission of SO_2 , NO_x , CO, and particulates were compiled and listed in Table 2.

The total suspended air particulates collected in March 1991 using high volume samplers on three locations in the Eastern Province of Saudi Arabia (i.e. Dhahran, Tanajib, and Nuayriyah) were analyzed for toxic metal concentration and oil hydrocarbons including some carcinogenic organic compounds. The metals covered in this study were arsenic, cadmium, cobalt, barium, chromium, copper, manganese, lead, and titanium while the organic analysis was conducted mainly for the aliphatic hydrocarbons and polynuclear aromatic compounds. Metal concentrations were determined using Inductively Coupled Argon Plasma Analyzer (ICAP). The concentrations of arsenic were determined using hydride generation technique. The aliphatic hydrocarbons were analyzed using a Varian 6000 Gas Chromatograph (GC) equipped with FID detector while the polynuclear aromatic compounds were analyzed using HPLC system equipped with UV and fluorescence detectors.

The findings, although preliminary due to limited number of samples, are summarized below:

- 1. Samples collected from Nuariyah, a bordering city near Kuwait, contained relatively high concentration of most of the metals. Barium zinc, lead, and copper were found high in Dhahran samples.
- 2. The analysis showed that all of the air particulate filters were contaminated with the aliphatic and polynuclear hydrocarbons. Analysis carried out previously on particulate samples collected from the same locations showed significantly low concentration of PAHs compounds. It is worth mentioning that the levels of PAHs found on March 5, 1991 was much higher than those found on other dates.

The concentration of the total suspended particulates in March on 24-hour basis was found in the range of 50 microgram/cum to about 300 microgram/cum in Dhahran area.

Soil samples were also collected from different locations in March and April and were analyzed for nickel and Vanadium. The concentration of metals decreased with an increase in the distance from the border. Kuwaiti crude oil contains 10 mg/kg and 30 mg/kg of nickel and vanadium respectively. Atmospheric fallout from Kuwait oil fields seem responsible for distance — metal concentration correlation.

Real time measurements of various pollutants in the ambient air are being carried out on continuous basis in Dhahran, Abqaiq, Rahimah, Jubail, and Tanajib. By analyzing the measured values at these locations, no significant impact of the burning of oil wells in these areas has been observed. Other pollutants although not reported here, were much lower than their respective limits as specified by MEPA. The standard specified by MEPA are listed in Table 3.

Short-duration measurements were also carried out by the US EPA and British scientific team in Kuwait area and also in the plume. The highest SO2 concentration reported by these team was less than 2 ppm. MEPA has moved one of its mobile laboratories to the bordering Saudi cities for continuous monitoring.

MODELING ACTIVITIES

In order to assess the impact of burning of oil wells, the modeling activity has also been initiated. A number of available air pollution modelling packages were reviewed. The following two types of air pollution modeling packages are currently being used by the Research Institute:

UNAMAP's RAM Model

The institute has initiated the application of RAM (a multiple-point and area-source algorithm), a software within Users' Network for Applied Modeling (UNAMAP) to assess the impact of burning of oil wells in the Kuwaiti oil-fields. This package requires surface meteorological data on wind speed and direction, temperature, mixing height, and stability classes on hourly basis (Ref. 2-3).

The estimated concentration of SO_2 on 1-hourly and 24-hourly basis at the selected receptor points (cities) for the same period is listed in Table 4. These concentration values are compared with the standard specified by MEPA as listed in Table 3. Similar analysis is conducted on daily basis and the periodic status report is prepared and submitted th MEPA on regular basis.

2. ARL-ATAD Model

SO₂, once released to the atmosphere, is dispersed vertically in the mixing layer. Once SO₂ is completely mixed within the transport layer depth or mixing depth, further dilution in the concentration is due to horizontal dispersion; subsidence of

clean air into the mixing depth, and removal and transformation processes (Ref. 4). The removal of SO₂ due to dry deposition on the ground is related to the deposition velocity. The processes by which the removal of SO₂ under wet conditions occur are rainout and washout. Rainout is the absorption of airborne material within a cloud, followed by removal in rain. Washout is the removal of rain falling below the cloud base. Transformation of SO₂ to SO₄ take place during transport and due to dry and wet removal processes.

The methods of calculating the dispersion of SO_2 are, therefore, basically dependent on the factors such as the decay rate of SO_2 in dry and wet conditions, the rate of transformation of SO_2 to sulfates, and depth of mixing layer. These factors are usually not considered in a short-range steady-state modeling while the long-range transport models take into account some of these factors.

To trace the movement of plume from burning sites on long range basis, and also to estimate concentration and deposition of pollutants on regional basis (within and outside the Kingdom), we are planning to use another package called Air Resources Laboratory, Air Transport and Dispersion Model (ARL - ATAD) (Ref. 5). This model plots trajectories of the plume for a long duration originating from a number of sources. Each trajectory is calculated using transport winds averaged in a vertical layer. Dispersion calculations are also made from these trajectories. The trajectory position can be mapped. Time averaged surface air concentration and deposition amounts can also be calculated and mapped.

To run this model effectively, upper air data on wind speed, wind direction, temperature, and pressure are required on a number of locations at 6-hour interval. In the eastern part of Saudi Arabia, upper air data, at present, is collected only at Dhahran meteorological station at 00 and 12z. An other station in the northern part is Qaisumah where two launches a day are made. Based on the limited data on these two stations, it was not possible to use the model to draw trajectories and estimate concentration and deposition of the pollutants. It was, therefore, decided to retrieve information on upper air data from weather charts available for synoptic, 850 mb, and 700 mb pressure levels. These weather charts are prepared by the Meteorology and Environmental Protection Administration (MEPA) twice a day. MEPA office in Dhahran supplies these charts on daily basis. KFUPM/RI personnel have been trained by MEPA on how to read these charts and retrieve the desired meteorological

information. Eight locations in the Arabian Gulf region and in the Eastern Kingdom have been selected on which the information on wind speed and direction, temperature, pressure, and height are retrieved.

The use of ARL-ATAD model is demonstrated in Figs. 13 to 16 for a typical day in March, 1991 by tracing (a) the movement of smoke from the Kuwaiti oil burning sources in the form of trajectories originating at 00, 06, 12, and 18z, (b) estimating the transport layer depth with time for each trajectory, and (c) calculating the concentration of SO₂ at different locations with and without deposition option on daily basis, and (d) calculating the average deposition on the surface for a specific period.

CONCLUSIONS AND RECOMMENDATIONS

In this paper, the activities being conducted by KFUPM/RI in collaboration with MEPA, US Air Team, Ministry of Health, and Saudi ARAMCO are summarized to assess the impact of pollutants due to burning of oil wells in the Kuwaiti oil fields. The preliminary results presented in this report demonstrate the need of such research plan to study the behavior of the plume, its movement, decay of the pollutants with time, dispersion, and deposition with the distance and time, and long-term impact on human health and surrounding environment.

The results presented in this report are based on uncertainties in the source input data and climatological variables. For the effective use of the model, it is important to have reliable information on the chemistry of the source, burning efficiency, amount of oil being burnt from each oil well, and exact number of wells and their locations. In order to study the dispersion and deposition characteristics and to validate the model, it is equally important to intensify air quality and meteorological network in the gulf region. US Air Team has prepared a detailed plan on the intensification and the expansion of the Gulf regional air monitoring and meteorological network with emphasis on the collection of particulate sampling and development of database.

For more reliable prediction of the plume movement, plume rise, and the concentration estimates, the boundary layer variables should be estimated reliably. To

APPENDIX VI

accomplish this, ARL-ATAD model should be coupled with the planetary boundary layer model. Model should also be integrated with the general circulation model applicable in the desert conditions with the sea-breeze conditions in the coastal region.

ACKNOWLEDGEMENT

We are grateful to Saudi ARAMCO and Royal Commission for Jubail and Yanbu for supplying air quality and metrological monitoring data on regular basis. The technical support provided by the US Air Team is highly acknowledged.

REFERENCES

- 1. U.S. Environmental Protection Agency, 'Compilation of Air Pollutant Emission Factors' Second Ed. AP-42, Research Triangle Park, N.C., 1985.
- 2. U.S. Environmental Protection Agency, 'User's Guide for RAM Volume 1. Algorithm Description and Use, PB 294 791, Nov. 1978.
- 3. Novak, J.H., and Turner, D.B., 'An Efficient Gaussian-plume Multiple-source Air Quality Algorithm', J. Air Pollution Control Association, 26(6), pp. 570-575, 1976.
- 4. Fisher B.E.A., 'The Long-range Transport of Air Pollutants Some Thoughts on the State of Modeling', Atmospheric Environment, Vol 18, No. 3, pp. 553-562, 1984
- 5. Heffter J.L., Taylor, A.D., and Ferber G.J., 1975: A Regional Continental Scale Transport Diffusion and Deposition Model, NOAA Tech. Memo., ERL ARL-50, Air Resource Labs., Silver Spring, MD 2090, 29 pp.
- 6. Heffter J.L., 1980, Air Resource Laboratories Atmospheric Transport and Dispersion Model (ARL-ATAD), NOAA Technical Memorandum, ERI ARI-81, 24 pp.

Table 1: Data on Oil Fields, Well Capacity, and Associated Gases (based on February 24, 1991)

Oil Fields	No. of Wells Under Fire	Production Capacity of each Well in bbls/day	Associated Gas/Barrel in cubic meter	Total Oil Burnt in bbls/day	Total Gas Burnt in million cubic meter/ day
Wafra (P1)	25	350	14.14	8750	0.124
Romeilla (P2)	75	4000	14.14	300,000	4.242
Raudhatain (P3)	50	4000	14.14	200,000	2.828
Umm Gudair (P4)	. 50	4000	14.14	200,000	2.828
Bahrah (P5)	25	4000	14.14	100,000	1.414
Mina Gesh (P6)	50	4000	14.14	200,000	2.828
Burgan (P7)	350	4000	14.14	1,400,000	19.796
TOTAL	625			2,408,750	34.060

-12

SO₂ CO NO_X Particulates Due to Oil Burning 241 60 169 21,197 Due to Burning of Associated Gases 2.7 1,213 11 486 TOTAL 22,410 252 171.7 546

Table 2: Total Emission of Gases in Tons/day (based on February 24, 1991)

Table 3. MEPA air quality standards.

Averaging Time	Maximum Concentration	Exceedances
Sulfur Dioxide (SO	2)	
1 hour	730 µg/m³ (0.28 ppm)	twice a month
24 hours	365 'μg/m ³ (0.14 ppm)	once a year
1 year	80 μg/m³ (0.03 ppm)	(none)
Inhalable Particulat	es (IP)	
24 hours	340 µg/m³	once a year
l year	80 µg/m ³	(none)
Photochemical Oxid	ants (Defined as Ozone, O3)	•
1 hour	295 μg/m³ (0.15 ppm)	twice a month
Nitrogen Oxides (D	efined as Nitrogen Dioxide,	NO ₂)
1 hour	660 μg/m ³ (0.35 ppm)	twice a month
1 year	100 μg/m ³ (0.05 ppm)	(none)
Carbon Monoxide (CO) .	
1 hour	40 mg/m ³ (35 ppm)	twice a month
8 hours	10 mg/m ³ (9 ppm)	twice a month
Hydrogen Sulfide (H ₂ S)	
I hour	195 μg/m ³ (0.14 ppm)	twice a month
24 hours	40 μg/m ³ (0.03 ppm)	once a year
Fluorides (F-)		
30 days	1 μg/m ³ (0.001 ppm)	(none)

Source: MEPA 1402 H

Table 4: Simulated Values of SO₂ Concentration Using RAM Model (US EPA) (March 22; Hourly Met. Data - Jubail)

Name of City/	Highest	Time	Highest	
Town	1-Hourly		24-Hourly	
	(microgram/cum)		(microgram/cum)	
Dhahran	3	0900	. 0	
Jubail	9	0900	0	
Hofuf	4	0900	Ō	
Riyadh	10	1100	1	
Nariyah	27	0900	1 .	
Manifa	19	0900	1	
Safaniya	40	0900	2	
Khafji	170	0900	14	
Shedgum	12	0900	· 1	
Juraibiya	0	-'	0	
Bakr	0	-	0	
Jaladi	39	0900	2	
Fadhili	112	0900	2 5	
Jaham .	. 3.	1100	0	
Khurais	0 .	-	0 .	1
Abu Jifan	0 _	-	0	
M. Ahmadi	1770 *	0500	242	
Kuwait City	203	0900	8	•
Basrah	0	-	0	
Luhais	369 865* ₊	2400	20	
Zuluf	865 [*] _	0600	77	
Bubyan	1220*	0400	101	
Falaykah	306	0100	13	
Mina Saud	2691*	0800	176	
Marjan	705	0600	68	
Tanajib	70	0900	3	
Rastanura	0	-	0	•
Abqaiq	22	0900	1	
Sarrar	55	0900	2	
Nita	10	0900	. 0	
Mulayjah	10	0900	Ö	
Jararah	12	0900	1	
Al Ula	11	0900	Õ	
		-	•	

^{*}The concentration exceeded MEPA limit of 730 microgram/cum.

**The concentration exceeded MEPA limit of 365 microgram/cum.

REPORT ON U.K. AIRCRAFT MEASUREMENTS IN THE GULF

The MRF C-130 aircraft, based at Bahrain, arrived on 22 March 1991 and departed on 2 April. Seven successful flights were made into the oil plume, totalling 55 hours airborne, at a wide range of altitudes and different distances from Kuwait.

From helicopter flights into the middle of the burning oil wells, different modes of burning were observed; mostly thick black smoke, others white, and a few (presumably only gas) were clean.

C-130 measurements through the plume at about 100 km from Kuwait showed maximum concentrations (about 200 m altitude) of about 1000 ppb of SO₂; 50 ppb of nitrogen oxides, and nearly 30,000 particles of aerosol (0.1-10.0 microns diameter) per cubic centimeter. Ozone concentration is generally reduced close to source. Levels of sunlight are reduced to essentially zero; night-time lighting was required on the aircraft flight deck.

Filters of teflon or quartz were exposed on long booms wound out from the aircraft, and stainless steel bottles were filled with outside air; these await analysis in the U.K.

Further downwind, strong windshear often carries the top of the plume away to the northwest, with the remainder typically blowing down the west Gulf coast. At 100 km from source, the plume top is typically 3-4000 m high, with a base at 1000-1500 m. Here, enhanced levels of ozone are seen, but only up to about 80 ppb.

At distances of about 1000 km from Kuwait, aerosol particle concentrations were reduced to less than 1000 counts per cc, and only the very smallest particles remain suspended.

The mission was very successful in fulfilling its objectives, thanks in particular to the skill of the RAF air crew and the excellent co-operation from the authorities in Bahrain and other Gulf states.

SUMMARY OF THE U.S.A. INTER-AGENCY SCIENCE PLAN

PHASE I

The Phase I experimental goals for two research aircraft and their auxiliary support from satellite observations, forecasting and plume trajectory analysis are, in brief, as follows:

- To characterize the regional emission rates of smoke particles and trace gases.
- To measure radiative properties of the smoke particles, and the net radiative effects of the plumes, with attention to how radiation affects the altitudes of the plumes and the stability of the atmosphere.
- To measure characteristics of the smoke particles and determine if the particles have a hygroscopic component (or acquire such a component through chemical transformations) that would accelerate their removal from the atmosphere.
- To search for direct evidence that the smoke particles are scavenged in clouds, and to determine the effects of the smoke on the composition and radiative properties of clouds.
- To measure the chemical composition of the plume and determine how that composition changes with time. Such measurements will aid in developing estimates of the smoke's atmospheric residence time.
- To study regional weather anomalies associated with these smoke emissions.

The primary tools used to meet these goals are the research aircraft of the National Center for Atmospheric Research (Lockheed Electra) and the University of Washington (Convair C-131A):

- The Electra will be extensively equipped to provide smoke aerosol characterization, to study aerosol/cloud interactions, to measure (by a combination of in-situ and remote sensing) the regional mass flux of aerosols and trace gases, to detail the chemistry of the smoke and its alterations with time, and to examine the dynamical interactions of solar heating on the plume. With more than twice the range of the Convair and a superior service ceiling the Electra will devote extra effort to the aged plume and Eulerian experiments along great lengths of the plume.

The Convair, with a long history of studying large fires, is similarly equipped with special strengths in characterization of the smoke's optical properties, and the plume's spectral albedo. The use of grab samplers makes the aircraft especially valuable in the characterization of individual sources and in measuring specialized emission factors with the carbon balance method.

PHASE II

In Phase II, U.S. scientists will focus on longer term issues and will emphasize surface based monitoring, though at some point the programme would allow the airborne team to return to revisit issues which remain unresolved. Tentatively, the surface stations would focus on radiation balance, optical depth, and precipitation chemistry and would include at least one precipitation formation over the heat sources, in the smoke downwind and in unaffected areas to look for acute meteorological anomalies. Some elements of Phase II would be of sufficient duration so that the results of the decay of the sources, as fires are extinguished can be observed. This may be especially important if weather anomalies are observed that may have comparatively low initiation thresholds.

An issue of some importance in both Phase I and II studies is the monitoring of changes in surface albedo associated with wet and dry deposition of the soot. While redistribution and covering of the sooted soil may occur rather rapidly, it is easy to see that, given the high insolation and already high surface temperatures, a large change in surface albedo could dramatically raise the already high surface temperatures.

Research Goals

The research goals are:

- a. Regional emission rates of smoke particles and trace gases,
- b. Radiative properties of the smoke particles and smoke plume,
- c. Smoke particle characteristics,
- d. Smoke plume/cloud interactions,
- e. Effects of plume aging, and
- f. Regional weather anomalies.

Programme Schedule

The Phase I airborne experiment is scheduled to depart the United States on approximately 1 May, 1991 for a field experiement of roughly 30 days duration. Both research aircraft plan to fly about 100 hours devoted to their research missions basing either Bahraín or Dhahran, Saudi Arabia. The month of May is the soonest the airborne teams can reasonably depart. It is at the crucial-meteorological transition to a dry season allowing observations of the fate of the smoke under both cloudy and cloud free conditions. Climatological modelling of the plume trajectories show that more than 80% of the time the plumes will remain in airspace accessible to our aircrafts out to plume travel times of 5 days or more.

The Phase II schedule has not been determined at this time, although the aircraft should take samples during the period with the highest precipitation probability.

U.S.S.R. AIRCRAFT PROGRAMME FOR THE GULF

1. U.S.S.R. AIRCRAFT MEASUREMENTS OF THE GEOGRAPHICAL DISTRIBUTION AND CHARACTERISTICS OF POLLUTANTS RESULTING FROM THE OILFIELD FIRES IN THE GULF

1.1 Introduction

Timely and objective information on the characteristics and geographical distribution of various combustion products is required. The existing observational network in this region has no possibility to get the information.

The first objective is to get experimental data on the physical characteristics of the fire products and of their geographical distribution using an aircraft-meteorological laboratory IL-18 "Cyclone" (four-engine turboprop).

Onboard instrumentation of this special aircraft-meteolab allows to measure a wide range of parameters including:

- characteristics of aerosols (optical depth, vertical profile and spectral distribution);
- gaseous contaminants (CO, CO₂, CH₄, ethane, ethylene, benzo(a)pyrene);
- solar radiation (incident and reflected);
- thermodynamics (temperature, wind, pressure, dew point);
- remote sensing (IR-temperature of the surface, oil spills).

The second objective is to analyze experimental data in terms of potential influence on the ecology of the particular country.

The third objective is to get this information to the interested countries, their institutions and to international bodies for further analysis and consideration.

1.2 Flight plan

Some ideas on the possible flight routes are shown on the map of the area. Total flight time required goes up to 95 flight hours which takes about 30 days to fulfill (see Figure IX for tentative flight plan).

1.3 Cost of the project

The preliminary estimate of project's cost is U.S.\$ 600,000. This includes: jet fuel, air traffic control, insurance, aircraft service, hotel, per diem, etc. A list of Parameters measured by on board equipment of IL-18 aircraft meteolab is given in the next table

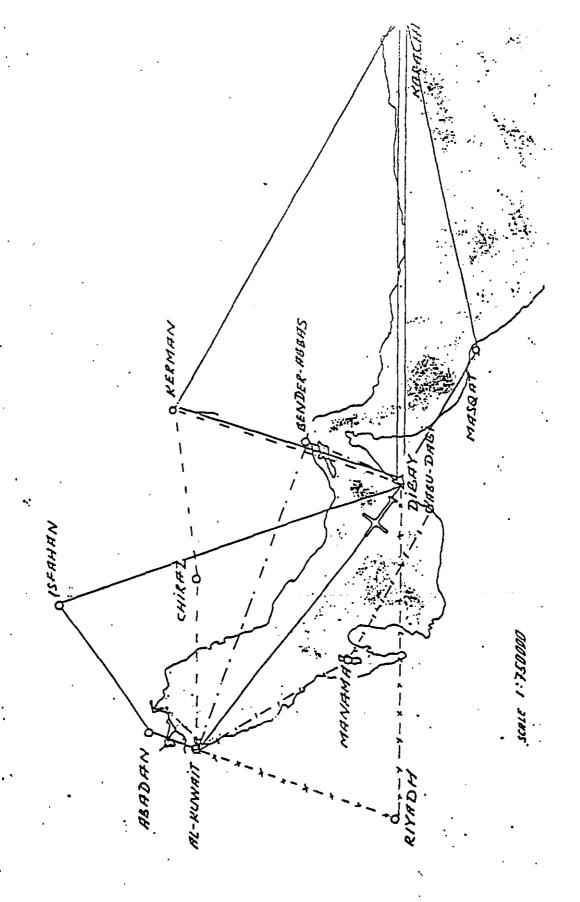


Fig. IX.1. Projected flightroutes in the USSR aircraft measurement plan.

Infrared radiometer

Lidar-polarimeter

A.	CHAR	ACTERISTICS OF AEROSOL			
	1. 2. 3. 4.	Optical depth of the atmosphere Vertical profile of aerosol concentration Modal size of aerosol particles Spectra of aerosol particles	Sun spectrometer Lidar-polarimeter Lidar-polarimeter Particle size polarimeter		
.B.	AIR	CONCENTRATIONS			
	5.	CO, CO ₂ , CH ₄ , ethane, ethylene, benzo(a)pyrene	Sampling of gas probes aboard followed by chromatography analysis on the ground		
c.	SOLAR RADIATION				
	6. 7.	Incident solar radiation Reflected solar radiation	Pyranometer Pyranometer		
D.					
	8.	Air Temperature	Resistance thermometer		
	9.	Dew point	Condensation		
	10.	Wind velocity	hydrometer Inertial navigation		
	11.	Pressure	Barometric sensor		

Remarks:

Ε.

SURFACE DATA

- 1. Real-time geographic position of the aircraft and other supporting parameters are measured and registered.
- 2. Scientific data are registered using IBM PC compatible formats.

12. Radiation temperature of surface

`13. Oil spill detection on water surface

PROGRAMME ON AIRCRAFT INVESTIGATIONS INTO THE ATMOSPHERE POLLUTION

2.1 Introduction

The main measurement objectives are to detect the atmospheric pollution level, pollutant emissions, fluxes, spatial distribution, and transformation and removal of the atmospheric pollutants from the oilfield fires.

The main pollutants are sulfur dioxide and sulfates, nitrogen oxides and nitrates, ozone, benz(a)pyrene, petroleum hydrocarbons, mercury vapour and heavy metals.

2.2 Outline of flight plan

The way of investigation can be schematized as follows: the emitted pollutants are scanned by aircraft in various sections at distances R_1 , R_2 ..., R_n from the source at heights h_1 , h_2 , ..., h_n . The maximum section height is selected to be above or equal to the plume height. The pollution concentration is measured at each section. The ambient concentrations in the plume at various distances $Q(R_1)$, $Q(R_2)$, ..., $Q(R_n)$ are found from the result of aircraft observations in the various sections through integration. The function Q = Q(R) is determined by $Q(R_1)$ values.

The emission value Q_o is found through the function Q(R) at R=0. The mean time residence of the pollutant in the plume or (t) is calculated from the above function relative to the distance and wind velocity, where t=R/V and V the mean wind velocity. Concentrations measured at various distances and heights $C(R_i, h_j)$ make it possible to estimate possible maximum concentrations at the ground level $C(R_i, h_i=0)$ and their threat to human health and environment. The values Q_o and M(t) are the major parameters required to provide a reliable estimate of the dispersion of pollutants from the oil well fires. The experience gained in the U.S.S.R. with the airborne studies demonstrates that not less than 200 flight hours are needed to get reliable values of $C(R_i, O_o)$ and the parameters Q_o and M(t) under available fire scales. 100 flight hours are sufficient to estimate roughly the characteristics of the dispersion.

2.3 Additional information

A detailed theory of the environmental pollution assessments from aircraft measurement data is given in Yu. A. Izrael, I.M. Nazarov and Sh. D. Fridman's monograph "Air pollutant transboundary transport modelling", Leningrad, Hydrometeoizdat, 1987, 303 p.

The Institute of Global Climate Ecology under Goskomhydromet and the U.S.S.R. Academy of Sciences can provide the aircraft operations on the condition that the expenditures are paid in hard currency.

3. THE AIRCRAFT LABORATORY AN-30R

An aircraft laboratory was designed in the U.S.S.R. on the basis of a two-engine aircraft AN-30, to measure atmospheric and surface radioactive and chemical pollution. It has been operated on a routine basis since 1984. In 1987, the aircraft laboratory was used in the international experiment on the study of long-range pollutant transport in Czecho-Slovakia. The laboratory includes gas analyzers, sampling systems, a gamma spectrometer and a dismountable small-size remote-controlled vehicle.

3.1 Aircraft specifications:

- flight speed 300 to 450 km/hr;
- flight altitude 200 to 7000 m;
- range 2000 km;
- load-carrying capacity 3 tons;
- flight time 5 hours;
- fuel consumption 1 t/hr;
- crew 5 persons;
- number of flight operators 4 persons;
- ground servicing of the aircraft 2 persons.

3.2 Laboratory equipment specifications

A. Gas measurements

Gases are measured with gas analyzers during the flight (see Table 1).

Table 1

Pollutant	Detection limit	Measurement regime and technique
Hydrogen sulfide	2 μg/m³	continuous, plasma photometry
Nitrogen oxides	4 µg/m³	continous, chemiluminescence
Ozone	3 μg/m³	UV-absorption
Mercury vapour	10 ⁻⁵ μg/m ³	discrete, atom absorp- tion with gold sorbent for collection

B. Aerosol measurements

Aerosol sampling is performed on special filters using two types of samplers. Samples are analyzed at the laboratory.

Sampling of the first type ensures simultaneous collection of one to three samples. The collection filter diameter for single sampling is 120 mm and the air flow rate through the filter is 20 m³/hr. In case of a three sample collection filter, the diameter is 50 mm and air flow rate through each filter is 6.5 m³/hr. Filters are changed during the flight. The sampling period in the plumes of industrial sources equals to several minutes. At background pollution levels the period normally makes up about 30 minutes. Table 2 presents the most typical pollutants measured. Detection limits are given as a pollutant amount per sample.

Pollutant .	Detection limit	Measurement technique		
Sulfate	3 µg	Turbidimetry with barium chloride		
Nitrate	6 µg	Colorimetry		
Ammonium	6 µg	Colorimetry		
Benz(a)pyrene	10 ⁻⁴ μg	Linear spectra		
Petroleum hydrocarbons	10 μg	Gas chromatography		
Soot carbon	20 μg	Optical IR spectrometry		
Heavy metals	10 ⁻³ -10 ⁻² μg	Plasma spectrometry, atom absorption		
Radon decay products	0.3 Bq	γ-ray flight measure- ments		

Second type sample provides collection of two large volume (up to $1510^3 \ m^3/hr$) samples during a flight. Filters are changed only at the ground.

C. Measurements of the Surface Radioactive Contaminiation

Measurements are performed by $\gamma-{\rm ray}$ detection using a dosimeter and a semi-conductor gamma spectrometer.

D. Small-Size Remote Controlled Vehicle (SRCV)

The aircraft laboratory AN-30R includes a dismountable miniature remote controlled vehicle equipped with a sampling device. SRCV is serviced by two operators and transported by a motor car. SRCV is dedicated to aerosol and gas sampling near emission sources, e.g. plant stacks, where aircraft laboratory flights are inhibited for safety requirements.

Main specifications of SRCV:

- maximum mass 6.8 kg;
- payload 1.4 kg;
- wing span 2.3 m;
- length 2 m;
- flight speed 50 to 120 km/hr;
- flight altitude up to 2000 m;
- flight time up to 1.5 hours;
- maximum distance from the operator 3 km;
- air rate through the filter up to 10 m³/hr.

3.3 Tentative estimate of aircraft operation costs

According to sanitation standards, the crew is allowed to perform flights with a total duration of 100 hours (20 5-hour flights) per month.

The approximate cost of 100 flight hours are:

- 1. Aircraft lease 160,000 rubles which may be paid by the Institute of Global Climate and Ecology, Goscomhydromet/U.S.S.R. Academy of Sciences.
- 2. Operation costs in Kuwait (fuel, airfield maintenance, wages, hotel expenditures, per diem expenses of the crew and operators) 150,000 U.S. dollars. The cost of fuel and airfield maintenance 75,000 U.S.

It would be expedient to urge the countries concerned to provide fuel free of charge (60,000 U.S. dollars). In this case the cost would equal to 90,000 U.S. dollars.

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REGIONAL ATMOSPHERIC MODELLING RECOMMENDATIONS AND REVIEW

RECOMMENDATIONS

The following material was presented to the meeting R.E. Meyers, and endorsed as a recommendation from the experts:

The range of important regional atmospheric modelling capabilities presented to the meeting included both real-time and research meteorological and air quality models. There is no single model which is sufficient for the accurate characterization and mitigation of the oil fire problem. However, there are relevant research and operational modelling capabilities.

- a. On a priority basis near real-time operational models should be used in the near term to provide forecasting of meteorology, concentrations, dose, and visibility. Both forecast and diagnostic models can be used to advantage for health, research operations, placement of sensors, and tactical decisions.
- it is prudent to upgrade modelling capabilities as improved models, modules, and scientific formulations become available.

Since unique modelling capabilities are spread over many scientists and institutions, it is necessary that several modelling capabilities be developed, both for real-time and research, and that these efforts be coordinated. Expertise should be drawn from the widest possible circle.

The oil fires produce effects interrelated on many scales (micro, local, regional, and global) and it is recommended that multi-scale models be developed which incorporate high resolution source, chemistry, transport and diffusion, deposition, heat, and complex terrain modules.

The following enhancements to the models were discussed:

- a. Surface boundary layer (sbl) parameterization throughout the diurnal cycle,
- Improved flux relations of heat, moisture, momentum, energy, and chemical species,
- Influences of complex terrain on sbl,
- d. Influences of oil fires on sbl and entire atmospheric boundary layer.

- e. A better coupling of fire modelling and meteorological modelling whereby fires affect the meteorology and vice versa,
- f. Improvement in numerical methods which allow solution of the model equation on multiple scales, including development of adaptive grids, moving grids, nesting, and mixed eulerian and lagrangian numerical modelling capabilities to solve the Navier-Stokes Equations efficiently and with high accuracy,
- g. Major emphasis should be placed on solving the Navier-Stokes equations in as detailed and systematic a manner as is possible for the multi-scale problem,
 - h. Improved closures must be made in the turbulence terms of the Navier-Stokes equation (the lessons learned from Large Eddy Simulations and Direct Simulations of the atmosphere must be brought to bear on the oil fire-atmospheric problem),
 - i. Improved deposition, both dry and wet:
 - 1. Dry deposition better gas/aerosol interaction with the turbulence and surface,
 - Wet deposition better cloud/rain interaction models.
 - j. Better chemistry modules which more closely represent the heterogeneous and homogeneous chemical reactions in the oil, combustion, and atmospheric chemicals,
 - k. The technology from regional and urban air pollution models, such as those used in the Los Angeles area, must be adapted to the oil fire-atmospheric problem,
 - Because a large portion of the Kuwait oil fire affected region involves coastal zones, it is important to model the effects of land-sea interfaces in the models,
 - m. Models should be tested against combined sets of air quality and meteorological data in the Kuwait-Gulf area,
 - n. The oil fire plumes can themselves be used in verifying mesoscale models, and
 - o. The electromagnetic radiation interaction with the oil fire pollution should be measured and modelled in detail.

Improvements are also needed in the characterization and modelling of atmospheric transport and diffusion. To aid in this, safe tracers such as SF6, which are non-reactive and conservative, should be used in field experiments to characterize plume growth rates under different conditions. Comparisons should be made with ambient chemicals available in the smoke plume which are subject to deposition and chemical reaction.

REVIEW

The following are summaries of the regional models discussed at the meeting. The presenter and affiliation are also listed.

 (DLR) Institute for Atmospheric Physics, Federal Republic of Germany Presented by: U. Schumann

The modelling effort here employed non-hydrostatic solutions of the Navier-Stokes Equation (MESOSCOP) over a 30 x 30 x 12 km domain for oil fire meteorology and air pollution (see Fig. X.1). The model can be enhanced in resolution and domain coverage as more computer resources are applied. The modelling effort employed meteorological and source terms estimated to be representative of the Kuwait oil fire problem. The methodology is based on first principles and would be appropriate for nesting in larger scale models.

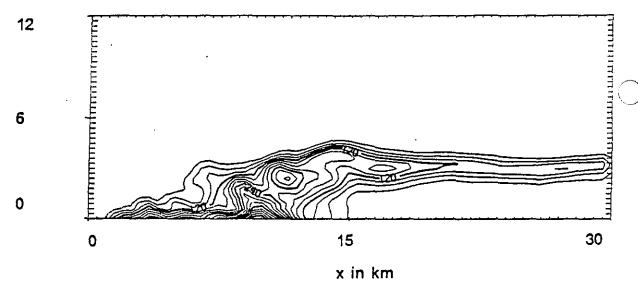
 Building and Fire Research Laboratory, NIST, U.S.A. Presented by: H. Baum

NIST has developed advanced fire modelling capabilities. Individual fires and ensemble of fires have been modelled. Detailed fire plume models allow calculation of some of the effects of the fires on the surrounding meteorology and of the meteorological effects on the fires. The presenter argues persuasively for integrated meteorological and fire models. The presenter also reviewed verification of NIST fire models and indicates field measurement capabilities of NIST which can be implemented to provide key source information and for model verfication.

TASC, Reading, Massachusetts, U.S.A.
 Presented by: R.Chase and A. Bass

TASC has developed and has been using operationally a near realtime meteorological and air pollution impact assessment models using in-house and government (U.S.) support. These are tied together in an integrated interactive modelling capability. Starting from a detailed and updated source database TASC computes the downwind concentration, dose, and deposition from their dispersion model (see Fig. X.2). The dispersion and transport model gets its meteorology from a spectral global circulation model and can run from historical analyses or model forecasts. An improved plume model is included to represent the oil fire effects, as is a chemical reaction simulation. Detailed concentration, dose, and deposition fields can be graphically displayed as computer and hardcopy color images. TASC has begun comparisons of its model output with satellite visualizations of oil fire plumes and general agreement is found. TASC intends to continue developing its capabilities to include more detailed diffusion, transport, chemistry and meteorology.





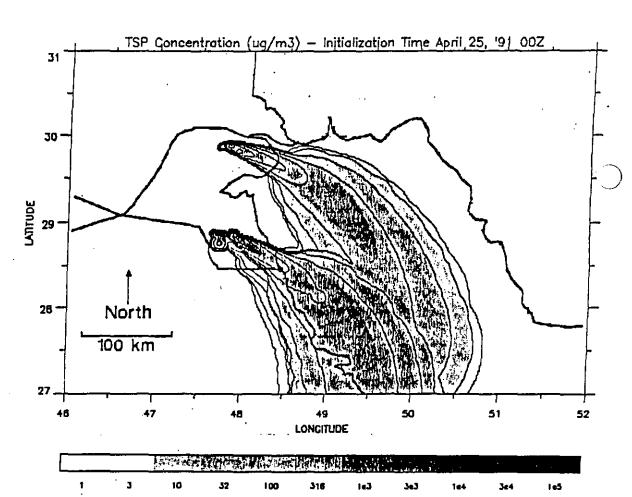


Fig. X.1. (top) Contours of soot concentration afters 2 hours of simulation (mg/kg). The contour interval spacing is 0.3 mg/kg).

Fig. X.2. (bottom) TSP concentration (micr. $g./m^3$). The initialization time was 25 April 1991, 00z.

 Lawrence Livermore National Laboratory, U.S.A. Presented by: T. Sullivan

The Atmospheric Release Advisory Capability (ARAC) which has been used as an essential tool in mitigating atmospheric hazards (particularly nuclear ones) has been applied to model optical density in the larger Kuwait area. The capability provides near-real-time assessments of concentrations, dose, and deposition, and employs a diagnostic meteorological model (MATHEW) to add physical constraints such as complex terrain influences to the Air Force Global Weather Control forecasts and analyses (see Figure X.3). Concentration, dosage, and deposition are included in the analyses. Improved plume rise modelling has been included in the ARAC models. Dispersion is calculated by second generation particle—in—cell methods. The presenter recommends use of ARAC capabilities for Kuwait oil fire operations.

5. ARL (NOAA) U.S.A. Presented by: J. Heffter

ARL produces operational forecasts of tajectories in the 850-700 mb height range of 36 to 72 hours after Z time (see Figs. X.4-X.6). These forecasts can be made available around the world. Trajectories are integrated from NOAA meteorological forecast and analysis products. The ARL trajectory capability has been developed, tested, and utilized over many years. ARL is also investigating the use of more detailed mesoscale meteorological models such as the CSO-RAMS model (R. Pielke). NOAA is looking toward implementing a full capability real-time hazard assessment and forecast capability in the near future using advanced computers and communications technology. NOAA is already supporting and will continue to support operations in the Kuwait area with its modelling tools.

6. Météorologie Nationale, France Presented by: F. Bompay

Two main numerical weather models are currently in operation: Emeraude, a global model, and Peridot, a limited area model. During the Gulf war, Peridot was applied to Kuwait and used its forecasts operationally. The model has a 40 x 40 km resolution. A Eulerian model of atmospheric dispersion was developed (MEDIA). It can use input data from Emeraude or Peridot and yield an operational survey of the pollution in Kuwait after some changes. It may be considered to implement it in its operational system of the French weather service so that it can provide daily outputs (of air concentration, cumulative deposition, etc.) models, starting in October.

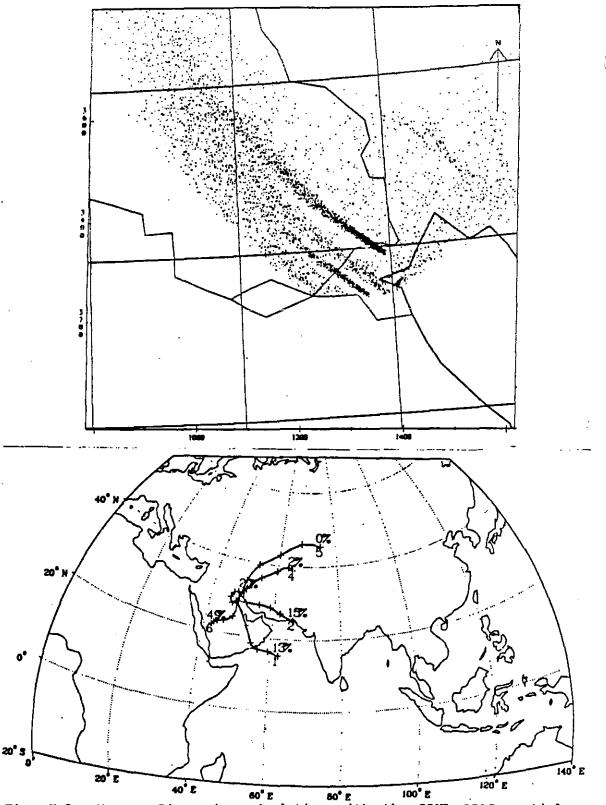


Fig. X.3. (top) Dispersion simulation with the LLNL ARAC particle disperion model, after a 24 hr. simulation. The initialization date was 2 February 1991, 00Z; (These data are currently provided on an experimental basis)

Fig. X.4. (bottom) 850 mb trajectory clusters originating in Kuwait. The numbers refer to the relative frequency of occurrence. For the clusters, over 300 trajectories were used.

Meteorological Office, U.K.
 Presented by: F.B. Smith

A 3-D Monte Carlo model has been used to simulate the transport of the plume and to assess dry and wet deposition, surface layer time-integrated concentrations, and episodes of highly acidic rain likely to be damaging to crops (see Figure X.7). The model plume is compared with a subjectively analyzed meteosat visible plume picture.

8. Max Planck Institute für Chemie, Federal Republic of Germany Presented by: G. Carmichael

Two models could be applied to the Gulf region. Both are eulerian transport/chemistry/deposition models designed for analysis of air quality on an event basis.

The Local Scale Model (CALGRID) is an urban-scale air pollution model designed for California Air Resources Board. It covers spatial scale up to $300 \times 300 \text{ km}^2$, with a grid resolution of 2-5 km. This "system" contains a model to prepare meteorological fields from observations, or hydrostatic meteorological model, and a transport/chemistry/dry deposition model. It calculates 3-D distribution of SO_2 , sulfate, VOCs, NO_x , ozone for events for a few days.

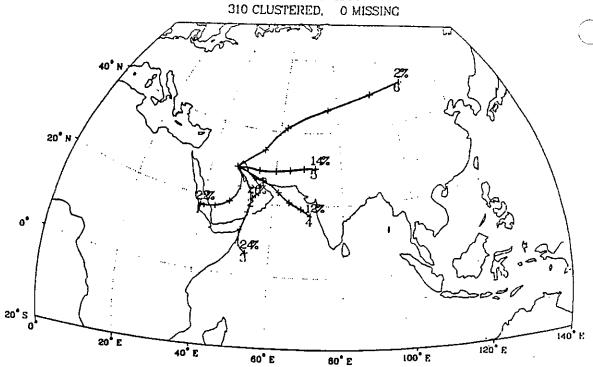
The Regional Scale Model (STEM-II) covers spatial domains up to 4000 x 4000 km², with horizontal resolution of 20 to 80 km. It calculates 3-D distributions of SO_2 , sulfate, CO, VOCs, NO_x , ozone for events for days to weeks and includes dry and wet deposition, and size resolved aerosols (dust and inorganic, but can easily add soot).

9. Cologne University, Federal Republic of Germany Presented by: H.J. Jakobs

A regional scale numerical model, EURAD (European Acid Deposition Model) may be used for episodic case studies during the burning. The model is described by Hass et al. (1990), it is a eulerian model, which calculates the transport, chemical transformation and deposition of atmospheric pollutants. It was designed for case studies of high pollution events over the European region (Hass et al., 1990 and Ebel et al., 1991). Although EURAD runs for European applications it can easily be transformed to other regions of the world like the Middle East. Besides soot (5-10% of the burning oil) the main atmospheric pollutants like $\rm SO_2$ and $\rm NO_x$ are emitted. EURAD is able to calculate not only the transport but also the chemical transformation and the dry and wet deposition of these constituents.

In the first phase it is planned to prepare the meteorological fields for several episodes in March - May 1991. Typical weather situations are selected for the case studies with the EURAD Model (including frontal passages for the assessment of the wet deposition). An

700 MB TRAJECTORIES FROM KUWAIT MAY 1986-1990



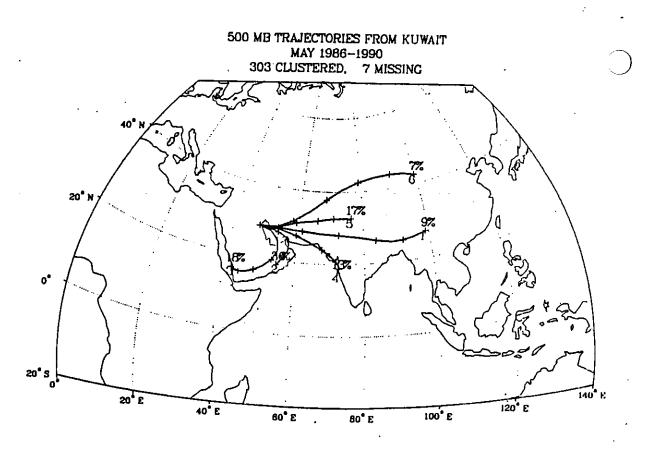


Fig. X.5. (see Fig. X.4) 700 mb level.

Fig. Y.6. (see Fig. X.4) 500 mb level.

appropriate emission scenario must be developed for this EURAD application, neglecting in the first step the backgound emissions, because this information is difficult to incorporate in a short time period. When the simulation experiments are conducted, the results have to be compared and validated with measurements (satellite, aircraft and surface observations).

Ebel A., Hass H., Jakobs H. J., Memmesheimer M., Laube M., Oberreuter A., Geiss H. and Kuo Y. H., Simulation of Oxone Intrusion caused by a Tropopaus Fold and Cut-Off Row, Atmospheric Environment, in press, 1991.

Hass H., Memmesheimer M., Geiss H., Jakobs H.J., Laube M., and Ebel A., Simulation of the Chernobyl Radioactive Cloud over Europe using the EURAD Model, Atmospheric Environment, 24A, 673-692, 1990.

10. Royal Netherlands Meteorological Institute (KNMI)
Presented by: G. Verver

The Royal Netherlands Meteorological Institute and collaborating scientists developed and validated with good results a real-time puff dispersion model for application to emergency situations. The model has a two layer boundary layer structure plus one "reservoir layer" aloft. Puffs, nominally released every hour, are transported by winds, and split to resolve wind shear. A grid is also used to resolve larger pollution patterns. The model calculates deposition, concentrations, and total column values. It uses meteorology and atmospheric boundary layer information from the European ECMWF prognostic model. The model can be run against archived meteorological data or can produce forecasts. Research to improve the atmospheric boundary layer formulation is underway. The model is operational both in forecast and analysis mode (see Figure X.8).

U.S. Army Atmospheric Sciences Laboratory, U.S.A. Presented by: R.E. Meyers

The U.S. Army Atmospheric Sciences Laboratory (ASL) has developed the Model of Atmospheric Chemical Hazards (MACH) which is a real-time interactive modelling-computer system which calculates downwind chemical hazards. This modelling capability predicts downwind concentrations, doses, and deposition over complex terrain including the Kuwait and greater Gulf region. The model reconstructs or forecasts wind flows and resulting pollution fields using mesoscale prognostic and diagnostic models, and advanced transport, diffusion air chemistry modules. The model and computer system are available for technology transfer.

Additional related research at ASL includes mesoscale modelling, Large Eddy Simulation modelling and gas and aersol flow modelling over complex terrain and complex structures (including dense, neutral, and buoyant gases and aerosols). ASL has a large number of unique research resources which can be brought to bear on the Kuwait oil fires problem including:

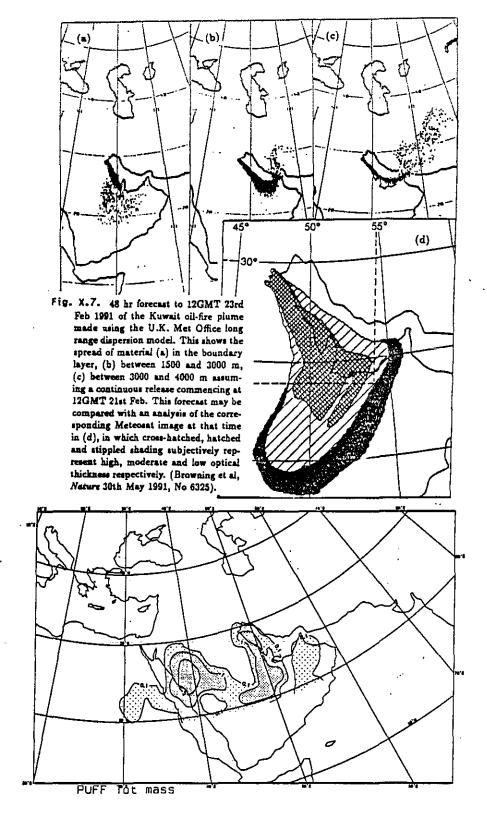


Fig. X.8. Total column SO_2 mass (mg/m^2) for Sunday 28 April 1991, based on a forecast made on 25 April 1991 by the Dutch operational dispersion model.

- (a) multi-scale field data for verification of models (project WIND)
- (b) aerosol, gas, and high resolution optical-spectrographic sensing equipment
- (c) mesoscale modelling verification capabilities
- (d) automated meteorological sensing equipment

12. U.S. Department of Defense Presented by: R.E. Meyers

The US Department of Defense (DOD) is coordinating, via Defense Nuclear Agency, a large number of research and operational efforts in support of mitigating the adverse effects of the Kuwait oil fires. These effort utilized not only DOD resources, but also those of other agencies such as the National Science Foundation (NSF) and NCAR. Research is underway or has been proposed in the following areas: meteorology upwind of fire site; chemical analysis of raw oil and gas; oil, gas, water expulsion rate from well; fire structure; photographic records of plume; flame temperatures; combustion chemistry; physics of smoke production; smoke yield based on carbon balance; sulfur dioxide gas concentrations; carbonyl sulfide gas concentration; hydrogen sulfide gas concentration; trace gas chemistry (SO₂, NO, NO_x, NO_y, H₂O₂, O₃); organic fraction of smoke; fire effects on close-in meteorology; chemical analysis of effluent gases in plume and at numerous ranges downwind; smoke physical parameters in plume and at numerous ranges downwind (particle morphology, mass density, particle size distribution, optical indicies of smoke particles); aerosol chemistry; aerosol particulate carbon fraction, aerosol size distribution, aerosol morphology, size-fractionalized particulate matter; smoke particulate constituent concentrations (CO, CO₂, PAN); meteorology downwind of fire size (temp., relative humidity, winds, position); transport/diffusion of smoke and gases (regional and global scales); smoke buoyancy due to solar absorption; smoke and cloud track and dimensions; .agglomerate structure, primary sphere size; cloud nucleation activity; cloud droplet size distribution; prompt/late-time scavenging (particle attachment, agglomeration, sedimentation); effect of atmospheric moisture on scavenging; rain chemistry/precipitation scavenging; interaction of smoke with dust; effects of cloud seeding; light extinction, IR scattering, absorption, single scatter albedo; optical depth, plume spectral emission profiles; plume radiation map; solar radiation flux; bulk effects of smoke on solar radiation, visible light, IR transmission, photon attenuation, loss of contrast for imaging; ozone parameters; settled particulate matter, mass, and conductivity; analysis of material settled on ground (effect on target appearance, effects on biological systems); rate of contamination and clogging of air filters; corrosive films on electronic equipment; rate of corrosion and contamination of electrical equipment; organic trace elements in precipitation; of degradation of historic artifacts (both outdoors and within museums); flame extinction during blowout; high speed photography of flame suppression.

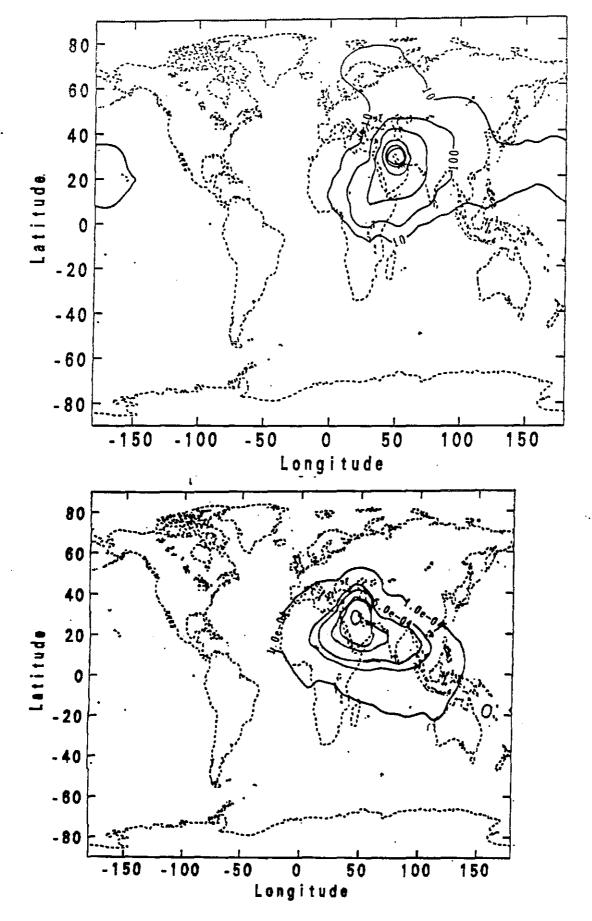


Fig. X.9. (top) Soot surface concentration (ng/m_3) due to estimated Kuwait emissions.

Fig. X.10. (bottom) Total column soot (g/m^2) for July, due to Kuwait emissions.

Further proposals for research related to the oil fires can be sent to:

Dr. Mohammud Owais Technical Manager, Radiation Policy Div. Defense Nuclear Agency 6801 Telegraph Rd. Alexandria, Virginia 22310-3398 U.S.A.

or

Dr. David Auton Chief Radiation Policy Div., DNA 6801 Telegraph Rd. Alexandria, Virginia 22310-3398 U.S.A.

Additional information can be obtained from:

Ronald E. Meyers, Physicist
U.S. Army Atmospheric Sciences Laboratory
White Sands Missile Range
New Mexico, 88002
U.S.A.
Telephone #: 505-678-4037

 Lawrence Livermore National Lab., U.S.A. Presented by J. Penner

The estimated soot emissions from Kuwait are fully two-third of the total world-wide emissions and represent the largest contributor of soot within the regions. The source rate from Kuwait (spread over a 5 degree by 5 degree zone) would equal almost 15,000 kg/km²/yr.

The source of sulfur from the Kuwait fires may also be estimated to be 2.5×10^{10} gS/d. This is 10-15% of the total sulfur emissions in the latitude band between 20 to $35^{\circ}N$.

The sources of soot and sulfur from Kuwait fires were input into the LLNL global climate/chemistry model (c.f. Penner et al. 1991b). It uses the winds and precipitation fields from the National Center for Atmospheric Research (NCAR) Community Climate Model (version CCM1) with an resolution of approximately 4.5° latitude by 7.5° longitude. The model also assumed a 6-day e-folding lifetime for conversion of SO_2 to SO_4^{-1} to simulate aqueous conversion processes. Each species in the model may experience deposition if parcels are in the lowest 100 mb. Soot, SO_2 , and SO_4^{-1} were also scavenged by precipitation and rates proportional to the rate of precipitation in the model. The scavenging coefficients were set to 2.5 cm⁻¹, 2.5 cm⁻¹ and 1.0 cm⁻¹, respectively.

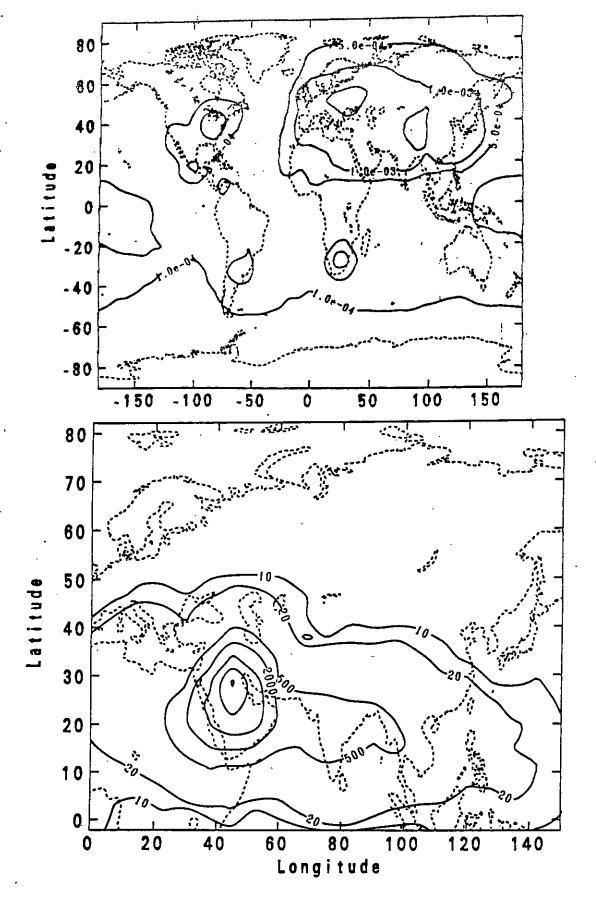


Fig. X.11. The same as Fig. X.10, for the global total fuel consumption.

Fig. X.12. Sulfate concentrations due to Kuwait emissions (pptv).

The monthly averaged surface concentrations for soot (in ng/m3) for March is shown in Figure X.9. In March, high winds carry soot as far east as Mauna Loa. This is particularly interesting in view of the recent tentative identification of soot at Mauna Loa from the Kuwait fires (R. Schnell, private communication, 1991). The soot emissions are retained closer to the source in July, but average concentrations of more than 100 ng/m³ are experienced throughout the Indian subcontinent and parts of southwest Asia. This concentration contour also encompasses much of northeast Africa and extends northward to the Black Sea. Much of this region will experience a doubling of the concentration of soot as a result of the fires. Figures X.10 and X.11 show the column abundance of soot from the oil fires in July and from the ambient fossil fuel calculations for July, respectively. These figures may be approximately converted to absorption optical depth by multiplying by a factor of 10. In Figure X.10, there is a column abundance of up to 0.05 gm⁻² centered over Kuwait. A large region, extending from the middle of Africa to southwest Asia experiences column abundances of more than 0.001 gm⁻². These column abundances for soot may be compared to the abundances calculated for the ambient fossil fuel scenario. These are shown in Figure X.11. The 0.001 gm-2 contour interval in this case extends over much of Europe, northwest Africa, Saudi Arabia, and to eastern Asia. Two areas, over eastern Europe and China, experience column abundances of 0.005 gm⁻². The Kuwait fires appear to be capable of increasing the optical depths from soot by at least a factor of two over a large area surrounding the source region.

Contour intervals of the predicted monthly averaged surface concentrations of SO_4^{-} (in ppt) for July are shown in Figure X.12. SO_4^{-} is widely spread and covers much of India and parts of southeast Asia. This is due to the several days time required to form SO_4^{-} from SO_2 in the model and the slower rate of removal.

Most of the H_2S is confined to the local region, although concentrations as high as 10 ppt reach out towards India in the east, towards northeast Africa in the west, up to the Black Sea in the north and to Saudi Arabia in the south.

The potential emissions of soot from the Kuwait oil fires are large relative to the global emissions of this substance. The spread of soot may reach as far as Mauna Loa in some seasons. In other seasons, the loading of soot within a large area centered about the fires may more than double. This soot will certainly have regional implications for climate, but its global consequences should be investigated. The smoke could either warm the climate or cool it, depending on its altitude in the atmosphere and on whether it is thermally coupled or

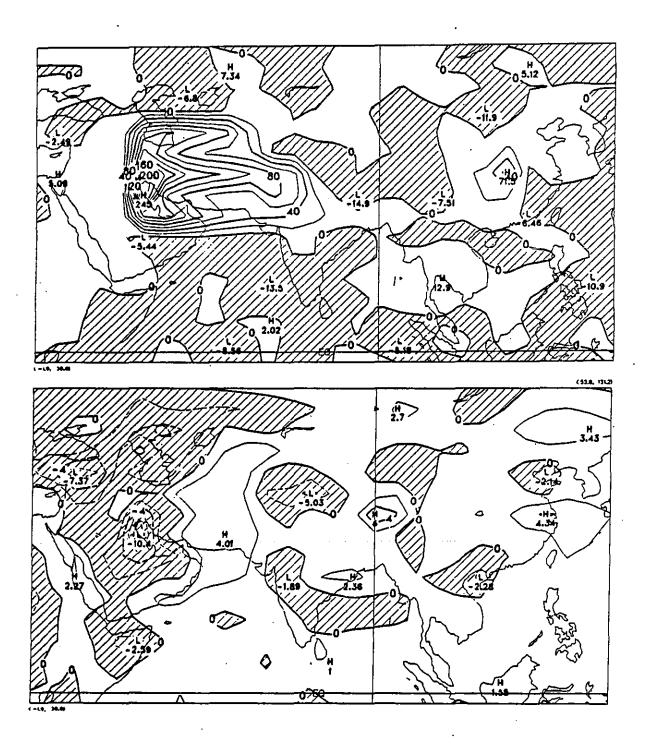


Fig. X.13. (top) Estimated change in solar heating due to soot in the lower atmosphere (W/m^2) .

Fig. X.14. (bottom) The corresponding change of the ground temperature (K) for July.

decoupled from the surface (Ghan and Penner, 1991). Enhancements to existing monitoring stations throughout the region should be pursued in order to quantify the amount and spread of the soot.

The sulfur emissions from the fires are a large source relative to other sources in the area. The monitoring of SO_2 and $SO_4^{\tilde{a}}$ throughout the region could help quantify the spread of this pollutant as well.

Ghan, S.J. and J.E. Penner, "The effects of smoke on climate," Encyclopedia of Earth System Science, in press, 1991.

Novakov, T., J.E. Penner, and H. Eddleman, "An inventory for global soot emissions from fossil fuel combustion," presented at the 4th International Conference on Carbonaceous Aerosols in the Atmosphere, Vienna, Austra, April 3-5, 1991.

Penner, J.E., S.J. Ghan and J.J. Walton, "The role of biomass burning in the budget and cycle of carbonaceous soot aerosols and their climate impact," in Global Biomass Burning: Atmospheric, Climatic, and Biospheric Impolications, J. Levine, Ed., in press, MIT Press, Cambridge MA 1991a.

Penner, J.E., C.S. Atherton, J. Dignon, S.J. Ghan, J.J. Walton, and S. Hameed, "Tropospheric nitrogen: A Three-dimensional study of sources, distributions, and deposition," J. Geophys. Res., 96 959-990, 1991b.

Walton, J.J., M.C. MacCracken and S.J. Ghan, "A global scale Lagrangian trace species model of transport, transformation, and removal processes, J. Geophys. Res., 93, 8339-9354, 1988.

14. Atmospheric Environment Service, Canada Presented by J.P. Blanchet

The effects of smoke on the local and regional meteorological conditions and short-term climate perturbations has been investigated. The concentration of soot in the smoke cloud is evaluated assuming steady state between a constant injection rate and a prescribed removal rate. An "e-folding time" of 5-10 days is assumed to account for removal processes from the volume by dry and wet deposition as well as advection. Soot concentration depends only on the volume of atmosphere being filled. This approach is a gross simplification of the actual situation.

The Canadian Climate Centre General Circulation Model (CCC/GCM) with a spectral resolution of T32 wavenumbers is used together with a 1-D radiative convective photochemical model (RCPM). The 1-D RCPM evaluates "static" solutions for equilibrium surface temperature and the corresponding radiative forcing. There is a broad agreement between the 1-D and GCM for the surface temperature versus optical

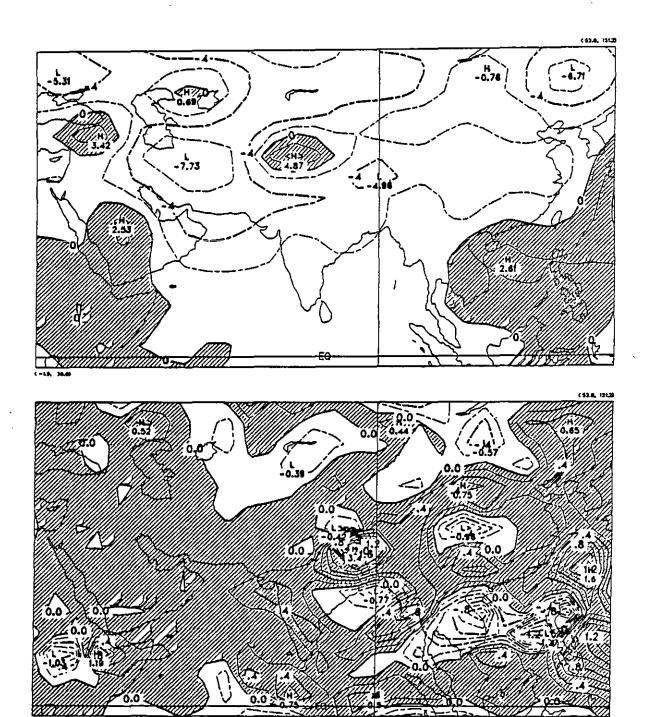


Fig. X.15. (top) Changes in surface pressure (mb) for July.

Fig. X.16. (bottom) Changes in monsoon precipitation $(10^{-5} \text{ kgm}^{-2}\text{s}^{-1})$. The same area as in Fig. X.15 is shown.

depth at most scales. Only on small scales, near the source, smoke produces surface cooling due to reduced insolation. The large coolings reflect large optical depths. At regional scale and above, and for soot located in the lower troposphere, the effects on temperature change to warming. This is mostly due to relative increase of the long-wave atmospheric radiation. The magnitude is particularly sensitive to the height of the smoke layer.

Secondly, the GCM is used for a seven month simulation (January-July) with the intention of investigating the links between smoke concentration, radiation and heat budgets, surface and air temperatures, snow melt, and eventually monsoon activity. In this experiment, smoke is restricted to the 700-900 mb layers of the GCM. The maximum optical depth is reduced to about 2 over Kuwait and decreases with volume extending eastward from the source. Figure X.13 shows mostly solar heating due to soot in the lower atmosphere. It is also a good indicator of the smoke distribution in this model run. Figure X.14 shows the corresponding change of ground temperature for July. In the Kuwait area, the model produces cooling of the order of 5-10 degrees centigrade. Downwind from the source, warming around 2 degrees are obtained. Beyond 1000 km downwind from Kuwait, natural variability dominates and nothing can be inferred from this short run. It is important to note that those temperature changes are larger than actually expected due to the assumed large optical depths. This experiment is not a forecast of the actual situation but a means to investigate the relationships between smoke and meteorological parameters. It also indicates a trend and provides a scale for assessment purposes. Figure X.15 shows the corresponding change of surface pressure in July. With warming east of Kuwait, a relative thermal low is formed. Figure X.16 shows increases in monsoon precipitation over India due to increased convection and moist flow in low levels. Figures X.13-X.16 illustrate potential links between oil fire smoke and meteorological parameters. Those results are very preliminary and need to be extended and fully diagnosed before drawing final conclusions. A substantial amount of soot is being deposited on the snow surface. It is also a concern that the snow reflectivity would be altered by black carbon. Even a minute amount of soot increases considerably the amount of solar energy absorbed by the surface. We stress the need for monitoring large-scale background soot concentration, particles, size distribution, and smoke optical properties for the evaluation of short-term climate and environmental changes.

15. Max PLanck Institute for Meteorology, Federal Republic of Germany Presented by H. Graf

Model calculations have been carried out with a global circulation model (T21). It was assumed that present emissions continued during a year. Two different scenarios were taken for the wave length dependence of the radiation absorption cross sections. Results obtained pertain to changes in net surface solar radiation, surface temperature and precipitation in different months. (Some examples are given in Figs. X.17, X.18).

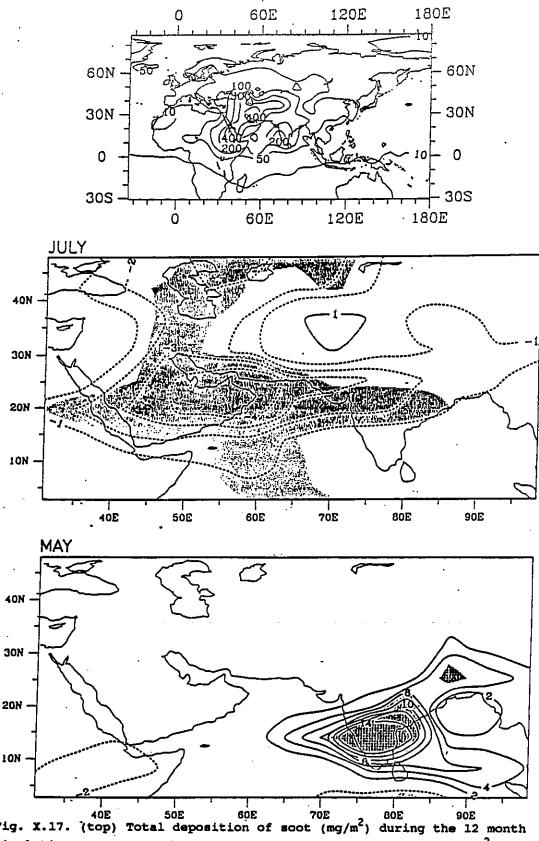


Fig. X.17. (top) Total deposition of scot (mg/m^2) during the 12 month simulation. Contour of 10, 50, 100, 200, 300 and 400 mg/m^2 are depicted.

Fig. X.18. Climate response in summer. Anomalous 2 m temperature for July (middle); the contour interval is 1 °C. Anomalous precipitation for May (bottom); the contour interval is 2 mm/day. The zero contours have been suppressed. Shading indicates regions with local significance levels larger than 95 %.

A significant cooling of about $4^{\circ}C$ was computed for the summer over the Gulf region (=500 x 500 km²). On a global scale non-significant changes were predicted. Due to the relatively short residence time of the soot, it is expected that soon after the extinction of the fires, effects, if any, will disappear. A significant weakening of the Indian summer monsoon was estimated to be unlikely.

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AN AIRCRAFT MONITORING STRATEGY

Aircraft should give priority to the following measurements:

- a. Source strength and characterization of soot including characterization of particles size, shape and composition which will affect lifetime, optical properties and effects.
 - i) Source strength (for individual oilfields and total emissions) using, where possible, all four methods (integral of mass, lidar backscatter, measurement of optical thickness, and comparison of observed and predicted) used in combination. Flights should be coordinated with ground-based observations as well as lidar and satellite measurements.
 - ii) Characterisation of particles including PAH measurements (chronic health hazard), organic carbon/black carbon ratio in particles, trace elements, size spectrum, and morphology.
- b. Wind and concentration field in near to medium distances (up to 200 kms) of SO_2 NO_x , O_3 , particles mass and characterization, optical density, VOC's, HCHO, CO, CO_2 .
- c. Evolution of plume chemistry at long distances downwind (greater than 200 km) of SO_2 , SO_4 aerosol, NO_x , NO_y , NO_3 aerosol, VOC's, O_3 , optical density, particle mass and characterization. For such measurements a local based station will be needed for grab sample analysis.
- d. Temporal variation of source strength, as above, as fires are put out.

The coordination of aircraft flights should proceed as follows:

- a. A sequence of aircraft flights should be made covering each month with some overlap, where possible, for intercomparison of measurements.
- b. WMO should assist in arranging the coordination of aircraft activities through national focal points.
- c. WMO should assist aircraft teams to obtain access to national air space in the region.
- d. Local support for aircraft teams in the Gulf area is essential. The meeting recommended that WMO maintain information on the appropriate contacts in the area throughout the observational period.

- e. Assistance is needed in providing aircraft teams with model forecasts for flight campaigns. These forecasts should cover a variety of timescales.
- f. The WMO should assist in the distribution of flight data as it becomes available, recognizing that some data need processing at national facilities. Wide distribution of flight data will assist in the planning of subsequent aircraft activities and provide test data for model evaluation.
- g. The WMO should assist, within the next few months, in the organization of at least one workshop to compare and discuss aircraft results.
- h. The experts noted that the U.K., U.S.A. and German airplane measuring programmes were bilateral in character. While recognizing the need for urgent measurements, the meeting urged these programmes and future aircraft monitoring programmes to be structured under the framework of the WMO project.
- i. The list of planned measurement campaigns is not complete and because all relevant data are highly useful, further campaigns (aircraft and otherwise) at later dates are encouraged.

The status of plans for aircraft monitoring identified at meeting is summarized in the Table:

Status of Aircraft Plans, 30 April 1991

Number	·Country	Organization	Period Dura	tion Fundin	g Meetir	ng Contact
1	U.K.	U.K. Meteoro- logical Office	March/April	2 weeks	Done	Smith
2	U.S.A.	NCAR University of Washington	mid-May mid-May	3 weeks 3 weeks	Available Available	Baumgardner Hobbs*
1	Germany	Umwelt Bundes-	May/June	2 weeks	Available	Sartorius
2	U.S.S.R.	State Committee for Hydrometeo- rology	Unknown	50 hours	Partial	Tsaturov
		Institute of Global Climate and Ecology	10 July 91	100 to 200 hours	Partial	Nazarov
		Central Aerolo- gical Observa- tory	20 June 91	100 to 150 hours	Partial	
2.	Germany	DLR	June, July, August	2-3 weeks	Partial	Schumann
1	U.S.A.	Pac.NW Labs	_	4 weeks	Unknown	Hales*

^{*} Not present at the meeting

Collaborative work in association with the aircraft programme is necessary:

- a. Field measurements and laboratory studies associated with source characterizations should commence as soon as possible.
- b. Near-field modelling of individual plumes is important for the aircraft programme. Attendant to this, a micro-network of meteorological field monitoring stations is needed in addition to those already planned or in place for other purposes. These should include precipitation and dry deposition sampling.
- c. Collaborative laboratory studies between atmospheric fire scientists and aerosol chemists are needed to expand understanding of critical carbonaceous aerosols including formation, chemistry, characterization, and aerodynamic properties.

The following items require immediate consideration:

- a. The WMO aircraft coordinator should contact UNEP and appropriate officials within Kuwait immediately to coordinate establishment within Kuwait of a focal point for coordination and logistical support of personnel and projects involved in the implementation of the aircraft operations.
- b. Funding for provision of logistical support for field projects, especially aspects of the aircraft programme, must be provided to WMO by participants either directly or through the U.N. Interagency Fund (through UNEP),
- c. All data collected by parties to this programme, particularly in the region, should be made available to all parties through WMO, in a timely manner, in view of the multiple uses for the data and the urgency of the matter.
- d. A very high priority needs to be placed on the re-establishment of capabilities in Kuwait for collection of source and local meteorological data.
- e. In view of the continuing critical importance of accurate source term data, it is essential that efforts be implemented immediately and provision be made for continuing updates and dissemination of data.

For determination of the amount of soot released per time unit, the mass-flux is required. It was therefore recommended measuring:

- The mean wind field across the plume by aircraft and sondes,
- b. The extent and relative concentration field within the total plume. (These can be obtained by Lidar measurements from, for example, the German Falcon by flying across the plume's cross-section at altitude above the plume (about 5 km) at a distance from Kuwait where the optical depth is small enough to get signals from the ground),

- c. In-situ measurements of soot concentration at approximately the same time and at least one flight level within the plume,
- Total sulfur concentration by probes,
- e. Increase in water vapour within the plume. (The German aircraft proposes to try DIAL measurements. However, it was noted that the increase in water vapour may be too small to be detected.)

The following possibilities were considered for flight patterns:

- a. vertical profiles near the source (30 to 80 km),
- b. vertical cross-sections along main plume axis at distances from 30 km to 300 km and
- c. vertical cross-sections at large distances from the sources (up to at least 1000 km). (This measurement has high priority because of its importance for global modelling).

Gulf Regional Air Monitoring Plan (GRAMP)

Andrew E. Bond

Atmospheric Research and Exposure Assessment Laboratory Office of Research and Development U.S. Environmental Protection Agency

Phased Air Monitoring Plan

Phase I. Provide a Framework for an Early Warning Advisory

Phase II. Establish a PM¹⁰ Monitoring Network

Phase III. Characterize the Aerial Plume

Phase IV. Develop a More Complete Profile of the Smoke Plume Constituents

Phase V. Develop a Gulf Regional Air Monitoring
Network to Track the Impact of the Plume

Phase I. Provide a Framework for an Early Warning Advisory

- Gather Daily Weather Forecasts to Predict Meteorological Conditions
- Use Visual Observations
- Gather Existing Air Monitoring Data from Fixed and Mobile Sites Operated by Saudi MEPA, Saudi ARAMCO, and the Governments of Kuwait and Bahrain

Phase I. Provide a Framework for an Early Warning Advisory

- Establish a Daily Briefing
- Develop a Daily Map Depiction of the Aerial Distribution of the Smoke Plumes
- Issue a Daily General Statement about the Expected Behavior(s) of the Oil Fire Plumes

Phase II. Establish a PM¹⁰ Monitoring Network Using Portable PM¹⁰ Monitors

Working in Conjunction with the Saudi Arabian
Meteorology and Environmental Protection Agency
(MEPA), the Proposed Plan Has Been Developed to Collect
Information on PM¹⁰, Which Represents Particulate Matter
with Particles Less Than 10 Microns in Diameter (at the
present time there is little or no PM¹⁰ monitoring in the Gulf
Region)

Phase II. Establish a PM¹⁰ Monitoring Network Using Portable PM¹⁰ Monitors

- Conduct a PM¹⁰ Saturation Sampling Study to Determine the Temporal and Spatial Features of the Impact of the Oil Well Fires and Attempt to Reconcile the Data with Existing Model Estimates
- Total of 15–20 Portable PM¹⁰ Samplers Equipped with Quartz Filters Would Be Run Simultaneously on a Daily Basis

Phase II. Establish a PM¹⁰ Monitoring Network Using Portable PM¹⁰ Monitors

(continued)

The Recommendation for Siting of the Portable PM¹⁰
 Samplers is Predicated on Providing a Large Area of
 Coverage for Developing a Better Estimate of the
 Areas Impacted by the Plume, a Cross-Sampling of
 Population Centers, and to Provide the Opportunity
 to Transfer this Technology to Saudi Arabia, Kuwait,
 and Bahrain

Phase III. Characterize the Aerial Plume

- To Achieve This Goal, Many of the Same Plume Measurements Collected by the Existing and Proposed Ground Level Measurement Locations Should Be Provided by the Aerial Sampling Platform
- The Aerial Sampling Activities May Be Separated into Measurements Which Address the Three General Zones of Plume Characteristics, from a Meteorological Sense
 - Close-In Zone
 - Intermediate of Transition Zone
 - Extended or Distant Zone

Phase IV. Develop a Complete Profile of the Smoke Plume Constituents

- Obtain Additional Equipment to Expand Existing Continuous Monitoring High Priority Sites in Kuwait and Saudi Arabia
- The Survey Conducted by the Team During Phase I of This Plan Indicated That within the Region, Respirable Particulate Sampling Technology, Aerosol and Total Particulate Sampling and Analysis for Volatile Organic Compounds (VOC), Semi-Volatile Organic Compounds (SVOC), and PAHs Were Either Not Available or Insufficient to Properly Characterize the Effects of the Oil Well Fires on the Population Centers and the Troop Concentrations within the Region

Phase IV. Develop a Complete Profile of the Smoke Plume Constituents

(continued)

 The Plan Proposes to Expand the Continuous Air and Meteorological Monitoring Currently Being Conducted within the Region at Six Sites

Phase IV. Proposed Monitoring Equipment

- TSP High Volume Sampler
- PM¹⁰ High Volume Sampler
- PM¹¹¹ Dichotomous Sampler
- VOC Canister Sampler
- Polyurethane Foam (PUF) Low Volume Sampler
- Optional Tenax/Charcoal/XAD-2 Tubes

- This Phase of the Proposal Will Be Developed in Series of Stages
- The Network is Directed at Long Term Fixed Site Monitoring,
 Which Will Collect a Battery of Both Air Quality and
 Meteorological Data
- Particular Attention Will Be Given to Providing an Early Warning System Advising the Effected Public on What Cautionary Steps Should Be Taken to Minimize the Impact of Air Pollution on Health

- Recommended Measurement Parameters at Each Site
 - Meteorological Variables
 - Wind Speed and Direction
 - Temperature
 - Moisture Content of the Air
 - Dew Point, Relative Humidity
 - Solar Radiation
 - Precipitation
 - Air Quality Variables

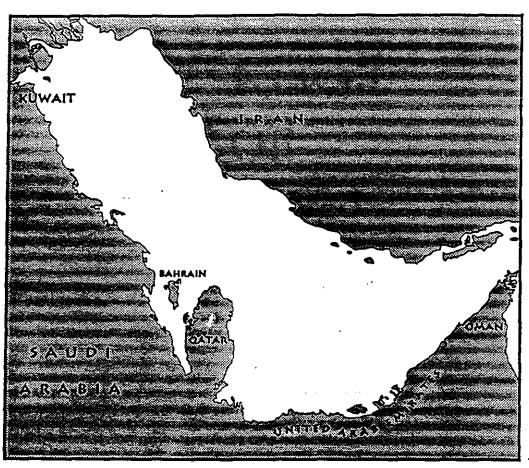
Episodic/Early Warning Measurements	Longer Term Monitoring	
PM¹º (continuous)	Acid Aerosols	
TSP	VOCs	
SO ₂ (continuous)	Aldehydes	
O ₃ (continuous)	B[a]P, Other PAHs	
NO, NO (continuous)	Trace Elements	
CO (continuous)	Fine Particulates	
H ₂ S (continuous)		

- Health Monitoring Survey
 - Health Questionnaires
 - Blood Samples
 - Urine Samples
 - Hair Samples
 - In Vivo Animal Studies
 - Forced Expiratory Volumes
 - Other Morbidity Parameters

(continued)

Distribution of Existing and New Sites Air Monitoring Sites

Locations	Existing	New Sites	
Saudi MEPA	4	10	
Saudi ARAMCO	11	0	
Kuwait	3	8	
Bahrain	0	2	
Other Locations	8	4	



Kuwait Oil Fires:

Interagency Interim Report

April 3, 1991

KUWAIT OIL FIRES INTERAGENCY INTERIM REPORT

I. SUMMARY

More than 500 oil well, storage tank and refinery, and facility fires are currently raging in Kuwait and each day produce an enormous amount of smoke and other pollutants. The quantity and character of the smoke plumes are not yet certain, and the fires are expected to continue for some period. The fires originate in seven oil fields, located both north and south of Kuwait City, with the majority centered in the Al Burgan oil field south of the Kuwait City airport. The fires may represent one of the most extraordinary manmade environmental disasters in recorded history.

In response to this situation, the Saudi Government requested U.S. technical assistance on the public health and environmental impact of the fires. The U.S. Embassy in Saudi Arabia concurred in this request, and voiced its additional concerns about the health effects of the fires on the hundreds of thousands of U.S. troops in the region as well as the thousands of American citizens residing in Saudi Arabia and the other Gulf countries. Similar concerns were also expressed in Kuwait. An Interagency Air Assessment Team consisting of representatives from the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the Department of Health and Human Services was formed and deployed to the Persian Gulf area. In country, this team was supplemented by representatives of the United States Coast Guard, the Department of Defense, and the Department of Energy.

The specific mission of the team was to assess the conditions through air sampling and monitoring in oil fields and other areas to determine the effect on public health; to review the health infrastructure; to determine the capability of the region to deal with the health threat through air monitoring and appropriate corrective action; to provide technical assistance; and to consider appropriate follow-up action.

Meteorological conditions over the past two months have tended to transport the smoke plume toward the southeast, with periodic excursions toward the northeast. March through July are relatively windy months; there are normally 30 days of very strong winds from the northwest in this period, which produce sandstorms and rapidly ventilate the smoke. From August to October, the incidence of strong winds should drop sharply. The plume is generally below about 12,000 feet. As the summer progresses, it is possible that the height of the plume will increase and that it will then be evident to greater distances.

Emissions from oil fires may have the potential of causing health effects of both an acute and chronic nature, although there is considerable uncertainty as to the extent of the threat. Chemicals such as sulfur dioxide and hydrogen sulfide as well as carbon monoxide and polycyclic aromatic hydrocarbons are often found along with particulate matter in oil fires. While only a limited assessment is possible at this time, the Team did not detect such chemicals in any significant quantity; also, preliminary analysis of the substantial amount of particulate matter did not reveal any chemicals at levels of concern. Additional testing is needed to better define if other toxic materials may be associated with the high levels of particulates found.

The host nation governments also provided the Team with an abundance of preexisting air monitoring information covering the past several years in Saudi Arabia, Kuwait, and Bahrain. These data provide

a useful baseline on limited parameters for comparing the conditions that exist and may evolve during the next several months. The Team concurred with the Saudi Government's view that the considerable Saudi public and private sector competence in air monitoring would need to be supplemented with support and technical assistance. This situation is even more acute in Kuwait City due to the lack of power and to the disruption of the governmental and scientific infrastructure. The Team considered it of critical importance that additional technical assistance be made available to the countries, if requested.

There is need to consider the overall problem from several perspectives so as to ensure economy as well as success. First, because high levels of particulates were found in the air, and prolonged exposure to particulate matter may contribute to respiratory discomfort and perhaps long-term or permanent respiratory disorder, it will be necessary to find out what is in the plume and how it varies over time and distance. Second, we should assess the immediate and long-term human health risk. Third, we should quantify effects on the environment, especially on crops and climate.

II. TEAM'S ACTIVITIES AND FINDINGS

With the assistance of the Saudi and Kuwaiti Governments, the U.S. Interagency Air Assessment Team has been conducting a reconnaissance survey of the fire plumes and their effects in Kuwait and Saudi Arabia since March 10, 1991. The primary objective of the Team was to obtain preliminary, short-term data on the emissions from the smoke emanating from the oil well fires at a variety of locations, in order to:

- Determine if there is an acute health threat associated with the Hydrogen Sulfide (H₂S)
 and Sulfur Dioxide (SO₂) and particulates, three pollutants that might be emitted from
 burning oil wells;
- 2. Identify and quantify the gaseous and particulate byproducts being produced from the burning oil wells; and
- 3. Determine if the materials associated with these fires are affecting areas where American citizens are located.
- 4. Assess the potential extent of the health effects related to the emissions from the fires and the status of the Kuwaiti and Saudi health infrastructure.

Based on these objectives, limited, real-time data was obtained directly from the Kuwait oil fields, as well as from Kuwait and Saudi Arabia locations where embassy officials, troops, and citizens work and reside. Additionally, the Team conducted a number of interviews with health officials to evaluate the extent of acute respiratory problems related to smoke exposure. While only a cursory assessment is possible at this point, some data obtained by the team were encouraging. The preliminary findings are as follows:

- Limited sampling did not reveal the existence of high concentrations of sulfur dioxide or hydrogen sulfide near the burning wells or in population areas in the path of the oil well emissions;
- 2. High levels of particulate were found in the air;

- 3. The results of the current monitoring findings and health interviews with medical personnel in the affected areas suggest that at the present time susceptible subpopulations, such as individuals with asthma and chronic obstructive lung disease, may experience exacerbation of their symptoms. Special health concerns, warnings, advisories, and precautions are clearly warranted for these individuals. This situation does not appear to be life threatening under current exposure conditions but, if meteorological conditions change, i.e., poor air mixing or plume touchdown, there could be adverse health effects for these susceptible individuals; and,
- 4. The long-term effects on health are not readily ascertainable at this time due to insufficient data on the populations exposed, the composition of the smoke plume, the impact of oil pools, and long-term meteorological patterns. Both the Kuwaiti and Saudi health communities have expressed great interest in obtaining training and support from the US medical community that can be continued by themselves in future years. Aggravating the problem is the severe damage done to the scientific infrastructure of Kuwait thus limiting the current in-country analytic capabilities. Any response by the US would have to include both training and equipment.

The Team has stressed, however, that their observations represent only a preliminary assessment and that considerable follow-up will be necessary to evaluate definitively the nature and magnitude of the human health, ecological, and atmospheric effects of the oil fires. Such follow-up activities will need to be carefully coordinated with the governments in the region as well as with other governments and international organizations, such as WMO, WHO, and UNEP, which are seeking to assist in evaluating the situation.

III. PROPOSED PROGRAM

The local populations are being exposed to an increased health risk, the magnitude of which cannot be estimated with any degree of certainty without further measurements and surveys. The extent to which conditions may worsen needs to be understood and a forecast capability developed. Without such measurements and assessment, and development of a predictive capability, the regional population remains exposed to an uncertain risk, and reconstruction of the area may be impeded. Moreover, without such input, an accurate and defensible quantification of environmental effects will not be possible.

In addition to providing direct answers to questions regarding the effects of the smoke plumes on the atmospheric environment, intensive studies of the plumes will accelerate progress in understanding manmade effects on regional and global air quality, meteorology, and climate. Because the expected changes in air chemistry, solar radiation, and cloud microstructure are so large, observations of these processes could circumvent the need for many years of study directed at much lesser phenomena.

The program proposed below is comprised of three primary elements: human health surveillance and risk assessment, air monitoring, and development of a forecast capability. These elements will be closely linked to achieve the goals of understanding and predicting the degree of human health risk and the effects on atmospheric processes.

1. Air Monitoring

The objective of the air monitoring program is to collect the necessary data to determine the nature and concentration of pollutants associated with the fires, and demonstrate the recovery of the environment as the fires are extinguished.

The development and deployment of an integrated monitoring network will serve several interrelated purposes. It will assure data consistency throughout the region. It will provide better data to assess the immediate health risk and potential for long term risks. It will be used to initiate, test, and refine forecast models discussed later in this plan, and thus greatly assist in the development of location and condition specific alerts -- assisting in issuing special advisories for populations at risk under unique conditions. Lastly, it will provide a better basis for scientific understanding and knowledge of the important regional and international issues and will assist in assessing possible extended consequences of the fires.

The U.S. Interagency Air Assessment Team is working with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA), Saudi ARAMCO, and King Fahd University of Petroleum and Minerals to develop an air monitoring plan for the Gulf Region that will provide the air monitoring data to assess the impact of the Kuwaiti fires in Saudi Arabia. While focused primarily on the needs of Saudi Arabia, the plan forms the general basis for a regional network that should meet the needs of other Gulf nations as well.

The following activities are proposed in cooperation with and support of the host governments:

- Immediate steps would be taken to collect and analyze meteorological observations and forecasts, record visual observations of the smoke plume, and review existing monitoring data. Plume observations via satellite would be obtained daily, supplemented by periodic on-scene aerial transects designed to characterize the overall geometry of the plume.
- A ground-based sampling network of portable equipment would be installed by EPA and others at approximately 15-20 locations to measure particulate matter less than 10 microns in diameter (the particle size most likely to penetrate deeply into the lungs). The ratio of the less than 10 micron particles to total particulate load would be established. Limited organic analysis would be undertaken.
- Measurements of carbon monoxide, carbon dioxide, methane, hydrogen sulfide, sulfur dioxide, particle size distribution, elemental and organic carbon, metals, polycyclic aromatic hydrocarbons, and acid aerosols would be obtained close to the fires by NASA and NIST. These measurements should attempt to characterize and categorize emissions from several specific wells.
- Specially equipped aircraft from the University of Washington (April 15 to May 15), NCAR (May 1 to June 1), and NOAA (July 1 to August 1) would be deployed to measure downwind plume composition and dispersion, radiative properties and climatic effects, and effects on clouds and precipitation. On the basis of the initial aircraft results, a longer-term sampling program would be designed to monitor the relaxation of the atmospheric environment as the fires are extinguished.

- Six additional comprehensive air quality monitoring stations would be established along the general axis of the plume from Kuwait City to Saudi Arabia to collect data on particulates, as well as on the organic and inorganic constituents of the plume.
- Meteorological stations would be co-located at as many as possible of the selected monitoring sites. Data would be collected on wind, temperature, humidity, direct and diffuse radiation, soil temperature, and precipitation: Ten precipitation monitoring stations operated by WMO would be upgraded to measure departures in precipitation chemistry and restabilization to normal levels.
- A data and information system would be designed to provide world-wide access to data of all types related to the fires. High speed data transmission capability would be established to enable image, graphics, and text exchange among participants in the monitoring, forecast, and health elements of the program. In the short-term a temporary archive would be developed to avoid loss of key data sets.

2. Development of a Forecast Capability

The objective of this activity is to develop an early warning advisory system for the Gulf and downwind regions. The system would forecast the trajectory of plumes created by the fires and compute the atmospheric concentrations of several constituents of known human health and potential environmental impact.

Mathematical models of the fires and their effects are being developed by institutions in Saudi Arabia and the United States to assess the impact of the fires. The models detail the combustion process associated with each well, and predict plume rise, chemical transformations, transport and dispersion, and particle deposition. These models are in turn linked to other algorithms and databases to predict the impact of the plume on human health, and the local and distant environment (including effects on crops).

A number of activities would be undertaken to complete the development of a forecast system:

- Short-term meteorological forecasts would be used immediately to predict the orientation and general concentration of the smoke plume throughout the region.
- Existing models in the U.S., Saudi Arabia, and elsewhere would be tested through air quality measurements obtained through the monitoring program described in the preceding section. As testing is completed, the models would be used to adjust the location of portable monitoring stations for optimal sampling and provide improved forecasts of plume characteristics.
- Selected models, when tested, would be assembled into a single computer system linked to weather forecast models available through NOAA's National Climatic Data Center. The system would form the basis of an early warning system with terminals into the system available both in the United States as well as from the Gulf region.
- At the conclusion of model development and testing, training and equipment would be provided to allow the modeling capability to be fully operated by appropriate agencies in the Gulf region.

3. Human Health Surveillance and Risk Assessment

The objectives of this activity are to assess initial data obtained by the U.S. Interagency Air Assessment Team, to set up the needed infrastructure, and to conduct medical surveillance, epidemiological studies, and clinical field studies for the purpose of examining specific health endpoints in order to ascertain whether there are short-term and/or long-term trends in morbidity and mortality associated with exposure to the oil smoke plumes and deposition.

Developing plans for and conducting a cross-disciplinary approach to human health risk assessment and health advisories is a difficult, complex and time-consuming task. The plan presented below can proceed only after accomplishing a coordinated interagency evaluation and assessment of the EPA monitoring data and other information. At that time, additional monitoring and modeling may be required. On that basis, the scope of effort, the type and number of health personnel both here and abroad, equipment, and other items cannot be identified in any detail. However, continued coordination and collaboration with the DOD and the Kuwaiti and Saudi health authorities is necessary to maintain established information sharing. Continued information sharing will aid in the development of baseline data for a complete human health risk assessment. In addition, this can help provide Kuwait with some important needed assistance in reestablishing their medical and health care infrastructure.

The following tasks need immediate attention:

- Health advisories should be reviewed and updated for use by military and non-military personnel based on an assessment of the U. S. Interagency Air Assessment Team data and observations.
- Interim preventive measures should be identified and initiated including, but not limited to, the use of dust masks and limiting exercise during periods of severe smoke.
- Medical facilities should be alerted to the potential increased frequency of asthma attacks and eye irritations and ensure adequate supplies of appropriate medications. Protocol should be established to alert military, indigenous, and other non-military transient populations of potential health risks, particularly for high risk populations such as asthmatics, people with heart disease or chronic obstructive pulmonary disease, children, and pregnant women.
- A plan should be developed to collect needed medical and demographic information on affected populations including health examinations and a permanent archive of service records for all U.S. personnel stationed in the Gulf. These records will be vital in order to answer future questions on the health impact of U.S. personnel serving in the Gulf.
- Host governments should be assisted, as requested, in baseline studies of affected populations.
- Develop plans for conducting medium- and long-term epidemiological and clinical studies, and establishing medical surveillance systems.
- Establish criteria for assessing the effectiveness of an early warning system to protect
 the U.S. and civilian personnel. Based on the monitoring system established by the
 host countries, an early warning health advisory system should be established.

These efforts should promptly follow:

- Non-plume and plume samples for short-term in-vitro, and in-vivo toxicity and mutagenicity testing and dose response assessment should be collected.
- Acute and chronic health risks based on integrating information from exposure assessments, epidemiological/clinical studies, and in-vitro and in-vivo toxicity studies must be assessed.
- Assess the impact of oil pooling and combustion deposition on potential exposure pathways.

IV. INTERNATIONAL COORDINATION

The U.S. Interagency Air Assessment Team currently working in the Gulf region has undertaken several first steps to coordinate planning with the governments of Saudi Arabia, Kuwait, and Bahrain. To achieve the objectives of this plan, several further steps toward international coordination are necessary:

- Arrangements should be made with the government of Kuwait to complete the reactivation of the three air monitoring stations which were operating before the war.
 These stations will be critical to obtaining key observations near the source of the fires.
- The British Meteorological Office is currently conducting long-range sampling of the fire plume by aircraft. Coordination of data exchange and research plans between programs should be arranged through WMO.
- WMO should also be requested to arrange for collaboration of modeling efforts with Canadian and British scientists who work on similar programs.
- Collaboration is needed with Kuwaiti and Saudi health authorities to assess the
 effectiveness of an early warning system to limit or reduce air pollution-related
 mortality and morbidity, and to monitor trends in respiratory disease.
- The design and conduct of short-and long-term epidemiological and clinical studies must be integrated between Kuwaiti, WHO, and other countries providing assistance.
- To the extent feasible, and, when requested, U.S. agencies should work with multinational organizations to rebuild the public health infrastructure in Kuwait.

APPENDIX A

AIR SAMPLING AND MONITORING

The initial air sampling and monitoring program conducted by the U.S. Interagency Air Assessment Team in Kuwait and Saudi Arabia had the following objectives:

1. Determine if there is an acute health threat associated with the Hydrogen Sulfide (H2S) and Sulfur Dioxide (SO2) gases being emitted from the burning oil wells.

This objective was accomplished by collecting Real Time Measurements (i.e. instantaneous readings) using portable instruments for the following parameters: H2S, SO2, oxygen, and total particulate. These measurements were collected at 13 locations in Kuwait and Saudi Arabia, U.S. Embassies in Kuwait and Riyadh, MEPA Dhahran, at five oil well fields, and at various locations near the oil fields in Kuwait. The results from the March 13-20 monitoring are summarized in Table 2.

The highest readings were recorded from measurements taken in the smoke plumes in the oil fields. The results from this monitoring did not indicate an acute health threat. However, if conditions change, (i.e., fires are extinguished without capping, allowing high levels of gases) an acute threat near the wells may occur.

The highest levels observed were: particulate 5.4 mg/m3, VOCs 2.5 ppm (adjacent to large pools of oil), H2S 42 ppb, and SO2 2 ppm. It should be noted that the detection limit for the SO2 monitor is 1-2 ppm. A different SO2 monitor with a detection limit 0.1 ppm did not indicate SO2. Also, the field personnel wer, unable to detect any sulfur odors at any of the locations. Therefore, the SO2 levels of 1-2 ppm should be used with caution.

The only elevated levels observed in the monitoring conducted in the population areas were for particulates. A reading of 480 ug/m³ was obtained at MEPA in Dhahran, Saudi Arabia. Based on field observation this reading was probably a combination of smoke from the fires and sand. Baseline particulate levels due to blowing sand in Saudi Arabia and Kuwait range from 200-3000 ug/m³.

Further sampling and monitoring occurred from 3/24 - 3/27. These results are also attached. The results from this monitoring are similar the previous monitoring results. In general, the particulate concentrations at ground level in the oil fields were lower than in the downwind areas outside the fields, except when in the direct path of a ground level plume. The downwind locations most heavily affected vary, depending on wind speed, temperature, humidity, and other diurnal factors.

The real time particulate readings during this phase are 15 and 20 minute averages. The highest reading occurred at the Ahmadi Hospital, with a 20 minute average reading of 0.935 mg/m³ with a single highest reading of 1.16 mg/m³. Other successive 20 minute averages taken at this location display the variation in particulate levels at the same location, as conditions such as wind direction change.

2. The second objective was to identify and quantify the gaseous and particulate byproducts that are associated with the burning oil wells.

This objective has partially been accomplished. Samples from 10 locations have been analyzed by ERT's laboratory in the U.S. The air samples were collected for the following parameters at all

locations: volatile organic (VOCs), polycyclic aromatic hydrocarbons (PAHs i.e naphthalene, benzo(a)pyrene), heavy metals, SO2, and inorganic acids (i.e. sulfuric, nitric, etc.). A limited number of samples were collected for H2S, formaldehyde, CO, and total nuisance dust. For specific findings relevant to these samples see the section entitled "Air Sampling Results."

3. The third objective was to determine if the materials associated with the fire were effecting areas where American citizens were located.

This objective will partially be accomplished by reviewing the data from the samples taken at MEPA Dhahran, Saudi Arabia, U.S. Embassies in Kuwait and Riyadh, Camp Freedom Kuwait, and Port Shuaybah, Kuwait, and reviewing the air monitoring data being collected by MEPA and ARAMCO in Saudi Arabia air monitoring stations and sulfur dioxide data taken at temporary hospital locations in Kuwait City.

In order to complete this objective in a sound scientific manner, sampling for PM₁₀ particulate (i.e. particulate less than 10 microns in size), which are the respirable particulate, and samples from the plume above ground level should be taken. Also, the air monitoring network proposed by the U.S. Interagency Air Assessment Team should be implemented.

AIR SAMPLING RESULTS:

The results from the air samples collected for sulfur dioxide, volatile organics, and inorganic acids from 3/13 - 3/20 in Kuwait and Saudi Arabia confirmed the real time measurements and sampling and analysis performed by the Kuwaitis and the Saudis. These results confirmed the conclusion of the U.S. Interagency Air Assessment Team that the primary hazards from the oil well fire is with the particulate matter.

The highest level of sulfur dioxide (0.68 ppm) was detected in the smoke plume of the Burgan Oil Field. This level is above the EPA 24 hour (0.14 ppm) and 3 hour (0.5 ppm) limit. None of the sulfur dioxide samples collected in populated areas exceeded the EPA air quality limits.

The organic vapor analysis showed that compounds associated with petroleum (i.e. benzene, toluene, and aliphatic hydrocarbons such as n-heptane (n-C7)) were detected. The highest levels (i.e. 10-20 ppb level) were detected in the smoke plume in the oil fields and a grab (SUMMA) sample collected at ground level near a pool of oil in the Sabiriyah well field. The inorganic acid analysis showed low ppb levels for both sulfuric and nitric acid. Based on this limited data, the sulfur dioxide and nitrous oxide that may be byproducts from the burning of the oil are not being formed in large amounts.

The results from the particulate analysis for polycyclic aromatic hydrocarbons (PAHs) and heavy metals showed very low levels of both parameters in the samples collected in the populated areas and in the oil fields. The only metals detected were those associated with materials found in the sand particles (i.e. sodium, aluminum, magnesium, etc.).

Based on these limited number of samples, the major hazard associated with the oil well fires seems to be the particulate matter being emitted. The monitoring and sampling program discussed in the Air Monitoring Strategy Plan should help further define the hazards associated with the particulates.

The complete results from the sampling are summarized in the attached exhibits. Only the compounds detected are listed.

PARAMETERS:

The air samples collected at the oil well fields, Camp Freedom, MEPA Dhahran, Saudi Arabia, and U.S. Embassies in Kuwait and Riyadh, Saudi Arabia were analyzed for the following parameters:

PAHs: (NIOSH Method 5515)

Naphthalene, 2-Methylnaphthalene, 1-Methylnapthlalene, Biphenyl, 2,6-Dimethylnaphthalene, Acenaphthylene, Acenapthene, Dibenzofuran, Fluorene, Phenanthrene, Anthracene, Carbazole, Fluoranthene, Pyrene, Benzo[a]anthracene, Chrysene, Benzo[b]fluoranthene, Benzo[k]flouranthene, Benzo[e]pyrene, Benzo[a]pyrene, Indeno(1,2,3-cd)pyrene, Dibenzo[a,h]anthracene, Benzo[g,h,i]perylene.

Inorganic Acids: (NIOSH Methods 7903)

Hydrochloric, Phosphoric, Sulfuric, Nitric, Hydrofluoric.

Metals: (NIOSH Methods 7300)

Platinum, Titanium, Molybdenum, Zirconium, Silver, Aluminum, Beryllium, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Magnesium, Manganese, Sodium, Nickel, Lead, Tin, Vanadium, Zinc.

Volatile organics: (Modified Method 1500, 1501, 1003)

1,1,1-Trichloroethane, Cyclohexane, Carbon Tetrachloride, Benzene, Cyclohexene, 1,2-Dichlorpropane, (n-C7), Trichloroethane, 1,4-Dioxane, Methylcyclohexane, Methylisobutylketone, Toluene, n-Octane Tetrachloroethane, Chlorobenzene, Ethylbenzene, para-Xylene, Bromoform, Styrene, o-Xylene, n-Nonene, n-Nonane (n-C9), 1,1,2,2-Tetrachloroethane, Cumene, Mesitylene, Alpha-methylstyrene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene, 1,2-Dichlorobenzene, Benzyl Chloride, alpha-Terpine, D-Limonene, 4-tert-Butyltoluene, 1,2,4-Trichlorobenzene, Naphthalene, 4-Phenylcyclohexene, n-Decane (n-C10), n-Decene, n-Undecene, n-Undecane (n-C11), n-Nonanal, n-Dodecane (n-C12), n-Tridecane (n-C13), n-Tetradecane (n-C14), n-Pentane (n-C15), n-Hexadecane (n-C16).

Others:

Formaldehyde and Sulfur Dioxide.

EXHIBT 1: Air Sampling Results

U.S. EMBASSY, KUWAIT

Results for 3/16

PAHs:

none detected

detection limit: 2 - 4.6 ppb

Sulfur Dioxide:

none detected

detection limit: 0.04 mg/m3

Inorganic Acids:

HNO₃ 5ppb

detection limit: 1 - 6 ppb

VOCs:

Benzene 0.4 ppb, n-Heptane 0.13 ppb, Toluene 0.61 ppb, Ethylbenzene 0.1 ppb, para-Xylene 0.29 ppb, o-Xylene 0.12 ppb.

Metals:

Na < 1.0 ug/m3, Mg 2 ug/m3, Fe 2 ug/m3, Ca 8 ug/m3, Al 2 ug/m3.

Results for 3/17

PAHs:

Naphthalene 0.31 ppb

Sulfur Dioxide:

< 0.02 mg/m3

Inorganic Acids:

HCl 3.0 ppb, H2SO4 1.0 ppb, HNO3 2.0 ppb

VOCs:

Cyclohexane 1.31 ppb, Benzene 4.0 ppb, n-Heptane 6.0 ppb, TCE 0.7 ppb, Methylcyclohexane 2.0 ppb, Toluene 7.7 ppb, n-Octane 3.0 ppb, Ethylbenzene 1.7 ppb, p-Xylene 5.4 ppb, Styrene 0.4 ppb, o-Xylene 2.4 ppb, n-Nonane 1.9 ppb, Cumene 0.2 ppb, Mesitylene 0.6 ppb, D-Limonene 0.1 ppb, n-Decane 1.5 ppb, n-Undecane 1.0 ppb, n-C12 0.7 ppb, n-C13 0.4 ppb.

Metals:

Na 10 ug/m3, Mg 2 ug/m3, Fe 3 ug/m3, Ca 10 ug/m3, Al 2 ug/m3.

EXHIBT 1: Air Sampling Results

U.S. EMBASSY, KUWAIT, continued

Results for 3/18

PAHs:

Naphthalene 0.16 ppb

Sulfur Dioxide:

< 0.05 mg/m3

Inorganic Acids:

HCl 6 ppb, HNO3 2 ppb, H2SO4 1.0 ppb.

VOCs:

Cyclohexane 1.2 ppb, Benzene 5.2 ppb, n-C7 8.1 ppb, Methylcyclohexane 3.0 ppb, Toluene 14.6 ppb, n-C8 4.7 ppb, Ethylbenzene 3.2 ppb, p-Xylene 9.3 ppb, o-Xylene 4.7 ppb, n-C9 2.7 ppb, Cumene 0.3 ppb, Mesitylene 1.3 ppb, Naphthalene 0.18 ppb, n-C10 1.7 ppb, n-C11 1.0 ppb, n-C12 0.7 ppb, n-C13 0.3 ppb.

Metals:

Na 5 ug/m3, Mg 1 ug/m3, Fe 1 ug/m3, Ca 7 ug/m3, Al 1 ug/m3.

CAMP FREEDOM

Results For 3/17

PAHs:

Naphthalene 0.09 ppb, 2-Methylnaphthalene 0.06 ppb, 1-Methylnaphthalene 0.04 ppb.

Sulfur Dioxide:

0.12 mg/m3 0.045 ppm

Inorganic Acids:

HCI 16 ppb, HF 23 ppb, H2SO4 31 ppb

VOCs:

Cyclohexane 7 ppb, Benzene 4.6 ppb, n-C7 25.6 ppb, Methylcyclohexane 9.5 ppb, Toluene 13 ppb, n-C8 18 ppb, Ethylbenzene 2.7 ppb, p-Xylene 8 ppb, o-Xylene 4.5 ppb, n-C9 10.9 ppb, Cumene 0.5 ppb, Mesitylene 1 ppb, Naphthalene 0.18 ppb, n-C10 6.3 ppb, n-C11 4.1 ppb, n-C12 2.3 ppb, n-C13 0.9 ppb, n-C14 0.5 ppb. These levels may also include emissions from vehicles in the area.

Metals:

No Data.

Results for 3/18

PAHs:

Naphthalene 0.28 ppb

Sulfur Dioxide:

< 0.04 mg/m3, < 0.015 ppm

Inorganic Acids:

HNO3 4.0 ppb, H2SO4 4 ppb.

VOCs:

Cyclohexane 2.8 ppb, Benzene 6.9 ppb, n-C7 9.7 ppb, Methylcyclohexane 3.9 ppb, Toluene 16 ppb, n-C8 5.4 ppb, Ethylbenzene 3.1 ppb, p-Xylene 9.5 ppb, Styrene 0.3 ppb, o-Xylene 4.5 ppb, n-C9 3 ppb, Cumene 0.3 ppb, Mesitylene 1.1 ppb, n-C10 1.5 ppb, n-C11 0.8 ppb, n-C14 0.2 ppb.

Metals:

Al 2 ug/m3, Ca 8 ug/m3, Fe 2 ug/m3, Mg 2 ug/m3, Na 3 ug/m3.

MEPA DHAHRAN, SAUDI ARABIA

Results For 3/13

PAHs:

none detected

Sulfur Dioxide:

<0.1 mg/m3, <0.037 ppm

Inorganic Acids:

H2SO4 5 ppb.

VOCs:

Benzene 0.3 ppb, Cyclohexane 0.1 ppb, Toluene 0.5 ppb, Ethylbenzene 0.1 ppb, p-Xylene 0.2 ppb, o-Xylene 0.1 ppb, Mesitylene 0.04 ppb.

Metals:

Al 2 ug/m3, Ca 5 ug/m3, Fe 2 ug/m3, Mg 2 ug/m3, Na 1 ug/m3. Cd o.o1 ug/m3

Results For 3/14

PAHs:

none detected

Sulfur Dioxide:

< 0.08 mg/m3, < 30 ppb.

Inorganic Acids:

HNO3 2 ppb, H2SO4 6 ppb.

VOCs:

Cyclohexane 0.2 ppb, Benzene 0.5 ppb, n-C7 0.8 ppb, Methylcyclohexane 0.3 ppb, Toluene 0.7 ppb, n-C8 0.4 ppb, Ethylbenzene 0.1 ppb, p-Xylene 0.3 ppb, o-Xylene 0.1 ppb, n-C9 0.3 ppb.

Metals:

Al 3 ug/m3, Ca 14 ug/m3, Fe 3 ug/m3, Mg 4 ug/m3, Na 8 ug/m3.

U.S. EMBASSY RIYADH, SAUDI ARABIA

Results For 3/28

PAHs:

none detected

Sulfur Dioxide:

< 0.08 mg/m3, < 30 ppb

Inorganic Acids:

NO3 3 ppb, H2SO4 < 2 ppb.

VOCs:

Benzene 0.3 ppb, Toluene 0.6 ppb, Ethylbenzene 1.0 ppb, p-Xylene 0.3 ppb.

Metals:

Al 8 ug/m3, Ca 4 ug/m3, Fe 1 ug/m3.

PORT SHUAYBAH

Results For 3/17

PAHs:

no data

Sulfur Dioxide:

< 0.05 mg/m3, , 19 ppb

Inorganic Acids:

H2SO4 19 ppb.

VOCs:

Benzene 4.2 ppb, n-C7 13 ppb, Methylcyclohexane 5.3 ppb, Toluene 15 ppb, n-C8 5.6 ppb, p-Xylene 6.9 ppb, Ethylbenzene 2.2 ppb, o-Xylene 2.9 ppb, n-C9 3.8 ppb, Cumene 0.2 ppb, n-C10 2.9 ppb, n-C11 1.9 ppb, n-C12 1.4 ppb, n-C13 0.8 ppb.

Metals:

Ca 4 ug/m3, Na 7 ug/m3, AL 2 ug/m3.

AI MAQUA OIL FIELD

Results for 3/15

PAHs:

no data

Sulfur Dioxide:

<0.3 mg/m3, <0.1 ppm

Inorganic Acids:

no data

VOCs:

Cyclohexane 0.6 ppb, Benzene 1.8 ppb, n-C7 3.2 ppb, Methylcyclohexane 1.1 ppb, Toluene 2 ppb, Ethylbenzene 0.4 ppb, p-Xylene 1.4 ppb, o-Xylene 0.8 ppb, n-C9 2.8 ppb, Mestilylene 0.3 ppb, n-C10 3.3 ppb, n-C11 3.5 ppb, n-C12 3.3 ppb, n-C13 1.8 ppb, n-C16 1.1 ppb.

Metals:

Al 8 ug/m3, Ca 6 ug/m3, Fe 6 ug/m3.

AI AHMADI OIL FIELD

Results For 3/16

PAHs:

none detected

Sulfur Dioxide:

0.45 mg/m3 , 0.17 ppm

Inorganic Acids:

H2SO4 27 ppb, HNO3 10 ppb, HCl 9 ppb.

VOCs:

Cyclohexane 0.4 ppb, Benzene 3.9 ppb, n-C7 2.5 ppb, Methylcyclohexane 1 ppb, Toluene 2 ppb, n-C8 2.3 ppb, Ethylbenzene 0.5 ppb, p-Xylene 1.5 ppb, o-Xylene 0.9 ppb, n-C9 2.9 ppb, Mesitylene 0.4 ppb, Naphthalene 0.5 ppb, n-C10 3.4 ppb, n-C11 3.8 ppb, n-C12 4 ppb, n-C13 2.9 ppb, n-C14 2.9 ppb, n-C15 2 ppb, n-C16 1.7 ppb.

Metals:

Al 7 ug/m3, Ca 4 ug/m3, Fe 20 ug/m3.

Formaldehyde:

8 ppb.

Hydrogen Sulfide: ND 0.3 ppm - detection limited .

SUMMA Data:

SO2 0.2 ppm; CO 1.9 ppm

AI BURGAN OIL FIELD

Results For 3/17

PAHs:

none detected; detection limit 50 ppb

Sulfur Dioxide:

1.8 mg/m3, 0.67 ppm

Inorganic Acids:

H2SO4 30 ppb, HNO3 32 ppb, HCl 15 ppb.

VOCs:

Benzene 8.7 ppb, n-C7 4.6 ppb, Methylcyclohexane 2.5 ppb, Toluene 4.31 ppb, n-C8 5.1 ppb, Ethylbenzene 1.3 ppb, p-Xylene 4.2 ppb, o-Xylene 2.4 ppb, n-C9 7.1 ppb, Naphthalene 1.6 ppb, n-C10 9.1 ppb, n-C11 10.4 ppb, n-C12 11.3 ppb, n-C13 7.8 ppb, n-C14 7.4 ppb, n-C15 5.4 ppb, n-C16 4.6 ppb.

Metals:

Al 20 ug/m3, Ca 120 ug/m3, Fe 20 ug/m3, Mg 30 ug/m3.

Formaldehyde:

20 ppb;

SUMMA Data:

SO2 0.23 ppm, CO 1.6 ppm, H2S none detected (0.1 ppm detection limit.)

AI WAFRA OIL FIELD

Results for 3/19

PAHs:

no data

Sulfur Dioxide:

none detected 0.3 mg/m3, 0.11 ppm.

Inorganic Acids:

none detected 10 ppb detection limit

VOCs:

Benzene 2.3 ppb, n-C7 0.6 ppb, Methylcyclohexane 1.6 ppb, Ethylbenzene 0.3 ppb, o-Xylene 0.4 ppb, Mesitylene 0.4 ppb

Metals:

no data

Hydrogen Sulfide:

ND 0.16 ppm dection limited.

SABIRIYAH OIL FIELD

Results For 3/17

SUMMA DATA:

Ground Level Sample:

H2S none detected (0.1 ppm); SO2 0.13 ppm; CO 1.1 ppm; NO and NO2 none detected

VOCs:

Benzene 9.8 ppb, Toluene 8.7 ppb, Ethylbenzene 10 ppb, m&p-Xylene 27.8 ppb o-Xylene 24 ppb, m-Ethyltoluene 15.8 ppb, n-C6 83 ppb, n-C7 60 ppb, n-C8 91 ppb, n-C9 91 ppb, n-C10 89 ppb, n-C11 65 ppb.

3000 ft Sample:

H2S none detected; SO2 0.08 ppm, CO none detected; NO and NO2 none detected 0.5 ppm.

1000 ft Sample:

H2S, SO2, CO, NO, and NO2 none detected.

Table 1
Kuwait Oil Well Fires Real Time Monitoring
March 13-20, 1991

Site, Date, Time	Total Particulate mg/m³	Suifur Dioxide ppm	Hydrogen Sulfide ppm	Volatile Organics ppm
1) MEPA Faciltiy, Dhahran, SA 3/13 1100 hrs	.170	. 0.0	0.0	0.0
MEPA Facility 3/14 1300 hrs	.480	0.0	0.0	0.0
2) Al Dhuba 3/15 1430 hrs	.420	0.0	0.0	0.0
3) Umn Al Haiman 3/15 1500 hrs	.320	0.0	0.0	0.0
4) Mina Abdulla 3/15 1530 hrs	.250	0.0	0.01	0.6
5) Near Al Maqwa Oil Field 3/15 1630 hrs	.010	0.0	0.024	0.8
6) In Al Maqwa Well Plume 3/15 1700 hrs	5.4	0.0	0.006	0.8
7) U.S. Embassy 3/06 0900 hrs	.01	0.0	0.001	0.0
L.S. Embassy 3/18 1230 hrs	.055	1.0	0.005	0.2
8) In Al Ahmadi Well Plume 3/16 1230 hrs	· 	0.0	0.032	0.0
In Al Ahmadi Oil Field 3/16 1300 hrs	.120	1.0	0.009	
9) In Al Burgan Well Plume 3/17 1100 hrs	. —	1.0	0.015	0.0
10) In Sabiriyan Well Plume, Pooled Oil 3/18 1530 hrs		1.0	0.042	2.5
11) In Al Wafra Well Plume 3/19 1200 hrs	.050	2.0	0.015	0.0
12) Freedom City				
13) U.S. Embassy Riyadh, SA 3/20 1300 hrs	.032	0.0	0.0	0.0

Table 2
Kuwait Oil Well Fires Real Time Monitoring
March 24-27, 1991

]
Site, Date, Time	Total Particulate mg/m³	Sulfur Dioxide ppm	Hydrogen Sulfide ppm	Volatile Organics ppm
1) Al Safer Motorway and Wafra Road 3/24 1440 hrs	.825 (15 min. avg.)	2.0	0.0	0.3
2) Al Ahmadi Gathering Center #22 3/24 1530 hrs	.359 (15 min. avg.)	0.0	0.0	0.0
3) Al Ahmadi Hospital 3/24 1530 hrs	.222 (32 min. avg.)	0.0	0.0	0.0
4) 1 mi. NW of Station 2 in Ahmadi Oil Field 3/24 1730 hrs	.256 (10 min. avg.)	0.0	0.0	0.0
5) Al Maga Oil Field, .5 mi south of 7th Ring Road near oil pool 3/25 1400 hrs	.034 (17 min. avg.)	1.0	0.0	0.6
6) Al Ahmadi Oil field (same as Station 4) 3/25 1500 hrs	.561 (13 min. avg.)	0.0	0.003	0.6
7) Al Ahmadi Hospital (same as Station 3) 3/25 1545 hrs	.295 (15 min. avg.	0.0	0.0	0.0
8) Al Safer and Wafra Road 3/25 1615 hrs	.065 (16 min. avg.)	0.0	0.002	0.0
9) Al Ahmadi Hospital (same as Station 3 and 7) 3/27 1020 hrs	.935 (20 min. avg.)	0.0	0.0	0.2
10) Al Ahmadi Hospital (same as Stations 3, 7, and 9) 3/27 1040 hrs	.457 (20 min. avg.)			
11) Al Ahmadi Hospital (same as Stations 3, 7, 9, and 10) 3/27 1100 hrs	.457 (20 min. avg.)			
12) Shuaiba Port 3/27 1215 hrs	.468 (15 min. avg.)	0.0	0.0	0.0

Site, Date, Time	Total Particulate mg/m³	Sulfur Dioxide ppm	Hydrogen Sulfide ppm	Volatile Organics ppm
13) Al Safer Motorway and Wafra Road 3/27 1300 hrs	.119 (12 min. avg.)	0.0	0.0	0.0
14) 16 Kilo-meters SE of Al Safer and Wafra Roads 3/27 1330 hrs	.257 (12 min. avg.)	0.0	0.0	0.0
15) 27 Kilo-meters SE of Al Safer and Wafra Roads 3/27 1350 hrs	.227 (15 min. avg.)			
16) 5 Kilometers South of Khafji, Saudi Arabia 3/27 1510 hrs	.072 (14 min. avg.)			

Table 3
Sulfur Dioxide Bubbler Measurements
(Acidimetric Method)
Temporary Hospital Locations in Kuwait City
March 13-24

Hospital	Date	Concentration (ug/m³)
Adan	3/14/91 3/17/91 3/18/91 3/19/91 3/20/91 3/23/91 3/24/91	40.31 43.88 39.34 26.18 27.68 28.16 15.99
Mubarek Al Kabeer	3/13/91 3/18/91 3/19/91 3/20/91 3/23/91 3/24/91	193.66 56.48 58.11 42.34 43.43 23.72
Al Farwaniya	3/13/91 3/16/91 3/17/91 3/18/91 3/19/91 3/20/91 3/23/91 3/24/91	81.32 19.21 29.56 134.81 218.65 27.57 26.66 10.54
Al Jahra	3/16/91 3/18/91 3/19/91 3/23/91 3/24/91	32.03 66.59 32.54 13.92 9.90

APPENDIX B

A REGIONAL GULF AIR MONITORING PLAN IN RESPONSE TO THE 1991 KUWAITI OIL FIELD FIRES

I. INTRODUCTION

Purpose of the Plan Team Membership Concerns and Questions - Short and Longer Term Basic Understandings

II. BACKGROUND

Nature of the Fires and Oil Field Locations Qualitative Meteorological Observations Preliminary Air Quality Information Health Issues and Concerns Data Bases and Information Management

III. RECOMMENDATIONS

Preliminary Findings and Conclusions to Date Phased Steps for Expanding the Network Measurement Parameters at each Site Health Monitoring Surveys

IV. SUMMARY

Preliminary Findings and Conclusions to Date Basic Network Requirements Urgency and Timing Phased Approach to Implementation Unresolved Issues

ATTACHMENTS

List of existing and proposed air monitoring sites Locations of existing and proposed air monitoring sites

APPENDIX B

A REGIONAL GULF AIR MONITORING PLAN IN RESPONSE TO THE 1991 KUWAITI OIL FIELD FIRES

1. INTRODUCTION

The U.S. Interagency Air Monitoring Team is working with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA) to develop an air monitoring plan for the Gulf region that will provide information to assess the Impact of the [Kuwaiti] fires in Saudi Arabia. This plan is being discussed and developed with the King Faud University of Petroleum and Minerals in Dhahran, the Cooperation Council for the Arab States of the Gulf (CCG), and the Saudi Arabian Oil Company (ARAMCO). The plan is being developed at the request of Dr. Tawfiq, Vice President of the Saudi Arabian MEPA. Meetings have been held with officials from all of the above mentioned organizations.

1.1 Approach

The Team is gathering information on the existing air monitoring networks in the region operated by MEPA, ARAMCO, Kuwait, Bahrain, and the Royal Commission of Jubayl and Yunbo. The spatial distribution of the existing network in the Region is being reviewed as to the location of sites, the air pollutants and meteorological variables that are monitored at each of these sites and the quality of existing data. That review is to determine if the existing network needs to be expanded in terms of the air pollutants and meteorological variables monitored and additional air monitoring stations to determine the impact from the oil fires. The capabilities of the existing agencies and governments to deal with a more complete network is also being investigated.

1.2 Objectives of Air Monitoring in the Gulf Region

Air monitoring data is needed for the following reasons:

- a. To provide an Early Warning Health Advisory System for the Guif Region to respond to the air pollution resulting from the Kuwaiti oil fires. The proposed Early Warning System could be based on an adaptation of the U.S. Air Quality Index, the Pollutant Standards Index (PSI), which can be modified to use Saudi air quality standards. The index would provide for health advisories to the affected populations so they can minimize their exposure to high pollution levels.
- b. To track the air pollution from the Kuwaiti oil field fires over time to asses the potential long term health and ecological effects. The air monitoring network proposal being developed is being coordinated with a parallel effort to develop a health monitoring information system.
- c. To collect samples of airborne particles to perform toxicity testing and dose response assessment utilizing in-vivo animal models.
- d. To facilitate evaluations of models which are use to predict the local and regional scale behavior of the oil field emissions. Data from the expanded GULF REGIONAL AIR MONITORING NETWORK of ambient air quality and meteorological data will be important for those evaluations.

2. BACKGROUND

2.1 Preliminary Investigation of the Existing Monitoring Networks

The air quality monitoring sites listed in Table 1 have been identified for each of the Gulf nations that could contribute monitoring information within the sphere of influence of airborne effluents from the Kuwait oil fires.

Based upon our review of the existing networks, the principal pollutants which are missing are in the Saudi network and in the present Kuwaiti network are PM₁₀, which represents particulate matter with particles less than 10 microns in diameter, polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOC). With respect to PM₁₀, these are the particles which are most likely to penetrate deeply into the lung. It should be noted that Kuwait has collected particulate data using an Anderson Cascade Impactor, with limited size distributions below seven microns within a total suspended particulate sample. Because of the importance of this particular pollutant and the extensive particulate resulting from the oil fires, the Team is recommending that special efforts be initiated to gather PM₁₀ data and if possible to determine its constituents - trace metals and hydrocarbons. The PM₁₀ data collection effort should be supplemented with the collections of PAH samples and if possible, grab samples for VOC analysis.

An ongoing effort is being conducted to examine the analytical laboratory support for air monitoring in Kuwait, MEPA, KFUPM, and Saudi ARAMCO. The Kuwaiti laboratory capability to analyze air and particulate samples has been left largely intact. As of March 27, 1991, two of the three continuous monitoring stations have been activated and are collecting data. The remaining site has its continuous sampling equipment however, like the analytical laboratory, is without electrical power. There is no projected date for power at these locations. The analytical laboratory has had experience with polyurathane foam (PUF) extractions for PAH measurements (PS-1 sampler) and has done pesticide extraction and analysis research. The most critical need for the laboratory is obviously power to provide the basis of future support to the sampling plan. Additionally training must be provided with documented procedures for these new sampling and analytical procedures, and lastly they are in need of a complete set of standards to support instrument calibrations for their existing continuous monitors and the new proposed technologies. Quality control and quality assurance samples and support for the network should be developed within the available laboratories but, should be supplemented from an external source.

The analytical laboratory at King Faud U.P.M. has recently been provided the above procedures to permit a self assessment of their equipment availability to conduct these detailed analyses. Currently, the K.F.U.P.M. is conducting experiments on PAH's analysis of high volume filters as a first step in this program. K.F.U.P.M. has not had any experience with PUF, VOC canister analysis, or PM₁₀ sampling and analysis. They have on hand the capability to expand their current analytical capability to provide support to the proposed network.

The analytical laboratory of Saudi ARAMCO as with MEPA has had no experience in collecting and analyzing particulate PM₁₀ samples, PUF, and canister samples for VOC speciation and PAHs.

In summary, the current level of technical competence within all of the facilities visited, MEPA, King Faud U.P.M., Saudi ARAMCO, and Kuwait, indicates that upon the procurement of adequate equipment, standards, and training, they all could support the sampling and analysis required for this program.

TABLE B-1.	The Di	stribution of Air Pollutant	and Meteorological Monitoring Sites by Gulf Nation.
<u>Nation</u>		Organization	Number of Air and Met Sites
SAUDI ARABIA		MEPA	3 fixed sites - meteorology and air pollution at different locations of the same city
			1 mobile site - meteorology and air pollution
			1 fixed meteorology site
		Saudi ARAMCO	8 air quality sites with meteorology
			6 additional meteorology sites
	,	Royal Comm. for Jubayl & Yunbo	Cluster of Five Stations in Jubayl
KUWAIT		,	3 sites with continuous monitors (2 with power, 1 without power).
			4 sites with Anderson samplers, high vols. and dustfall buckets. (no power)
			1 additional TSP site (no power)
	•	;	6 additional dustfall sites
			4 temporary S02 bubbler sites located at 4 hospitals (some power)
		·	·
BAHRAIN			2 sites
		·	
QATAR			3 mobile monitoring sites
IRAN			unknown
IRAQ			unknown

A substantial number of meteorological measurement sites exist within the eastern provence of Saudi Arabia and the nations of the Gulf Region. Most of those sites are along the shoreline of the Gulf. ARAMCO operates 14 sites with meteorological data. Eight of those sites have collocated air quality measurements. Three of those sites are over the Gulf waters on platforms or on an island. MEPA (Saudi Arabia) has five sites with collocated air quality measurements. In addition, there are surface observations collected at many of the airports throughout the kingdom. Surface meteorological data are being collected at other Gulf region locations. Their locations may be identified through the WMO publications. Previously, there were other surface measurement sites within Kuwait but their operational status remain unknown at this time.

Two upper air bailoon sounding sites are operating within Saudi Arabia. One site is at Dhahran and the other is about 115 miles to the SW of Kuwait City at Al Qaysumah. Twice daily soundings are collected at those locations, at 0000 and 1200 GMT. Prior to the war in Kuwait, twice daily upper air soundings were made at the Kuwait International Airport. the resumption of those soundings could be of substantial benefit to describing the airflow across the areas of Kuwaiti oil fires.

2.2 Meteorological Observations

The following summarizations are based upon first hand observations of the smoke plumes and fires. Those observations were made during overflights and during vehicle traverses both within the oil fields and along roads outside of the burning oil fields.

For any given day, the prevailing large-scale meteorological pattern will be the main driving feature which determines where the smoke plumes will be located and how dense they will be.

Individual smoke plumes appear to act in manners typical of buoyant plumes from ground level sources or plumes from short chimneys. Plume rise, the development of a bent-over plume geometry, etc., seem to apply to the individual well-head fires; some have jets of fire and others are nearly surface based burnings of the more combustible fractions of crude oil spread across the ground in the vicinity of the well. Most of the fire plumes rise to between 500 to 1000 feet above ground level before becoming mostly bent over, although some plumes have a significant amount of smoke remaining within a few hundred feet of the ground.

Collectively, as groups of multiple fires within oil fields with a high density of burning wells (particularly Greater Burgan), they assert a meteorological influence of their own. It is suggested that the grouping of fires with a horizontal diameter of 15 to 25 miles provides enough of an intense "heat-island" that significant additional vertical rise of the smoke occurs inside the area. That additional plume rise lifts smoke to elevations often 3000, 4000, to 5000 feet above ground within the initial few miles downwind. Eventually, portions of the smoke rise even more, with multiple layers often forming at heights up to 8000, 9000, even 12000 to 13000 feet. Between such layers and at the tops of layers many tens of miles downwind, a generally diffuse and homogenous zone of smoke has been observed. The eventual smoke height limits are bounded by the regional vertical temperature structure and synoptic weather characteristics. Information reviewed to date suggest that those maximum heights are mostly 8000 to 12000 feet within the initial 100 to 200 miles downwind from the Kuwaiti oil field fires.

With the creation of a local heat-island, a distinct inflow of near surface air has been observed within the initial 500 to 1000 feet above ground level. At times, that inflow of wind is estimated to be 5 to 15 m/sec in strength. Smoke plumes at the peripheral bounds of the burn area tend to slant inward toward the center of the burning field instead of pointing downwind with direction of the expected ambient wind.

Local variations in daily wind flow, along with the fire-storm like winds, are likely to produce preferred locations and times of day at which more concentrated smoke plume exposures reach ground level. Prevailing winds are from the northwest throughout the year. During the daytime a sea breeze can be expected to develop at the Gulf shoreline and progress inland as the day progresses. That inflow of air can readily clear out the smoke plumes and yield substantially cleaner air at ground level on the Gulf side. Along the leading edge of the sea breeze front there likely may be a zone of extended and elevated exposures to fire effluent. That zone may well extend down the shoreline from Kuwait City some 100 km. The area of greatest susceptibility appears to be to the southeast of fires in the Al Ahmadi oil field (part of the greater Burgan field).

2.3 Data Base Management

In addition to evaluating the existing air monitoring networks, the Team made an initial review of existing data systems to handle the air monitoring data. The previous meteorological, air quality, and visual observations of the oil field fire plumes should be archived, along with data to be obtained during the period of on-going Kuwaiti fires. A dedicated facility for the performance of that archiving does not appear to exist. The data management task is likely to be a sizeable task and extended of a period of a year and more.

Some of the general functional needs of the data management system include the following. The data which will need to be assembled into the data base will likely come from many different sources and exist in diverse formats and media. One role of the data base management activity will be to assemble all information into a common, uniform structure. The second and equally important part of the data archiving is the provisions of a uniform and consistent mechanism for the retrieval of data by participating agencies. The degree to which that data base is well formulated, will significantly affect the efforts of users of the data as they attempt to study and interpret the measurements.

A number of possible methods exist for the set-up of a computerized data base. Commercial software and hardware of various degrees and complexity and cost exist which would satisfy the data management needs. Before the choices of system software and hardware are made, the functionality of the overall system and the manners in which users work with the data sets should be considered. For example, it may be required that the data base be a "relational" data base. Other sources of software that might be used to handle a large volume of data would be the U.S. Environmental Agency's (USEPA) Aerometric Information and Retrieval System. That system can handle hourly data and has considerable software available to both summarize and analyze the ambient air data.

MEPA has asked the Team to recommend the type of computer and associated software needed to manage the data collected in order to implement the monitoring plan. For now, it is more appropriate to defer specific recommendations. A number of general performance characteristics may be stated but specific details should be formulated in conjunction with data base specialists at a later date.

RECOMMENDATIONS

While preliminary, the Team believes that the following recommendations should be implemented based on our initial data gathering exercise. A general objective is listed as a recommended goal and below that objective are listed several needed items or activities to facilitate the achievement of the overall goal.

1. Objective: Provide a framework for an early warning advisory capability for areas expected to be impacted by effluents from Kuwaiti oil field fires.

Needs: a. Meteorological data observations and forecasts

b. Visual observations from key receptor areas

c. Review existing monitoring data

d. Calculate smoke trajectories and concentrations

2. Objective: Provide a cursory wide-area indication of the distribution and composition of the Kuwaiti oil field fire effluents.

Needs: a. Establish 10 to 15 PM₁₀ monitoring locations using portable monitors.

b. Train personnel in the operation of the portable PM-10 monitors and develop the analytical support capability within Saudi Arabia and Kuwait.

c. Define the PM₁₀ to TSP ratios.

d. Define the composition of the plume by XRF analysis for limited organic identification.

e. Establish a central media preparation and analysis location.

 Define the baseline contribution of the ambient aerosol from the surrounding desert.

3. Objective: Characterize the aerial smoke plume.

Needs: a. Collect many of the same plume measurements recommended for the ground monitoring array

 Collect descriptions of the width and vertical extent of the smoke plume at several downwind distances

Characterize the regional background by samples outside of the smoke plumes

4. Objective: Develop a more complete profile of the smoke plume constituents

Needs: a. Procure equipment for a limited number of comprehensive air quality monitoring stations to collect: TSP, PM₁₀, organic, and inorganic constituents

b. Establish a limited number of comprehensive air quality monitoring stations to collect: TSP, PM₁₀, organic, and inorganic constituents. These should be collocated with the continuous monitors wherever possible.

c. Train individuals to operate and maintain the sampling instrumentation in support of the monitoring program

d. Procure the necessary analytical laboratory equipment required for analyses of the samples collected under this objective

e. Train laboratory personnel in the preparation of the sampling media, QA/QC procedures required and the subsequent sample analytical procedures.

5. Objective: Determine the need for expansion of the monitoring network to a wider regional coverage.

Needs: a. Review the data developed from the limited network.

 Assess the current and projected status of control of the oil field fires and emissions.

Review the population health survey statistics.

d. Review the suitability of the sampling strategy, and modify where needed

 Expand the limited network as the situation requires, data analysis indicates an additional need for data, the response of the affected populations indicate, or the model requires additional parameters.

Many of the same considerations listed for air quality above also apply to meteorological considerations.

6. Objective: Provide a meteorological data stream to facilitate the modeling and prediction of areas expected to be impacted by effluents from Kuwaiti oil field fires.

Needs:

- Upper air balloon sounding data representative of the Kuwaiti oil field fire area and Gulf region plume transport.
- b. Supplemental surface based measurements of wind speed and direction, temperature, moisture content of the air (dew point, relative humidity, etc.), solar radiation, atmospheric pressure, precipitation.
- 7. Objective: Provide a meteorological data set to investigate the areas of climate modifications occurring due to effluents from Kuwaiti oil field fires.
 - Needs: a. Supplemental surface based measurements diffuse and direct solar radiation.
 - b. Special collections of precipitation throughout the region to examine the pH and chemistry of the rains.
 - c. Aircraft soundings and profiles of smoke, winds and temperatures, air quality related measurements of plume compositions and concentrations representative of the Kuwaiti oil field fire area and Gulf region transported plumes.

4. PHASED AIR MONITORING PLAN

This section of the report discusses a prioritized plan of stepwise incremental actions for the phased implementation of the recommendations discussed above. Five phases for implementing the plan follow.

4.1 Phase 1. Provide a Framework for an Early Warning Advisory

In order to accomplish this task, the following action items need to be initiated or incorporated into the task framework.

- 1. Gather daily weather forecasts to predict meteorological conditions which would effect pollution potential in both Saudi Arabia and Kuwait.
- Use visual observations from key receptor sites to determine possible pollution levels.
- Gather existing air monitoring data from fixed and mobile sites operated by MEPA, Saudi ARAMCO, and the governments of Kuwait and Bahrain to develop a data base of existing data.
- 4. Establish a daily briefing for representatives of the many entities concerned with behaviors and fate of the aerial effluents from the oil field fires in Kuwait.
- 5. Develop a daily map depiction of the aerial distribution of the smoke plumes across the region using satellite imagery, for each day since initiation of the oil field fires.
- 6. Issue a daily general statement about the expected behavior(s) of the oil fire plumes.

 Areas of potentially adverse conditions could be treated as locations for which advisories would be issued.
- 7. Provide forecast meteorological conditions across the region for the next 2 to 3 day period, including the expected location(s) of the smoke.
- 8. Obtain data from the MEPA network throughout the eastern province.
- Direct the crews of the SLAR aircraft, (USCG Falcon Jet), to continue on a regular basis
 the present visual observation and mapped notations concerning the horizontal extent of
 the smoke plumes and the estimations of altitudes of layer bases and tops.
- 10. The above information could be compiled initially in hard copy form. Later it should be stored on electronic media in a way that an existing PC data management system could readily incorporate it.

4.2 Phase 2. Establish a PM₁₀ Monitoring Network Using Portable PM₁₀ Monitors.

Working in conjunction with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA), the proposed plan has been developed to collect information on PM_{10} , which represents particulate matter with particulates less than 10 microns in diameter. At the present time there is no PM_{10} monitoring in the Gulf region.

OBJECTIVES

The objectives for this effort are as follows:

- 1) Determine the magnitude or the health threat to residents of population centers and field-based military personnel impacted by the oil field fires and typical sources (windblown desert soils).
- 2) Establish a scientifically based capability to alert these affected populations prior to the onset of the potential health threats from real-time measurements.
- 3) Establish a technical basis for executing predictive air quality dispersion models which simulate the oil well fire emissions, background sources, and consequent impacts over space and time.
- 4) Establish a regional network of PM₁₀ stations using a consistent monitoring methodology across the countries of Saudi Arabia, Kuwait, and Bahrain.
- 5) Train personnel to operate and analyze the media produced by the network from each of the participating countries.
- 6) Develop a regional data base and encourage the sharing of data developed from the network with all participants.

The above objectives convert the foregoing goals into discrete actions:

- 1) Determine the spatial temporal frequency, and severity of the impact to the resident populations and military centers affected through the application of saturation sampling techniques with portable PM_{to} samplers.
- 2) Establish the correlation of real-time surrogate monitoring data to date generated from direct sampling methods through the collocation and simultaneous operation of both methods over time.
- 3) Where possible use impact data collected from samplers as an input to the dispersion model, run the model "backwards" to develop a better estimate of the emission rates of the fires and produce a higher level of confidence in the predictive modeling results.
- 4) Obtain from the literature and/or develop from source sampling analysis chemical profiles of all major pollutant sources in order to:
 - a) identify those contaminants that pose the greatest health concerns and to develop an estimate of acceptable ambient levels (AALs) prior to the conduct of field work,
 - b) identify the chemical "signature" of the major contaminants and other tracers characteristic of the primary sources.
 - c) enable apportionment of these contaminants and other tracer compounds from a simple total mass concentration measured by the ambient samples, and

- d) attempt to relate these levels in turn to the surrogate real-time monitoring methods for use in issuing timely health risk alerts.
- 5) Ensure that the data generated by the network are of a demonstrably high quality (precision & accuracy), completeness, representativeness, and comparability.

TIME	POSITION (LAT/LONG)	BASE/TOP	WIND (DIR/SPD)
0545	N2623E50-31	CLR VIS 15 M	332/23
0600	N2700E4958	CLR	321/19
0615	N2744E4916	CLR	300/20
0630	N2822E4839	TOPS 070/030	331/008
0645	N2918E4819	SMOKE 060/030	335/10
0700	N2932E4810	SMOKE 070/030	344/10
0715	N29344830	SMOKE 070/030	265/7
0730	N29354857	THIN SMOKE 050/030	215/6
0745	N2925E4920	VERY THIN SMOKE 090	133/003
0800	N2833E4945	THICKER SMOKE 090/ 080	326/006
0815	N2738E5035	THIN SMOKE 090/080	280/005
0830	N2702E5111	SMOKE 090/060	192/010
0845	N2625E5148	SMOKE/HAZE 080/060	. 215/12
0900	N2618E5118	SMOKE/HAZE 070/SURF	230/009

APPROACH

Conduct a PM₁₀ saturation sampling study for the determination of the temporal and spatial features of the impact of the oil well fires and attempt to reconcile the data with existing model estimates. PM₁₀ mass concentrations would be available within 24-48 hours following sampling. No onsite meteorological, gas, or aerosol monitoring or chemical analysis is required (chemistry could be attempted later on the preserved media). One or more portable nephelometers would be collocated at several sampling sites to develop correlations between manual and continuous (real-time) methods for alert advisories.

A total of 15-20 portable PM₁₀ samplers equipped with quartz filters would be run simultaneously on a daily basis or "triggered" (impact forecast) basis throughout the study area. Network design would involve a "nested" approach to address the objectives:

1) samplers sited at background locations (not impacted) by the smoke plume and samplers in populated areas.

2) samplers in populated areas impacted by smoke.

Samplers could be "ganged" (2 or more) and programmed to run consecutively at individual sites if filter clogging problems occur because of high loading. Further, multiple samplers could be collocated at certain sites to collect fine particulates (less than 2.5 microns) and coarse particulates (2.5-10 microns) on teflon sample filters (facilitating XRF elemental analysis). One of the 10-12 sampling sites would be equipped with duplicate samplers in an effort to develop sampling precision estimates.

This comprehensive program will yield the following:

- 1) short turnaround PM10 concentrations,
- 2) gross estimates of the fire-specific contributions to total mass could be derived by subtracting background concentrations from the impact site concentrations,
- applying assumptions on the source profiles to pollutant loading attributable to the well fires, estimates of individual target compound loadings could be computed and a comparison to AALs made,
- 4) correlations factors can be determined between real-time surrogate methods and manual methods, and
- 5) impacted sampling media would be available for subsequent intensive chemical analysis in an attempt to reconcile assumed source signatures and extracts can be used to perform any other analytical tests (mutagenicity). Special precautions may be needed to preserve the sample integrity during storage and transfer.

Limitations: no on-site meteorological data to calculate emissions rates, no on-site chemistry (unless developed) to confirm critical assumptions, and no concurrent gas or acid aerosol measurements to evaluate or correlate with the particulate data.

Resources: 1-2 professionals, 1 field technician per site, if it must be operated individually (actual number contingent upon the network logistics and potential "clogging" implications), portable PM₁₀ saturation samplers, portable nephelometers, lap-top computer, microbalance, expendables and sundry support gear.

In summary, this approach is PM₁₀ mass data-rich, and assumption rich and in contrast to being reconciliation and broad pollutant characterization-poor.

SAMPLING AND ANALYTICAL METHODS

The alternate approaches identified above involve the use of a variety of sampling and analytical methods summarized below:

Portable PM₁₀ Saturation Samplers

- segregate and capture of filter, particulates of 10 micron size (respirable particles) and smaller.
- battery-operated, lightweight, rugged, inexpensive, small, and quiet.
- easily deployed and operated.
- programmable timer for unattended on and off.

- rechargeable battery packs.
- continuous operation up to 30 hours on a single charge.
- precise and accurate.
- low detection limit of approximately 5 ug/m3
- sustained operation under high particulate loadings, e.g. 100 ug/m3 or more.
- electronic-sample flow regulation.
- electronic sample flow totalizer.
- low flow shutoff/warning.
- can accept a variety of other pollutant sampling media (e.g. PUF, DNPH, charcoal, denuders, etc.) or take whole air samples (Tedlar bags) with little or no modification.

Portable nephelometers

- many of the same attributes of the PM₁₀
- battery operated
- effectively measure particulates of 1 micron diameter or smaller.
- continuous reading, storing five minute averages.
- rechargeable.
- continuous operation from 2-48 hours on a single battery charge.
- internal storage for up to nine days of sampling data.
- data download to a portable lap-top computer through RS232 serial port.
- operationally equivalent to standard nephelometers.

Microbalance

- five to six place balance.
- rugged, transportable while precise and accurate.

Field XRF Unit

- similar MQLS with situ laboratory units.
- rugged. ;

Support Gear

calibration and audit gear, tools and diagnostic equipment, etc.

PROPOSED NETWORK DESIGN

The recommendation for siting of the portable PM₁₀ samplers is predicated on providing a large area of coverage for developing a better estimate of the areas impacted by the plume, a cross-sampling of population and troop centers, and to a capability to provide a technology transfer to Saudi Arabia, Kuwait, and Bahrain.

SAUDI ARABIA

- collocated site at K.F.U.P.M. (2 sites)
- two sites in Riyadh (1 U.S. Embassy & 1 MEPA location)
- one site Royal Commission at Jubayi
- one site Saudi ARAMCO at Tanajib
- one site MEPA at Khafji

Total of seven (7) sites.

KUWAIT

- three sites (3) located at the two operational continuous monitoring sites within Kuwait City (one site collocated)
- one site at Camp Freedom
- One site U.S. Embassy
- One site Al Hamadi (Kuwait Oil Company Hospital)

Total of six (6) sites.

CENTCOM

two sites at selected troop locations

Total of two (2) sites.

BAHRAIN

one site to be determined

Total of one (1) site.

A total of sixteen samplers are committed to field sampling with the remainder as spares or as changes to the sampling plan requires.

Phase 3. Characterize the Aerial Plume.

This phase should follow closely with Phase 2, in order to characterize the 3-dimensional nature of the smoke plumes from the fires in Kuwaiti oil fields. To achieve that goal, many of the same plume measurements collected by the existing and proposed ground level measurement locations should be provided by the aerial sampling platform. Obviously, the longer time integrated samples (e.g., 24 hour total values, averages, etc.) cannot be reproduced by aircraft borne devices. Short-term and across plume integrated measurement descriptions may be obtained to characterize the special extent and details of actual constituents of the elevated portions of the oil fire plumes.

The aerial sampling activities may be separated into measurements which address the three general zones of plume characteristics, from an a meteorological sense. Those zones are the 1) close-in zone, 2)intermediate or transition zone and 3)extended or distant zone. Measurements very near the wellhead are difficult to impossible to obtain due to excessive heat and great levels of turbulence. Measurements at intermediate distances will be difficult and many locations within the clustered groups of burning wells may be unsafe for aerial traverses due to the extremely dense smoke and hidden turbulent plumes. Measurements at the longer distances, a few miles downwind of the burning wells, should be possible. Measurements from a few to several hundred miles downwind of the fire area should be feasible. Within that distance range the approximate concentrations, plume dimensions, and estimated mass flux in the downwind directions may be approximated. The aerial sampling strategies should concentrate on the obtaining of those types of information.

4.4 Phase 4. Develop a Complete Profile of the Smoke Plume Constituents.

Obtain additional equipment to expand existing continuous monitoring high priority sites in Kuwait and Saudi Arabia

The survey conducted by the Team during Phase 1 of this plan indicated that within the region, respirable particulate sampling technology, aerosol and total particulate sampling and analysis for volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), and PAHs were either not available or insufficient to properly characterize the effects of the oil well fires on the population centers and the troop concentrations within the region.

This phase of the plan proposes to bring into the region several new technologies and to train personnel within the region to operate samplers, to condition, and analyze the several new media necessry to support this expanded network. The objective of this process is to develop a stand-along capability within each participating country for aerosol and particulate monitoring which will support the Gulf regional air quality characterization and index plan outlined in Phase V.

During this phase of the plan the Team proposes to expand the continuous air and meteorological monitoring currently being conducted within the region at six sites. These sites are recommended based on the need to jointly develop the sampling and analytical capability within the region to ensure that it becomes self-sufficient and sustainable. The particular technologies outlined below are not currently operated within the rgion nor are the analytical procedures required to support them currently being utilized. However, the Phase I survey indicates that with sufficient training, additional equipment, and some experience with actual field samples the transfer should be relatively smooth.

initially, the Team's recommendation of six sites strategically placed along the axis of the area of greatest impact by the oil well fire plume will generate sufficiaent samples for the required training, while also providing critical data not currently being collected by the existing networks or available through the portable PM₁₀ network proposed in Phase II. As this data base develops it can be used to better define the constituents of the plume and thus permit a more accurate assessment of the potential long-term health risk.

The equipment listed below should be collocated with the full compliment of continuous air and meteorological monitors described in Phase V at these six proposed sites. A brief description of the equipment is provided below:

TSP High Volume Sample - used to collect a 24-hour sample of the total suspended particulates, operated nominally at 50 OFM, and typically uses 8x10 inch glass fiber, quartz, or teflon filter media.

PM₁₀ High Volume Sampler - used to collect a 24-hour sample of the 10 micron and smaller sized fraction of the total suspended particulate sample collected by the TSP sampler above, sampler is typically operated at 40 CFM, and utilizes an 8x10 inch Quartz or teflon filter media. Note: glass fiber media should not be used if there is concern for a known sulfate artifact formation problem.

 PM_{10} Manual Dichotomous Sampler - used to collect a 24-hour sample of the 10 micron particulate size fraction of the TSP, sampler operates at 16.7 liters/minute, and utilzes two (2) 37 mm diameter Teflon filters to collect a fractionated sample with a cut point of 0-2.5 micron (fine fraction) and 2.5 - 10 micron (coarse fraction).

VOC Canister Sampler - used to collect up to a 24- hour integrated whole air sample in six-liter evacuated stainless steel canisters, interior walls are passivated to minimize sample degradation, samples volume can be rgulated by either limiting the volume to ambient pressure or pumping in addition sample to an approximate volume of 16 liters, these samples can be used for the determination of total hydrocarbons or analyzed for specific hydrocarbons, multiple analysis are available from a single pressurized canister sample. Note: An extensive canister cleanup process is required prior to the collection of additional air samples.

Polyurethane Foam (PUF) Low Volume Sampler - used to collect 24-hour aerosol samples utilizing small AC or battery operated pumps at flow rates less than five liters per minute on relatively small glass cartridges containing a PUF plug, these samples can be extracted and analyzed for PAHs, or other SVOCs. Note: Both the glass cartridge and PUG plug require an extensive cleanup procedure prior to re-use.

Optional Tenex/Charcoal/XAD-2 tubes - these media can be used with same type of low volume pumps described above to collect additional samples for further definition of the constituents of the plume for SVOCs.

Organic compounds will be present in all three phase distributions (particle bound, SVOC, and VOC) and each phase will have to be sampled and then a determination will have made as to importance of each.

The particle bound is phase can be collected for extractible organic analysis from both quartz, teflon impregnated glass fiber gilters, or teflon.

The SVOC phase can be collected on PUF and within the canister. The VOC phase can be collected with canisters and charcoal tubes. Employment of Tenex and SAD-2 sampling tubes in conjunction with PUF, charcoal tubes, and canisters in an overlapping sampling matrix, can be used to confirm of the presence or absence of compounds which could be missed by a less complex sampling matrix.

Proposed locations for the initial six expanded sites:

The Team recommends that the six locations follow the general axis of plume drift from Kuwait City south into Saudi Arabia. It is further suggested that the operation of these sites be divided amongst the key network managers within the two countries: Kuwait, MEPA, and Saudi ARAMCO. This division of respnsibility supports the philosophy to jointly develop both the sampling and analytical capability within all three entities.

Kuwaiti Locations

The Team recommends that two (2) of the sites be located at the existing operational continuous monitoring stations located in Kuwait City. A third site should be established in Al-Abmadj at the Kuwaiti Oil Company Hospital. This location is situated within 300 - 400 meters of several burning wells and is adjacent to the closest residential area associated with any of the oil fields.

Saudia Arabian Locations

The Team recommends that a site be established at King Fahd University of Petroleum and Miners (K.F.U.P.M.) in Dharhran, one site to be collocated with Saudi ARAMCO site in Tanajib and the

last site should be collocated with the MEPA sie in Khafji which currently is only collecting meteorology data.

Episodic/EARLY WARNING measurements

Longer term monitoring

PM ₁₀	(continuous)	Acid aerosols
TSP	·	VOCs
SO2	(continuous)	Aldehydes
O3	(continuous)	BaP, other PAHs
NOx, NO	(continuous)	Trace elements
co ·	(continuous)	Fine particles
H2S	(continuous)	•

Health Monitoring Survey

Air monitoring data collected through the proposed air monitoring network will provide basis for interpreting the results of health surveys of the populations and ecosystems potentially effected by the effluents from the oil fires in Kuwait. The kinds of health data that could be collected include:

Health questionnaires
Blood samples
Hair samples
In-vivo animal studies
Forced expiratory volumes
Other morbidity parameters

Distribution of Proposed and Existing Air Monitoring Sites

Table 2 shows the location of the existing and proposed air monitoring sites, while Table 3 lists the locations of the proposed air monitoring sites. In order to complete the network in an orderly manner, it is proposed that the network be developed in several stages. The first order of business would be to upgrade the existing monitoring locations so that there exist a full complement of air and meteorological monitoring equipment, as well as add new critical air monitoring stages (Stage 1). The second stage would be to establish those sites that would satisfy the minimum requirements for tracking the plume caused by the oil fire and to provide an early warning system for Saudi Arabia, Kuwait, and Bahrain (Stage 2). The third and final stage would be to complete the final network following a review of the quality and quantity of findings to date (Stage).

5. SUMMARY

The initial measurements made by the Team suggest that there is not an imminent threat from SO2 and H2S to the urban populations, while short term measurements of particulate are frequently high. Historically, this region has high particulate levels due to wind blown dust. The particulate measurements that were collected by the Team reflect total particulate, as opposed to respirable particulates, that is PM₁₀. There has not been a principal focus in the Region on total particulate, PM10₁₀, and organics up to now. Therefore, the Team developed the five phased monitoring plan with an emphasis on better understanding particulates and the aerosol organics associated with the oil fires in Kuwait. Particulates and organics could be a source of concern for both health and ecological effects.

The air monitoring proposals presented in this report represent the Team's collective judgement on what needs to be done. Those judgements are based upon an on-site evaluation of the situation in Kuwait, discussions with officials from the Saudi Arabian MEPA, Kuwait, Saudi ARAMCO, and the King Faud University of Petroleum and Minerals. Needless to say more work is needed regarding data management, statistical design, data analysis and quality assurance. Because of the complexity and immediacy of this problem, an extended time commitment will be needed on the part of all Gulf nation agencies to achieve the objectives outlined in this report.

Cost estimates for the various tuypes of air and meteorological monitors are attached to this plan, along with documentation on the U.S. Environmental Protection Agency's Pollutant Standards Index (PSI).

TABLE 2. Location of existing air and meteorology monitoring stations

NATION	ORGANIZATION	LOCATION .	STAGE OF IMPLEMENTATION
EXISTING SITES			
Saudi Arabia	MEPA	Damman	1
<u>, .</u> .		Hofuf	2
		Tanagib (Mobile Site)	1
		Riyadh	1
		Khafji (Met Only)	1
		Udayliyah	3
		Shedgum	3
		Abqaiq	3
•		Dhahran	2
		Tartut	2
		Rahimah	2
		Juaymah	1
		Tanajib	1 .
	·	Saffaniyah Oil Field (met only)	3
		Marjan Oil Field (met only)	3
		Farisiyah Island (met only)	2
<u>.</u> :	The Royal Comm. for Jubyayl and Yunbo	Cluster of 5 stations in Jubyayl	1
Existing Sites: Kuwait		SITE 1	1
		SITE 2	1
		SITE 3	1
Existing Sites: Qatar		3 mobile units, unknown locations	2

TABLE 3. Location of proposed air and meteorology monitoring stations

NATION	ORGANIZATION	LOCATION	STAG E
Proposed Sites: Saudi Arabia	MEPA	Awiyah	3
		Shumlul	2
		Serrar	2
		Nuayriyah	2
		Lisafah	3
		Uafar al Satin	1
		28 deg 6 min latitude, 47 deg 51 min longitude	2
·		28 deg 30 min latitude 48 deg 1 min longitude	1
		28 deg 55 min latitude 47 deg 32 min longitude	2
·		29 deg 7 min latitude 46 deg 39 min longitude	2
Kuwait		Mina Saud	1
		U.S. Embassy	1
		Al Ahmadi (Hospital)	1
		International Airport	1
		29 deg 23 min latitude 46 deg 55 min longitude	2
		29 deg 50 min latitude 47 deg 15 min longitude	2
		30 deg 4 min latitude 47 deg 42 min longitude	2
		29 deg 33 min latitude 47 deg 50 min longitude	2
Bahrain		Manamah	2
Qatar		Dawhah	2
United Arab Emirates		Aub Dhabi	3
		Dubai	` 3
Oman		Muscat	3

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DR. TERRI DAMSTRA

APPENDIX B

A REGIONAL GULF AIR MONITORING PLAN IN RESPONSE TO THE 1991 KUWAITI OIL FIELD FIRES

I. INTRODUCTION

Purpose of the Plan
Team Membership
Concerns and Questions - Short and Longer Term
Basic Understandings

II. BACKGROUND

Nature of the Fires and Oli Field Locations Qualitative Meteorological Observations Preliminary Air Quality Information Health Issues and Concerns Data Bases and Information Management

III. RECOMMENDATIONS

Preliminary Findings and Conclusions to Date Phased Steps for Expanding the Network Measurement Parameters at each Site Health Monitoring Surveys

IV. SUMMARY

Preliminary Findings and Conclusions to Date Basic Network Requirements Urgency and Timing Phased Approach to Implementation Unresolved Issues

ATTACHMENTS

List of existing and proposed air monitoring sites Locations of existing and proposed air monitoring sites

APPENDIX 8

A REGIONAL GULF AIR MONITORING PLAN IN RESPONSE TO THE 1991 KUWAITI OIL FIELD FIRES

1. INTRODUCTION

The U.S. Interagency Air Monitoring Team is working with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA) to develop an air monitoring plan for the Gulf region that will provide information to assess the impact of the [Kuwaiti] fires in Saudi Arabia. This plan is being discussed and developed with the King Faud University of Petroleum and Minerais in Dhahran, the Cooperation Council for the Arab States of the Gulf (CCG), and the Saudi Arabian Oil Company (ARAMCO). The plan is being developed at the request of Dr. Tawfiq, Vice President of the Saudi Arabian MEPA. Meetings have been held with officials from all of the above mentioned organizations.

1.1 Approach

The Team is gathering information on the existing air monitoring networks in the region operated by MEPA, ARAMCO, Kuwait, Bahrain, and the Royal Commission of Jubayi and Yunbo. The spatial distribution of the existing network in the Region is being reviewed as to the location of sites, the air pollutants and meteorological variables that are monitored at each of these sites and the quality of existing data. That review is to determine if the existing network needs to be expanded in terms of the air pollutants and meteorological variables monitored and additional air monitoring stations to determine the impact from the oil fires. The capabilities of the existing agencies and governments to deal with a more complete network is also being investigated.

1.2 Objectives of Air Monitoring in the Gulf Region

Air monitoring data is needed for the following reasons:

- a. To provide an Early Warning Health Advisory System for the Gulf Region to respond to the air pollution resulting from the Kuwaiti oil fires. The proposed Early Warning System could be based on an adaptation of the U.S. Air Quality Index, the Pollutant Standards Index (PSI), which can be modified to use Saudi air quality standards. The index would provide for health advisories to the affected populations so they can minimize their exposure to high pollution levels.
- b. To track the air pollution from the Kuwaiti oil field fires over time to asses the potential long term health and ecological effects. The air monitoring network proposal being developed is being accordinated with a parallel effort to develop a health monitoring information system.—
- c. To collect samples of airborne particles to parform toxicity testing and dose response assessment utilizing in-vivo animal models.
- d. To facilitate evaluations of models which are use to predict the local and regional scale behavior of the oil field emissions. Data from the expanded GULF REGIONAL AIR MONITORING NETWORK of ambient air quality and meteorological data will be important for those evaluations.

2. BACKGROUND

2.1 Preliminary investigation of the Existing Monitoring Networks

The air quality monitoring sites listed in Table 1 have been identified for each of the Gulf nations that could contribute monitoring information within the sphere of influence of airborne effluents from the Kuwait oil fires.

Based upon our review of the existing networks, the principal pollutants which are missing are in the Saudi network and in the present Kuwaiti network are Ridge which represents particulate matter with particles less than 10 microns in diameter, polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOC). With respect to PM₁₀, these are the particles which are most likely to penetrate deeply into the lung. It should be noted that Kuwait has collected particulate data using an Anderson Cascade Impactor, with limited size distributions below seven microns within a total suspended particulate sample. Because of the importance of this particular pollutant and the extensive particulate resulting from the oil fires, the Team is recommending that special efforts be initiated to gather PM₁₀ data and if possible to determine its constituents - trace metals and hydrocarbons. The PM₁₀ data collection effort should be supplemented with the collections of PAH samples and if possible, grab samples for VOC analysis.

An ongoing effort is being conducted to examine the analytical laboratory support for air monitoring in Kuwait, MEPA, KFUPM, and Saudi ARAMCO. The Kuwaiti laboratory capability to analyze air and particulate samples has been left largely intact. As of March 27, 1991, two of the three continuous monitoring stations have been activated and are collecting data. The remaining site has its continuous sampling equipment however, like the analytical laboratory, is without electrical power. There is no projected date for power at these locations. The analytical laboratory has had experience with polyurathane foam (PUF) extractions for PAH measurements (PS-1 sampler) and has done pesticide extraction and analysis research. The most critical need for the laboratory is obviously power to provide the basis of future support to the sampling plan. Additionally training must be provided with documented procedures for these new sampling and analytical procedures, and lastly they are in need of a complete set of standards to support instrument calibrations for their existing continuous monitors and the new proposed technologies. Quality control and quality assurance samples and support for the network should be developed within the available laboratories but, should be supplemented from an external source.

The analytical laboratory at King Faud U.P.M. has recently been provided the above procedures to permit a self-assessment of their equipment availability to conduct these detailed analyses. Currently, the K.F.U.P.M. is conducting experiments on PAH's analysis of high volume filters as a first step in this program. K.F.U.P.M. has not had any experience with PUF, VOC canister analysis, or PM₁₀ sampling and analysis. They have on hand the capability to expand their current analytical capability to provide support to the proposed network.

The analytical laboratory of Saudi ARAMCO as with MEPA has had no experience in collecting and analyzing particulate PM_{in} samples, PUF, and canister samples for VOC speciation and PAHs.

In summary, the current level of technical competence within all of the facilities visited, MEPA, King Faud U.P.M., Saudi ARAMCO, and Kuwait, indicates that upon the procurement of adequate equipment, standards, and training, they all could support the sampling and analysis required for this program.

TABLE B-1. The Distribution of Air Pollutant and Meteorological Monitoring Sites by Gulf Nation. Number of Air and Met Sites Nation **Organization** SAUDI ARABIA 3 fixed sites - meteorology and air pollution at different MEPA locations of the same city 1 mobile site - meteorology and air pollution 1 fixed meteorology site 8 air quality sites with meteorology Saudi ARAMCO 6 additional meteorology sites Royal Comm. Cluster of Five Stations In for Jubayi Jubayl & Yunbo KUWAIT 3 sites with continuous monitors (2 with power, 1 without power). 4 sites with Anderson samplers, high vols. and dustfall buckets. (no power) 1 additional TSP site (no power) 6 additional dustfall sites 4 temporary S02 bubbler sites located at 4 hospitals (some power) **BAHRAIN** 2 sites **QATAR** 3 mobile monitoring sites **IRAN** unichown IRAQ unknown

A substantial number of meteorological measurement sites exist within the eastern provence of Saudi Arabia and the nations of the Gulf Region. Most of those sites are along the shoreline of the Gulf. ARAMCO operates 14 sites with meteorological data. Eight of those sites have collocated air quality measurements. Three of those sites are over the Gulf waters on platforms or on an island. MEPA (Saudi Arabia) has five sites with collocated air quality measurements. In addition, there are surface observations collected at many of the airports throughout the kingdom. Surface meteorological data are being collected at other Gulf region locations. Their locations may be identified through the WMO publications. Previously, there were other surface measurement sites within Kuwait but their operational status remain unknown at this time.

Two upper air balloon sounding sites are operating within Saudi Arabia. One site is at Dhahran and the other is about 115 miles to the SW of Kuwait City at Al Qaysumah. Twice daily soundings are collected at those locations, at 0000 and 1200 GMT. Prior to the war in Kuwait, twice daily upper air soundings were made at the Kuwait International Airport. the resumption of those soundings could be of substantial benefit to describing the airflow across the areas of Kuwaiti of fires.

2.2 Meteorological Observations

The following summarizations are based upon first hand observations of the smoke plumes and fires. Those observations were made during overflights and during vehicle traverses both within the oil fields and along roads outside of the burning oil fields.

For any given day, the prevailing large-scale meteorological pattern will be the main driving feature which determines where the smoke plumes will be located and how dense they will be.

Individual smoke plumes appear to act in manners typical of buoyant plumes from ground level sources or plumes from short chimneys. Plume rise, the development of a bent-over plume geometry, etc., seem to apply to the individual well-head fires; some have jets of fire and others are nearly surface based burnings of the more combustible fractions of crude oil spread across the ground in the vicinity of the well. Most of the fire plumes rise to between 500 to 1000 feet above ground level before becoming mostly bent over, although some plumes have a significant amount of smoke remaining within a few hundred feet of the ground.

Collectively, as groups of multiple fires within oil fields with a high density of burning wells (particularly Greater Burgan), they assert a meteorological influence of their own. It is suggested that the grouping of fires with a horizontal diameter of 15 to 25 miles provides enough of an intense "heat-island" that significant additional vertical rise of the smoke occurs inside the area. That additional plume rise lifts smoke to elevations often 3000, 4000, to 5000 feet above ground within the initial few miles downwind. Eventually, portions of the smoke rise even more, with multiple layers often forming at heights up to 8000, 9000, even 12000 to 13000 feet. Between such layers and at the tops of layers many tens of miles downwind, a generally diffuse and homogenous zone of smoke has been observed. The eventual smoke height limits are bounded by the regional vertical temperature structure and synoptic weather characteristics. Information reviewed to date suggest that those maximum heights are mostly 8000 to 12000 feet within the initial 100 to 200 miles downwind from the Kuwaiti oil field fires.

With the creation of a local heat-island, a distinct inflow of near surface air has been observed within the initial 500 to 1000 feet above ground level. At times, that inflow of wind is estimated to be 5 to 15 m/sec in strength. Smoke plumes at the peripheral bounds of the burn area tend to stant inward toward the center of the burning field instead of pointing downwind with direction of the expected ambient wind.

Local variations in daily wind flow, along with the fire-storm like winds, are likely to produce preferred locations and times of day at which more concentrated smoke plume exposures reach ground level. Prevailing winds are from the northwest throughout the year. During the daytime a sea breeze can be expected to develop at the Gulf shoreline and progress inland as the day progresses. That inflow of air can readily clear out the smoke plumes and yield substantially cleaner air at ground level on the Gulf side. Along the leading edge of the sea breeze front there likely may be a zone of extended and elevated exposures to fire effluent. That zone may well extend down the shoreline from Kuwait City some 100 km. The area of greatest susceptibility appears to be to the southeast of fires in the Al Ahmadi oil field (part of the greater Burgan field).

2.3 Data Base Management

In addition to evaluating the existing air monitoring networks, the Team made an initial review of existing data systems to handle the air monitoring data. The previous meteorological, air quality, and visual observations of the oil field fire plumes should be archived, along with data to be obtained during the period of on-going Kuwaiti fires. A dedicated facility for the performance of that archiving does not appear to exist. The data management task is likely to be a sizeable task and extended of a period of a year and more.

Some of the general functional needs of the data management system include the following. The data which will need to be assembled into the data base will likely come from many different sources and exist in diverse formats and media. One role of the data base management activity will be to assemble all information into a common, uniform structure. The second and equally important part of the data archiving is the provisions of a uniform and consistent mechanism for the retrieval of data by participating agencies. The degree to which that data base is well formulated, will significantly affect the efforts of users of the data as they attempt to study and interpret the measurements.

A number of possible methods exist for the set-up of a computerized data base. Commercial software and hardware of various degrees and complexity and cost exist which would satisfy the data management needs. Before the choices of system software and hardware are made, the functionality of the overall system and the manners in which users work with the data sets should be considered. For example, it may be required that the data base be a "relational" data base. Other sources of software that might be used to handle a large volume of data would be the U.S. Environmental Agency's (USEPA) Aerometric information and Retrieval System. That system can handle hourly data and has considerable software available to both summarize and analyze the ambient air data.

MEPA has asked the Team to recommend the type of computer and associated software needed to manage the data collected in order to implement the monitoring plan. For now, it is more appropriate to defer specific recommendations. A number of general performance characteristics may be stated but specific details should be formulated in conjunction with data base specialists at a later date.

RECOMMENDATIONS

White preliminary, the Team believes that the following recommendations should be implemented based on our initial data gathering exercise. A general objective is listed as a recommended goal and below that objective are listed several needed items or activities to facilitate the achievement of the overall goal.

1. Objective: Provide a framework for an early warning advisory capability for areas expected to be impacted by effluents from Kuwaiti oil field fires.

Needs:

- a. Meteorological data observations and forecasts
- b. Visual observations from key receptor areas
- c. Review existing monitoring data
- d. Calculate smoke trajectories and concentrations
- 2. Objective: Provide a cursory wide-area indication of the distribution and composition of the Kuwaiti oil field fire effluents.

Needs:

- a. Establish 10 to 15 PM₁₀ monitoring locations using portable monitors.
- Train personnel in the operation of the portable PM-10 monitors and develop the analytical support capability within Saudi Arabia and Kuwait.
- Define the PM_{to} to TSP ratios.
- d. Define the composition of the plume by XRF analysis for limited organic identification.
- e. Establish a central media preparation and analysis location.
- Define the baseline contribution of the ambient aerosol from the surrounding desert.
- 3. Objective: Characterize the aerial smoke plume.
 - Needs: a. Collect many of the same plume measurements recommended for the ground monitoring array
 - Collect descriptions of the width and vertical extent of the smoke plume at several downwind distances
 - c. Characterize the regional background by samples outside of the smoke plumes
- Objective: Develop a more complete profile of the smoke plume constituents
 - Needs: a. Procure equipment for a limited number of comprehensive air quality monitoring stations to collect: TSP, PM₁₀, organic, and inorganic constituents
 - Establish a limited number of comprehensive air quality monitoring stations to collect: TSP, PM_{io}, organic, and inorganic constituents. These should be collocated with the continuous monitors wherever possible.
 - c. Train individuals to operate and maintain the sampling instrumentation in support of the monitoring program
 - d. Procure the necessary analytical laboratory equipment required for analyses of the samples collected under this objective
 - Train laboratory personnel in the preparation of the sampling media, QA/QC procedures required and the subsequent sample analytical procedures.
- Objective: Determine the need for expansion of the monitoring network to a wider regional coverage.
 - Needs: a. Review the data developed from the limited network.
 - Assess the current and projected status of control of the oil field fires and emissions.
 - c. Review the population health survey statistics.
 - d. Review the suitability of the sampling strategy, and modify where needed

 Expand the limited network as the situation requires, data analysis indicates an additional need for data, the response of the affected populations indicate, or the model requires additional parameters.

Many of the same considerations listed for air quality above also apply to meteorological considerations.

- 6. Objective: Provide a meteorological data stream to facilitate the modeling and prediction of areas expected to be impacted by effluents from Kuwaiti oil field fires.
 - Needs:

 a. Upper air belloon sounding data representative of the Kuwaiti oil field fire area and Gulf region plume transport.
 - Supplemental surface based measurements of wind speed and direction, temperature, moisture content of the air (dew point, relative humidity, etc.), solar radiation, atmospheric pressure, precipitation.
- 7. Objective: Provide a meteorological data set to investigate the areas of climate modifications occurring due to effluents from Kuwaiti oil field fires.
 - Needs: a. Supplemental surface based measurements diffuse and direct solar radiation.
 - Special collections of precipitation throughout the region to examine the pH and chemistry of the rains.
 - c. Aircraft soundings and profiles of smoke, winds and temperatures, air quality related measurements of plume compositions and concentrations representative of the Kuwaiti oil field fire area and Gulf region transported plumes.

4. PHASED AIR MONITORING PLAN

This section of the report discusses a prioritized plan of stepwise incremental actions for the phased implementation of the recommendations discussed above. Five phases for implementing the plan follow.

4.1 Phase 1. Provide a Framework for an Early Warning Advisory

In order to accomplish this task, the following action items need to be initiated or incorporated into the task framework.

- 1. Gather daily weather forecasts to predict meteorological conditions which would effect pollution potential in both Saudi Arabia and Kuwait.
- 2. Use visual observations from key receptor sites to determine possible pollution levels.
- Gather existing air monitoring data from fixed and mobile sites operated by MEPA, Saudi ARAMCO, and the governments of Kuwait and Bahrain to develop a data base of existing data.
- Establish a daily briefing for representatives of the many entities concerned with behaviors and fate of the aerial effluents from the oil field fires in Kuwait.
- 5. Develop a daily map depiction of the serial distribution of the smoke plumes across the region using satellite imagery, for each day since initiation of the oil field fires.
- lasue a daily general statement about the expected behavior(s) of the oil fire plumes.
 Areas of potentially adverse conditions could be treated as locations for which advisories would be issued.
- 7. Provide forecast meteorological conditions across the region for the next 2 to 3 day period, including the expected location(s) of the smoke.
- Obtain data from the MEPA network throughout the eastern province.
- Direct the crews of the SLAR aircraft, (USCG Falcon Jet), to continue on a regular basis
 the present visual observation and mapped notations concerning the horizontal extent of
 the smoke plumes and the estimations of altitudes of layer bases and tops.
- 10. The above information could be compiled initially in hard copy form. Later it should be stored on electronic media in a way that an existing PC data management system could readily incorporate it.

4.2 Phase 2. Establish a PM, Monitoring Network Using Portable PM, Monitors.

Working in conjunction with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA), the proposed plan has been developed to collect information on PM_{ie}, which represents particulate matter with particulates less than 10 microns in diameter. At the present time there is no PM_{ie} monitoring in the Gulf region.

OBJECTIVES

The objectives for this effort are as follows:

- 1) Determine the magnitude or the health threat to residents of population centers and field-based military personnel impacted by the oil field fires and typical sources (windblown desert soils).
- 2) Establish a scientifically based capability to alert these affected populations prior to the onset of the potential health threats from real-time measurements.
- 3) Establish a technical basis for executing predictive air quality dispersion models which simulate the oil well fire emissions, background sources, and consequent impacts over space and time.
- 4) Establish a regional network of PM₁₀ stations using a consistent monitoring methodology across the countries of Saudi Arabia, Kuwait, and Bahrain.
- 5) Train personnel to operate and analyze the media produced by the network from each of the participating countries.
- 6) Develop a regional data base and encourage the sharing of data developed from the network with all participants.

The above objectives convert the foregoing goals into discrete actions:

- 1) Determine the spatial temporal frequency, and severity of the impact to the resident populations and military centers affected through the application of saturation sampling techniques with portable PM₁₀ samplers.
- Establish the correlation of real-time surrogate monitoring data to date generated from direct sampling methods through the collocation and simultaneous operation of both methods over time.
- 3) Where possible use impact data collected from samplers as an input to the dispersion model, run the model "backwards" to develop a better estimate of the emission rates of the fires and produce a higher level of confidence in the predictive modeling results.
- 4) Obtain from the literature and/or develop from source sampling analysis chemical profiles of all major pollutant sources in order to:
 - a) identify those contaminants that pose the greatest health concerns and to develop an estimate of acceptable ambient levels (AALs) prior to the conduct of field work.
 - b) identify the chemical "signature" of the major contaminants and other tracers characteristic of the primary sources,
 - c) enable apportionment of these contaminants and other tracer compounds from a simple total mass concentration measured by the ambient samples, and

- d) attempt to relate these levels in turn to the surrogate real-time monitoring methods for use in issuing timely health risk alerts.
- 5) Ensure that the data generated by the network are of a demonstrably high quality (precision & accuracy), completeness, representativeness, and comparability.

TIME	POSITION (LAT/LONG)	BASE/TOP	WIND (DIR/SPD)
0545	N2623E50-31	CLR VIS 15 M	332/23
0600	N2700E4958	CLR	321/19
0615	N2744E4916	CLR	300/20
0630	N2822E4839	TOPS 070/030	331/008
0645	N2918E4819	SMOKE 060/030	335/10
0700	N2932E4810	SMOKE 070/030	344/10
0715	N29344830	SMOKE 070/030	265/7
0730	N29354857	THIN SMOKE 050/030	215/6
0745	N2925E4920	VERY THIN SMOKE 090	133/003
0800	N2833E4945	THICKER SMOKE 090/ 080	325/006
0815	N2738E5035	THIN SMOKE 090/080	280/005
0830	N2702E5111	SMOKE 090/080	192/010
0845	N2625E5148	SMOKE/HAZE 080/060	215/12
0900	N2618E5118	SMOKE/HAZE 070/SURF	230/009

APPROACH

Conduct a PM_{Io} saturation sampling study for the determination of the temporal and spatial features of the impact of the oil well fires and attempt to reconcile the data with existing model estimates. PM_{Io} mass concentrations would be available within 24-48 hours following sampling. No onsite meteorological, gas, or aerosol monitoring or chemical analysis is required (chemistry could be attempted later on the preserved media). One or more portable nephelometers would be collocated at several sampling sites to develop correlations between manual and continuous (real-time) methods for allert advisories.

A total of 15-20 portable PM_{is} semplers equipped with quartz filters would be run simultaneously on a daily basis or "triggered" (impact forecast) basis throughout the study area. Network design would involve a "nested" approach to address the objectives:

1) samplers sited at background locations (not impacted) by the smoke plume and samplers in populated areas.

2) samplers in populated areas impacted by smoke.

Samplers could be "ganged" (2 or more) and programmed to run consecutively at individual sites if filter clogging problems occur because of high loading. Further, multiple samplers could be collocated at certain sites to collect fine particulates (less than 2.5 microns) and coarse particulates (2.5-10 microns) on teffon sample filters (facilitating XRF elemental analysis). One of the 10-12 sampling sites would be equipped with duplicate samplers in an effort to develop sampling precision estimates.

This comprehensive program will yield the following:

- 1) short turnaround PM, concentrations,
- 2) gross estimates of the fire-specific contributions to total mass could be derived by subtracting background concentrations from the impact site concentrations,
- applying assumptions on the source profiles to pollutant loading attributable to the well fires, estimates of individual target compound loadings could be computed and a comparison to AALs made.
- 4) correlations factors can be determined between real-time surrogate methods and manual methods, and
- 5) impacted sampling media would be available for subsequent intensive chemical analysis in an attempt to reconcile assumed source signatures and extracts can be used to perform any other analytical tests (mutagenicity). Special precautions may be needed to preserve the sample integrity during storage and transfer.

Limitations: no on-site meteorological data to calculate emissions rates, no on-site chemistry (unless developed) to confirm critical assumptions, and no concurrent gas or acid aerosol measurements to evaluate or correlate with the particulate data.

Resources: 1-2 professionals, 1 field technician per site, if it must be operated individually (actual number contingent upon the network logistics and potential "clogging" implications), portable PM₁₀ saturation samplers, portable nephelometers, lap-top computer, microbalance, expendables and sundry support gear.

In summary, this approach is PM_{ie} mass data-rich, and assumption rich and in contrast to being reconciliation and broad pollutant characterization-poor.

SAMPLING AND ANALYTICAL METHODS

The alternate approaches identified above involve the use of a variety of sampling and analytical methods summarized below:

Portable PM₁₀ Saturation Samplers

- segregate and capture of filter, particulates of 10 micron size (respirable particles) and smaller.
- bettery-operated, lightweight, πισged, inexpensive, small, and quiet.
- essiv deployed and operated.
- programmable timer for unattended on and off.

- rechargeable battery packs.
- continuous operation up to 30 hours on a single charge.
- precise and accurate.
- low detection limit of approximately 5 ug/m3
- sustained operation under high particulate loadings, e.g. 100 ug/m3 or more.
- electronic sample flow regulation.
- electronic sample flow totalizer.
- low flow shutoff/warning.
- can accept a variety of other pollutant sampling media (e.g. PUF, DNPH, charcoal, denuders, etc.) or take whole air samples (Tedlar bags) with little or no modification.

Portable nephelometers

- many of the same attributes of the PM₁₀
- battery operated
- effectively measure particulates of 1 micron diameter or smaller.
- continuous reading, storing five minute averages.
- rechargeable.
- continuous operation from 2-48 hours on a single battery charge.
- internal storage for up to nine days of sampling data.
- data download to a portable lap-top computer through RS232 serial port.
- operationally equivalent to standard nephelometers.

Microbalance

- five to six place balance.
- rugged, transportable while precise and accurate.

Field XRF Unit

- similar MQLS with situ laboratory units.
- rugged.

Support Gear

- calibration and audit gear, tools and diagnostic equipment, etc.

PROPOSED NETWORK DESIGN

The recommendation for siting of the portable PM₁₀ samplers is predicated on providing a large area of coverage for developing a better estimate of the areas impacted by the plume, a cross-sampling of population and troop centers, and to a capability to provide a technology transfer to Saudi Arabia, Kuwalt, and Bahrain.

SAUDI ARABIA

- collocated site at K.F.U.P.M. (2 sites)
- two sites in Riyadh (1 U.S. Embassy & 1 MEPA location)
- one site Royal Commission at Jubayi
- one site Saudi ARAMCO at Tanajib
- one site MEPA at Khafli

Total of seven (7) sites.

KUWAIT

- three sites (3) located at the two operational continuous monitoring sites within Kuwait City (one site collocated)
- one site at Camp Freedom
- One site U.S. Embassy
- One site Al Hamadi (Kuwait Oil Company Hospital)

Total of six (6) sites.

CENTCOM

two sites at selected troop locations:

Total of two (2) sites.

BAHRAIN

one site to be determined

Total of one (1) site.

A total of society samplers are committed to field sampling with the remainder as spares or as changes to the sampling plan requires.

Phase 3. Characterize the Aerial Plume.

This phase should follow closely with Phase 2, in order to characterize the 3-dimensional nature of the smoke plumes from the fires in Kuwaiti oil fields. To achieve that goal, many of the same plume measurements collected by the existing and proposed ground level measurement locations should be provided by the aerial sampling platform. Obviously, the longer time integrated samples (e.g., 24 hour total values, averages, etc.) cannot be reproduced by aircraft borne devices. Short-term and across plume integrated measurement descriptions may be obtained to characterize the special extent and details of actual constituents of the elevated portions of the oil fire plumes.

The serial sampling activities may be separated into measurements which address the three general zones of plume characteristics, from an a meteorological sense. Those zones are the 1) close-in zone, 2) intermediate or transition zone and 3) extended or distant zone. Measurements very near the wellhead are difficult to impossible to obtain due to excessive heat and great levels of turbulence. Measurements at intermediate distances will be difficult and many locations within the clustered groups of burning wells may be unsafe for serial traverses due to the extremely dense smoke and hidden turbulent plumes. Measurements at the longer distances, a few miles downwind of the burning wells, should be possible. Measurements from a few to several hundred miles downwind of the fire area should be feasible. Within that distance range the approximate concentrations, plume dimensions, and estimated mass flux in the downwind directions may be approximated. The aerial sampling strategies should concentrate on the obtaining of those types of information.

4.4 Phase 4. Develop a Complete Profile of the Smoke Plume Constituents.

Obtain additional equipment to expand existing continuous monitoring high priority sites in Kuwait and Saudi Arabia

The survey conducted by the Team during Phase 1 of this plan indicated that within the region, respirable particulate sampling technology, aerosol and total particulate sampling and analysis for volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), and PAHs were either not available or insufficient to properly characterize the effects of the oil well fires on the population centers and the troop concentrations within the region.

This phase of the plan proposes to bring into the region several new technologies and to train personnel within the region to operate samplers, to condition, and analyze the several new media necessry to support this expanded network. The objective of this process is to develop a stand-along capability within each participating country for aerosol and particulate monitoring which will support the Gulf regional air quality characterization and index plan outlined in Phase V.

During this phase of the plan the Team proposes to expand the continuous air and meteorological monitoring currently being conducted within the region at six sites. These sites are recommended based on the need to jointly develop the sampling and analytical capability within the region to ensure that it becomes self-sufficient and sustainable. The particular technologies outlined below are not currently operated within the rgion nor are the analytical procedures required to support them currently being utilized. However, the Phase I survey indicates that with sufficient training, additional equipment, and some experience with actual field samples the transfer should be relatively smooth.

Initially, the Team's recommendation of six sites strategically placed along the axis of the area of greatest impact by the oil well fire plume will generate sufficiaent samples for the required training, while also providing critical data not currently being collected by the existing networks or available through the portable PM₁₀ network proposed in Phase II. As this data base develops it can be used to better define the constituents of the plume and thus permit a more accurate assessment of the potential long-term health risk.

The equipment listed below should be collocated with the full compliment of continuous air and meteorological monitors described in Phase V at these six proposed sites. A brief description of the equipment is provided below:

TSP High Volume Sample - used to collect a 24-hour sample of the total suspended particulates, operated nominally at 50 OFM, and typically uses 8x10 inch glass fiber, quartz, or teflon filter media.

PM₁₀ High Volume Sampler - used to collect a 24-hour sample of the 10 micron and smaller sized fraction of the total suspended particulate sample collected by the TSP, sampler above, sampler is typically operated at 40 CFM, and utilizes an 8x10 inch Quartz or telion filter media. Note: glass fiber media should not be used if there is concern for a known sulfate artifact formation problem.

PM₁₀ Manual Dichotomous Sampler - used to collect a 24-hour sample of the 10 micron particulate size fraction of the TSP, sampler operates at 16.7 liters/minute, and utilizes two (2) 37 mm diameter Teflon filters to collect a fractionated sample with a cut point of 0-2.5 micron (fine fraction) and 2.5 - 10 micron (coarse fraction).

VOC Canister Sampler - used to collect up to a 24- hour integrated whole air sample in six-liter evacuated stainless steel canisters, interior walls are passivated to minimize sample degradation, samples volume can be rgulated by either limiting the volume to ambient pressure or pumping in addition sample to an approximate volume of 16 liters, these samples can be used for the determination of total hydrocarbons or analyzed for specific hydrocarbons, multiple analysis are available from a single pressurized canister sample. Note: An extensive canister cleanup process is required prior to the collection of additional air samples.

Polyurethane Foam (PUF) Low Volume Sampler - used to collect 24-hour aerosol samples utilizing small AC or battery operated pumps at flow rates less than five liters per minute on relatively small glass cartridges containing a PUF plug, these samples can be extracted and analyzed for PAHs, or other SVOCs. Note: Both the glass cartridge and PUG plug require an extensive cleanup procedure prior to re-use.

Optional Tenex/Charcoal/XAD-2 tubes - these media can be used with same type of low volume pumps described above to collect additional samples for further definition of the constituents of the plume for SVOCs.

Organic compounds will be present in all three phase distributions (particle bound, SVOC, and VOC) and each phase will have to be sampled and then a determination will have made as to importance of each.

The particle bound is phase can be collected for extractible organic analysis from both quartz, teflon impregnated glass fiber gitters, or teflon.

The SVOC phase can be collected on PUF and within the canister. The VOC phase can be collected with canisters and charcoal tubes. Employment of Tenex and SAD-2 sampling tubes in conjunction with PUF, charcoal tubes, and canisters in an overlapping sampling matrix, can be used to confirm of the presence or absence of compounds which could be missed by a less complex sampling matrix.

Proposed locations for the initial six expanded sites:

The Team recommends that the six locations follow the general axis of plume drift from Kuwait City south into Saudi Arabia. It is further suggested that the operation of these sites be divided amongst the key network managers within the two countries: Kuwait, MEPA, and Saudi ARAMCO. This division of responsibility supports the philosophy to jointly develop both the sampling and analytical capability within all three entities.

Kuwaiti Locations

The Team recommends that two (2) of the sites be located at the existing operational continuous monitoring stations located in Kuwait City. A third site should be established in Al-Abmadi at the Kuwaiti Oil Company Hospital. This location is situated within 300 - 400 meters of several burning wells and is adjacent to the closest residential area associated with any of the oil fields.

Saudia Arabian Locations

The Team recommends that a site be established at King Fahd University of Petroleum and Miners (K.F.U.P.M.) in Dharhran, one site to be collocated with Saudi ARAMCO site in Tanajib and the

last site should be collocated with the MEPA sie in Khafji which currently is data.

Episodic/EARLY WARNING measurements

Longer term mc

PM, _o	(continuous)	Acid aeros
TSP	•	VOCs
SO2	(continuous)	Aldehydes
O3	(continuous)	BaP, other PAI.
NOX, NO	(continuous)	Trace elements
CO	(continuous)	Fine particles
H2S	(continuous)	•

3. Health Monitoring Survey

Air monitoring data collected through the proposed air monitoring network will provide bas interpreting the results of health surveys of the populations and ecosystems potentially effected by to effluents from the oil fires in Kuwait. The kinds of health data that could be collected include:

Health questionnaires
Blood samples
Hair samples
In-vivo animal studies
Forced expiratory volumes
Other morbidity parameters

Distribution of Proposed and Existing Air Monitoring Sites

Table 2 shows the location of the existing and proposed air monitoring sites, while Table 3 lists the locations of the proposed air monitoring sites. In order to complete the network in an orderly manner, it is proposed that the network be developed in several stages. The first order of business would be to upgrade the existing monitoring locations so that there exist a full complement of air and meteorological monitoring equipment, as well as add new critical air monitoring stages (Stage 1). The second stage would be to establish those sites that would satisfy the minimum requirements for tracking the plume caused by the oil fire and to provide an early warning system for Saudi Arabia, Kuwait, and Bahrain (Stage 2). The third and final stage would be to complete the final network following a review of the quality and quantity of findings to date (Stage).

5. SUMMARY

The initial measurements made by the Team suggest that there is not an imminent threat from SO2 and H2S to the urban populations, while short term measurements of particulate are frequently high. Historically, this region has high particulate levels due to wind blown dust. The particulate measurements that were collected by the Team reflect total particulate, as opposed to respirable particulates, that is PM₁₀. There has not been a principal focus in the Region on total particulate, PM10₁₀, and organics up to now. Therefore, the Team developed the five phased monitoring plan with an emphasis on better understanding particulates and the aerosol organics associated with the oil fires in Kuwait. Particulates and organics could be a source of concern for both health and ecological effects.

The air monitoring proposals presented in this report represent the Team's collective judgement on what needs to be done. Those judgements are based upon an on-site evaluation of the situation in Kuwait, discussions with officials from the Saudi Arabian MEPA, Kuwait, Saudi ARAMCO, and the King Faud University of Petroleum and Minerals. Needless to say more work is needed regarding data management, statistical design, data analysis and quality assurance. Because of the complexity and immediacy of this problem, an extended time commitment will be needed on the part of all Gulf nation agencies to achieve the objectives outlined in this report.

Cost estimates for the various tuypes of air and meteorological monitors are attached to this plan, along with documentation on the U.S. Environmental Protection Agency's Pollutant Standards Index (PSI).

TABLE 2. Location of existing air and meteorology monitoring stations

NATION	ORGANIZATION	LOCATION	STAGE OF IMPLEMENTATION
EXISTING SITES	·	·	
Saudi Arabia	MEPA	Damman	1
		Hofut	2
		Tanagib (Mobile Site)	1
	·	Plyadh	1
		Kharji (Met Only)	11
		Udayiiyah	3
		Shedgurn	3
		Abqaiq	3
		Chehran	2
		Tertut	2
		Rehimeh -	2
	, i	Jusymeh	1
		·· Tanajib	1 .
		Seffeniyah Oli Field (met only)	3
		Marjan Oll Field (met only)	3.
		Farielysh Island (met only)	2
	The Royal Comm. for Jubyayi and Yunbo	Cluster of 5 stations in Julyeyi	1
Existing Sites: Kuwait		SITE 1	1
		\$ (TE 2	1
		SITE 3	1
Existing Sites: Octar		3 mobile units, unknown locations	, 2

TABLE 3. Location of proposed air and meteorology monitoring stations

NATION	ORGANIZATION	LOCATION	STAG E
Proposed Sites: Saudi Arabia	MEPA	Awiyah	3
	<u> </u>	Shumiul	2
•		Sarrar	2
		Nuayriyah	2
		/ Lisefah	3
		Usfar al Betin	1
		28 deg 6 min latitude, 47 deg 51 min longitude	2
		28 deg 30 min latitude 48 deg 1 min langitude	1
		28 deg 55 min latitude 47 deg 32 min longitude	2
		29 deg 7 min latitude 46 deg 39 min longitude	2
Kuwait		Mine Seud	1
		U.S. Embasey	1
·		Al Ahmadi (Hospital)	1
		International Airport	1
		29 deg 23 min latitude 46 deg 55 min longitude	2
		29 deg 50 min latitude 47 deg 15 min longitude	2
		30 deg 4 min letitude 47 deg 42 min longitude	2
		29 deg 33 min latitude 47 deg 50 min longitude	2
Behrain		Menemah	2
Cetar		Dawhah	2
United Arab Emirates		Aub Dhabi	3
		Dubai	3
Omen		Muecet	3

UN INTERAGENCY ACTION PLAN ON THE KUWAIT OIL FIRES

AREAS OF CONCERN

- MARINE AND COASTAL ENVIRONMENT
- ATMOSPHERIC POLLUTION
- INLAND TERRESTRIAL CONTAMINATION
- HAZARDOUS WASTE MANAGEMENT

UN INTERAGENCY ACTION PLAN ON THE KUWAIT OIL FIRES

APPROACH

- MULTIDISCIPLINARY SURVEYS AND ASSESSMENTS
- DEFINING REQUIREMENTS FOR EXPERTISE, EQUIPMENT AND FUNDS
- FORMULATION OF A PLAN OF OPERATION
- FIELD IMPLEMENTATION

WMO GOORDINATION OF THE ATMOSPHERIC COMPONENT

- ATMOSPHERIC COMPOSITION AND AIR QUALITY
- LONG-RANGE TRANSPORT
- ASSESSMENT OF GLOBAL SCALE EFFECTS
- PROVISION OF ATMOSPHERIC DATA FOR IMPACT STUDIES ON TERRESTRIAL AND AQUATIC ECOSYSTEMS

WMO COORDINATION OF THE ATMOSPHERIC COMPONENT

- AIR AND PRECIPITATION SAMPLING (100-3000 km)
- REHABILITATION AND ENHANCEMENT OF THE METEOROLOGICAL NETWORK (WWW AND GAW) INCLUDING EQUOIPMENT AND TRAINING
- DATA AND COMMUNICATION FOR MODELLING AIR POLLUTION DISPERSION AND DEPOSITION
- ADVICE TO DECISION MAKERS
- SCIENTIFIC ASSESSMENTS

WMO assessment of the atmospheric consequences of the KUWAIT OIL FIELD FIRES

o QUESTIONS

- WHAT IS THE COMPOSITION AND AMOUNT OF GASEOUS AND PARTICULATE BYPRODUCTS BEING PRODUCED
- WHAT IS THE MAGNITUDE OF THE EXPOSURE IN THE IMMEDIATE VICINITY (TO SERVE WHO HUMAN HEALTH RELATED STUDIES)
- WHAT ARE THE POSSIBLE CONSEQUENCES AS REGARDS LONG-RANGE TRANSPORT AND ENHANCED BACKGROUND AIR POLLUTION AND DEPOSITION
- WILL THERE BE SIGNIFICANT GLOBAL EFFECTS

o TOOLS

- MONITORING
- MODELLING

MONITORING OBJECTIVES

TO ESTABLISH A DATA BASE FOR

- O AIR AND PRECIPITATION COMPOSITION AND THEIR TRENDS
- O MONITORING ANOMALOUS TROPOSPHERIC CHEMISTRY AND RELATED EFFECTS
- O AIR POLLUTION TRANSPORT MODELLING
- O ASSESSING CLIMATE EFFECTS
- O MONITORING ATMOSPHERIC COMPOSITION CHANGES IN THE FIRE EXTINGUISHING PROCESS

GROUND BASED MONITORING

- METEOROLOGICAL PARAMETERS
- PRECIPITATION CHEMISTRY
- RADIATION (INCLUDING OPTICAL DEPTH)
- TOTAL CARBON AND SOOT
- GASEOUS COMPONENTS (CO_2 , CO, CH_4 , SO_2 , H_2S , O_3 , VOC's including PAH)
- AEROSOL

MONITORING LOCATIONS

- O NEAR THE SOURCES (DETERMINATION OF EMISSIONS, LOCAL IMPACT)
- O MEDIUM RANGE (REGIONAL EFFECTS)
- O LONG RANGE (GLOBAL EFFECTS)

GLOBAL ATMOSPHERE WATCH

(A SYSTEM FOR ENVIRONMENTAL POLLUTION MONITORING AND RESEARCH)

main long term objectives (1)

O TO PROVIDE AUTHORITATIVE
SCIENTIFIC INFORMATION AND
ADVICE ON THE COMPOSITION AND
BEHAVIOUR OF THE GLOBAL
ATMOSPHERE

main long term objectives (2)

- O TO ESTABLISH AND CO-ORDINATE
 AN OPERATIONAL SYSTEM TO
 DETERMINE GLOBAL AND REGIONAL
 LEVELS AND TRENDS OF NATURAL
 AND MAN-MADE ATMOSPHERIC
 CONSTITUENTS (INCLUDING THOSE
 WITH A POSSIBLE IMPACT ON
 CLIMATE)
 - TO FORECAST FUTURE STATES
 OF, AND STRESSES ON, THE
 ENVIRONMENT
 - TO ENABLE GOVERNMENTS TO TAKE PROMPT ACTIONS TO REDUCE POLLUTION

- O TO FURTHER THE UNDERSTANDING OF THE CHEMISTRY AND PHYSICS OF THE ENVIRONMENT
 - TO APPLY THIS IN THE FIELD OF METEOROLOGY AND CLIMATOLOGY (ATMOSPHERIC MODELLING)
- O TO PROMOTE STUDIES OF THE INTERACTION OF THE ATMOSPHERE WITH THE MARINE AND TERRESTRIAL BIOSPHERE
- O TO MEET THE RESPONSIBILITIES
 OF WMO TO PROVIDE LEADERSHIP
 AND GUIDANCE FOR THE
 PROTECTION AND MANAGEMENT OF
 THE ATMOSPHERIC ENVIRONMENT

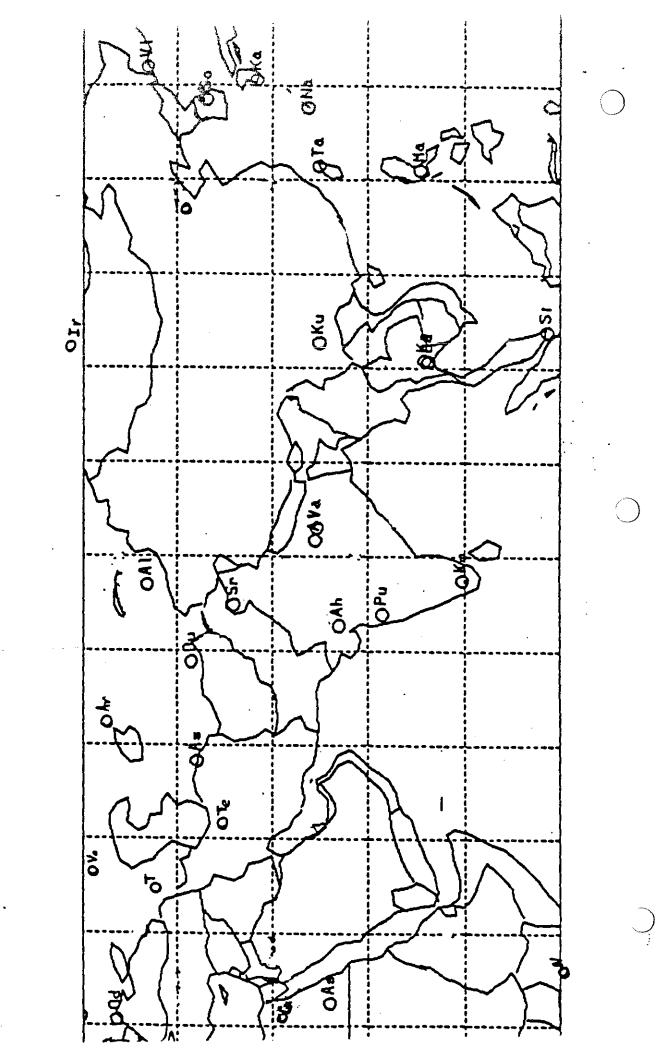
GLOBAL ATMOSPHERE WATCH

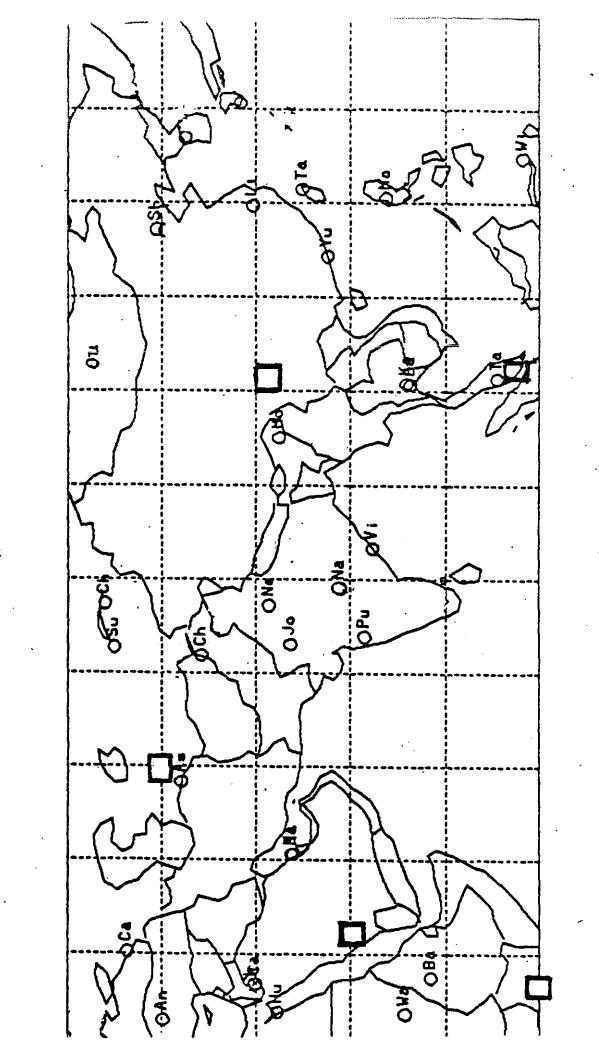
ESSENTIALS

- O RELATIONSHIP ATMOSPHERIC
 COMPOSITION AND CLIMATE CHANGE
- O IMPACT OF CLIMATE CHANGE ON ATMOSPHERIC CHEMICAL COMPOSITION
- O LONG RANGE TRANSPORT AND DEPOSITION OF POTENTIALLY HARMFUL SUBSTANCES
- O ATMOSPHERE/OCEAN/BIOSPHERE CHEMICAL CYCLES AND ANTHROPOGENIC IMPACT

ELEMENTS OF GAW

- O GLOBAL OZONE OBSERVING SYSTEM (GO_3OS)
- O BACKGROUND AIR POLLUTION
 MONITORING NETWORK (BAPMON)
- O DISPERSION, TRANSPORT, CHEMICAL TRANSFORMATION AND DEPOSITION OF ATMOSPHERIC POLLUTANTS OVER LAND AND SEA ON DIFFERENT TIME AND SPACE SCALES
- O EXCHANGE OF POLLUTANTS BETWEEN THE ATMOSPHERE AND OTHER ENVIRONMENTAL COMPARTMENTS AND INTEGRATED MONITORING

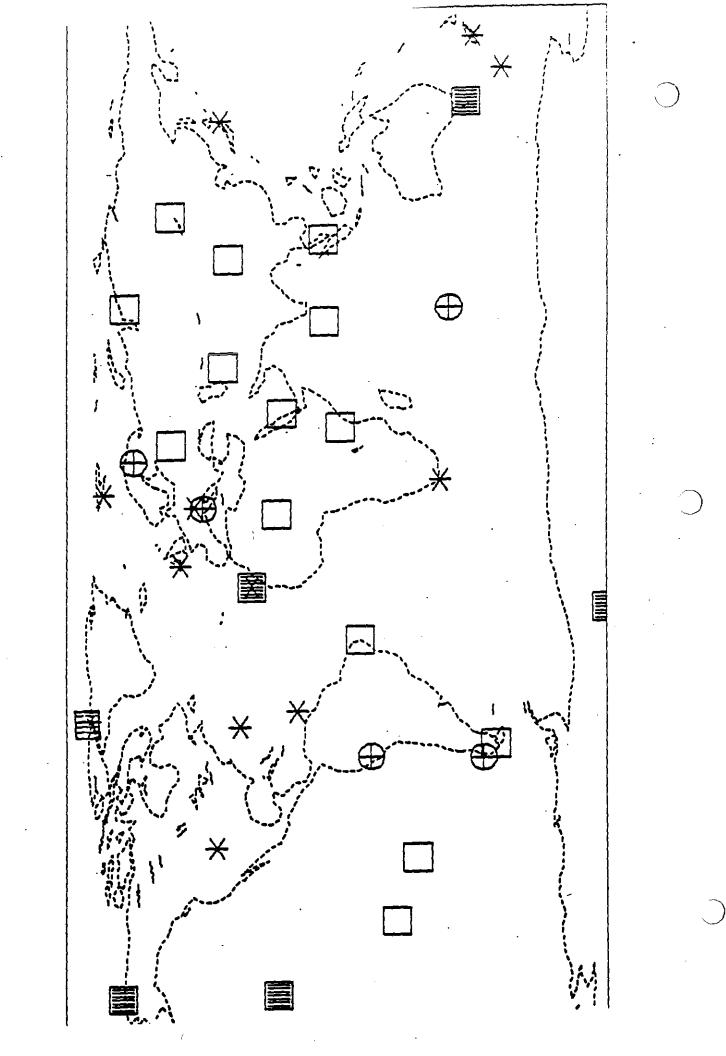




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AIRBORNE MEASUREMENTS

- O EMISSION RATES OF SMOKE PARTICLES AND TRACE GASES
- O THE VERTICAL AND HORIZONTAL EXTENT OF THE SMOKE "PLUME"
- O THE CHANGES IN CHEMICAL COMPOSITION DURING THE EVOLUTION OF THE "PLUME"
- O VERTICAL PROFILES OF ATMOSPHERIC SHORT AND LONG-WAVE RADIATION
- O PHYSICAL AND CHEMICAL PROPERTIES
 OF THE SOOT (HYGROSCOPY,
 SCAVENGING POTENTIAL, CHEMICAL
 TRANSFORMATION, COAGULATION,
 CONDENSATION NUCLEI POTENTIAL)

MODELLING REQUIREMENTS

- EMISSIONS AND SOURCE CHARACTERISTICS
- CLIMATOLOGICAL DATA IN THE GULF REGION
- ANALYSED 6 HOURLY WINDFIELDS FROM 1 FEBRUARY 1991 ONWARDS
- SYNOPTIC METEOROLOGICAL DATA (INCLUDING PRECIPITATION AND UPPER AIR DATA) OF THE REGION

MODELLING STRATEGY

- URBAN AIR QUALITY CLIMATOLOGICAL MODELS
- TRAJECTORY CALCULATIONS WITH PREDICTIVE CAPACITY
- REAL TIME OPERATIONAL REGIONAL SCALE TRANSPORT AND DEPOSITION MODELS (FOR MONITORING ASSISTANCE AND REGIONAL IMPACTS)
- GLOBAL CIRCULATION MODELLING (CLIMATE EFFECTS, SCIENTIFIC ASSESSMENTS)

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CHECK AGAINST DELIVERY

My

STATEMENT BY MISS HANCEMENT J. ANSTER
DIRECTOR-CEMERAL, UNITED NATIONS OFFICE AT VIENNA, AND
PERSONAL REPRESENTATIVE OF THE SECRETARY-GENERAL,
TO COORDINATE UNITED NATIONS EFFORTS
TO COUNTER THE IMPACT OF THE HUNNING OIL WELLS
AND OTHER ENVIRONMENTAL CONSECUENCES OF THE GUF CONFLICT
IN RUMALT AND IN THE REGION

Mr. Chairman, Distinguished delegates,

By a strange twist of fate I have had the unique - and, I may add, unenviable - experience: to behold, within the space of a few months, the devastation caused by the two greatest man-made environmental disasters humanity has known: Chernobyl in April; and then, in early October, the burning oil wells in Kuwait and the war-ravished desert, air and marine environment of the Gulf.

In both cases the Secretary-General has given me special responsibilities to coordinate activities and seek the best means of mobilizing international cooperation to counteract their cataclysmic effects.

The causes of these two sombre reminders of the fragility of the world in which we live were very different. Yet there are striking similarities. Both were unprecendented in their scope and nature. Both were insidiously pervasive in their compass, disdaining man-made frontiers, spreading their evil harvest indiscriminately in regions far from the original site, and sowing fear and anxiety in their wake. In a world where the words "international" and "interdependence" have become commonplace, these events gave them a new and sinister meaning.

Even more strikingly, both happenings will stretch over time as well as space. Some of their consequences are immediately and hideously visible. Others are not, and cannot be measured accurately, or counteracted, except with the passage of years and careful and sustained monitoring. The costs in either case are thus incalculable with any degree of precision but inevitably very high. That means the even more difficult task of ensuring sustained international interest and support over many years during which new disasters will predictably capture the headlines.

I have already addressed this Committee on the subject of Chernobyl on 17 October. But in the context of your broader discussion on environment, it seemed to me important to bring out the affinities between these two phenomena, each in its own way so peculiarly characteristic of the hazards faced by - indeed, caused by - humanity at the end of the twentieth century.

It was no doubt with these kind of analogies in mind that the Government of Kuwait requested the Secretary-General to make similar arrangements to those for Chernobyl in respect of coordinating efforts to

counter the impact, in Kuwait and the region, of the burning oil wells and other environmental consequences of the Gulf conflict. In response the Secretary-General appointed me as his Personal Representative on 19 September.

It was in this capacity that I made a first visit to Kuwait in early October. While there, I had discussions at the highest level of government, meeting with His Highness, the Emir, His Highness, the Crown Prince and Prime Minister, and His Excellency, the Deputy Prime Minister and Minister of Foreign Affairs. I also had extensive talks on technical aspects of the problem, notably with Dr. Abdul Rahman Al-Awadi, Head of the Emergency Environmental Committee and Executive Secretary of the Regional Organization for the Protection of the Marine Environment (who I am delighted to see will be giving this Committee the benefit of his extensive and first-hand experience) and with the Kuwait Environmental Protection Council. On my mission I was accompanied by representatives of UNEP and UNDP to ensure consistency with work already in hand.

Most memorably of all, I was taken to see the burning oil wells themselves, by land, and flown by helicopter over the waters and lands laid waste by war. It has left an indelible impression.

So much has been written, and so many voluminous studies are available, that it would be superfluous for me to add to them here. I would only say that, whatever one has read, or even seen portrayed in photographs or films of the disaster, pales into insignificance compared to the reality. At the end of the road, as far as it was safe to go, we found our way barred by an impenetrable wall of billowing black smoke, hundreds of metres high, interspersed with great bursts of flame, generating intolerable heat. The thundering roar of gas expelled from the wells made speech virtually impossible. All around us, the desert surface itself was a blackened crust of burnt oil, flecked with charred vegetation and interspersed with large lakes of oil.

Dante's Inferno was the immediate comparison that came to mind - his words "All hope abandon, ye who enter here" never rang more true.

And yet, if humanity has shown a deplorable capacity to heap disasters on itself, it has also shown a remarkable resilience in dealing with them. When the full extent of the oil well fires was first known, estimates of the time needed to quell them extended into years. I was much struck by the remark of a senior official of the Kuwaiti Oil Company, that when contingency planning for an eventuality of this sort was undertaken in the United States while the conflict was still raging, the "worst scenario" was 100 wells. The verdict was that, beyond that number, it would be impossible to cope.

Notwithstanding, on 6 November the last oil well, of a staggering total of 732 originally on fire, was capped, barely seven months after the end of the war. It was particularly fitting that this should be done by a Kuwaiti team, and I would like to draw attention to the fact that that team was headed by a Kuwaiti woman engineer, Miss Sarah Salah.

The capping of the oil wells was a remarkable achievement by any standard. It was made possible by an unprecedented demonstration of international cooperation, involving twenty-seven teams from nine countries, applying many different, and often ingeniously inventive methods to quench the flames, and all working in almost intolerable conditions of heat, noise and daily danger.

Yet, while we applaud this outcome we must beware of the dangers of concluding that the worst is now over. It would be tragic indeed if the act of extinguishing the last flames, whose apocalyptic images have captured the attention of media and public alike over these months, were to signify also the extinction of international concern and interest.

The effects, as I said before, are likely to be with us for many years to come. Nor are the problems confined to the consequences of the burning oil wells: there is also the effect of oil spills into the waters of the Gulf; the omnipresence of mines; the problem of hazardous waste; the depredations caused to the fragile ecology of a desert by modern warfare.

The resulting environmental problems can be divided into three main areas of concern:

- air pollution, and its effects on the health of the population (especially for particularly vulnerable groups - the elderly, children, asthmatics, people with chronic bronchitis or cardiac diseases)
- land pollution, and its implications for grazing and agriculture,
 and the dangers to the delicate ecology, flora and fauna of the
 desert
- marine pollution, and its effects on the marine environment, fisheries and wild life

The latter two inevitably also pose an additional health risk for the population, through the consumption of polluted agricultural produce, and through their dependence on the marine environment as a source of drinking water and food such as fish and shrimp.

In approaching my task, I have been conscious of the need to avoid duplicating anything that has been done before, or that is already underway. This is harder than one might think because the sheer enormity of the disaster has brought forth a multiplicity of responses from innumerable and diverse sources - governmental, non-governmental, UN system, academic and scientific institutions, private sector and individuals.

It also seemed very clear to me from the outset that, in coordinating the actions and mobilizing sustained international support for the very long process of rehabilitation that lies ahead, three main aspects must be addressed:

<u>First</u> and foremost, the <u>technical</u> aspect, embracing initial survey, the assessment of impact, the identification of requirements and the design of the actions needing to be taken;

<u>Second</u>, the <u>international</u> aspect and the need to give prominence to the dimensions of the problem and its worldwide significance on a sustained basis;

Third, the provision of adequate <u>funding</u> and other resources to ensure implementation of the agreed Plan of Action.

<u>Technical</u> aspect

The technical aspect is, understandably, the one in which work is most advanced, especially as regards assessment of impact and preliminary identification of needs. Considering the short lapse of time since the cessation of hostilities and the almost insuperable obstacles faced, I would go so far as to say spectacular progress has been made.

I was particularly impressed by what has been achieved by the Kuwaiti authorities themselves, under the able leadership of Dr. Al-Awadi, despite the fact that their scientific research capability, including equipment and records, has been decimated. Many other countries in the Gulf region are, of course, also very active, and the work of the Regional Organization for the Protection of the Marine Environment (ROPME), now expanded to other areas as well, has also been of key importance. So has the contribution of the Saudi Arabian Meteorology and Environmental Protection Agency, especially in assessing and cleaning up the damage done to coastal areas and the marine environment by oil spills in the Gulf.

Nor has the international community stood idly by. An early assessment was made by the UN mission led by
Mr. Abdulrahim Abbe Farah which visited Kuwait from 16 March to 4 April, and I would particularly refer you to sections IV and V (paras. 136 - 225) of that mission's report to the Security Council (S/22535) of 29 April 1991.

In the ensuing weeks all the relevant agencies of the UN system worked energetically on the problem under the leadership of UNEP, and in close cooperation with ROPME. I have had the benefit of a personal briefing on these activities from Dr. Mostafa Tolba, the Executive Director of UNEP, as well as from Dr. Al-Awadi.

This has been a situation in which the smaller technical agencies, particularly IMO and WMO, have been able to demonstrate their value. Other UN agencies and organizations involved have been UNDP, WHO, FAO, IAEA, UNCHS (Habitat), IOC/UNESCO, UNIDO and UNDRO. In addition, non-governmental organizations such as the World Conservation Union (IUCN), the World Wide Fund for Nature (WWF), Earthtrust, Friends of Earth, and Green Peace, and a host of research institutions contributed to this collective effort. Many of these activities were financed by Member States on a bilateral basis or through the UN system.

As a result, a report on the first phase of an Inter-Agency Plan of Action, comprising initial surveys and preliminary assessments, was presented by UNEP to a ministerial meeting of ROPME on 16 - 17 October and accepted as a framework for future work. The immediate future work consists of drawing up detailed and costed programmes and projects to address the problems identified in the first phase document.

It is hoped that this will provide the basis for a document to be presented, among others relating to countries outside the Gulf area, at the Funding Strategy Meeting for the Proposed Programme for the Socio-Economic and Environmental Revival of Countries Affected by the Gulf Crisis, being convened in New York on 16 December by the United Nations Development Programme, in response to a decision by its Governing Council.

I am sure that Dr. Al-Awadi and Mr. Mansfield (the representative of UNEP) will be addressing the technical aspects in their statements to this Committee, so I will not dwell on them here, except to stress once again the essentially open-ended and long-term nature of the phenomenon which makes immediate definitive assessments impossible.

Let me illustrate this as regards the effects on health. All of the monitoring studies carried out, whether by the Government, the UN system or other outside technical groups, seem to concur that, so far as Kuwait is concerned, by a fortunate chance of meteorological conditions, the unexpected evaporation of some of the toxic elements in the smoke plume, and the rapid actions in putting out the oil fires before seasonal wind directions veered consistently in the direction of Kuwait City, the impact has not been as severe as could have been feared.

I must stress, however, that these observations refer only to the immediate, short-term, effects on health caused by the smoke and other pollutants now no longer being ejected into the atmosphere. No one knows what the longer-term effects on health can be, since no population has ever previously been exposed to this particular phenomenon, and it will require a very long period of monitoring before these consequences can be reliably determined. There is also the incalculable psychological effect inflicted on the population which has been subjected to the unnerving experience of an apparently permanent eclipse of the sun, of day turned into night, and the anxiety and stress of not knowing what form the ultimate effects will take - another characteristic in common with the victims of Chernobyl.

<u>International aspect</u>

As I have intimated, in addition to the ongoing technical work, a major challenge will be to maintain international concern and support. We must be very clear that this is not just a problem - however deplorable - affecting a limited number of member states in a particular region.

It is an <u>international</u> problem: the fall-out (if I may use that term) has already been experienced in many places much farther afield.

More importantly, it is of concern to governments and peoples everywhere. A vital part of our common and universal heritage is at stake. And the lessons that science and societies everywhere can derive from this tragedy are countless. The initial favourable response from countries in the first months of the tragedy must be continued.

I am therefore particularly pleased that the issue is being given the prominence it deserves in this Committee and hope that this will lead to conclusions that will ensure that it is kept squarely in the sights of the General Assembly and of the international community in the future.

I believe it is also very important that it should receive special attention at the United Nations Conference on Environment and Development in Rio de Janeiro in June next year.

Resources and Funding

Sustained understanding of the importance and international nature of the issue is of course also vital to the assurance of adequate funding from a wide variety of sources.

I have no illusions that fund-raising will be easy. At the present time, given the imponderables I have mentioned, it is impossible, and would be rash, to attempt to give a global figure of the likely cost. All one can say with some certainty, is that it will be in the range of several billions of dollars. A more precise estimate can be made, I hope relatively soon, as the work of preparing costed programmes and projects evolves.

Then there is the question of where the resources will come from.

UNEP has managed to raise a fund of US \$ 2.6 million but this is already either spent or committed for initial technical work.

It should also be noted that international cooperation is required not only in the form of money, but also in kind, through the provision of services and equipment, loan of scientific personnel, etc. One very important first requirement is to restore the shattered research capability of Kuwait itself.

The quest for funding should also be varied and wide-ranging, embracing non-governmental organizations and scientific institutions, universities, etc., as well as governments.

Three main sources spring to mind:

- the UN Compensation Fund
- Kuwait and the governments of the region
- the international community

As to the first of these, UN Security Council resolution 687 includes damage to the environment and to natural resources among the areas for which claims may be made on the Compensation Fund. I have had

preliminary conversations in Geneva with the Chairman of the Fund's Governing Council and its Executive Secretary about the best way of proceeding in this regard. While there is agreement that this avenue must certainly be pursued, there is recognition that the process is likely to be lengthy.

The needs, however, are immediate.

As a result - and here I pass to the second on my list of categories - Kuwait, Saudi Arabia, Iran and other countries in the region have already spent considerable sums in clean-up and assessment operations.

I have been assured that this will continue, but there is an understandable feeling that the full burden of payments for an international problem with implications for many other countries and peoples should not fall on the region alone.

Moreover, the oil well fires have had a severe economic impact on Kuwait in addition to the environmental consequences. Fighting the fires is estimated to have cost the country US\$2 billion. Assessments of the damage to the wells themselves are still not complete but the Government estimates that 2% of the country's 100 billion barrels of reserves has been lost and that up to 30% of the wells will have to be abandoned. Barely 45% will be able to return to production with only minor repairs and overall production is not expected to return to its former levels before 1994.

Aside, therefore, from the international character of the disaster, the financial impact on Kuwait is very great.

For all of the reasons just cited, it is therefore my hope, and that of the Secretary-General, that the international community, drawing, as I suggested earlier, not only on the resources of member governments but many others as well, will also respond generously. What we hope to do, through a concerted effort of the UN system, is to assist the governments of the region and ROPME in their efforts to draw up a detailed plan of action which will provide a valid framework for all assistance provided, in whatever form and through whatever channel. Only in this way can the optimal use of contributions be ensured for priority areas of action.

In speaking of resources, I have also to mention that such work as I have done so far has been accomplished "within available resources". My own office is tiny and as the work gathers momentum will be unable to cope without some modest strengthening. I hope this can be borne in mind when the Committee decides on future actions.

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Mr. Chairman, distinguished delegates, my appointment as the Secretary-General's Personal Representative took effect only a few weeks ago. So far, I have, as I said, visited Kuwait at the invitation of the Government, made personal contact with all the UN organizations involved or likely to become involved, and consulted with the UN Compensation Fund.

Time and limited resources have not made it possible for me to visit the other countries in the region that are immediately affected and to have the indispensable consultations on the ground required to complement the many reports I have read. That is why my statement today may seem to focus more narrowly. I want to make clear that it is my intention, early in 1992, to make a wider visit to the area, providing, naturally, that this is the wish of each government concerned.

Mr. Chairman, a very long and difficult task - of rehabilitating one of nature's most precious preserves, and of protecting and monitoring the human beings whose health has been placed in jeopardy - lies ahead of the international community. I do believe, however, that, thanks to the efforts already deployed on so many sides, we have a sound basis to move forward. What we need now are those all too rare qualities of sustained commitment and perseverance.

Preliminary Scientific Report - Kuwait Oil Fires

INTRODUCTION

On June 4, 1991, scientists from Bahrain, Oman, the Federal Republic of Germany, the United Kingdom, and the United Sates met in Manama, Bahrain, to discuss preliminary observations related to the smoke plumes from the oil fires in Kuwait. The meeting was convened by the Environmental Protection Committee of Bahrain. The following is a summary of the meeting prepared by the National Oceanic and Atmospheric Administration (NOAA).

GROUND-BASED OBSERVATIONS

The Manama scientific meeting was opened with a discussion of ground-based data obtained in Saudi Arabia and Bahrain since the onset of the fires in Kuwait.

Saudi Arabia representatives discussed the Gulf Regional Air Monitoring Program, and indicated that several aspects of the program were proceeding toward full implementation. Gaseous pollutants of concern in Saudi Arabia have remained within allowable limits at all air monitoring stations. Concentrations of total suspended particulates (TSP) have also been within the allowable range, however peaks in TSP have approached safe limits on two occasions. Values for nickel and vanadium in the atmosphere appear to drop sharply from the Kuwait border south into Saudi Arabia. Only low levels of polynuclear aromatic hydrocarbons (PAH) have been observed. Temperature depressions of up to 10 degrees C have been noted in northern Saudi Arabia in areas influenced by the plume.

Bahrain representatives indicated that levels of all gaseous pollutants have similarly been low at local ground monitoring stations, however particulate levels have been above normal. Especially high levels of PM10 (respirable particles below 10 microns in diameter) were observed in May. High levels of sulfuric acid have been recorded, however no baseline on this substance exists for comparison with the levels observed.

AIRCRAFT MEASUREMENTS

As of 9 June 1991, there have been four aircraft involved in the smoke plume investigation. The following table summarizes operational details regarding the four programs:

Flight Organization	<u>Dates</u>	<u>Aircraft</u>	<u>Flights</u>	Flight Hours
British Meteorological Office - UK	23 Mar - 31 Mar	C-130	8	57
University of Washington - USA	16 May - 15 Jun	C-131	12	77
National Center for Atmospheric Research - USA	19 May - 4 Jun	Electra	15	97
Goethe University - FRG	18 May - ?	Piper	16	55

Flight Program Objectives

The objectives of all of the above programs have generally been to:

- To characterize the physical, chemical and optical properties of the plume and determine changes in the plume's characteristics over time.
 - To determine the effects of the plume on atmospheric conditions.

Smoke Distribution

The distribution of the plume varies form day to day depending on meteorological conditions. In stable conditions, with low wind speeds, the plume is shaped in the form of a large cumulus cloud, extending from a base of 1 to 2,000 feet to a height of 8 to 10,000 feet or more. Excursions as high as 22,000 feet have been noted on some occasions. In most instances, the plume initially rises rapidly due to the heat of combustion. A further rise, termed "self lofting", has been noted to occur due to solar heating of the predominantly black plume.

When the atmosphere exhibits a more complex structure with the presence of one or more inversion layers, the plume may separate into segments with relatively clean areas between layers. If the lower thermal barrier is at low altitude, smoke may occur close to the ground, even at long distances from the source.

There is no indication the plume will reach into the stratosphere, a key factor in limiting the area of effect of the plume. Aircraft and satellites have tracked the plume to distances of 1000 kilometers, however at this distance the plume is generally only barely detectable. While it is possible that some very small fraction of the particulate material may travel large distances, reports of the plume reaching Hawaii and Wyoming are generally discounted.

Particulate Concentration and Form

The size distribution of particulates in the plume tends to be bimodal, with the peaks centered around about 0.2 and 2 micrometer diameter. Maximum concentrations of approximately 100,000 particles per cc have been observed near the source (the ambient level of particulates in clean air in the region is only a few hundred particles per cc). The smaller particles encountered near the source tend to form chain aggregates early in the life of the plume; these aggregates may tend to either fall out of breakup at later stages in the lifetime of the plume.

The plume is diverse in color and optical properties. The occasional white smoke tends to scatter sunlight effectively, while the blacker smoke tends to be highly absorbing of visible light. The black smoke, however, absorbs less in the near-infrared than the white smoke. The plume exhibits no backscattering in the visible spectrum, but substantial backscattering in the near infrared.

Most of the particles appear to be effective cloud condensation nuclei (CCN), another factor which will limit the lifetime of the plume. Such particles, as they encounter ambient moisture clouds along their trajectory, will readily be removed from the atmosphere by precipitation.

Chemical Composition

The following typical and maximum values were reported for the various chemical constituents of the plume. (Because these were measured in the densiest portions of the plume aloft, they should represent maximum values that might, under certain conditions, be reached at the surface.)

Species	near Field ~ 100 km	Mid-Field ~ 450 km	Far Field ~ 1000 km
Hydrogen sulfide Sulfur dioxide*	Very low (specific va 100 to 500 ppbv	lues not yet available) 5 to 20 ppbv	1 to 3 ppbv
Carbon monoxide** Ozone***	0.1 to 0.5 ppmv	<0.1 ppmv	undetectable
	20 to 45 ppbv	35 to 55 ppbv	background
Nitrogen oxides	10 to 30 ppbv	2 ppbv	undetectable
Carbon dioxide****	400 to 460 ppmv	375 ppbv	365 ppbv

^{*} Maximum value of 1 ppmv observed 15 km south of Burgan field

**** Background carbon dioxide is about 360 ppby

Future Plans for Aircraft Observations

Flights remaining for the University of Washington will primarily be directed to the characterization of individual plumes to allow the uniqueness of the chemical composition associated with various wells to be determined, and flux measurements in the composite plume. Thus far individual plumes have shown no striking difference in chemical composition based on real-time readings for the above chemical compounds. Detailed, post-flight chemical analysis will be directed at this question.

Three additional aircraft programs are currently under development for continued investigation of the plumes under varying meteorological conditions:

- A helicopter-based series of investigation of various individual plumes is planned for two weeks in late June. This investigation will be undertaken by NASA and EPA in cooperation with regional scientists.
- A fixed-wing aircraft program in the summer season (July 15 August 30) is planned by the Department of Energy (Battelle Laboratories). This program will be undertaken aboard a Gulfstream I aircraft.
 - NOAA plans a winter study for the month of December aboard a P-3 aircraft.

Detailed plans for the above programs are currently being prepared for the approval of the host governments.

^{**} Values are generally about 100 x concentrations of sulfur dioxide

^{***} Ozone depletion in the near field appears due to formation of nitrogen oxides

DATA MANAGEMENT

Two to three years will be required to fully analyze the data collected form the variety of aircraft and ground-based programs undertaken thus far. In order that scientists in other nations may participate effectively in the data analysis process, agreement was reached among the investigators to rapidly make raw data available in a form that lends itself to independent interpretation.

Agreement was reached among the investigators to share raw data from ground-based, aircraft, and satellite obsevations, under the auspices of WMO. The US National Center for Atmospheric Research (NCAR) agreed to adapt specialized software programs developed at the Center for archival, display, and analysis of the combined data set. in general the NCAR data management program allows the analysis of data obtained from a variety of sources at a specified time and location. This would enable, for example, the correlation of ground-based measurements with aircraft observations taken near the same location at the same time. A subsequent meeting was scheduled to refine this concept.

FOLLOW-UP BRIEFINGS

On June 5, NOAA and the University of Washington briefed the American Embassy in Kuwait and the Kuwait Environmental Protection Council on the outcome of the June 4 meeting. The Kuwait EPC offered considerable background data obtained within the country that will contribute to a fuller understanding of the scope of the problem.

On June 6, NOAA briefed the American embassy in Riyadh on the findings of the meeting, followed by a briefing on the American Embassy in Manama on June 8. Further briefings in UAE are scheduled later this week. Briefings for the WMO staff are planned for June 10.

An Updated Briefing on the Kuwaiti Oil Fire Smoke Experiment (KOFSE)

A part of Gulf Regional Air Monitoring Program (GRAMP)

Lawrence F. Radke
National Center for Atmospheric Research
and
Peter V. Hobbs
University of Washington
Co-Principal Investigators

Research Sponsors:

National Science Foundation National Geographic Society Chevon Corporation

Defense Nuclear Agency Department of Energy

16 00 "

Why are the Kuwaiti Oil Fires an Important Research Topic?

- Resulting black smokes were forecast to have a host of disastrous environmental effects, including:
 - Global cooling via the nuclear winter hypothesis
 - Modification of global and regional weather patterns, including interruption of the Indian monsoon
 - Regional cooling and heating
 - Regional precipitation modifications, including precipitation amounts, acid rain and black rain
 - Release of greenhouse gases

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Why are the Kuwaiti Oil Fires an Important Research Topic? (cont.)

- Concern about toxicity hazards to humans and marine life, as well as other threats to both. These threats included:
 - Emissions of highly toxic hydrogen sulfide
 - Emissions of other toxic trace gases, including those trace hydrocarbons considered potential carcinogens.
 - Respiratory threat from high concentrations of submicron particles
 - Deposition on land and sea of large soot particles and unburned oil droplets coating and possibly killing food chain elements.

Why are the Kuwaiti Oil Fires an Important Research Topic? (cont.)

• Finally, and perhaps in the long term most importantly, the fires provide an exaggerated example of anthropogenic pollution. Given the difficulties of establishing cause and effect for more benign examples of pollution, exaggerated examples are often keys to understanding.

The Kuwait Oil-Fire Smoke Experiment

Primary Objectives

- To characterize the regional emission rates of smoke particles and trace gases.
- To measure radiative properties of the smoke particles and the radiative effects of the plumes with attention to how radiation affects the altitudes of the plumes and the stability of the atmosphere.
- To measure characteristics of the smoke particles, i.e. size, shape, composition, and optical properties.
- To evaluate the degree to which smoke particles are scavenged in clouds their subsequent effects on composition and radiative properties of clouds.
- To measure how the properties of the plume change with time.
- To study regional weather anomalies associated with these smoke emissions.

The Kuwait Oil-Fire Smoke Experiment Box Score on Primary Objectives

- Successful characterization of emission rates of pollutants.
- Excellent multi-spectral radiometric data on the plumes and dynamic measures of solar forcing of stability of the atmosphere.
- Excellent full characterization of the smoke particles.
- Limited data on smoke/cloud interactions and scavenging due to a lack of clouds. Important finding that most of the mass of the smoke particles are cloud condensation nuclei
- Successful characterization of plume transformation out to ranges of 1600km (48 hrs) downwind.
- Limited observations of "weather anomalies" beyond observed dynamics, radiative, and stability changes.

Participants on Electra

NCAR

Baumgardner, Cooper, Kok, Luke, Radke, Schwiesow, Twohy

> SRI Bruce Morley

University of Hawaii

Antony Clarke

Drexel University
Alan Bandy

NOAA/ERL/CIRES
Barry Bodhaine, Russ Schnell, Pat Sheridan

Desert Research Institute
Jim Hudson

NIST George Mulholland

University of Rhode Island
Barry Huebert

Bahrain Environmental Protection Committee

KUWAITI SMOKE

HIGHLIGHTS AND SURPRISES

- Smoke was optically far whiter than expected.... $\tilde{\omega} = 0.5 0.6$ (JP-4 pool fires $\tilde{\omega} = 0.3$, forest fires 0.4 0.9, water clouds 0.99).
- Solar self-lofting was observed, but dilution makes it self limiting. Most smoke remained below 3km. A small fraction lofted as high as 6km in 24 hrs, but no smoke was seen to go higher after 48 hours.
- SO₂ flux smaller than expected based on fraction of S thought in fuel.

- Contrary to some predictions smoke particles were found to be very effective Cloud Condensation Nuclei. CN/CCN ratio approached 1.0! Obviously acts to reduce the smokes tropospheric lifetime.
- Oil precipitation was found up to 100km downwind. Directly emitted? Condensation and coagulation?
- At smoke ages of ~48 hrs and distances down wind of ~1600km concentrations were approaching "normal" levels of urban pollution.

Atmospheric Residence Time of Kuwaiti Smoke Particles

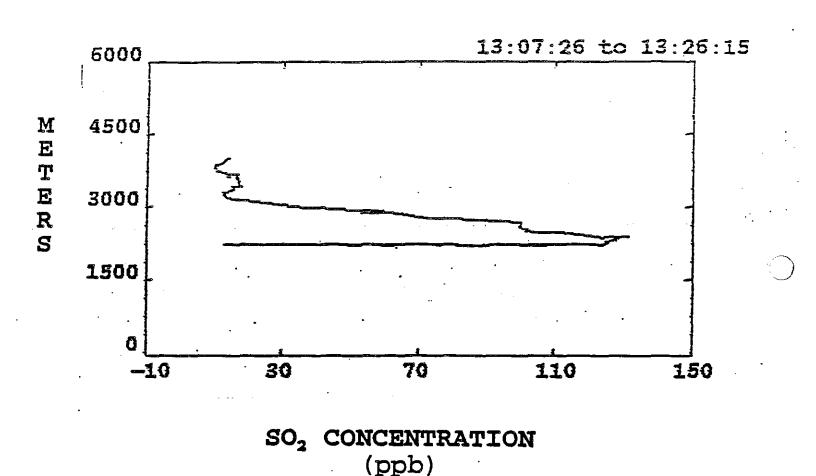
Scientists from the National Center for Atmospheric Research, British Meteorological Service, and the University of Washington concur:

- Early suggestions that the smokes would be "hydrophobic" and thus resistant to atmospheric removal processes have been shown to be WRONG.
- ♦ The smokes have proven to be largely "hydrophilic" acting as the nuclei for cloud droplet formation. This places them in the class of particles most easily cleansed from the atmosphere.

Atmospheric Residence Time of Kuwaiti Smoke Particles (cont.)

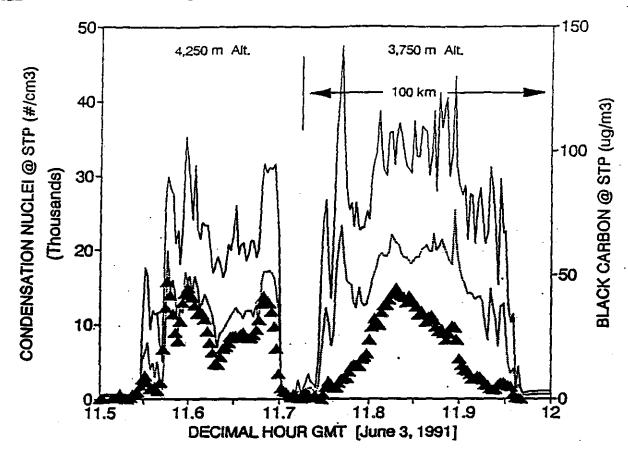
- Early suggestions that the smokes would rise rapidly in the atmosphere by solar self-lofting and thus escape many particle scavenging mechanisms has been shown to be largely INCORRECT.
- ♦ Solar self-lofting was observed, but the combination of a rather low initial stabilization height for the plume, larger than expected smoke albedo, and dilution have acted to <u>LIMIT</u> self-lofting and render it an interesting, but inefficient mechanism.

Sounding of SO₂ by the NCAR Electra



On June 1, 1991, the Kuwaiti smoke plume was over Bahrain (≈350 Km downwind) producing a bright hazy sky and dark horizons. The aircraft climbed to the top of the smoke plume.

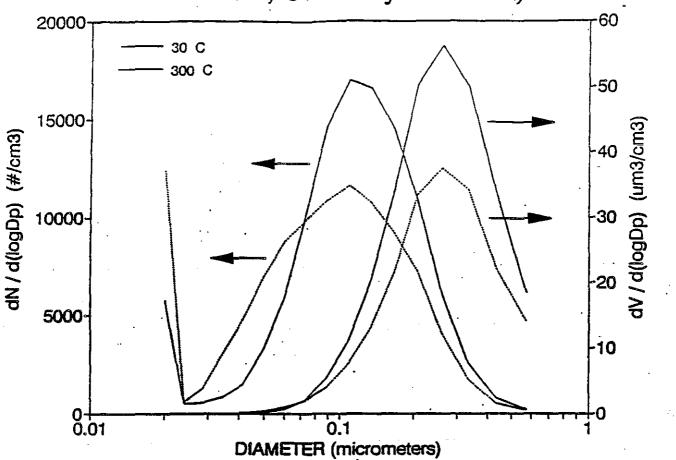
Two transects of the Kuwaiti smoke plume on May 27, 1991, 200 km downwind of the fire. The first was at 4,250m near plume top, and the second at 3750m.



Time series of total particle concentrations larger than $0.003\mu\text{m}$ (—), larger than 0.015 μm diameter (—) and the mass concentration of elemental (black) carbon (Δ). The data suggests photochemical production of nuclei mode particles near the edges of the plume.

Kuwaiti oil fire smoke particle size distributions

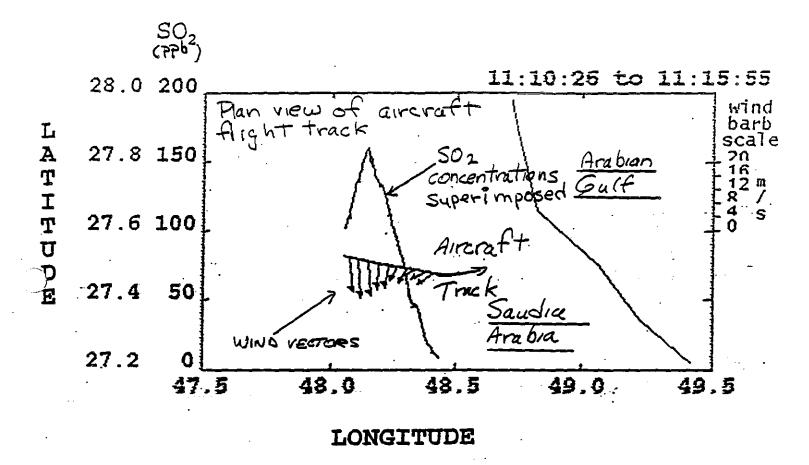
(differential mobility analysis by T. Clarke, University of Hawaii)



Number and volume distributions of the smoke on June 3, 1991.

Samples are heated to 30°C to remove water and then 300°C to remove remaining volatile fractions. Roughly 30% of the total particle volume (mass) was removed at 300°C. Data shows that the number mode was internally mixed, while the volume mode was externally mixed.

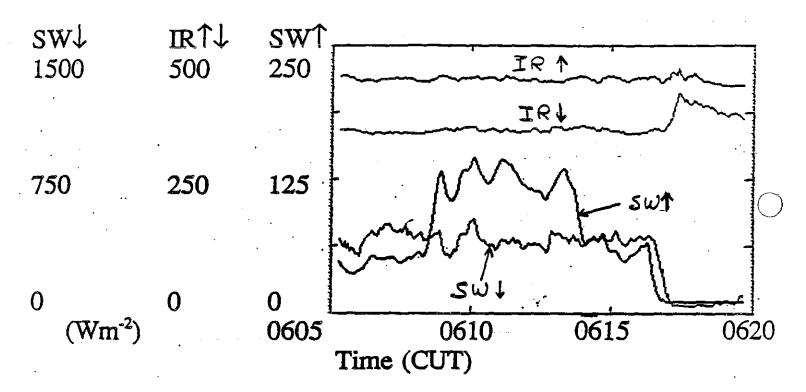
Smoke Plume Convergence



Marked convergence in the horizontal wind field was a frequent observation during penetrations of plume perpendicular to its axis.

A Passage from Day to Night

a transect of the center of the Burgan oil field (350 wells ablaze) at 500m (MSL)



Approaching the oil field we note a steady SW↓ and the changes in surface albedo causes marked variation in SW↑. Both visible (SW) went to zero inside of the plume. VERY DARK!

Observations of CO₂, CO and CH₃

(Communication from T.J. Conway, NOAA CMDL and G. Kok, NCAR)

- Emission of CH₃ (methane) and other light hydrocarbons are surprisingly low.
- ♦ This indicates that these gases (like H₂S) are efficiently combusted and that there are probably no gas-rich wells which are not burning.
- CO₂ emissions are rather large but have no global significance since roughly equivalent amounts would be released if this oil was used (as in normal times) as fuel.
- CO emissions are rather low, roughly 1% of CO₂, indicating unexpectedly efficient combustion in what visually appears to be a rather inefficient one.
- ♦ Therefore, the fires' are a minor contribution to the global CO budget.

Trace gas concentrations: A Local Impact?

(W. Luke, G. Kok and R. Schillawski, NCAR)

- Peak concentrations of carbon monoxide (CO), ozone (O₃), nitrogen oxides (NO_x) and sulfur dioxide (SO₂) in the smoke plume at 130 km from the fires was everywhere less than the U.S. National Ambient Air Quality Standards with the exception of SO₂ which occasionally exceeded the standards.
- ♦ While these observations are dependent on meteorological conditions (primarily wind speed and mixing) they clearly provide an indication that beyond the local region, these pollutants do not constitute a hazard even if the elevated smoke plume were lowered to the surface.

Observations of Kuwaiti Smoke at Great Distance

- There are reports from Hawaii and Wyoming that specialized sampling has detected Kuwaiti smoke high in the troposphere.
- Do these observations contradict the contentions that the smoke will be efficiently scavenged and inefficiently selflofted?

Observations of Kuwaiti Smoke at Great Distance (cont.)

- ♦ At this time I see no contradiction. The concentrations of smoke particles observed over Wyoming are highest during those periods of rapid meteorological transport (jet stream). At the highest concentrations observed, Hofman states them to be without climatological significance an interesting remnant only.
- ♦ Similarly, if the smoke wasn't self-lofted, how did they get to the upper troposphere? Clouds provide a useful (if high loss) mechanism for lofting smoke as does frontal meteorological activity. These mechanisms are the <u>normal</u> "lofters" of all pollution into the upper troposphere and lower stratosphere. Our interest in self-lofting was as an additional and efficient mechanism for raising the altitude of the smoke.

Sulfur Dioxide

Emissions of (SO₂) from the Kuwaiti fires and other sources of interest (preliminary results)

Source	Time Interval		Amount (million tons)	
Kuwait	1 year	3.2 4.0 6.0	(1) (2) (3)	
US Electric Utilities (1988)	1 year	14	(2)	
Mt. Pinatubo	2 weeks	15-20	(4)	

- 1) P. Hobbs, 11 July, 1991
- 2) B. Hicks, NAPAP Newsletter (to be published)
- 3) A. Bandy, 26 July, 1991
- 4) Global Environmental Change Report, 3 July, 1991

Summary of Preliminary Observational Review and Data Analysis

- Global impact of "black carbon" particulate emissions continues to be small.
- Global impact of trace gases is small.
- Regional climate and weather change remains and open question. Primary impact seems likely to be limited to less than 1000 km.
- Local impact on climate and ecology continues to be large with some effects being accumulative.

Just How Big ARE the Fires in Kuwait?

- Based on estimated oil and gas combustion rates and mindful of some uncertainties in combustion efficiency, I calculate a heat release rate of about 5x10¹⁴ Joules per hour.
- Modest test fires I have studied where about 1000 acres of logging debris is burned in about an hour have heat release rates of roughly $10x10^{14}$ Joules per hour.
- The Yellowstone wildfire of a few years ago sustained a similar heat release rate (twice Kuwait) for more than 30 days.

Just How Big ARE the Fires in Kuwait? (cont.)

- The National Academy of Science estimates that about 1.2×10^{10} m² of the earth's surface is burned over each day by deliberate and wild biomass fire. This yields a heat release of 5×10^{15} Joules per hour or about the equivalent of 50 Kuwait fires.
- ♦ While biomass fires and the Kuwaiti oil fires are not entirely comparable, both yield similar (biomass somewhat more) amounts of smoke per unit of heat released. Such scaling helps us retain our sense of perspective for large scale fire phenomena.
- ♦ Clearly, the Kuwaiti fires are large, but hardly without precedent and small compared to global biomass burning.





مجلس حماية البيئة ENVIRONMENT PROTECTION COUNCIL

STATEMENT BY

OR. ABDULRAHMAN A. AL AWADI

CHAIRMAN OF EMERGENCY COMMITTEE,

ENVIRONMENT PROTECTION COUNCIL (EPC)

OF KUWAIT TO THE SECOND COMMITTEE,

UNITED NATIONS GENERAL ASSEMBLY

NOVEMBER 20, 1991

Mr. Chairman

Ladies and Gentlemen

I am honoured to address this august body and express my country's appreciation for the essential role the United Nations have played in securing the liberation of Kuwait.

I beg your indulgence in presenting an overview of the extent of the environmental damage inflicted upon my country and the region by the Iraqi regime and the efforts that have been exerted to assess the state of the environment and the associated risks to human health. I will also address the challenges ahead and the need for an internationally supported programme for the rehabilitation of the environment and follow up of the long term health and ecological damage sustained by the people and the natural environment of Kuwait.

Kuwait and the Gulf region in general suffered the largest air, water and soil pollution episodes ever recorded. This incident is different from any other reported in history by the fact that this was premeditated. The Iraqi troops discharged millions of barrels of oil into the Gulf and put explosives on the oil wells and detonated all the producing and experimental wells. Out of 943 wells only 155 were intact, 613 were on fire, 76 were gushing and 99 were badly damaged. This resulted in the ignition of 6m barrels/day of oil and 100 mm³/day of gas and discharge of 743 thousand barrels from the gushing oil into the soil.

The air was polluted by thousands of tons of soot, sulfur and nitrogen oxides, carbon monoxide and carbon dioxides. The estimates about the quantities were staggering; 60,000 tons of 80_2 , 3000 tons of 80_2 and 80_2 and 80_2 and 80_3 tons of soot. The quantity of 80_2 added to the air ranged from 1-2 m tons. These pollutants are not new to the environment, they are known by-products from heat generation and industrial activities. What is new is that they are burnt for no useful purpose. What happened in Kuwait is irrational and unforgivable.

The pollutants are discharged in a very vulnerable environment. The ground based inversion is found almost every night, elevated inversion is also very common. The background dust load is quite high and can reach very high levels with dust storms. The role of dust as carrier for the pollutants and hence as a health hazard is well recognized. The other air pollution problem is the high level of hydrocarbons mostly of geogenic source. The solar radiation and the probability of oxidants come with the scorching heat. This is the background to what is added to the pollutants emitting from the well fires.

The real picture of the air pollution in Kuwait will never be fully appreciated. The air quality monitoring system was designed to verify the problems arising from traffic, power plants and industry. The problem of the well fires was not anticipated or accounted for. No monitoring facilities have been stationed in the townships to the west of the urban area or to the south on the coastal strip. The air

pollution mobile laboratories that were used to support the existing system were looted by the Iraqis. Many of the equipment were also either stolen or damaged.

Two more serious handicaps had to be faced. The Iraqi regime destroyed the basic infrastructure of the whole State and we had to cope with the lack of power for weeks before starting up the monitoring. The other problem was the severe shortage of trained mampower. Many of our technicians were out of the country at the time of the invasion and did not come back, many of those who were in the country were forced to leave. This included the operators and the maintenance crew.

All the information we have about the first weeks of the pollution episode is that from one site, Mansoria, in the urban area away from the wake of the plume. With the other station Reqa in the coastal strip, the electric power was connected late and it relied on generators and the voltage was unstable and this interrupted the recording very much. The levels of soot, sulfur dioxide and nitrogen oxides in the period April-July 1991 was comparable to those seen in the same months in 1990. The usual sources of these pollutants, power plants, industry and traffic were not back to normal. The wind was most of the time taking the plume away from the measuring site and the plume was rising to high levels during the day times and the established ground based inversions were obstructing the fall back of pollutants to the ground at night.

The mean level of methane and non-methane hydrocarbons were appreciably high in 1991 compared to 1990. The maximum was seen up to 11 ppm for methane and 20 ppm for non-methane. The most likely source was the oil pools in the oilfield. The hydrocarbons by the natural environment or under the influence of the intense heat generated by the well fires are emitted at ground level and do not go up with the plume. With calm winds and with stagnant condition the levels would give the air the the characteristic smell of oil. The level of CO were mostly lower in 1991 compared to 1990. This could be attributed to the much lower traffic movement. The lower level of CO which is a component of the plume will show that the plume was passing over the monitoring site.

The need for mobilization of resources and manpower delayed the active participation of UN specialized agencies in the monitoring and assessment efforts. Scientific teams from many countries moved in to help with the monitoring. The US EPA started as early as 13 or March by taking measurements from the air at several points in the burning fields, to the south of Kuwait City and within the US Embassy. The measurements were made by hand held equipment. Levels of SO_2 reaching 20 ppm were detected inside the oil fields in one of the cases and from 0-1 ppm and 2 ppm on two other occasions. The levels of particulates were quite high (.01-.933 mg/m 3) and levels of up to >.4 mg/m 3 were detected in the oil well plumes.

More comprehensive information was provided with the help from the French Ministry of Environment who kindly loaned Kuwait a well

equipped mobile laboratory. Unfortunately the laboratory was made available only for two weeks. SO_2 levels measured in Ahmadi township was in the region of 3-268 ppb, levels of CO were between .4-2.6 ppm and O_3 7-36 ppb. All are associated with health risks particularly to the children, the elderly and those in critical health. Ahmadi is an inhabited area and before the invasion had 30,000 people. The levels are in line with the measurements taken by the staff of Ahmadi Hospital using hand held equipment. The 16 hour mean was 1.65 ppm. This is a level that exceeds the WHO health criteria.

The increase of particulates and smoke in the air has resulted in a significant decrease in solar radiation and air temperatures. The air temperature decreased by 3-4°C in the mid day during the first few months. The level of particulates was measured during March at the sites of the general hospitals due to the availability of electricity and only total suspended particulated could be measured. However, by May nine portable PMIU instruments designed to measure particles of 10 microns or less which fall within the inhalable fraction were provided on loan basis to Kuwait from the US EPA. The values during the period from May to July were in the range of 250-338 micrograms/m³. PM10 levels at Ahmadi (338) and Fahaheel (309), two residential areas in the vicinity of the Burgan oil fields, were higher than those found in the other areas. It was also interesting to note that the levels fluctuated widely and that with calm winds the levels were higher.

The levels of polycyclic aromatic hydrocarbons (PAH) and

volatile organic compounds (VOC) were determined by several teams. The measurements taken in summer should be assessed with caution. The heat reduces the efficiency of trapping of these compounds as they remain in the vapour phase. The levels in Ahmadi were measured by the French team and results were generally in line with the results by Kuwait EPD which show maximum levels of benzo(a)pyrene (30 ng/m 3). This is a compound representative of the PAHs having carcinogenic properties. The Norwegian Institute for Air Research (NILU) team took 4 air samples from the area of Umm Quasr to the north near the Iraqi borders. The total PAH varied between 207-412 ng/m 3 . The average total PAH contribution was 296 ng/m 3 .

Control ot Air Pollution:

The State gave top priority to extinguishing of the oil well fires. Estimates of the time needed to overcome the problem was in the range of 2-5 years. The first oil well was controlled on 20th March 1991, less than 3 weeks after liberation. The number of wells successfully capped during each week in the period April to October showed a very sharp rise in the number of wells with the increase in the number of teams. An average of nearly 3 wells/day was achieved with a peak of 13/day. The record number of wells controlled on a single week was 52.

The Health Alert:

The prediction done by NOAA for the period July-December for

the level of SO_2 between the ground and up to 1 km showed that the level of SO_2 may reach 1000 ug/m³. The prediction was based on the meteorological data for the last two years. The prediction agrees well with those done by KEPD though a worse situation was anticipated in October followed by November and December. The prediction was based on historical data between 1957-1982.

The Health Alert System was established to handle the worst probability. Three air quality monitoring stations were connected by telephone lines. The hospitals and the organisations participating in the contingency plan would be alerted. The general hospitals and some designated polyclinics were asked to prepare clean rooms where the air is filtered.

The health plan have been elaborated and discussed with the WHO and other interested organisations. The plan included informing the physicians and nursing staff of their role in providing needed care during pollution episodes. Several health studies were initiated. At the Adan hospital, asthma accounted for 6% of the visits and chest problems for 29% more. These figures are higher than the percentage of the complaints received by the hospital in the same period in 1986 for which data are available. A more extensive survey of the visits to 7 health centres distributed among the different regions is running since the beginning of September 1991. A survey of the asthmatics attending the Allergy Centre has been carried out since June 1991. All the asthmatics were called to join the study. A questionnaire about their exposure, lung function testing and physical examination

is given to each patient. The peak flow is measured twice daily and a diary is kept.

A cohort study of 1600 families residing in the area impacted by the oil fires and 400 control households in the City of Kuwait of the same socio-economic level was planned. The health exposure assessment location study (HEAL) is running with the help of, WHO, US EPA and Harvard School of Public Health. Personal samplers are used to determine the exposure of a random sample of 400 Kuwaiti citizens above 10 years to particles 10 microns or less. A diary of the different activities is kept. The level of PM10 and PM2.3 are measured indoor and outdoors of the houses in half of the cases. Exposure to PAH using a personal sampler will be determined for another family member.

by US and German teams. The American study was based on taking blood from 14 volunteers mostly from the troops serving in Kuwait. A large number of volatile compounds were detected in the blood. The German study covered both the environmental and biological monitoring. The biological monitoring was done by examining samples of blood or urine for volatile organic compounds or other substances taken from 32 persons working in Shuaiba industrial complex. Relatively high levels of benzene and other aromatic hydrocarbons, toluene and m-xylene were detected in the blood of a group of non-smokers that cannot be explained by the low levels detected in the environment which were generally lower than the concentrations found in German cities.

rsychological impacts resulting from oppression during the occupation and the social impact of forced immigration of the Kuwaiti population outside the country are probably substantial. The familial separation and the lack of communication is an example of the problems that should be addressed. The psychological impacts experienced by the prisoners of war and by those who suffered from the torture by the Iraqis have been investigated. Preliminary results show that among a number of male prisoners of war who were subjected to psychological torture, 69% had depression, 24% had anxiety and 3/% surfered from sleep disturbances. The prevalence of night mares (21%), lack of concentration (39%) and nervousness (34%) were very common. A large proportion suffered from agitation (39%) and social withdrawal was seen in 9% of the cases.

Another study addressing the heavioural abnormalities in Kuwaiti children who stayed all the time in Kuwait during the occupation and those who suffered from familial separation out of the country was done. The results will be released soon. Investigation of the post traumatic stress disorders (PTSD) have been planned for the first degree relative of the martyrs, missing prisoners of war and victims of injuries during the invasion and post liberation due to the mines implanted by the Iraqis.

The Marine Environment:

The Arabian Gulf has experienced the largest oil polLution

episode in the recent history. The Arabian Gulf constitutes an almost closed body of shallow water, 1000 km long by 300 km wide, with an average depth of 35 m. It is a highly productive plankton water body, but it is also regarded as being one of the most fragile and vulnerable marine ecosystems. Its low tidal displacement means that it has little discharge of its water into the Indian Ocean and thus little opportunity to flush out pollutants.

The oil spills started on January 19 when Iraq started pumping oil from five tankers moored near the Mina Al Ahmadi oil terminal. The quantity is estimated to be up to 500,000 tons. On 30th January, this was reported to cause a slick some 50×15 miles in extent coverng an area of about 750 square miles. It has not come ashore, its impact was mostly on marine birds. A second spill started around January 20, when the pipelines on the Sea Island terminals about 12 km off-shore from Mina Al Ahmadi oil terminal were opened. Oil continued to spill into the sea from these pipelines until January 26, when U.S. aircraft destroyed the manifolds that controlled the oil flow to the terminal from storage tanks located > miles inland. The quantity of oil released ranged from 100,000 to 1 million tons. Between 24 April and 8 May oil was observed stranded on shorelines in both Kuwait and Saudi Arabia. In early May the entire coastline of Saudi Arabia trom the Kuwaiti border to Jabail was to varying degrees affected by the spills.

The monitoring programme run by EPD was resumed in September 1991. The level of heavy metals in October 1991 compared to 1989

showed much higher means for copper, iron and lead in 1991. The mean for nickel in 1991 was slightly higher. The mean petroleum hydrocarbons was higher inside the Kuwait Bay where war wrecks were tound and in the points near the destroyed South Pier or near the marine base. However, no oil deposits were found around the coral reefs, but evidence of damage by explosives was seen.

The effects of the crisis on fisheries of Kuwait is most obvious in the direct devastation of the fishing industry. The United Fisheries of Kuwait lost all 15 of its well-equipped, 26 m shrimp trawlers which were taken by the Iraqi authorities.

The problem of sunken ships needs concerted international efforts. Preliminary survey of the ships that were sunk in the Gulf War is about 80, added to the ships that were sunk in the Iraqi-Iranian war and were not salvaged.

The sewage system suffered heavily from disrepair during the occupation. Raw sewage was being discharged into the Gulf through a number of emergency outfalls that opened directly on the beach. Pollution by sewage-related bacteria in the coastal area extending to hundreds of meters on both sides of the outfall was detected during most of the summer months.

The plan to cope with the problem of pollution by oil and the marine environment in general covers several areas. The contingency plan for combating oil pollution was revised. The plan include

setting up the prediction model on a personal computer. Air surveillance using remote sensing is needed. Oil Skimmers, booms, pumps and dispersants were ordered to replenish the stores that were taken away by the Iraqis. Calling in the trained manpower or training other people if these were not available is an integral part of the plan.

The Terrestrial Ecosystem:

The impact of oil from the estimated /U gushing wells has resulted in the formation of a large number of pools covering several kilometers in area both to the north and south of the country. Estimates of the amount of oil in these pools is as high as 80 million barrels. Trenches tilled with oil by the iraqis, and overflow from wells just before capping, also resulted in extensive damage to the soil and vegetation.

The soot has covered large areas, polluting the soil and coating the vegetation. KEPD soil samples in June and July 1991 from the surface amd 10cm deep were taken from Mina Abdalla in the middle of the coastal strip, Wafra Road to the south of the country and trom Doha to the west of the urban area. Two small uninhabited islands Auha and Qaroh were also included in the investigation. The mean extractable organic matter (EOM) was appreciably higher in the surface samples. The difference was persistent. However, it was much higher in Mina Abdalla and Wafra Road which had the maximum mean. A similar picture is seen for the petroleum hydrocarbon (PHC) equivalents.

effect on the fragile ecosystem of the desert is likely to be substantial. The reflectivity of the sand will drop appreciably, the scorching heat in mid-summer will disturb the heat balance and raise the temperature of the soil and subsoil water. The microflora of the surface soil and the role of the chemical reaction may also be altered. The air exchange potential and the porosity of the soil as a result of cloggging the pores should be investigated.

Dealing with oil pools fall into two components, recovery of the oil and treatment of contaminated soils. Another problem related to the oil well tires is the extensive amount of saline water used for fire fighting. A total of 361 water lagoons the size of small lakes were prepared to support fire fighting operations. War bombings and shellings have considerable direct and indirect effects on Kuwait's fauna. Landmines still pose a threat to animal life. Bunkers and ditches will inevitably cause the disappearance of proper nabitats for some animals and the appearance of others. The impacts of the war on the agricultural development is far reaching. The invasion forced most of the workers to leave the country. The Iraqi troops looted all that was left in the abandoned farms. The lack of irrigation during the period of occupation caused the soil to suffer. The tertile top soil was blown out and it will take a long time tor the soil to recover.

The Hazardous and Domestic Wastes:

Inside the Shuaiba Area, the damage to the small- and

medium-scale industries located in the Shuaiba Central and Western Mina Abdulla were looted and set afire. Raw and auxiliary materials, and various chemicals have been mishandled, poured from their containers and spread on the ground.

The dumping of garbage presents an immediate threat to public health and safety. Hazardous wastes at abandoned or damaged industrial and commercial sites needs to be located, identified, and moved to safe interim storage or disposal facilities. Another issue is the release of PCB's from power transformers deliberately burned by the Iraqis. Some of the transformers are in residential areas which require immediate attention.

The extent of the problem of mines and unexploded ordnance is substantial. The area that had the highest density or mines was the snores, where about 11,000 mines were removed from an 8 km strech of the Kuwait water front. The safety problem is quite serious. Between March and June 1991, the general hospitals received 1257 victims, mostly males (74.7%). Children under 13 years accounted for 27% or the total. The mortality rate was quite high (10.5%) for ammunition and 5% for explosives burn injuries.

The problem of the depleted uranium and the risk of exposure to the radiation emitted thereof is being investigated by the Radiation Protection Department. The source of DU is the antitank munition used by the allied troops during the war and this may constitute a health problem.

The Challenges:

The immediate impact of the crisis is over. The well fires are extinguished. I am quite confident that the oil pools will be dealt with properly with the same enthusiasm. The question of mines is more difficult to handle. However, clearing the mines is an example of the international cooperation. Presently many teams belonging to 6 States are helping the local staff in dealing with the problem.

We are now entering a new phase, where we can plan ahead and act instead of reacting to the acute problems. Before the invasion, the KEPC prepared a plan of action for the period 1991-1996. The plan was addressing specific topics. Now the plan has to be revised and priorities allocated. The monitoring systems should be revised and the location of the existing stations and the parameters being monitored should be looked into. The system needs renovation and better facilities are required. The training of new technicians to replace those who left the country is another challenge which will take years to overcome.

With air pollution, we are faced by a unique situation where the total population of a country has been exposed to massive levels of pollution resulting from the burning or oil. The pollutants produced are not entirely different from those emitted from most power plants, automobile exhaust and industrial installations. However, the rate of release and the burning efficiency are different. The problem of inhalable and respirable particulates which was quite significant has acquired a new dimension. The sand and dust storms will not be the same. The soil in large areas of Kuwait is polluted by the fall out of petroleum droplets. This will be blown up by the winds and the health impacts will not be limited to the acute forms we are familiar with.

Pollution by hydrocarbons is likely to be much more intense. With the program of drilling new wells instead of the damaged ones will pollute the air with large quantities of non-methane and volatile organic compounds. It is anticipated to live with the problem for at least a number of years. The reaction of the hydrocarbons with the nitrogen oxides generated by the industrial activities, power plans and trattic and the generation of oxidants is likely in view of the intense UV that is characteristic of the clear skies and intense solar flux in the region.

with the health impacts, many challenges should be faced. A higher proportion of complaints of chest and asthma was reported by the emergency room visits in the general hospital close to the areas impacted by the plume. How far this is real will need more intensive investigation. The change in the pattern of mortality in the period the fires were blazing will be compared with similar period in the last years to confirm the validity of emergency room visits.

The chronic impacts is quite challenging. The cohort study of the presumably more exposed population is designed. A matched control

group living in the north was selected. However the total area of the urban area of Kuwait is quite small. The farthest point is only 50 km from the burning oil fields and the wind direction is variable. Comparing the results with similar population elsewhere may be sought.

The study by itself is quite challenging and the attrition rate should be kept to a minimum. Out of the 1600 households, probably half will be lost before the end of the period. The same is expected with the control group which is much smaller to begin with and statistical significance may be a problem. The motivation is waining with the extinguishing of the fires and the memory of the horrible days is likely to be suppressed.

The assessment of the exposure to particulates and PAHs is likely to address the problem of the risk involved. However, it started only one month before the fires were extinguished and so it missed the period where the exposure was more intense. The use of the data collected to assess the risk to the population to the PAH is likely to be difficult. Extrapolating the results to cover the acute episode is not an easy job. The expertise is not available locally and use of models developed in other regions of the world may be difficult.

The psychological impacts is also demanding. The people of Kuwait have been subjected to a horrifying and tragic experience by a brutal inhuman invasion carried out by the Iraqi regime. The seven-month occupation has severely impacted every aspect of life in

Kuwait and the over 800,000 Kuwaitis and another million people belonging to over /U nationalities who came to earn a decent living in a peaceful country. The destruction of property, looting, detention, rape, torture and killing of people was compounded by the worst premeditated mammade environmental disaster ever carried out by an occupying force.

The shock encountered by the occupation, the insecurity, fear and humiliation was an experience that will never be forgotten by the people who lived in Kuwait. The worries and home sickness of the Kuwaiti people outside Kuwait is the sigma of those who were abroad or were forced to leave the country. The loss of identity of the two groups is another experience. The grief and misery of the families that lost a family member is well known. The missing of imprisoned Kuwaitis reached 7455, out of which 110 were less than 12 years old. There are still over 2000 POWs in Iraq. For a small population and the family size, probably every family has lost one or two members. The psychological impacts experienced by the pressure of war and by those who suffered from the torture by the Iraqis are grave. The time needed for these people to recover is not known. A long term follow up study is needed and the resources should be made available. The behavioural abnormality of the children that lived in Kuwait under the oppression of the occupation and those who have been stranded abroad need to be addressed.

The long term impact on the marine environment is being addressed on both the national and regional levels. Studies to assess

through the Regional Organization for the Protection of the Marine Environment (ROPME) in cooperation with IOC, UNEP, IAEA, and US NOAA as well as National Focal Points and research institutions of the ROPME Member States. A short term and a more extensive oceanic cruises are being organized now for this purpose. The long term impacts on mangroves and tidal tlats and the rate of recovery should be monitored.

The problem of the sunken ships is quite demanding. Based on the experience gained from the Iraq-Iran war, this problem need a concerted international effort. The ships by themselves are a chronic source of pollution of metals and petroleum. The type of cargo should also be considered. The floating mines have almost been cleared from the navigation channels. However, the security is never complete and accidents may be expected.

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The impact of the plume on the marine environment is a sltudy topic that have not been frequently encountered in other regions. This needs to be investigated as an added stress to the marine environment. The organisms that are living and the extent of their tolerance and the new impacts is likely to cause untavourable reactions.

The terrestrial environment is more challenging. The oil lakes have covered a relatively small area $(30-40~\rm{km}^2)$. With the intense scorching heat, the volatiles will evaporate. The bacteria will eat

up some and the asphalt will be left as permanent scars disriguring the desert. Thousands of kilometers are covered by the soot and the fall out of the oil droplets from the plume. The effect of the black soot on the reflectivity of the desert is anticipated. The rise in the temperature and the effect on the ecobalance should be monitored.

The impacts of the salt water lagoons on the surface water and the probability of their impact on the survival of the desert plants is anticipated. The probability of the plants in the oil field to complete their life cycle is not likely. Transport of the seeds trom the other areas need to be investigated in view of the hostile environment. The impacts of the machinery on the earth crust is likely to be intense in the areas that have been used by the military vehicles. The equipment and vehicles used for fire fighting is not more friendly. The anticipated increase in dust and sand storms is likely to be substantial in the next few years.

Mr. Chairman, it is obvious that these challenges cannot be met by Kuwait alone, or by its sister countries in the region. With a crippled economy, tremendous rebuilding effort of infrastructures devastated by the Iraqis, Kuwait can only look towards the world community for assistance. The undertakings of the above challenges is expected to be technically complicated and costly. With the priority for reparations from war damages to be paid by Iraq in accordance with the Security Council Resolution No. 687, the share for the environment is expected to be slight and the procedure to be lengthy. However, the establishment of a more solid and continuous source of funding may

ensure the continuity of the studies and rehabilitation programmes. In this respect we fully trust the UN system to develop the arrangements that allow for action to begin. A resolution from your distinguished committee calling for placing a higher priority to the environmental and health studies and the rehabilitation of the environment programmes and to establish a funding mechanism to ensure their implementation would be most appreciated by the Kuwaiti people. Should such a resoltion be passed and endorsed by the General Assembly, then a meeting of the contributing parties could be held to review their various programmes proposed for the region including the national plans of action, the regional plan of action (ROPME) and that being developed by the UNDP. A joint fund management committee could be established involving donor as well as recipient countries and the UN special organizations concerned (e.g. UNDP, UNEP and others).

Thank you.

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Kuwaiti Oil Well Fires Updated

Joseph P. Riva, Jr. Specialist in Earth Sciences Science Policy Research Division

SUMMARY

Before being driven from the country, the Iraqis sabotaged all of Kuwait's oil wells. At present, some 500 are burning and dozens are flowing uncontrollably, creating huge lakes of crude oil. More than 70 of the wells have been shut-in by well control crews, at least ten of which were on fire. Well fire fighting has been hampered because sufficient water is not yet available. The loss in crude oil due to the damaged wells is estimated at about 4 million barrels per day.

Kuwaiti Oil Well Fires

At the time of the Iraqi invasion, about 858 of Kuwait's 1,386 wells were producing oil. This includes the wells in the Kuwaiti administered Neutral Zone. The Iraqi occupation troops, supervised by petroleum engineers, packed each wellhead with 30 to 40 pounds of Russian-made C-4 plastic explosives shortly after the invasion. It was an enormous undertaking, carried out with an extensive bureaucracy. The electric detonation systems were backed up by non-electric detonators. In December, six wells were ignited as experiments to determine the most efficient method of destruction. When the air war began, 60 wells were blown up by the Iraqis and as many as 34 more wells may have been destroyed by allied bombing. The explosives packed around the remaining wellheads were detonated by the Iraqi troops about a week before the beginning of the ground war and the subsequent liberation of Kuwait. Most of the wellheads were blown open at the base, with some of the surface casing also damaged. Maximum destruction was achieved by packing down the explosive charges with sandbags. About two-thirds of the wellheads were completely blown off, while others were badly damaged with above ground valves and pipes destroyed.

About seven wells survived because of malfunctions in the detonation devices, but until the plastic explosives are removed, remain susceptible to accidental detonation. Not all of the successfully sabotaged wells are burning. Oil is flowing uncontrollably from dozens of these wells, creating huge, flammable lakes of petroleum that are spreading toward highways and threatening residential areas and groundwater. Some of the flowing wells also

release hydrogen sulfide, which can be lethal, into the atmosphere. For health reasons, two of these wells were ignited so that, in burning, they produce sulfur dioxide instead, which is less toxic. Other flowing wells also may have to be ignited for the same reason. There remain about 500 sabotaged producing wells that are burning uncontrollably.

The wells burn at about 3,000 degrees Fahrenheit and can be under pressures as high as 7,000 pounds per square inch. Uncontrolled oil flow from a well could range up to 90,000 barrels per day, with a typical well flowing 10,000 to 15,000 barrels per day. Such wells would normally be choked back to a regulated flow between 3,000 and 12,000 barrels per day under usual production practices. The burning is extremely destructive, consuming an estimated 4 million barrels of oil per day (about \$80 million worth of oil). By way of comparison, the United States is now importing from all sources about 5.6 million barrels of crude oil per day.

Also, severe underground reservoir damage can be caused by long-term uncontrolled flow, whether or not the well is on fire. If the blowouts are not contained, water coning, gas migration, relative permeability reduction, and other irreversible petrophysical effects within the reservoir will further reduce ultimate petroleum recovery. Steam has been observed escaping from some of the wells, suggesting that formation and/or ground water is mixing with the oil in some locations. Some wells have burned themselves out as water flow increased in proportion to that of oil. As formation water encroaches into the fields along the edges and from below, natural gas (dissolved gas-to-oil ratios = 500-15,000:1) escapes and some of the heavier oil is left behind. The pressures in the oil fields then become uneven, with higher water levels in some parts and lower gas pressures in others. This adversely affects ultimate oil recovery, as up to 20 percent of proved reserves may become unrecoverable.

About 60 flowing wells that were not burning have been capped by well control crews that pumped thousands of pounds of mud and cement into the damaged wellheads. Thus far, the wells that have been plugged have been those that offered the fewest problems. In general, they were smaller producers that are close to roads and free of land mines and unexploded bombs. The supergiant Burgan field is still an inferno, with slow moving rivers of oil pouring across the dessert. (The smoke and soot from the burning wells is not considered a global threat. The warmer air above 18,000 feet is holding it down and dispersing it into a 1,000 mile-long plume across the Persian Gulf region, locally causing acid rainfall and lower than normal temperatures. Some may have entered the jet stream, as an increase in black carbon soot has been observed in Hawaii. However, it is not certain that the soot originated in Kuwait. British meteorologists have estimated from satellite monitors that the well fires are burning about 1.5 million barrels of oil per day, substantially less oil than the 4 million barrels per day estimated by the petroleum engineers on the ground. The two amounts can be considered as defining a range, with the actual amount of oil being burned fluctuating somewhere in between. The fluctuations, however, are generally downward as less oil is consumed over time. This reduction occurs as flowing wells are shut-in, associated gas burned off, and field pressures decrease.

The burning wells will have to be extinguished. Some 25 well firefighting crews are currently available. These are from four Houston companies: Cudd Pressure Control Inc. (7 crews), Wild Well Control, Inc. (6 crews), Boots and Coots, Inc. (5 crews), and Red Adair Co., Inc. (5 crews), plus Safety Boss, Ltd of Calgary (2 crews). These companies are working together in Kuwait for the first time. Kuwait also is negotiating with additional firefighting companies from Britain, France, China, Iran, Germany, and the Soviet Union to reduce the time required to extinguish all of the well fires from years to months. This would save billions of dollars of crude oil as well as greatly ease the environmental damage. There are questions, however, whether the additional firefighting companies have comparable expertise to the five already in Kuwait.

There are several methods of fighting oil well fires. The availability of enormous amounts of water is a basic requirement. Kuwait's water supply was sabotaged by the retreating Iraqis who blew up distillation and desalination plants. The Kuwait Oil Company is fashioning a 30 mile water pipeline from the Persian Gulf to the Burgan and Magwa oil fields to provide cooling water. When the system is in place it will produce great volumes of water, up to 15,000 gallons per minute, to fill plastic-bottomed ponds in the dessert. Each pond will be dug to a depth of 20 feet and will cover an area in excess of one-half square mile. Initially, a curtain of water will be sprayed from the ponds onto a burning well by a series of pumps, each with a capacity of 5,000 gallons per minute. The water alone will put out some of the well fires. In other cases, liquid nitrogen is effective. It is pumped into a large diameter venturi tube positioned over the burning wellhead, depriving the flames of oxygen as water is sprayed on the fire. Two small well fires have been put out by this method, but it does not appear to work on the larger fires. For such fires, a curtain of water will be employed to allow the damaged well equipment to be removed by cranes and what remains of the wellhead to be packed with 300 to 400 pounds of dynamite or an equivalent amount of C-4 plastic explosive. When the explosives are detonated, the explosion will often consume enough of the surrounding oxygen to snuff out the fire.

Past oil well fires have been rare and singular accidents. In Kuwait, with so many fires burning in close proximity, for the first time it will be possible to organize a coordinated oil well firefighting effort, moving from well to well. Also, it will be economic to fabricate large structures that may be used to fight the numerous fires. One device that is been considered is a 30-foot steel dome with a ten-foot diameter base that can be lowered over a burning oil wells from a heavy-lift crane. The weight of the dome would press its bottom edge into the oil soaked sand forming a fairly tight seal. As the oil fills the dome and the oxygen is consumed, the fire could continue burning only at the top of the dome where the gas is vented. Curved fins within the dome swirl the gushing oil toward the wall of the vessel where it would run down into a collection trough at ground level. From there it could be pumped out to collection pipes that lead to a production system. The oil flow rates would still be uncontrolled, but the

oil resource would no longer be lost and the burning gas would be less polluting than the previously burning gas/oil mixture.

The most difficult fires, that cannot be "blown out" by explosives, eventually can be extinguished with the assistance of directional drilling. A new well is drilled nearby and positioned to intercept the uncontrolled well near the top of the reservoir, far below the fire. Cement and mud is then pumped into the intercept well to stop the uncontrolled flow of oil to the surface. With its fuel cut off, the fire is extinguished. Directional drilling takes much more time than the use of water, liquid nitrogen, or explosives to put out well fires. Over one hundred of the burning wells in Kuwait may require this method of treatment. The most dangerous work comes after a fire has been extinguished. Gas can erupt from the well and oil sprays over the entire area. As the firefighters, drenched in oil, attempt to cap the blowout, any static electricity or flames from a nearby well could reset the fire. A major hazzard is the presence of Iraqi land mines and unexploded bombs buried in the oil fields. These weapons will have to be removed to allow the firefighters to work efficiently.

The final plugging of an uncontrolled well is accomplished by pumping in heavy mud (weighted with barium sulfide) and cement. If the well damage is considerable, hundreds of barrels of cement must be used. While a small plug of concrete easily can be drilled out when the well is put back into production, it is more economic to drill a new well near-by than to drill through a massive amount of concrete. This is especially true in Kuwait's fields, which are well known and rarely deeper than 5,000 feet. As the old wells are redrilled, new methods, such as horizontal drilling, could be used which could add to the efficiency of recovery.

In addition to the damaged and burning wellheads, the Iraqis destroyed more than 20 of the 26 gathering centers that separate the oil, gas, and water recovered from the reservoirs. Each of the gathering centers served 30 to 40 wells, and must be rebuilt before production can begin again. It is expected that it will take at least one year to put out all of the well fires, but it could take as long as from two to five years. \mathbf{E} ven at four million barrels per day, Kuwait would lose less than two percent of its 97 billion barrel oil reserves in a year. However, the reservoir damage caused by the uncontrolled flow of many wells could cause additional significant losses in ultimate oil recovery and, in spite of better engineering in the new wells, the pressure losses in the reservoirs will make future oil recovery generally more expensive, as more pumping will be required. Depending upon reservoir mechanics, there will be certain critical wells that should be controlled first to minimize reservoir damage. In spite of the damage, Kuwait may have 50,000 barrels per day of oil production on stream within two months, enough to run the local power plants. The next priority, after power restoration, is an additional 50,000 barrels per day of crude oil production to refine for domestic gasoline.

Kuwait Oil Fire Extinguishing Chronology

Gulf Program Office Office of the Chief Scientist National Oceanic and Atmospheric Administration

November 1991

Department of Commerce 14th and Constitution Washington, DC 20230

Sources:

Well numbers and dates: Kuwait Oil Company, Production Operations Department, "Oil Wells Survey Data," Kuwait, 1991 (unpublished).

Flow rates: calculated by The Analytic Sciences Corporation (TASC), Reading, Massachusetts pursuant to NOAA Contract No. 50-DGNA-1-00139. October 1991.

Kuwait Oil Fire Extinguishing Chronology

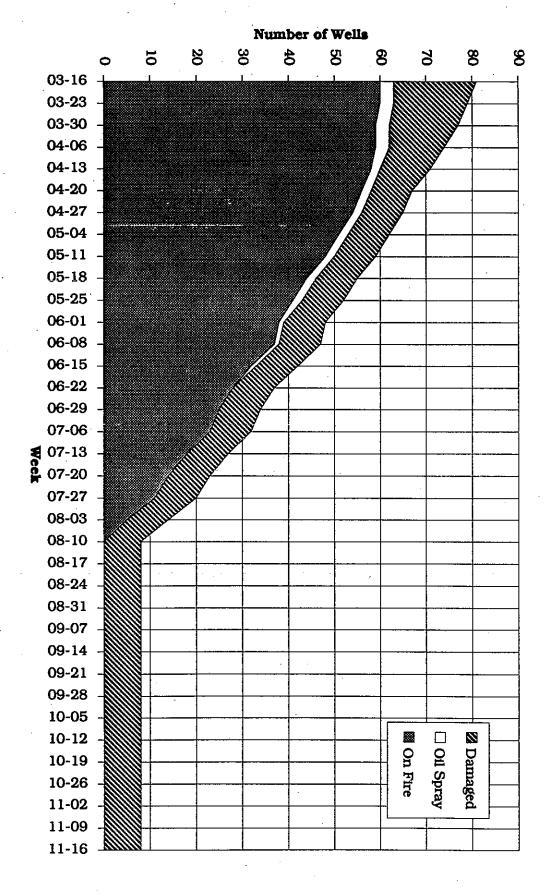
Prepared by The Gulf Program Office

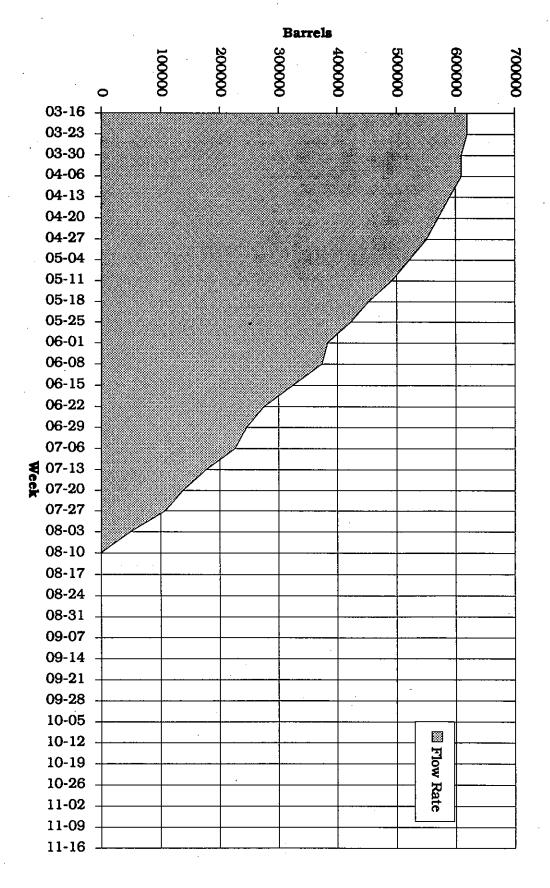
luliyah Field Histor	· y		- -		-	·
Well	Gathering	On	Oil			Date
Number	Center	<u>Fire</u>	Spray	Damaged	Intact	Capped
1	16				1	"
2	16			· · · · · · · · · · · · · · · · · · ·	1	
3	16				1	
4	16				1	
5	16			· · · · · · · · · · · · · · · · · · ·	1	·
Wells		0	0	0		
Wells Controlled		0	0	0		
Remaining		0	0	0		

Ahmadi Field Histor	,		 -		.	
Well	Gathering	On	Oil			Date
Number	Center	<u>Fire</u>	Spray	Damaged	Intact	Capped
1	22			1		Abandoned
3	20	1				5/29/91
4	20	1				5/24/91
5	22	<u> </u>		1		
6	20	1				6/23/91
7	22	- 1				6/3/91
8	20	1				4/17/91
9	22	1				7/8/91
10	22	1				5/20/91
11	22	1				7/17/91
12	22	1				7/7/91
13	19	1			·	6/10/91
14	22			1		
15	22	1				8/5/91
16	20	1		 	ĺ	4/22/91
17	22	1		·		6/10/91
18	22	1				7/9/91
19	22	1				7/9/91
20	22	1				7/14/91
21	22	1			-	6/1/91
22	22	1				5/18/91
23	22	1				6/1/91
24	20	1			· ·	3/30/91
25	20	1				4/29/91
26	20				1	
27	20	1				6/17/91
28	20	1			- 	6/20/91
29	20	1				5/13/91
30	20	7				6/13/91
31	22	1				7/31/91
32	19	1	-			6/24/91
33	19		·	1		0,21,01
34	19	1			_	7/15/91
35	22	1				7/12/91
36	19	1	-	<u> </u>		4/12/91
38	20		1		-	6/18/91
39	22	1	- -			5/18/91
40	22	ī			 	7/3/91
41	22	1				8/5/91
42	19	1		· · · · · · · · · · · · · · · · · · ·		6/20/91
43	19	1	_			8/4/91
43	20	<u> </u>	-	1	 	4/16/91
44	20	1		1	-	6/18/91
47	20	1				5/10/91
47	20	<u> </u>	1			0/10/81
L.	20		1	ï		4/11/91
49				1		3/20/91
50	20	1		4		5/19/91
52	20		_	1		8/5/91
53	20				1	
54	19			1		

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Capp
55	22	1				7/23/
56	22	 .		1	 	,,
57	20	1 -				5/3/9
58	20			1		3/26/
59	20				1	
. 60	20	. 1		· · · · · · · · · · · · · · · · · · ·		7/31/
61	20	1				4/21/
62	20			1		
63	20	1			-	5/9/9
64	20	1				5/3/9
65	20			1		3/20/
66	20			1		4/19/
67	20	1				4/20/
68	20	1		· · · · · · · · · · · · · · · · · · ·	<u> </u>	6/26/
69	19				1	
70	19			1		
71	22	1		•		6/13/
72	22	· · ·		1		3/31/
73	22	1 .	-			6/9/
74	22	1	<u> </u>			8/10/
75	22	1				8/2/9
76	22	1				7/21/
77	22	1				7/22/
78	22	1				7/30/
79	19			1		3/31/
80	19	1				8/8/
81	19		1			5/29/
82	22	1				7/16/
83	22			1		4/9/
84	22	1				8/1/9
85	22	1				7/29/
86	20	· T	•			5/12/
87	22	1				5/5/9
88	22	. 1				7/5/9
89	20			1		4/4/
Wells	<u> </u>	60	3	18	<u> </u>	
Wells Controlled		60	3	10		
Remaining	<u> </u> -	0	0	8		 _

	On	Oil	 	Flow	Flow
Week	Fire	Spray	Damaged	(bbs/day)	(kgs/sec
03-16	60	3	18	620000	1004.40
03-23	60	3	16	620000	1004.40
03-30	59	3	15	610159	988.46
04-06	59	3	12	610159	988.46
04-13	58	2	11	590476	956.57
04-20	56	2	9	570794	924.69
04-27	54	2	9	551111	892.80
05-04	51	2	9	521587	844.97
05-11	48	2	9	492064	797.14
05-18	44	2	9	452698	733.37
05-25	41	2	9	423175	685.54
06-01	38	1	9	383810	621.77
06-08	37	1	9	373968	605.83
06-15	32	1	9	324762	526.11
06-22	28	0	9	275556	446.40
06-29	25	0	9	246032	398.57
07-06	23	0	9	226349	366.69
7-13	18	0	9	177143	286.97
07-20	14	0	9	137778	223.20
07-27	11	0	9	108254	175.37
08-03	5	0	9	49206	79.71
08-10	0	0	8	0	0.00
08-17	0	0 ·	8	0	0.00
08-24	0	0	8	0	0.00
08-31	0	. 0	8	0	0.00
09-07	0	0	8	0	0.00
09-14	0	0.	8	0	0.00
09-21	0	0.	8	. 0	0.00
09-28	0	0	8	0	0.00
10-05	0	0	8	0	0.00
10-12	0	0	8	0	0.00
10-19	0	0	8	0	0.00
10-26	0	0	8	0	0.00
11-02	0	0	8	0	0.00
11-09	0	0	8	0	0.00
11-16	0	0	8	0	0.00





ahra Field History						
Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
2	24	1				10/10/91
4	24	1				10/12/91
6	24		1			10/3/91
8	24		1			10/11/91
9	24	1				10/13/91
Wells		3	2	0	0	
Controlled		3	2	0		
Remaining			0	0		

Week	On	Oil	<u> </u>	Flow	Flow
	Fire	Spray	Damaged	(bbs/day)	Okgs/sec
03-16	3	2	0	24000	38.88
03-23	3	2	0	24000	38.88
03-30	3	2	0	24000	38.88
04-06	3	2	0	24000	38.88
04-13	3	2	0	24000	38.88
04-20	3	2	0	24000	38.88
04-27	3	2	0.	24000	38.88
05-04	3	2	0	24000	38.88
05-11	3	• 2	0	24000	38.88
05-18	3	2	0	24000	38.88
05-25	3	2	0	24000	38.88
06-01	3	2	0	24000	38.88
06-08	3	• 2	0	24000	38.88
06-15	3	2	0	24000	38.88
06-22	3	2	0	24000	38.88
06-29	3	2	0	24000	38.88
07-06	3	2	0	24000	38.88
07-13	3	2	0	24000	38.88
07-20	. 3	2	0	24000	38.88
07-27	3	2	0	24000	38.88
08-03	3	2	0	24000	38.88
08-10	3	2	0	24000	38.88
08-17	3	2	0	24000	38.88
08-24	3	2	0	24000	38.88
08-31	3	2	0	24000	38.88
09-07	3	2	0	24000	38.88
09-14	3	2	0	24000	38.88
09-21	3	2	0	24000	38.88
09-28	3	2	0	24000	38.88
10-05	3	1	0	19200	31.10
10-12	1	0	0	4800	7.78
10-19	0	0	0	0	0.00
10-26	0	0	0	0	0.00
11-02	0	0	0	0	0.00
11-09	Ō	0	0	0	0.00
11-16	0	0	0	0	0.00

Bahra Field-Oil Well Status

Flow Rate - Bahra Fields

lurgan Field Histor					 -	-
Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
1	6	.1				9/12/91
2	11	•	·		1	
3	11				1	
4	2	1	 		 	9/9/91
5	1	1				6/13/91
<u></u>	14			1	 	4/30/91
7	14	1			-	4/20/91
9	11	•			1	1,20,01
10	6	1			 	10/6/91
11	1	1			-	9/20/91
12	1	1				9/4/91
13	1	1 .				9/4/91
	14	<u> </u>	1			8/13/91
<u> 14 · </u>	6					9/29/91
		1			ļ	8/29/91
16	1 2	1			<u> </u>	8/10/91
17	,	1				9/11/91
18	11		1			5/17/91
19	14				1	
20	2			<u>l</u>		6/5/91
21	1	1				9/13/91
22	2	1				9/6/91
23	14	1				8/26/91
24	11	1				7/7/91
25	2			1		5/27/91
26	2	·			1	
27	11				1	
28	11	1				8/17/91
29	2				1	
30	2	. 1				10/4/91
31	2		1			5/8/91
32	8	1				9/23/91
33	5	1				9/14/91
. 34	8	1				8/31/91
35	5 and 11				1	
36	12	1				10/23/9
37	3 and 21	1				10/20/9
38	2	1				9/7/91
39	1	1			-	9/12/91
40	7	1				10/22/9
41	3	1				9/11/91
42	8	1	,			10/12/9
	5	1			<u> </u>	
43	13					10/10/9
44		1		1		8/14/91
45	5		·	1	<u> </u>	7/16/91
46	13	1				10/21/9
47	7	1				10/3/91
48	7	1				10/26/9
49	12	1				10/20/9
50	4	1				8/22/91
51	13	1				9/1/91

Well	Gathering	On	Oil			Date			
Number	Center	Fire	Spray	Damaged	Intact	Capped			
52	13	1				7/25/91			
53	12	1		•		10/15/91			
54	12	1				10/12/91			
55	4	1				8/24/91			
56	4		1	, ,		8/7/91			
57	11 ·	1				7/3/91			
58	8	1				9/18/91			
59	5		1			7/20/91			
60	4	1				8/4/91			
61	5	1				7/22/91			
62	14	1				8/19/91			
63	4				1				
64	13	1		· <u> </u>		8/10/91			
65	4	1			-	8/27/91			
66	13	1				7/18/91			
67	7	1				6/10/91			
68	4	1				8/5/91			
69	4				1				
70	5	1				7/29/91			
71	4	1				10/4/91			
72	12	1				10/9/91			
. 73	5		1		<u> </u>	7/9/91			
74	14				1				
75	4	1		•		7/10/91			
76	11	1				7/2/91			
77	13	1				7/13/91			
78	4		1			8/8/91			
79	. 8	,	1			6/7/91			
80	7	1				10/4/91			
81	4		1			7/8/91			
82	2	1			<u> </u>	9/1/91			
83	4				1				
84	5		1	· · · · · · · · · · · · · · · · · · ·	1	 			
85	14	1				8/14/91			
86	19	1				5/24/91			
87	12	1				10/11/91			
88	11				1				
89	14	1				5/15/91			
90	11				i	0,10,1			
91	2		1		-	6/5/91			
92	11	1				6/18/91			
93	2	1				8/22/91			
94	2	<u></u>				5/13/91			
95	14	<u> </u>				8/20/91			
96	19	<u>-</u>	_			8/14/91			
97	14	<u></u>	<u> </u>			9/3/91			
98	3 and 21	1				10/5/91			
99	5 5	1			 -	9/8/91			
100	3	<u>î</u>				9/13/91			
101	5	<u>1</u>				9/6/91			

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Cappe
102	5	1				9/10/9
103	6	1			- 	9/27/9
104	6	1	· ·	,	 	10/4/9
105	2 and 6	 		····	1	
106	6	1				9/19/9
107	1	1				8/23/9
108	1	1				9/24/9
109	1.	1				9/23/9
110	1	1			 	9/18/9
111	8	1			 	10/6/9
112	21	1	 		 	9/24/9
113	1	1	- 		<u> </u>	9/26/9
114	13	1			 	10/20/
115	7	1 .				10/12/9
116	13	1	 -		 	10/22/9
117	7	1			 	10/6/9
118	12	1				11/2/9
119	21	1			<u> </u>	10/24/
120	13	1				8/18/9
121	12	1			1	10/23/
122	13	1				10/16/
123	13					10/15/
124	3				1	
125	8	1				10/7/9
126	12	1		1		10/14/
127	8	1				9/23/9
128	8	 -	1		 	6/9/9
129	8	1				9/10/9
130	8	· 1				9/7/9
131	11	-			1	0,.,0
132	2	1	_		 	8/28/9
134	14			 	1	0,20,0
136	1	1	_			9/27/9
137	13	1				11/1/9
190	2 and 5	1			+	9/23/9
139	8	<u> </u>			 	8/26/9
140	21	<u> </u>			 	10/21/
141	12	1			 	10/20/
142	12	1				10/7/9
143	5	1			1	9/5/9
144	13	1	- 		 	8/5/9
145	12	<u>i</u>	 		-	10/15/
146	4	1	 		_	9/3/9
147	7	1				10/2/9
148	4	1	 .		+	8/15/9
149	7	1	_			10/5/9
150	13	1			_	7/18/9
151	7	1	 			6/14/9
152	5	1			<u> </u>	10/10/

Well Number 153	Gathering		Oil			Date
	Center	On Fire	Spray	Damaged	Intact	Cappe
153	2	1	<u> Dy-wr</u>		222405	9/13/9
154	7		1			6/8/9
155	4	1	1		 ;	8/22/9
156	2	1				9/10/9
157	11		· · · · · ·		1	0/10/0
158	21	.1			 	10/12/
159	11	. =			1	10,12,
160	13	1			 	10/27/
161	11				1	,,
162	1	1	-		 	9/11/9
163	11	1			- 	5/20/9
164	2	1				9/5/9
165	11		.,	 	1	0,0,0
166	2	1			-	9/10/9
167	11				1	0,20,
168	8	1	-			9/18/9
169	2	1	 			9/12/9
170	11	<u> </u>		<u></u>	1	0/12/
172	21	1		<u></u>	+ -	11/2/9
173	5	<u> </u>				10/12/
174	11				1	10/12/
175	13	1				10/17/
176	12	1		 		10/24/
177	11	*		-	1	10/24/
178	12	1			-	10/17/
179	12	1.				10/1/9
180	8	1		.		8/17/
181	4	1				9/30/9
182	12	1	+		-	10/5/9
183	4	1	 			8/31/9
184	8	1	<u> </u>			5/28/9
185	12	1	-	1		10/14/
186	4	1		<u> </u>	-	9/1/9
187	7	1				10/29/
188	8	1	-			9/13/9
189	7	1	-		-	10/9/9
190	4					
190	7	<u></u>		1		7/23/9
192	4	1		-		10/3/
193	8	1		 		8/2/9
	8	1	_			9/26/
194 195		1	_			10/8/9
	4	1.	_			8/19/
196	5	<u> </u>				10/13/
197	4	1			 	8/13/9
198	5	1				9/12/9
199	4	1				7/10/9
200	6	1		<u></u>		9/22/
201	13			1		8/1/9
202	5 13	1				9/11/9 8/11/9

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Cappe
204	2	1				5/31/
205	13	1				8/17/
206	13	1				6/1/9
207	2	1				7/12/
208	13	1				7/15/
209	2		1			6/4/9
210	12	_	1			6/25/
211	. 14				1	
212	5	1				9/7/9
213	6	1	·			10/7/
214	5	1				9/12/
215	19	1				8/25/
216	6	1				10/2/
217	2		·		1	
218	19			1		6/18/
219	5	11		·		7/20/
220	19	1		······································		8/8/9
221	5	1			·	9/1/9
222	19	1				8/11/
223	5	1				7/30/
224	3	1				10/5/
225	19	1				6/29/
226	2	·	1			6/3/9
227	21	1				10/12
228	2	1		,		7/13/
229	21	1				10/22
230	2	1				8/27/
231	3	1				10/18
232	1	1				8/18/
233	21	1		·		10/15
234	13	1				7/22/
235	2			1		4/28/
236	13	1				7/20/
237	4	1			,	10/20
238	2	1				9/3/9
239	4		1			4/29/
240	4	1				8/7/9
241	4				1	
242	4	1				8/25/
243	4	1				8/26/
244	4	1				8/11/
245	4	1				9/22/
246	4	1	•			10/17
247	12	1	<u> </u>			10/12
248	12	1	<u> </u>			10/7/
249	12	·	1.	. , , , , , , , , , , , , , , , , , , ,		6/26/
250	7	1				10/1/
251 252	7 7	$\frac{1}{1}$				4/18/ 9/28/

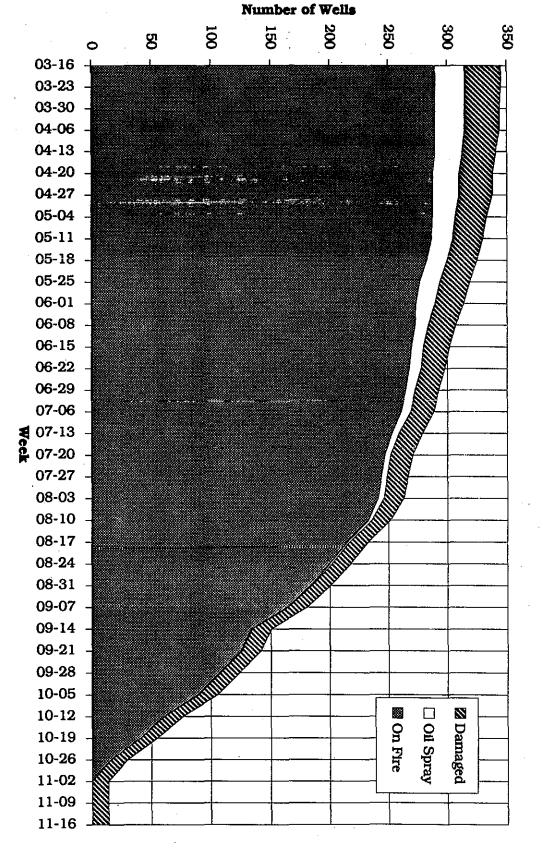
Well	Gathering	On	Oil		- -	Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
253	8		· -	1		6/12/91
254	14				1	<u>-</u>
255	14				1	
256	14	1				8/25/91
257	14	1	 			8/24/91
258	14	1				8/29/91
259	14				1	
260	2	1	1			5/11/91
261	2	1				8/31/91
262	1				1	
263	1	1			 	9/7/91
264	1	ī			 	9/13/91
265	1	1			· · · · · · · · · · · · · · · · · · ·	8/30/91
266	5	1			 	9/8/91
267	13	1			 	7/17/91
268	13	1		·	-}	8/11/91
269	12 and 4	<u> </u>				10/17/91
270	7	1				10/4/91
271	8	1			- 	10/9/91
272	8	1		•	+	9/26/91
273	$\frac{3}{2}$		-		1	0,20,01
275	14	1				9/6/91
276	14	<u> </u>		<u> </u>	1	0,0,02
277	19	1			- 	8/14/91
278	19			··· · · · · · · · · · · · · · · · · ·	1	0/11/01
279	19	1				7/4/91
280	19	1				7/5/91
281	19	1	-			8/19/91
282	14	1			 	8/12/91
283	13	<u> </u>				10/22/91
284	1	1			 	8/15/91
285	21	1			 	10/8/91
286	14	$\frac{1}{1}$				9/3/91
287	6	1				10/4/91
288	12	1				10/20/91
289	1	1				9/17/91
290	12	1		<u> </u>	- 	10/18/91
291	6	1				10/18/91
292	14		- 	<u>-</u>	1	10/9/91
293	14	<u> </u>				0.00.01
	14 and 3	1				9/8/91
294 295	7	Ţ	1			4/7/91
	7	1			- 	10/15/91
296		1				11/2/91
297	8	<u> </u>				10/17/91
298	11	1				5/25/91
299	11	1				6/23/91
300	11	1				6/17/91
301	11	1				6/23/91
302	19	1				8/10/91
303	3	ļ			-	9/27/91

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Cappe
304	19		_ _	1	- -	
305	11		- 	· · · · · · · · · · · · · · · · · · ·	1	
306	11			<u> </u>	1	
307	11			· · · · · · · · · · · · · · · · · · ·	1	
308	1	1			1	8/30/
309	1	ì				5/23/
310	1	1	 			5/15/
311	i	i	- 		<u> </u>	8/20/
312	1 .	1	•			9/10/
313	1	î			<u> </u>	9/13/
314	2	1			1.	9/11/
315	2	1			 	9/10/
316	2	1				9/8/9
317	5	ī				9/9/9
318	5	ī				10/7/
319	13	1	1			10/15/
320	13	1	<u> </u>			10/30/
321	12	1				10/29/
322	12	1			 	10/22/
323	14	<u> </u>		 .	 	8/20/
324	14	<u></u>		1		0/20/
325	14				1	,
326	2	1				7/8/9
327	1	<u> </u>				8/25/
328		<u> </u>	<u> </u>		- 	9/8/9
329	2	<u> </u>	_		1	3/0/0
330	6	1			 	9/21/
331	3		-			10/15/
332	13	1				10/30/
333	13	<u> </u>			-	10/39/
334	13	<u> </u>				10/29/
335	12	· •	1 1			10/25/
336	12	ī	1		- 	
337	12	<u> </u>				10/10/
338	7	1	_			
339	7	1	_			11/1/
	12	1				10/24/
	12	1				10/24/
341					 	10/20/
343 344	13	1			1	10/29/
	5				1	10/10
345	4	1		1	_	10/13/
348	4			1		
349	5			1		10.0
351	8	11			-	10/9/
352	11		<u> </u>		1	
353	6	1				9/24/
354	11	1				5/23/
355 356	19 6				1	
		1			1	9/25/

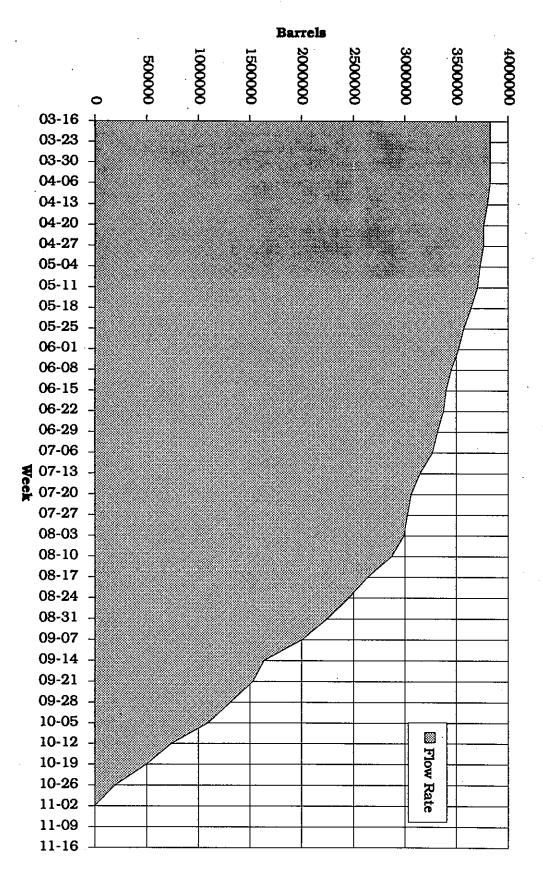
Well	Gathering	On	Oil	<u></u>	-	Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
358	19	1	<u> </u>	Daning Cu	*******	8/18/91
359	21	1				10/7/91
360	11	1				8/11/91
361	11			1	+	6/19/91
362	11	•		<u> </u>	1	0/10/01
363	3			1	+	
364	14				1	
365	14				1	
366	13	. 1			<u> </u>	7/12/91
367	13				1	1/12/01
368	3	1			-	10/29/91
369	13	<u> </u>			1	10/23/31
370	21	1			-	10/17/91
372	6	1				10/1//91
373	6	<u> </u>		· · · · · · · · · · · · · · · · · · ·	1	10/9/91
374	21			1	<u> </u>	-
375	21	1 .		<u></u>		10/23/91
376	21	1			 	10/23/91
377	21					10/31/91
378		1				10/27/91
379	21 5	1				10/25/91
		1				9/21/91
380	7	1				10/23/91
381	14		1			5/4/91
382	14		1			4/18/91
383	2		1		<u> </u>	4/9/91
384	19	<u></u>		1		4.0.701
385	19			1		4/8/91
386	14	1				8/13/91
387	14			1		8/9/91
388	1	1			-	9/22/91
389	11	·		1		5/8/91
390	11	*			1	
391	11	· <u></u>	1			8/27/91
392	19			1		3/25/91
393	11				1	
396	4	.,			1	
397	2	1				9/2/91
398	8				1	
399	5	1				9/16/91
399B	5				1	
400	14				1	
401	14				1	
402	14				1	
403	19	1				5/21/91
404	14				1	
405	14				1	
406	14				1	
407	19			1		
408	19	1	<u> </u>			8/14/91
409	14	1		<u> </u>		5/17/91

Well	Gathering	On	Oil			Dat
Number	Center	Fire	Spray	Damaged	Intact	Capi
411	19				1	
412	14		1	· · · · · · · · · · · · · · · · · · ·		5/4/
413	7		1		1	5/27
415	14				1	
416	11			1		
418	13			i		
419	1			1		
420	1	1				6/5/
421	7			1		
422	7			1		
423	11			1		
Wells		290	25	30		
Controlled	· · · · · · · · · · · · · · · · · · ·	290	25	16		
Remaining		0	0	14		

	On	Oil		Flow	Flow
Week	Fire	Spray	Damaged	(bbs/day)	(kgs/sec
03-16	290	25	30	3829218.75	6203.33
03-23	290	25	30	3829219	6203.33
03-30	290	25	29	3829219	6203.33
04-06	290	25	29	3829219	6203.33
04-13	290	23	28	3804906	6163.95
04-20	288	22	28	3768438	6104.87
04-27	288	22	28	3768438	6104.87
05-04	288	19	26	3731969	6045.79
05-11	287	18	25	3707656	6006.40
05-18	283	17	25	3646875	5907.94
05-25	277	17	25	3573938	5789.78
06-01	274	16	24	3525313	5711.01
06-08	273	11	23	3452375	5592.85
06-15	270	10	22	3403750	5514.08
06-22	268	10	20	3379438	5474.69
06-29	265	8	20	3318656	5376.22
07-06	261	8	20	3270031	5297.45
07-13	253	6	20	3148469	5100.52
07-20	247	5	19	3063375	4962.67
07-27	244	5	18	3026906	4903.59
08-03	241	5	17	2990438	4844.51
08-10	233	3	16	2868875	4647.58
08-17	215	2	16	2637906	4273.41
08-24	200	2	16	2 455563	3978.01
08-31	184	1	16	2248906	3643.23
09-07	164	1	16	2005781	3249.37
09-14	134	1	16	1641094	2658.57
09-21	125	1	16	1531688	2481.33
09-28	107	1	16	1312875	2126.86
10-05	89	1	16	1094063	1772.38
10-12	61	0	16	741531	1201.28
10-19	41	0	14	498406	807.42
10-26	16	0	14	194500	315.09
11-02	0	0	14	0	0.00
11-09	0	0	14	0	0.00
11-16	0	0	14	0	0.00



Burgan Field-Oil Well Status

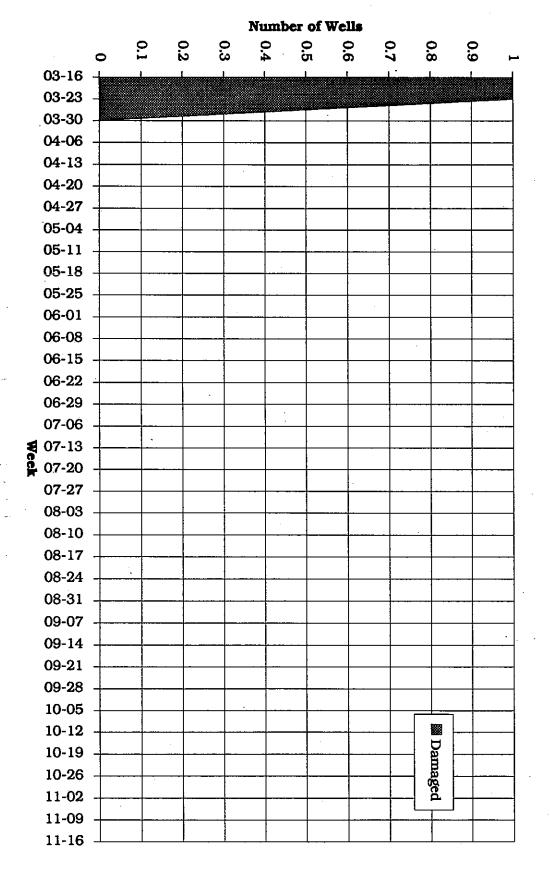


Flow Rate-Burgan Field

if Field History			• •			
Well	Gathering	On	Oil			Dat
Number	Center	Fire	Spray	Damaged	Intact	Capr
1	10				1	
3	10				1	
4	10				1	
Wells		0	0	0	-	
Controlled		0	0	0		
Remaining	-	0	0	0	<u> </u>	

Well	Gathering	On	OII	-	-	Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
5	9			. 1		3/28/91
6	9				1	
Wells		0	0	1		·
Controlled		0	0	1		
Remaining	· ·	0	0	0		

	On	Oil	 	Flow	Flow
Week	Fire	Spray	Damaged	(bbs/day)	(kgs/sec)
03-16	0	0	1	0	0.00
03-23	0	0	1	0 .	0.00
03-30	0	0	0	0	0.00
04-06	0	0	0.	0	0.00
04-13	0	0	0	0	0.00
)4-20	0	0	0	0	0.00
)4-27	0	0	0	0	0.00
5-04	0.	0	0	0	0.00
)5-11	0	0	0	0	0.00
5-18	0	0	0	0	0.00
05-25	0	0	0	0	0.00
06-01	0	0	0	0	0.00
06-08	0	0.	0	0	0.00
06-15	0	0	0	0	0.00
06-22	0.	0	0	0	0.00
06-29	. 0	0	0	0	0.00
7-06	0	0	0	0	0.00
7-13	0	0	0.	0	0.00
7-20	0	0	0	0	0.00
7-27	0	0	0	0	0.00
08-03	0	0	0	0	0.00
08-10	0	0	0	0	0.00
08-17	0	0	0	0	0.00
08-24	0	0	0	0	0.00
08-31	0	0	0	0	0.00
09-07	0	0	0	0	0.00
9-14	0	0	0	0	0.00
09-21	0	0	0	0	0.00
09-28	0	0	0	0	0.00
10-05	0	0	0	0	0.00
10-12	0	0	0	0	0.00
10-19	0	0	0	0	0.00
10-26	0	0	0	0	0.00
11-02	0	0	0	0	0.00
11-09	0	0	0	0	0.00
11-16	0	0	0	0	0.00

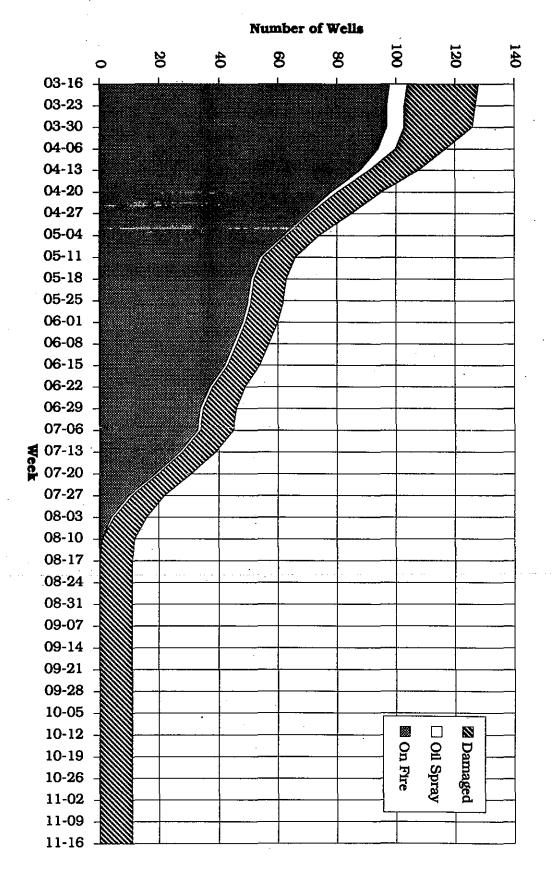


Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Cappe
1	9	1	BD-UI.	2	- ALLEY E	5/17/9
<u> </u>	9		1		 	4/25/9
3	10	<u> </u>				7/25/9
4	9			1		4/2/9
5	10	1		<u> </u>		7/11/9
6	9	$\frac{1}{1}$		·	 	5/22/9
7	10	i			 	4/28/9
8	9	<u>i</u>			-	5/2/9
9	10	$\frac{1}{1}$	 			4/27/9
10	10				1	7/21/3
11	9	1		<u> </u>		7/15/9
12	10	1	- 		-{ -	4/10/9
13	9					4/22/9
14	10	<u>1</u>	 -	1		7/16/9
15	9	<u>i</u>			 	
16	10					5/10/9
		1				4/25/9
17	10	1		<u> </u>		4/29/9
18	9	-		1	<u> </u>	4/3/9
19	20				1	
20	9			1		4/5/9
21	20	1	·			7/22/9
22	10	1 -	· · · · · · · · · · · · · · · · · · ·			4/21/9
23	10	1				6/29/9
24	9	1				5/5/9
25	10	1				5/28/9
26	10	1		, , , , , , , , , , , , , , , , , , ,		7/22/9
27	20	1				4/9/9
28	10				1	
29	10	1				8/9/9
30	22	1				7/18/9
31	22	1	····			7/11/9
32	10	1				7/13/9
33	10	1				4/20/9
34	10				 	4/15/9
35	9	1				7/24/9
 37	10	<u>-</u>	_			4/26/9
38		- <u>1</u>	- 			7/26/9
39	9	1			 	7/11/9
40	9	1				6/7/9
42	9	<u>1</u>	 			4/30/9
43	9	1			<u> </u>	7/20/9
44	9	1		<u> </u>	 _	
45	20	<u> </u>	1			4/6/9
		<u> </u>	<u> </u>			4/10/9
46	10	1	ļ		<u> </u>	8/14/9
47	19	1				8/5/9
48	9	1				5/11/9
49	10	1			<u> </u>	7/10/9
50 51	10	1			<u> </u>	7/8/9
_ ,	10			1	T .	4/16/9

Well	Gathering	On	Oil	· ·		Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
53	9	1	22-41	2.44.45		8/3/91
54	9			1		4/3/91
55	9	1			<u> </u>	5/26/91
56	9 .		 			4/19/91
57	9	1			- 	6/14/91
58	9	1			-	4/21/91
59	9	1			-	4/8/91
60	9	1				6/28/91
61	9		1			4/12/91
62	9	1	 		- 	7/30/91
63	10	1				7/14/91
65	9			1		Abandoned
67	9			1	-	Abandoned
68	9	·······	<u> </u>	1		<u> </u>
69	9	1		<u> </u>		4/28/91
70	20	T			-	
70				1	_	4/29/91
	20			1	-	3/26/91
72				 ,	1	
73	20				1	<u> </u>
74	20			<u> </u>	1	1
75	10	1			_	5/10/91
76	20	1				4/15/91
77	20	1 .				3/23/91
78	10	1				5/6/91
79	10	11			· ·	4/19/91
80	10				1	
81	10	1				4/17/91
82	10	1				6/20/91
83	10			1		
84	10	1		<u> </u>		7/4/91
85	10	. 1				4/14/91
86	. 9	1				5/6/91
87	9	1			-	4/13/91
88	9	1				5/4/91
89	9	1				4/26/91
90	9	1				4/27/91
91	9			1		4/29/91
92	10	1				8/1/91
93	10		_	 	1	0,2,02
94	10	1		· · · · · · · · · · · · · · · · · · ·		4/14/91
95	22	1	- 	 -		7/21/91
96	22	1			-	7/16/91
97	22	1			-	6/20/91
98	10	1				4/16/91
99	10	1				4/13/91
100	10					
	I I	1			 	4/17/91
101	10	4			1	F /F /01
102	10	11				5/5/91
103	10		1			8/6/91

Well	Gathering	On	Oil		 	Date
Number	Center	Fire	Spray	Damaged	Intact	Capp
105	10				1	
106	10				1	
107	22	1				.7/19/
108	9	1				4/2/
109	9	1				4/23/
111	10	1				6/19/
112	10	1				6/6/9
113	10			1		4/18/
114	19	1				8/2/
115	10	1				7/26/
116	9	Ţ				5/12/
117	9	1				6/6/
118	9	1				4/4/
119	10	·		1		4/2/
120	20	1				6/13/
121	9		1			4/17/
123	9	1				6/21/
124	10	1				5/12/
125	10	1				6/20/
126	10	1				8/6/
127	10			1		
128	10	-		1		
129	10	1		,		7/27/
130	10	1				4/28/
131	10	1				5/3/
132	10				1	
133	10	1		· · · · · · · · · · · · · · · · · · ·	- · · · · · · · · · · · · · · · · · · ·	5/6/
134	10	1		*****		8/3/
135	10	1			 	7/21/
136	10		1		 	4/11/
137	10	-	-	1		
138	10			l		
139	10			i		
141	10			i		
142	10	1				6/23/
143	10			<u> </u>	 	3,23,
144	10	- 1				7/18/
3.45	10	1			 -	6/10/
145	10			1		5/2/
148	9			<u>i</u>	-	4/2/
146		· · · · · · · · · · · ·	-		 	7/2/
Wells		98	6	24		
Controlled		98	6	13		
			- -	10	 -	 -
Remaining		0	0	11	- 	·

	On	Oil	- 	Flow	Flow
Week	Fire	Spray	Damaged	(bbs/day)	(kgs/sec
03-16	98	6	24	1030000	1668.60
03-23	97	6	24	1020097	1652.56
03-30	97	6	23	1020097	1652.56
04-06	94	6	17	990385	1604.42
04-13	88	3	17	901250	1460.03
)4-20	78	2	15	792308	1283.54
04-27	70	1	14	703173	1139.14
05-04	62	1	11	623943	1010.79
05-11	54	1	11	544712	882.43
05-18	51	. 1	11	515000	834.30
05-25	50	1	11	505096	818.26
06-01	48	1	11	485289	786.17
06-08	45	1	11	455577	738.03
06-15	42	1	11	425866	689.90
06-22	37	1	11	376346	609.68
06-29	34	1	11	346635	561.55
7-06	33	1	11	336731	545.50
7-13	27	1	11	277308	449.24
07-20	19	1	11	198077	320.88
07-27	10	1	11	108942	176.49
08-03	4	1	11	49519	80.22
08-10	1	0	11	9904	16.04
08-17	0	0	11	0	0.00
08-24	0	0	11	0	0.00
08-31	0	0	11	0	0.00
09-07	0	0	11	0	0.00
09-14	0	0 .	11	0	0.00
09-21	0	0	11	0	0.00
09-28	0	0	11	0	0.00
10-05	0	0	11	0	0.00
10-12	0	0	11	0	0.00
10-19	0	0	11	0	0.00
10-26	0	0	11	0	0.00
11-02	0	0	11	0	0.00
11-09	0	0	11	0	0.00
11-16	0. ,		11	0	0.00



Magwa Field-Oil Well Status

Flow Rate - Magwa Fields

Number Center Fire Spray Damaged Intact 1 16 1 <td< th=""><th>Well</th><th>Gathering</th><th>On</th><th>Oil</th><th></th><th></th><th>Da</th></td<>	Well	Gathering	On	Oil			Da
1 16 1 2 16 1 3 16 1 4 16 1 6 16 1 7 16 1 8 16 1 9 16 1 10 16 1 11 16 1 12 16 1 13 16 1 14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 24 16 1 25 16 1 26 16 1 27 16 1 28 16 1 30 16 1 31 16 1 33 16 1 33 16 1 34			Fire	Spray	Damaged	Intact	Cap
3	1	16	1				9/18
4 16 1 6 16 1 7 16 1 8 16 1 9 16 1 10 16 1 11 16 1 12 16 1 13 16 1 14 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 33 16 1 33 16 1 33 16 1 33 16 1 33 16 1 33 </td <td></td> <td>16</td> <td>1</td> <td></td> <td></td> <td></td> <td>9/21</td>		16	1				9/21
6	3		1				9/16
7 16 1 8 16 1 9 16 1 10 16 1 11 16 1 12 16 1 13 16 1 14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 24 16 1 25 16 1 26 16 1 27 16 1 28 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39	4	16	1				9/11
8 16 1 9 16 1 10 16 1 11 16 1 12 16 1 13 16 1 14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 24 16 1 25 16 1 26 16 1 27 16 1 28 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 4	6		. 1				9/26
9 16 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	. 7		1				9/19
10 16 1 11 16 1 12 16 1 13 16 1 14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 39 16 1 40 16 1 40 16 1 40 16 1			1				10/4
11 16 1 12 16 1 13 16 1 14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 39 16 1 40 16 1 Wells 27 0 8			1			Ţ	9/28
12 16 1 13 16 1 14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 39 16 1 40 16 1 Wells 27 0 8							10/9
13 16 1 14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 39 16 1 39 16 1 40 16 1 40 16 1 40 16 1	11	, ,	1				9/29
14 16 1 18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 40 16 1 40 16 1 40 16 1		I F	1				9/29
18 16 1 19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8					1		
19 16 1 20 16 1 21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8) 1			1		9/30
20 16 21 16 22 16 23 16 25 16 26 16 27 16 28 16 29 16 30 16 31 16 32 16 33 16 34 16 35 16 36 16 37 16 38 16 39 16 40 16 Wells 27 0 8		1			1		
21 16 1 22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1			1			·	9/24
22 16 1 23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8					1		
23 16 1 25 16 1 26 16 1 27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8			1		•		10/5
25 16 26 16 27 16 28 16 29 16 30 16 31 16 32 16 33 16 34 16 35 16 36 16 37 16 38 16 39 16 40 16 Wells 27 0 8					1		
26 16 27 16 28 16 29 16 30 16 31 16 32 16 33 16 34 16 35 16 36 16 37 16 38 16 39 16 40 16 Wells 27 0 8			1				9/9
27 16 1 28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8					1		
28 16 1 29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8					1		
29 16 1 30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8							9/17
30 16 1 31 16 1 32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8							9/18
31 16 32 16 33 16 34 16 35 16 36 16 37 16 38 16 39 16 40 16 Wells 27 0 8							9/26
32 16 1 33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8			1				9/12
33 16 1 34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8		1 1 -			1		
34 16 1 35 16 1 36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8		. ,					9/19
35 16 1 36 1 37 16 1 38 16 1 39 16 10 1 39 16 10 1 1 39 16 10 1 1 39 16 10 1 1 39 16 10 1 1						·	9/19
36 16 1 37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8		I .					9/10
37 16 1 38 16 1 39 16 1 40 16 1 Wells 27 0 8	35	16	1				9/8
38 16 1 39 16 1 40 16 1 Wells 27 0 8				-			9/8
39 16 1 40 16 1 Wells 27 0 8		1 1 .		•			9/12
40 16 1 Wells 27 0 8		I					9/13
Wells 27 0 8							7/19
	40	16	1				9/7
Controlled 27 0 1							
	Controlled		27	0	1		
Remaining 0 0 7							

	On	Oil		Flow	Flow
Week	Fire	Spray	Damaged	(bbs/day)	(kgs/sec
03-16	27	0	8	77000	124.74
03-23	27	0	8	77000	124.74
03-30	27	0	8	77000	124.74
04-06	27	0	8	77000	124.74
04-13	27	0	8	77000	124.74
04-20	27	0	8	77000	124.74
04-27	27	0	8	77000	124.74
05-04	27	0	8	77000	124.74
05-11	27	0	8	77000	124.74
05-18	27	0	8	77000	124.74
05-25	27	0	8	77000	124.74
06-01	27	0	8	77000	124.74
06-08	27	0	8	77000	124.74
06-15	27	0	8	77000	124.74
06-22	27	0	8	77000	124.74
06-29	27	. 0	8	77000	124.74
07-06	27	0	8	77000	124.74
07-13	27	0	8	77000	124.74
07-20	26	0	8	74148	120.12
07-27	26	0	8	. 74148	120.12
08-03	26	0	8	74148	120.12
08-10	26	0	8	74148	120.12
08-17 ⁻	26	0 .	8	74148	120.12
08-24	26	0	8	74148	120.12
08-31	26	0	8	74148	120.12
09-07	25	0	8	71296	115.50
09-14	17	0	8	48481	78.54
09-21	9	0	8	25667	41.58
09-28	5	0	8	14259	23.10
10-05	1	0	7	2852	4.62
10-12	0	0	7	0	0.00
10-19	0	0	7	0	0.00
10-26	0	0	7	0	0.00
11-02	0	0	7	0	0.00
11-09	0	0	7	0	0.00
11-16	0	0	7	0	0.00

Number of Wells

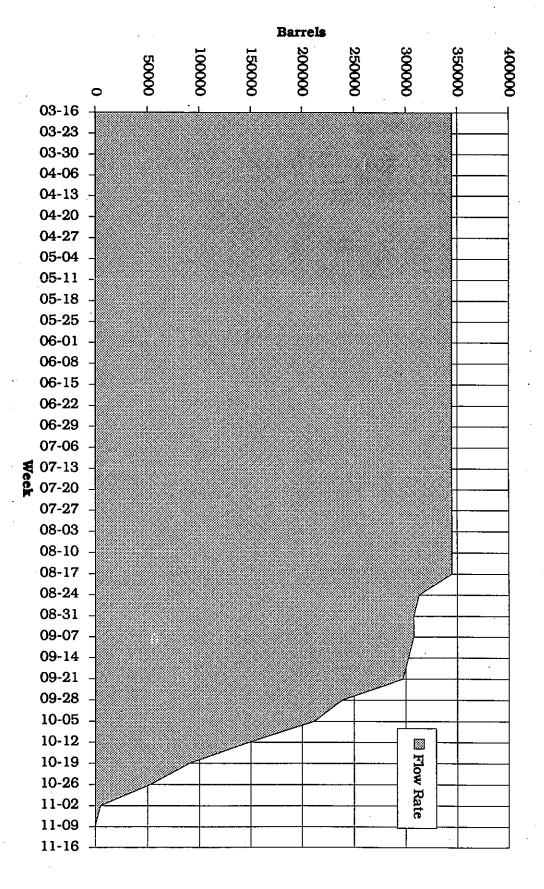
Minagish Field-Oil Well Status

Flow Rate - Minagish Fields

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Cappe
1	15	1				9/24/9
2	15		1			8/23/9
3	25	1				9/25/9
4	25	1				10/6/9
5	25	1				10/11/9
6	15	1				8/21/9
7	15	1	<u> </u>			10/22/9
-8	25	1				9/30/9
9	25	1				10/23/
10	15	1	<u> </u>			9/26/9
11	15	ī				8/26/9
12	25	1			 	9/27/9
13	25	1				10/31/
14	15	1			 	10/31/
15	25	1				9/24/9
16	15	1			 	10/9/9
17	25	1				10/18/
18	15	<u> </u>	 		 	10/7/9
19	25	1	 -		 	9/22/9
20	15	<u> </u>	 		 -	10/30/
21	15	ī	 -			10/30/
$-\frac{21}{22}$	25	1			-	10/2/9
23	25	$-\frac{1}{1}$				10/6/9
<u>24</u>	15	<u> </u>	1	<u> </u>		10/13/
25	25	<u>-</u> 1	 -		- 	10/6/9
26	15	<u></u>	 			10/25/
<u></u> -	15	<u>-</u>				9/17/9
30	15	<u> </u>	 			10/30/
33	25	i i			- 	10/15/
34	15	<u></u>				11/1/9
35	15	<u> </u>				10/19/
36	15	<u> </u>	· · · · · · · ·			9/23/9
37	25		- 			10/3/
38	15	1			 	10/9/9
43	15	<u></u>			1	10/0/
44	15		1		 	8/18/9
45	15	1	-			10/23/
46	15	<u>i</u>				11/6/9
47	15	1				10/25/
48	15	<u>_</u>			- 	10/23/
49	15	1			- }	10/29/
50	15	 1	_			10/25/
51	15	1				10/17/
52	25	1	 			10/16/
53	25	1	 			
						9/13/
54	25	1	·			9/27/
55 50	15	1				10/15/
56	15	1	- 			9/25/
57 58	15 25	$\frac{1}{1}$				10/9/9

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Cappe
59	15				1	
61	25		-		1	<u> </u>
62	15	1				10/24/9
63	25	1				10/17/
64	15			1		10/26/
65	15			1		
66	15	1				10/15/
67	15	1				10/18/
68	25	1				8/24/9
69	25	1				9/23/9
70	15			1		
71	15			1		10/15/
72	15			1		
7 3	15	. 1				10/31/
74	15	1				10/4/9
75	15	1				8/19/9
76	25	1				10/28/
77	25	1				8/21/9
78	25	1				10/10/
79	25	1				10/10/
80	15	1				10/12/
83	25			1		4/23/
84	25	1				9/23/
85	15				1	
Wells		62	3	6		
Controlled		62	3	3		·
Remaining		0	0	3		

<u> </u>	On	Oil		Flow	Flow
Week	Fire	Spray	Damaged	(bbs/day)	(kgs/sec)
03-16	62	3	6	345000	558.90
03-23	62	3	6	345000	558.90
03-30	62	3	6	345000	558.90
04-06	62	3	6	345000	558.90
04-13	62	3	6	345000	558.90
04-20	62	3	6	345000	558.90
04-27	62	3	5	345000	558.90
05-04	62	3	5	345000	558.90
05-11	62	3	5	345000	558.90
05-18	62	3	5	345000	558.90
05-25	62	3	5	345000	558.90
06-01	62	3	5	345000	558.90
06-08	62	3	5	345000	558.90
06-15	62	3	5	345000	558.90
06-22	62	3	5	345000	558.90
06-29	62	3	5	345000	558.90
07-06	62	3	5	345000	558.90
07-13	62	3	5	345000	558.90
07-20	62	3		345000	558.90
07-27	62	3	5	345000	558.90
08-03	62	3	5	345000	558.90
08-10	62	3	5	345000	558.90
08-17	62	3	5	345000	558.90
08-24	58	1	5	313154	507.31
08-31	57	1	5	307846	498.71
09-07	57	1	5	307846	498.71
09-14	56	1	5	302538	490.11
09-21	55	1	5	297231	481.51
09-28	44	<u>-</u>	5	238846	386.93
10-05	39	1	5	212308	343.94
10-12	27	1	5	148615	240.76
10-19	17	0	. 4	90231	146.17
10-26	10	0	3	53077	85.98
11-02	1	0	3	5308	8.60
11-09	0		3	0	0.00
11-16	0	0	3	0	0.00



Flow Rate-Raudhatain Field

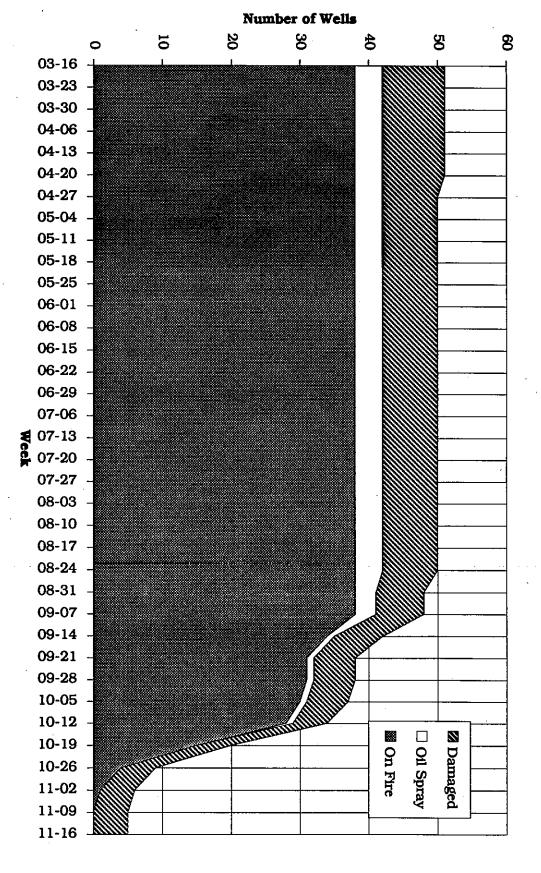
Raudhatain Field-Oil Well Status

laqua Field History						
Well Number	Gathering Center	On Fire	Oii Spray	Damaged	Intact	Date Capped
	***************************************	VELL HISTOR	DIES ADE NOT	AVAILABLE FOR	ायाद शास	
	INDIVIDUAL	TELE IIIOIOI	T T	TVIIII I DEL TON	THIS FIELD	<u>, </u>
Wells		0	0	0		<u> </u>
Controlled		0	0	0		
Remaining		0	0	0		
· · · · · · · · · · · · · · · · · · ·						

	!!!		I I		i	F
Well	Gathering	On	Oil	· · · · · · · · · · · · · · · · · · ·		· Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
1	23	1				10/23/9
2	23	1				10/25/9
3	23		-	1		
4	24		1			9/11/9
5	24	1			•	9/19/9
6	24			1		9/18/9
7	23	1				10/15/9
8	24	1				10/25/9
9	23			1		10/12/9
10	23			1		
11	23				1	
13	24			1		
14	24				1	
17	24	1		. ,		10/17/9
18	23	1				11/1/9
19	23	1				10/29/9
20	23		1			10/16/9
21	24	1				10/20/9
22	24	1				10/15/9
23	24	1				9/21/9
24	24	1				9/12/9
. 26	23	1				10/19/9
27	24	1			-}	10/20/9
28	23	1				10/17/9
29	23	1				10/1/9
30	23	1				10/18/9
31	24	1				10/21/9
32	24	1				9/15/9
33	24	1	·			10/14/9
34	23	1				10/26/9
35	23			<u> </u>		4/23/9
36	23	1				10/19/9
37	23	1				10/26/9
38	24	1				9/11/9
39	23 and 24	1				10/19/9
40	23	1				9/13/9
41	23	1				10/28/9
42	23		1			8/27/9
43	24	1			 	10/20/9
44	24	1	- 		 -	10/18/9
45	24	_ _	1			9/11/9
46	24	1	 -			10/15/9
47	24	1		·	-	10/19/9
48	23	1			-	11/6/9
49	24	1	 		-	9/13/9
50	24	1	- 		+	10/22/9
51	24	1	 		-	10/21/9
59	23			1	 	10/21/3
60	23			1		
61	23	1				10/12/9

oriyah Field Histo	ry (Continued)		· ·		·	<u> </u>
Well	Gathering	On	Oil			Date
Number	Center	<u>Fire</u>	Spray	Damaged	Intact	Capped
62	23			1		8/27/91
63	23	1			-	10/12/91
64	23	1				10/13/9
Wells		38	4	9	_	_
Controlled		38	4	4		
Remaining		0	0	5	_	·

_ 	On	Oil		Flow	Flow [kgs/sec]
Week	Fire	Spray	Damaged	(bbs/day)	
03-16	38	4	9	200000	324.00
03-23	38	4	9	200000	324.00
03-30	38	4	9	200000	324.00
04-06	38	4	9	200000	324.00
04-13	38	4	9	200000	324.00
04-20	38	4	9	200000	324.00
04-27	38	4	8	200000	324.00
05-04	38	4	8	200000	324.00
05-11	38	4	8	200000	324.00
05-18	38	4	8	200000	324.00
05-25	38	4	8	200000	324.00
06-01	38	4	8	200000	324,00
06-08	38	4	8	200000	324.00
06-15	38	4	8	200000	324.00
06-22	38	4	8	200000	324.00
06-29	38	4	8	200000	324.00
07-06	38	4	8	200000	324.00
07-13	38	4	8	200000	324.00
07-20	38	4	8	200000	324.00
07-27	38	4	8	200000	324.00
08-03	38	4	. 8	200000	324.00
08-10	38	4	8	200000	324.00
08-17	38	4	8	200000	324.00
08-24	38	4	8	200000	324.00
08-31	38	3	7	195238	316.29
09-07	38	3	7	195238	316.29
09-14	34	1	7	166667	270.00
09-21	31	1	6	152381	246.86
09-28	31	1	6	152381	246.86
10-05	30	1	6	147619	239.14
10-12	28	<u> </u>	5	138095	223.71
10-19	15	0	5	71429	115.71
10-26	4	0	5	19048	30.86
11-02	1	0	5	4762	7.71
11-09	0	0	5	0	0.00
11-16	0	0	5		0.00



Flow Rate - Sabriyah Fields

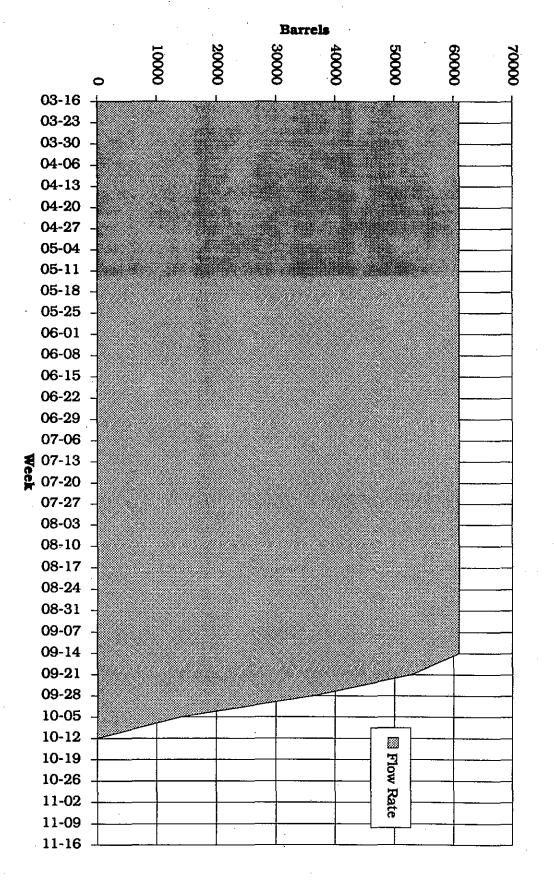
Well	Gathering	On	Oil			Date
Number	Center	<u>Fire</u>	Spray	Damaged	Intact	Capped
	INDIVIDUAL V	WELL HISTOF	UES ARE NOT	AVAILABLE FOR	THIS FIELD)
Wells		0	0	0	_	
Controlled		0	0	0		
Remaining		0	0	0		

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Capp
·						
	INDIVIDUAL V	VELL HISTORI	ES ARE NOT	AVAILABLE FOR	THIS FIELI)
10		0 .	0	0		
Wells	1					·
Wells Controlled		0	0	0		
		0	0	0		

Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
2	18	1			<u> </u>	9/17/91
3	17	1				10/3/91
4	17	1				9/26/91
5	18	i		······································		9/15/91
6	17	. 1	•	· · · · · · · · · · · · · · · · · · ·		10/7/91
7	18	ī	-		-	9/18/91
8	17	1				10/8/91
9	17	1				10/5/91
10	17	1				9/26/91
11	18			1		
12	17		1			9/26/91
13	17	1				10/1/91
14	18			1		9/20/91
15	17			1		9/28/91
16	18	1			<u> </u>	9/25/91
17	17	<u></u>				9/30/9
18	18	<u> </u>	-			9/22/91
19	17	$\frac{\overline{1}}{1}$	- 			10/2/9
20	18		<u> </u>	1	- 	10,0,0
21	17	1				10/5/9
22	17	1	-			10/4/9
23	18	<u> </u>		1		10, 1, 0.
24	17		-		-1	
25	17	· 1	-			10/6/9
26	18		-	1		10,0,0
27	17		1	•	-	9/30/9
28*	17		1	1		10/6/9
29	18	1	<u>.</u>	•		9/25/9
30	17	1				10/2/9
31	17		_	1		10/2/3
32	17			1		10/9/0
33	18			<u> </u>		10/8/9
34	17	1				9/26/9
		1		·		10/7/9
35	17	1	<u> </u>	· · · · · · · · · · · · · · · · · · ·		10/10/9
36	17			1		10/4/9
37	17				1	10 (1) (0)
38	17	1				10/1/9
39	17	1				10/7/9
40	17			1		9/30/9
41	17	1				9/27/9
42	16	1		· · · · · · · · · · · · · · · · · · ·		9/21/9
43	16	1				9/29/9
44	16			1		
Wells		27	3	12		
Controlled		27	3	6		

	On	Oil		Flow	Flow
Week	Fire	Spray	Damaged	(bbs/day)	(kgs/sec)
03-16	27	3	12	61000	98.82
03-23	27 · ·	3	12	61000	98.82
03-30	27	3	12	61000	98.82
04-06	27	3	12	61000	98.82
04-13	27	3	12	61000	98.82
04-20	27	3	12	61000	98.82
04-27	27	3	12	61000	98.82
05-04	27	3	12	61000	98.82
05-11	27	3	12	61000	98.82
05-18	27	3	12	61000	98.82
05-25	27	3	12	61000	98.82
06-01	27	3	12	61000	98.82
06-08	27	3	12	61000	98.82
06-15	27	3	12	61000	98.82
06-22	27	3	12	61000	98.82
06-29	27	3	12	61000	98.82
07-06	27	3	12	61000	98.82
07-13	27	3	12	61000	98.82
07-20	27	3	12	61000	98.82
07-27	27	3	12	61000	98.82
08-03	27	3	. 12	61000	98.82
08-10	27	3	12	61000	98.82
08-17	27	3	12	61000	98.82
08-24	27	3	12	61000	98.82
08-31	27	3	12	61000	98.82
09-07	27	3	12	61000	98.82
09-14	27	. 3	12	61000	98.82
09-21	23	3	11	52867	85.64
09-28	16	, 2	10	36600	59.29
10-05	6	1	8	14233	23.06
10-12	0	0	6	0	0.00
10-19	0	0.	` 6	0	0.00
10-26	0	0	. 6	0	0.00
11-02	0	0	6	0	0.00
11-09	0	0	6	0	0.00
11-16	0	0	6	0	0.00

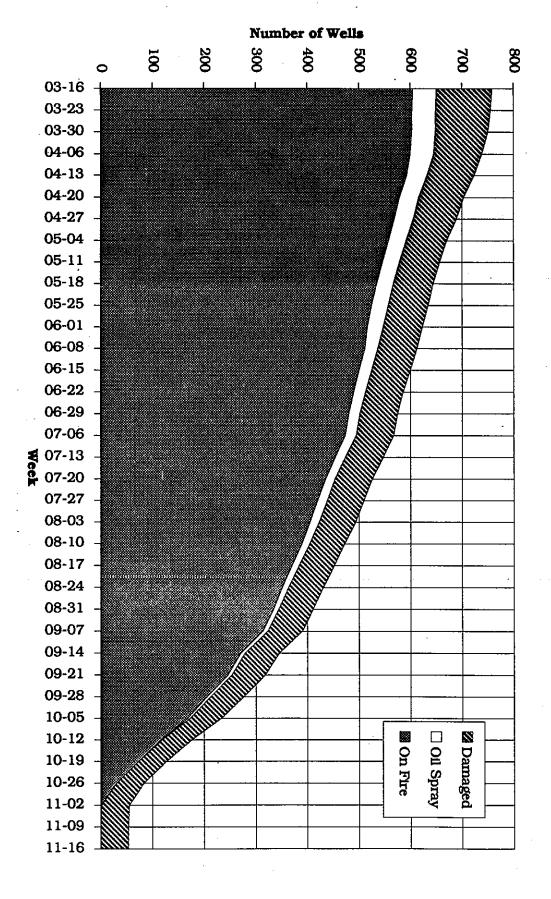
Umm Gudair Field-Oil Well Status



Flow Rate-Umm Gudair Field

Vafra Field History						
Well	Gathering	On	Oil			Date
Number	Center	Fire	Spray	Damaged	Intact	Capped
•	**INDIVIDUAL V	VELL HISTOR	IES ARE NOT	AVAILABLE FOR	THIS FIELD)**
Wells		6	33	N/A		
Controlled		6	33	N/A		
Remaining		0	0	N/A		

				Flow	
	On	011		(100,000	Flow
Week	Fire	Spray	Damaged	bbs/day)	(kgs/sec)
03-16	605	46	108	61.86	10021.67
03-23	604	46	106	61.76	10005.63
03-30	603	46	102	61.66	9989.69
04-06	600	46	93	61.37	9941.55
04-13	593	40	91	60.04	9725.88
04-20	579	38	87	58.39	9458.43
04-27	569	37	84	57.30	9282.15
05-04	558	34	79	55.84	9046.89
05-11	546	33	78	54.51	8831.32
05-18	535	32	78	53.22	8620.95
05-25	525	32	78	52.09	8438.92
06-01	517	30	77	51.01	8264.28
06-08	512	25	76	49.89	8082.05
06-15	501	24	75	48.61	7875.43
06-22	490	23	73	47.38	7676.11
06-29	481	21	73	46.18	7481.68
07-06	474	21	73	45.40	7354.98
07-13	455	19	73	43.10	6982.07
07-20	436	18	72	41.03	6647.47
07-27	421	18	71	39.48	6396.17
08-03	406	18	70	37.93	6145.16
08-10	390	15	68	35.83	5804.34
08-17	371	14	68	33.42	5414.13
08-24	352	12	68	31.28	5067.14
08-31	335	10	67	29.11	4716.04
09-07	314	10	67	26.65	4317.56
09-14	271	8	67	22.44	3634.92
09-21	246	8	65	20.84	3375.81
09-28	206	7	64	17.79	2881.92
10-05	168	5	61	14.90	2414.24
10-12	117	2	58	10.33	1673.53
10-19	73	0	55	6.60	1069.31
10-26	30	0	54	2.67	431.93
11-02	2	0	54	0.10	16.31
11-09	0	0	54	0.00	0.00
11-16	0	0	54	0.00	0.00
		· · · · · · · · · · · · · · · · · · ·	-		



Flow Rate - All Fields

Summary of the GULFEX flights. 23rd - 31st March 1991

bу

M.A.Gibbs, D.W.Johnson,
C.G.Kilsby and D.S.McKenna.

Meteorological Research Flight
Y46 Building
Royal Aerospace Establishment
Farnborough
Hants GU14 6TD

May 1991

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1. INTRODUCTION.

Between the 22nd March and the 2nd April 1991 the C-130 aircraft of the Meteorological Research Flight (MRF) was detached to the Gulf to assess the environmental effects of the smoke from the Kuwaiti oil well fires resulting from the Kuwait - Iraq war. The aircraft was based throughout the measurement phase of GULFEX (Gulf Experiment) in Bahrain. The major objective of the experiment was

To characterise the oil smoke plume at a number of downwind distances in terms of its dynamics, its particulate density, its chemical composition, its effect on solar and infra-red radiation and its interaction with water cloud in order to improve our assessments of the impact of the plume on the local, regional and global environment.

Secondary aims were to validate the predictions of the mesoscale and nuclear accident numerical models, to investigate the morphology of the smoke particulates and to study the microwave characteristics of the oil slicks on the sea.

C-130 MEASUREMENTS.

Eight scientific sorties were flown over a nine day period (totalling 57 hours flying time) from Bahrain over the Gulf, Kuwait, Saudi Arabia and Qatar. The measurements made can be split up into four categories.

(a) Standard meteorological parameters

- (i) temperature,
- (ii) dew point,
- (iii) wind speed and direction,
- (iv) vertical velocity,
- (v) liquid water.
- (vi) total water,
- (vii) position and
- (viii) forward and downward facing video.

(b) Radiation measurements

- broad band radiation fluxes made with the pyranometers and pyrgeometers in the solar, near infra red (0.3 - 3μm) and infra red wavelengths (4.0 - 50μm),
- (ii) narrow band radiances made with the multi channel radiometer (MCR) at both visible/near infra red (0.55 2.3μm) and infra red wavelengths (10 14μm),
- (iii) the total scattering coefficient was measured with the nephelometer,
- (iv) a PRT 4 radiometer was used to measure the cloud top temperature and sea surface temperature and
- (v) microwave measurements were made with the MARSS radiometer (89 and 157GHz).

(c) Chemistry measurements

- (i) Ozone chemi-luminescent detector,
- (ii) NO chemi-luminescent detector,
- (iii) NOx chemi-luminescent detector,

- (iv) SO2 hydrogen flame photometric detector,
- (v) electron capture gas chromatographs were used to measure trace chemicals such as PAN and
- (vi) bottle samples.
- (d) Cloud physics and aerosol measurements
 - (i) the passive cavity aerosol spectrometer probe (PCASP) was used to measure particles in the size range 0.1 - 3.0μm,
 - (ii) the forward scattering spectrometer probe (FSSP) was used to measure particles in the size range $1.0 45 \mu m$,
 - (iii) the 2D cloud probe was used to measure particles in the size range 25 $800 \mu m$
 - (iv) some holograms were exposed (these can resolve particles larger than $10\mu\mathrm{m}$) and
 - (v) filter samples.

Table I summarizes the instruments used on each flight and gives some idea of how they performed.

INSTRUMENT	A074	A075	A076	A077	A078	A079	A080	A081
Static Head	0.	0	0	Ō	0	0	0	Ö
Pitot-static	0	0.	0	0	0	0	0	0
Gust probes	0	0	0	0	0	0	Ô	0
ICTP	0	0	0	Ö.	0	Ô.	0	0
De-iced therm	Ō	0	0	0	0	0	0 .	0
Non de-iced therm	O	0	0	0	0	Ö	Ó	0
General Eastern hygro	0	· 0	.0	0	0	0	X	X
CCN	X	Ō	0	0	0	0	0	0
Nephelometer -	Ö -	0	Ō	0	0.	Ó	0	0
Filter boom	0	O	0	0	0	O	0	0
Bendix Ozone	0	0	0	0	0	0	0	0
Desibi Ozone	0	X	X	X	X	X	X	X
SO2	0	0	0 -	0 -	0 -	0	0	0
NOx	0	0	0	0	O	0	0	0.
Bottle samples	X	0	0	0	0	0	0	0
ECGCs	0	. 0	0	0	0	. 0	0	0
2D cloud probe	0	0	0	0	3	. 3	3	2
PCASP	0	0	0	0	0	0	0	0
FSSP	0	0	0	0	0	0	0	0
Holography	X	X	X	X	X	X	0	X
JW liquid water	0	0	0	0	0	0	0	0
Total water	0	0	0	0	0	Ö	0	0
BBR	0	0	0	0	0	0	0	0
Barnes PRT4	0	0	0	0	0	0	0	0
MARSS	1	X	0	0	0	0	0	0
MCR	0	0	0	0	0	0	Ó	0

O Instrument operated successfully

X Instrument did not operate

¹ MARSS switched off 1105

^{2 2}D cloud probe switched off during the flight

^{3 2}D cloud probe was very noisy

3.. Flight A074 GULFEX 1 23rd March 1991

This was the first GULFEX flight and, primarily, was undertaken as an instrument test. The operating area was to the south east of Bahrain as far east as Ras Al Khaimah and then south west over Saudi Arabia. Subsequent to the flight, the Nephanalysis carried out by S Div showed that the aircraft may have been flying in a very old plume. During the flight the boundary layer was extremely hasy but it was difficult to make out any significant smoke plume. Vertical saw tooth patterns were carried out for the majority of the flight with the aircraft going from 50ft to just above the convective boundary layer where the visibility improved considerably.

The synoptic situation showed an, active, developing low pressure system moving into the Gulf with a light south westerly ahead of the cold front.

Table 2 summarises the runs and profiles made in A074 and table 3 shows the MCR configuration used for each part of the flight. (N.B. the number in brackets after any times refers to a DRS event mark and the cabin column refers to whether the aircraft was pressurised or not during the run or profile. P = pressurised, U = unpressurised and B implies both states occurred during the run.)

RUN	START	END	HEIGHT	HEADING	CABIN	COMMENTS
NO	(GMT)	(GMT)	(ft)	(deg)		,
	101310					Take off Bahrain
· P1	102508(2)	105317(9)	50-20,000ft	100	P	Initial profile (over 7/8 Ci very hazy
R1.1	111310(15)	112132(17)	50-8,000ft	100	В	Start of saw tooth prover sea - ascending
R1.2	112202(18)	113216(21)	8,000-50ft	100	. 0	Saw tooth descending
R1.3	113216(21)	115743(29)	50-20,000ft	100	В.	Saw tooth ascending
R2.1	121724(35)	122331(37)	50-8,000ft	250	В	New saw tooth profile sea - ascending
R2.2	122715(39)	123237(41)	8,000-3,000ft	250	ΰ.	descending
R2.3	123237(41)	123810(43)	3,000-8,000ft	250	Ū	ascending
R2.4	123905(44)	124812(45)	8,000-50ft	250	Ū	descending
R2.5	124812(45)	125702(49)	50-8,000ft	230	Ū	ascending, 7/8 Ci hazy
R2.6	125702(49)	130550(53)	8,000-50ft	260	Ū	descending
R2.7	130550(53)	131447(54)	50-8,000ft	260	Ū	ascending
R2.8	131447(54)	132052(57)	8,000-2,000ft	250-200	Ü	descending, ending land (desert)
R3.1	132127(58)	132709(60)	2,000-8,000ft	190	Ū	New saw tooth profile of desert - ascending
R3.2	132748(61)	133350(62)	8,000-2,000ft	185	Ū	descending
R4.1	133434(63)	134025(65)	2,000-8,000ft	220	Ū	New saw tooth profile of desert - ascending
R4.2	134046(66)	134701(68)	8,000-2,000ft	220	Ū	descending
R4.3	134713(70)	135323(73)	2,000-8,000ft	210	Ū	ascending
P2	135812(74)	140844(77)	8,000-18,000ft	040	P	Profile ascent, 7/8 Ci v
P3	140844(77)	142949(87)	18,000-50ft	040-350	В	Profile descent over sea
P4	142949(87)	144514(91)	50-16,000ft	350-325	В	Profile ascent over the
		150435				Land Bahrain .

Table 2: Summary of profiles and runs for flight A074

RUN NO.	MCR CONFIGURATION
P1	CBB, HBB 104531, CBB 105115 (LW CAL)
R1.1	Nad
R1.2	Nad, HBB 112459, Off 112500, Nad 112811
R1.3	HBB 113806, Zen 1150 (SW CAL), Zen 1153 (LW CAL)
R2.1	Zen
R2.2	HBB, Zen 123047
R2.3	Zen
R2.4	Nad
R2.5	Nad
R2.6	CBB
R2.7	Nad
R2.8	Nad .
R3.1	Nad
R3.2	CBB
R4.1	CBB
R4.2	HBB, Zen 134046
R4.3	Zen, CBB 134810, HBB 135137
P2	Nad, CBB 140411, HBB 140744
P3	HBB, Zen 141218, Nad 142542
P4	Nad, HBB 144227
Ned - Nadir	<u> </u>

Zen - Zenith

CBB - Cold Black Body .

HBB - Hot Black Body

LW CAL - Long Wave Calibration

Table 3: Summary of MCR configurations for flight A074

4. Flight A075 GULFEX 2 24th March 1991

This was the first GULFEX flight to be flown through a visibly thick smoke plume. A large proportion of the flight was carried out in the northern Gulf close to Kuwait (i.e. in the near field of the sources) where the surface wind was a light north westerly. However the higher you went the more the wind went round to a south westerly. The smoke was very thick and appeared to be coming mainly from a source south of Kuwait City. All the smoke was present below 14,000ft and at times there was some cumulus and altocumulus mixed in with it.

The synoptic situation showed a deep low pressure system over Jordan, slowly moving east. The associated cold front had cleared through Kuwait and Bahrain overnight and had now become slow moving over the southern Gulf. Cloud from the front remained over the central Gulf.

Tables 4, 5, 6 and 7 summarize the runs and profiles, CCN counter operations, MCR configurations and bottle samples respectively for this flight.

NO	RUN	START	END	HEIGHT	HEADING	CABIN	COMMENTS
D64040						CAPIL	COMMENTS
R1.1 073706(8) 074209(10) FL200 250 P Initial profile ascending out of plume	140		(GMI)	(16)	(deg)		<u> </u>
R1.1 073706(8) 074209(10) FL200 250 P Box pattern above plume	<u></u>						
R1.1 073706(8) 074209(10) FL200 250 P Box pattern above plume R1.2 074330(11) 074846(15) FL200 160 P Box pattern R1.3 075241(16) 075642(17) FL200 070 P Box pattern R1.4 075750(18) 080124(19) FL200 335 P Box pattern R1.5 080401(20) 082156(22) FL200 225 P Over plume, some Cu associated with it R1.6 082523(23) 083330(24) FL160 045-155 Over plume Profile descending out of plume R2.1 085910(31) 091100(32) 1000ft 340 B Run across plume R3.1 091458(33) 092312(35) 2000ft 140 U Run across plume R3.2 092627(36) 093232(37) FL360 320 U Rin across plume R3.4 094451(38) 094420(40) FL140 150 P Run across plume R3.5 095953(44) 100759(4) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume R4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending Clear above hazy below P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.7 124235(9) 125106(10) 50ft	P1	064814(1)	071411(5)	50ft-FL200	320-250	P	
R1.2	<u> </u>	<u> </u>					!
R1.3 075241(16) 075642(17) FL200 070 P Box pattern							
R1.4 075750(18) 080124(19) FL200 335 P Box pattern R1.5 080401(20) 082156(22) FL200 225 P Over plume, some Cu associated with it R1.6 082523(23) 083330(24) FL160 045-155 Over plume P2 083823(27) 085732(30) FL160-50ft 155-335 Profile descending out of plume R2.1 085910(31) 091100(32) 1000ft 340 B Run across plume under ScAc layer R3.1 091458(33) 092312(35) 2000ft 140 U Run across plume R3.2 092627(36) 093232(37) FL050 320 U Run across plume R3.3 094151(38) 094420(40) FL140 150 P Run across plume R3.4 094851(41) 095353(42) FL100 310 P Run across plume R4.1 105027(5) 110122(7) FL100 230 P Run across plume R4.1 105027(5) 110122(7)			<u> </u>			L	<u> </u>
R1.5 080401(20) 082156(22) FL200 225 P Over plume, some Cu associated with it							
Ciated with it R1.6 082523(23) 083330(24) FL160 045-155 Over plume P2 083823(27) 085732(30) FL160-50ft 155-335 Profile descending out of plume R2.1 085910(31) 091100(32) 1000ft 340 B Run across plume under ScAc layer R3.1 091458(33) 092312(35) 2000ft 140 U Run across plume R3.2 092627(36) 093232(37) FL050 320 U Run across plume R3.3 094151(38) 094420(40) FL140 150 P Run across plume R3.4 094851(41) 095336(42) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Frofile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles - ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending P4.7 124235(9) 125106(10) 50ft-FL080 150 P As	R1.4	075750(18)	080124(19)	FL200	335		<u> </u>
R1.6 082523(23) 083330(24) FL160 045-155 Over plume	R.1.5	080401(20)	082156(22)	FL200	225	P	Over plume, some Cu asso-
P2 083823(27) 085732(30) FL160-50ft 155-335 Profile descending out of plume R2.1 085910(31) 091100(32) 1000ft 340 B Run across plume under ScAc layer R3.1 091458(33) 092312(35) 2000ft 140 U Run across plume R3.2 092627(36) 093232(37) FL050 320 U Run across plume R3.3 094151(38) 094420(40) FL140 150 P Run across plume R3.4 094851(41) 095336(42) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles-ascending P4.2	<u>. </u>			<u> </u>	<u> </u>		ciated with it
R2.1 085910(31) 091100(32) 1000ft 340 B Run across plume under ScAc layer	R1.6	082523(23)	083330(24)	FL160	045-155	_	<u> </u>
R2.1 085910(31) 091100(32) 1000ft 340 B Run across plume under ScAc layer R3.1 091458(33) 092312(35) 2000ft 140 U Run across plume R3.2 092627(36) 093232(37) FL050 320 U Run across plume R3.3 094151(38) 094420(40) FL140 150 P Run across plume R3.4 094851(41) 095336(42) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles ascending P4.3 120739(21) 121541(2) 50ft-FL080 140 P <t< td=""><td>P2</td><td>083823(27)</td><td>085732(30)</td><td>FL160-50ft</td><td>155-335</td><td></td><td>Profile descending out of</td></t<>	P2	083823(27)	085732(30)	FL160-50ft	155-335		Profile descending out of
R3.1 091458(33) 092312(35) 2000ft 140 U Run across plume		<u>-</u>					plume
R3.1 091458(33) 092312(35) 2000ft 140 U Run across plume R3.2 092627(36) 093232(37) FL050 320 U Run across plume R3.3 094151(38) 094420(40) FL140 150 P Run across plume R3.4 094851(41) 095336(42) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles ascending P4.2 115910 120739(21) FL080-50ft 140 P Ascending clear above hazy below	R2.1	085910(31)	091100(32)	1000ft	340	B	Run across plume under
R3.2 092627(36) 093232(37) FL050 320 U Run across plume R3.3 094151(38) 094420(40) FL140 150 P Run across plume R3.4 094851(41) 095336(42) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 B Descending P4.4 121	\ '						ScAc layer
R3.3 094151(38) 094420(40) FL140 150 P Run across plume R3.4 094851(41) 095336(42) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending		091458(33)	092312(35)	2000ft	140		\
R3.4 094851(41) 095336(42) FL100 310 P Run across plume R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6	R3.2	092627(36)	093232(37)	FL050	320	Ū	Run across plume
R3.5 095953(44) 100759(4) FL100 230 P Run across plume R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles - ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7	R3.3	094151(38)	094420(40)	FL140	150	P	Run across plume
R4.1 105027(5) 110122(7) FL100 080-040 P Run through plume, mixed cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles - ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Ascending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	R3.4	094851(41)	095336(42)	FL100	310	P	Run across plume
Cloud and smoke R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume	R3.5	095953(44)	100759(4)	FL100	230	P	Run across plume
R4.2 110408(9) 111634(10) FL120 215-200 P Run through plume P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles - ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	R4.1	105027(5)	110122(7)	FL100	080-040	P	Run through plume, mixed
P3 112651(12) 114918(16) FL200-250ft 220-080 P Profile through plume P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles - ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending		, ,	, ,				cloud and smoke
P4.1 115205(18) 115910 1000ft-FL080 140 B Start of sawtooth profiles - ascending P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	R4.2	110408(9)	111634(10)	FL120	215-200	P	Run through plume
P4.2 115910 120739(21) FL080-50ft 140 B Descending	P3	112651(12)	114918(16)	FL200-250ft	220-080	P	Profile through plume
P4.2 115910 120739(21) FL080-50ft 140 B Descending P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	P4.1	115205(18)	115910	1000ft-FL080	140	В.	Start of sawtooth profiles -
P4.3 120739(21) 121541(2) 50ft-FL080 140 P Ascending, clear above hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending		, ,		•			ascending
hazy below P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	P4.2	115910	120739(21)	FL080-50ft	140	В	Descending
P4.4 121541(2) 122444(6) FL080-50ft 150 P Descending P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	P4.3	120739(21)	121541(2)	50ft-FL080	140	P	Ascending, clear above
P4.5 122444(6) 123346(7) 50ft-FL080 150 P Ascending P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending			. ` `				hazy below
P4.6 123346(7) 124235(9) FL080-50ft 150 P Descending P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	P4.4	121541(2)	122444(6)	FL080-50ft	150	P	La
P4.7 124235(9) 125106(10) 50ft-FL080 150 P Ascending	P4.5	122444(6)	123346(7)	50ft-FL080	150	P	Ascending
	P4.6	123346(7)	124235(9)	FL080-50ft	150	P	Descending
	P4.7	124235(9)	125106(10)	50ft-FL080	150	P	Ascending
			130305				Land Banrain

Table 4: Summary of profiles and runs for flight A075

ALLEVIATOR	ALLEVIATOR	HEIGHT	COMMENTS
START	END		
0645??	064640	1,000ft	transit
0657??	065957	FL160	P1
0713??	0714??	FL200	P1
072400	072709	FL200	Transit
074311	074519	FL200	R1.2
075442	075656	FL:200 -	R1.3
081455	081655	FL200	R1.5
082633	083026	FL160	Calibrate, R1.6
084606	084818	FL100-FL060	Calibrate, P2
085728	085932	50 FT	P2
0922			Cabin air possibly saturated
0942??	094410	FL140	R3.3
0959??	-100147.	FL100	Possibly saturated, R3.5
102238	102515	FL200	Transit
103301	103540	FL200	Transit
105027	105233	FL100	Saturated, R4.1
105847	110048	FL100	Saturated, R4.1
110840	111042	FL120	Saturated, R4.2
114006	114220	FL100-FL080	Calibrate, saturated, P3
124938	125204	FL070-FL080	P4.7

Table 5: Summary of CCN counter operations for flight A075

RUN NO.	MCR CONFIGURATION
P1	Nad, HBB 065425 (LW CAL), Nad 070606, CBB 071216 (LW CAL)
R1.1	Zen (SW CAL)
R1.2	Zen
R1.3	Zen
R1.4	Zen
R1.5	Zen
R1.6	Zen, CBB 083823 (LW CAL)
P2	CBB
R2.1	CBB
R3.1	CBB, Zen 092035
R3.2	Zen
R3.3	Zen
R3.4	НВВ
R3.5	Zen
R4.1	HBB, Zen 105106
R4.2	Zen
P3	Zen (SW CAL) .
P4.1	HBB, Nad 115421
P4.2	Nad
P4.3	Nad
P4.4	Nad
P4.5	Nad
P4.6	HBB
P4.7	НВВ
NT 1 NT 11	

Zen - Zenith

CBB - Cold Black Body

HBB - Hot Black Body

LW CAL - Long Wave Calibration

Table 6: Summary of MCR configurations for flight A075

BOTTLE	PURGE	FILL	FILL	HEIGHT	COMMENTS
NO.	START	START	END		
R17	105000	105400	105700	FL100	Run 4.1
R31	110000	110538	110800	FL120	Run 4.2

Table 7: Summary of bottle samples for flight A075

5. Flight A076 GULFEX 3 25th March 1991

On the climb out of Bahrain the aircraft pressurization failed and for the rest of the flight the aircraft was forced to remain below 8,000ft. This caused problems with the DRS overheating and failing especially near the beginning of the flight. A thick smoke plume was once again encountered in the northern part of the Gulf and some cloud was mixed in with it. The majority of the flight was spent in this area i.e. in the near field of the plume. At the end of the flight a transit to Riyadh was made to pick up some spare parts for the acu. The nephanalysis indicates that this transit was close to or in the plume from the fires.

The synoptic situation showed a very slack pressure area over the northern Gulf and a slow moving, complex frontal system over the southern Gulf.

Tables 8, 9, 10 and 11 summarize the runs and profiles, CCN counter operations, MCR configurations and bottle samples respectively for this flight.

RUN NO	START (GMT)	END (GMT)	HEIGHT (ft)	HEADING (deg)	CABIN	COMMENTS
	064230					Take off Bahrain
R1.1	082934(1)	084224(2)	FL080	150	В	Run through plume
P1	084300(3)	085838(7)	FL080-50ft	225-45	·B	Profile through plume de- scending, very dark at times
P2	090154(10)	091527(20)	100ft-FL080	. 325	В	Profile through plume ascending
R2	095741(21)	101144(22)	FL060	150	В	Run through plume
R3	101708(24)	103122(25)	FL060	280	В	Run through plume
R4	103314(27)	105045(30)	FL060	075	В	Run through plume, high SO2 values
R5	110308(34)	112007(37)	FL080	140-205	В	Run through plume
		123612				Land Riyadh ACU U/S

Table 8: Summary of profiles and runs for flight A076.

ALLEVIATOR START	ALLEVIATOR END	HEIGHT	COMMENTS
0649??	0652??	FL080-FL100	Transit
0823		FL080	Cabin air
0830			Cabin air
0840			Saturated, cabin air
0848			Cabin air
0855			Cabin air
0904			Cabin air
1104			Cabin air
1112			Cabin air
112924	113104	FL080	Transit
114117	114425	FL080	Transit
115312	1155??	FL080	Transit
120431	120635	FL080	Transit

Table 9: Summary of CCN counter operations for flight A076

RUN NO.	MCR CONFIGURATION
R1.1	CBB, Zen
P1	Zen, HBB 0849, Nad 085647
P2	Zen.
R.2	Nad
R3	Zen
R4	HBB, Nad 103433, CBB 104635
R.5	СВВ

Zen - Zenith

CBB - Cold Black Body

HBB - Hot Black Body

LW CAL - Long Wave Calibration

Table 10: Summary of MCR configurations for flight A076

BOTTLE	PURGE	FILL	FILL	HEIGHT	COMMENTS
NO.	START	START	END		
R34	073300	073500	073800	FL080	No run Number
R03	075000	080200	.080600	FL080	•
R36	100100	102400	102600	FL060	•
R19	102900	104000	104200	FL060	SOx 500 increasing, 03 50
R06	110640	111545	111838	FL080	SOx 30, 03 62
R16	120339	120848	120913	FL080	SO2 20, 03 16, NOx 0, Transit to Riyadh

Table 11: Summary of bottle samples for flight A076

6. Flight A077 GULFEX 4 26th March 1991

For the first time during the detachment the surface winds were blowing down the Gulf and a visible plume could be seen from Kuwait to Bahrain over the sea. A long downwind run underneath the centre of the plume was carried out early in the flight. Unfortunately thunderstorms, associated with a 500mb trough and medium level instability, developed from midday onwards and these were too severe to fly through so flying through the plume was restricted to the northern part of the Gulf where the cloud cleared. Here the plume was very thick and dark and at times the visibility was nil. The saw tooth profiles at the end of the sortie along the Saudi Arabian coast from Kuwait showed that the main plume quite quickly moved offshore away from Kuwait but a thinner plume at a much lower altitude moving into Saudi Arabia was encountered as Bahrain was approached. During this flight measurements of the near and intermediate field were made.

The synoptic situation showed an upper trough to the west of the Gulf and thunderstorms were breaking out ahead of this.

Tables 12, 13, 14 and 15 summarize the MCR configurations, runs and profiles, CCN counter operations, and bottle samples respectively for this flight.

RUN NO.	MCR CONFIGURATION
R1.1	Zen (SW CAL)
R1.2	Zen
P1	Zen, HBB 080254 (LW CAL), CBB (LW CAL)
P2	Nad
R2	Nad, Zen 091044, HBB 092207
P3	HBB
R3.1	Nad
R3.2	Nad
R.3.3	Nad
P4	HBB
R3.4	Nad
P5	CBB
R4.1	Nad, Zen 122207
R4.2	HBB, Zen 123849
R4.3	Zen
R4.4	Zen, HBB 132809 (LW CAL), Zen 133052
R4.5	Zen, Nad 134511
R5.1	Zen, HBB 140256, Nad 140354
R5.2	Nad, CBB 142407
R5.3	CBB, HBB 142833, Nad 143254

Nad - Nadir

Zen - Zenith

CBB - Cold Black Body

HBB - Hot Black Body

LW CAL - Long Wave Calibration

Table 12: Summary of MCR configurations for flight A077

RUN	START	END	HEIGHT	HEADING	CABIN	COMMENTS
NO	(GMT)	(GMT)	(ft)	(deg)	l	<u> </u>
	064255					Take off Bahrain
R1.1	074702(22)	075300(23)	FL200	150	P	Flying into sun above plume
R1.2	075401(24)	075958(25)	FL200	060	P	Across sun above plume
P1	080234(26)	082437(34)	FL200-1000ft	005-255	B	Descending profile outside of plume
P2	083453(38)	083623(39)	1000ft-50ft	240	Ţ.	Ascending profile under plume
R.2	083745(40)	092247	1000ft	130	Ū	Run under plume downwind
P3	092247(43)	093620(46)	1000ft-FL150	050	В	Ascending profile through plume
R3.1	094359(47)	100000(50)	2000ft	270-230	Ū	Run across wind under plume
Run 3.2	100157(52)	101700(53)	4000ft	Q05-035	Ū	Run across wind through plume
R3.3	102534(55)	104104(56)	FL060	230	В	Run across plume
P4	104240(57)	104906(58)	FL060-FL120	- 060	В	Ascending profile to above plume
R3.4	105150(59)	110555(63)	FL120	230	P	Run across wind above plume
P5	115350(67)	121618(70)	FL220-50ft	240-025	В	Descending profile through plume
R4.1	122014(72)	123458(74)	FL040	215	Ū	Run across wind under plume
R4.2	123759(75)	125858(77)	FL070	025	บ	Run across wind through plume
R4.3	125440(78)	130943(79)	FL055	210	Ü	Run across wind through plume - enter base, out of top
R4.4	131206(80)	133256(83)	FL085	025-210	P	Run across wind through plume - enter top, out of base
R4.5	133524(84)	134959(86)	FL120	210	P	Run across wind above plume
R5.1	140140(88)	141420(91)	FL120-50ft	135-150	P	Start of sawtooth profiles - descending
R5.2	141420(91)	142442(93)	50ft-FL120	150-140	P	Ascending
R5.3	142442(93)	143804(96)	FL120-50ft	145	P	Descending
		145545				Land Bahrain

Table 13: Summary of profiles and runs for flight A077

ALLEVIATOR	ALLEVIATOR	HEIGHT	COMMENTS
START	END		
0540??		Ground	Calibration, possibly saturated
0645??	064721	FL090-FL110	Transit
0657??	065910	FL180-FL200	Transit
070848	071045	FL200	Transit
071950	072150	FL200	Transit
073054	0733??	FL200	Transit
074250	074548	FL200	Transit
0757??	075910	FL200	R1.2
080907	081115	FL140	P1
0823			Saturated, cabin air
0832			Saturated, cabin air
0844			Saturated, cabin air
0853			Saturated, cabin air
090730			Saturated, cabin air
0925			Cabin air
102543	102751	FL060	R3.3
104759	•		Cabin air
105416	1058??	FL120	R3.4
120855	121032	FL075-FL060	saturated, P5
1229			Saturated, cabin air
1238			Saturated, cabin air
131559	131941	FL085	Saturated, R4.4
133041	133248	FL085	Saturated, R4.4
134100	134300	FL120	R4.5
140515	140732	FL085	Possibly saturated, R5.1
141750	142023	FL050-FL075	R5.2
143014	143222	FL070-FL050	R5.3

Table 14: Summary of CCN counter operations for flight A077

T COURT T	D710 GB			TTELOTIO	COLORDINA
BOTTLE	PURGE	FILL	FILL	HEIGHT	COMMENTS
NO.	START	START	END		
R37	094436	094645	094706	FL020	Run 3.1, SO2 28,
					NOx 0, 03 70
R.29	100122	101124	101248	FL040	Run 3.2, SO2 28,
					NOx 0, 03 60
R14	102113	103126	103311	FL060	Run 3.3, SO2 9,
-			ļ		NOx 0, 03 (23) while
[filling
R23	090301	090418	090552	FL010	Under plume, SO2
		· '	 		40, NOx 0, 03 60
G01	105304	105836	110127	FL120	SO2 -, NOx 0, 03 56
R08	111222	111417	112104	FL120	03 58, 12000ft
	• •				climbing
· H03	114205	-115006	115300	FL220	03 70
H05	122005	122530	122649	FL040	Below plume
R04	123000	123400	123628	FL040	In plume
G02	123800	124100	124300	FL070	•
R02	125500	130300	130500	FL055	•
R18	130600	130700	130950	FL050	•
R30	131300	131530	131700	FL085	•

Table 15: Summary of bottle samples for flight A077

7. Flight A078 GULFEX 5 28th March 1991

From altitude two distinct sources are visible; one to the south of Kuwait City and a much weaker one to the north of Kuwait City. The aim of this flight was to make measurements at several altitudes, in the near field, across the plume from the southern source in order to calculate its source strength. A very thick plume up to 16,000ft with multiple layers in the vertical was encountered. The main layer of the plume was capped by a thin layer of Ac. Significant downwind evolution of the plume was found in the sawtooth profiles back to Bahrain.

The synoptic situation showed a weak high pressure system building over saudi Arabia giving light north westerly winds over the surface of the Gulf. However, there was significant wind shear in the vertical.

Tables 16, 17, 18 and 19 summarize the runs and profiles, CCN counter operations, MCR configurations and bottle samples respectively for this flight.

RUN	START	END	HEIGHT	HEADING	CABIN	COMMENTS
NO	(GMT)	(GMT)	(ft)	(deg)	·	
	092215					Take off Bahrain
R1.1	102617(8)	103001(9)	FL240	215	P	Survey run
R1.2	103220(10)	103805(11)	FL240	030	P	Survey run
P1	104025(13)	111514(27)	FL240-50ft	220-030	Р.	Descending profile upwind of plume
R2	112943(30)	113735(32)	FL160	120-110	P	Run above plume
P2	113735(32)	115405(33)	FL160-100ft	105-115	В	Descending profile through plume
R3.1	120704(36)	122730(37)	4700ft	215	Ū	Run across wind through plume
R3.2	123124(38)	125103(39)	FL065	025	Ū	Run across wind through plume
R3.3	125226(40)	130934(41)	FL080	215-210	Ū	Run across wind through plume
R3.4	131554(43)	132726(45)	FL145	030	P	Run across wind through plume
R3.5	133057(46)	134734(47)	FL145	220	P	Run across wind through plume
Р3	135125(49)	140705(50)	FL145-50ft	030	B .	Descending profile through plume
R3.6	141001(53)	142710(58)	2000-5000ft	210	Ū	Run through plume
R3.7	142814(59)	143802(60)	FL050	030	Ŭ	Run across wind through plume
R4.1	144118(61)	145722(66)	1000ft-FL170	145	В	Start of sawtooth profile ascending
R4.2	145722(66)	151417(67)	FL170-1000ft	150	В	Descending
R4.3	151500(68)	153046(69)	1000ft-FL170	150	В	Ascending
		155000				Land Bahrain

Table 16: Summary of profiles and runs for flight A078

ALLEVIATOR	ALLEVIATOR	HEIGHT	COMMENTS
START	END	<u> </u>	
0533		Ground	Calibrate
0930??	093144	FL090-1000 FT	Transit
094438	094652	FL200-FL210	Transit
095655	095933	FL240	Transit
100820	101155	FL240	Transit
1024??	102629	FL240	Transit
103959	104208	FL240-FL220	P1
1052??	105538	FL150-FL100	P1
111112	111327	2000-700 FT	Possibly saturated, P1
113248	. 113431	FL160	R2
132430	132630	FL150	Saturated, R3.4
133603	133840	FL150	Calibrate, saturated, R3.5
145357	145555	FL140-FL160	R4.1
152728	152940	FL160-FL170	R4.3

Table 17: Summary of CCN counter operations for flight A078

RUN NO.	MCR CONFIGURATION
R1.1	Nad
R1.2	Nad
P1	HBB (LW CAL), CBB 105028 (LW CAL), HBB 111417
R.2	CBB, Nad 113013
P2	Nad
R3.1	Zen
R3.2	Zen
R3.3	Zen
R3.4	HBB, Nad 132024
R3.5	Nad
P3	НВВ
R3.6	Zen
R3.7	Zen
R4.1	HBB, Zen 144218
R4.2	Zen
R4.3	Zen

Zen - Zenith

CBB - Cold Black Body

HBB - Hot Black Body

LW CAL - Long Wave Calibration

Table 18: Summary of MCR configurations for flight A078

BOTTLE	PURGE	FILL	FILL	HEIGHT	COMMENTS
NO.	START	START	END		
R42	133040	133400	133800	FL145	In 'lofted' plume

Table 19: Summary of bottle samples for flight A078

8. Flight A079 GULFEX 6 29th March 1991

The main aim of this flight was to study the plume in its far field (1,000Km or more). An old plume (more than 3 days old) was found over central and southern Saudi Arabia. It was suprisingly high (15,000ft) and very thin but still visible. Several runs through and across it were made. It was found to be well mixed i.e the plume had top hat characteristics, and was covering a very large area.

The synoptic situation showed a low pressure area over southern Saudi Arabia and the winds at upper levels from the west.

Tables 20, 21, 22 and 23 summarize the MCR configurations, runs and profiles, CCN counter operations, and bottle samples respectively for this flight.

RUN NO.	MCR CONFIGURATION
P1	Nad, HBB 065004
P2.1	CBB (LW CAL)
P2.2	CBB, HBB 074734
P2.3	HBB,Nad 081733
R1.1	Nad, Zen 082834
R2.1	Zen, Nad 083828
R3.1	Nad
R4.1	HBB, CBB 085220
R5.1	HBB
P3	Zen, CBB 101943, HBB 102836
R6.1	CBB, Zen 110035, Nad 110736
R.7.1	Zen, Nad 113506
P4	Nad, Zen 120331
R8.1	Zen, Nad 121945
R9.1	Zen
R10.1	Zen
R11.1	Nad
R12.1	Nad
R13.1	Zen
P5.1	Zen (SW CAL), HBB 135648 (LW CAL)
P5.2	HBB (LW CAL)
P5.3	CBB (LW CAL)
P5.4	CBB, Nad 1420

Nad - Nadir

Zen - Zenith

CBB - Cold Black Body

HBB - Hot Black Body

LW CAL - Long Wave Calibration

Table 20: Summary of MCR configurations for flight A079

			·			
RUN	START	END	HEIGHT	HEADING	CABIN	COMMENTS
МО	(GMT)	(GMT)	(ft)	(deg)		
·	063255		<u> </u>			Take off Bahrain
P1	064714(6)	071450(14)	50ft-FL200	335-320	В	Profile through thin plume - ascending
P2.1	071739(15)	074624(18)	FL200-50ft	140-120	В	Start of sawtooth profile - descending
P2.2	074624(18)	080149(26)	50ft-FL130	120-130	В	Ascending
P2.3	080149(26)	082019(30)	FL130-50ft	130	В	Descending
R1.1	082505(31)	083000(33)	FL050	220-221	Ū	Run across wind
R2.1	083300(34)	084505(37)	FL080	040	Ū	Run across wind
R3.1	084636(38)	084854(39)	FL080	315	P	Run across wind
R4.1	085052(41)	085829(45)	FL080	135	P	Run across wind
R5.1	090324(46)	091825(51)	FL120	230	P	Run across wind
P3	101749(65)	103534(72)	FL150-1000ft	•	В	Descending profile - look- ing for plume
R6.1	105331(78)	110811(86)	150ft	095-110	Ū	Run looking for plume
R7.1	112929(89)	114501(97)	150ft-FL150	295-300	В	Run looking for plume
P4	115435(99)	120553(105)	FL170-120	135	. P	Descending profile through plume
R8.1	121148(106)	122051(108)	FL145	215	P	Run through plume
R9.1	122134(109)	123315(110)	FL145	150	P	Run through plume
R10.1	123428(111)	125519(112)	FL145	265	P	Run through plume
R11.1	125645(113)	131611(114)	FL145	145	P	Run through plume
R12.1	131729(115)	133504(116)	FL145	265	P	Run through plume, FSSP and PCASP anti-correlated
R13.1	133613(117)	135201(118)	FL145	150	• P	Run through plume
P5.1	135540	140258(126)	FL170-FL100	360	· P	Start of sawtooth profile - descending
P5.2	140326(127)	141009(128)	FL100-FL170	360	P	Ascending
P5.3	141027(129)	141741(131)	FL170-FL100	360	P	Descending
P5.4	141757(132)	142528(133)	FL100-FL170	360	P	Ascending
P5.5	142546(134)		FL160-FL100	005	P	Descending
P5.6	143308(136)	144025(137)	FL100-FL170	360	P	Ascending
P5.7	144046(138)		FL170-FL100	360	P	Descending
P5.8	144809(140)	145532(141)	Fl100-FL170	360	.P	Ascending
P5.9	145555(142)	150308(143)	Fl170-FL100	005	P	Descending
P5.10	150325(144)	151045(145)	FL100-FL170	005-340	P	Ascending
P5.11	151103(146)	(147)	FL160-FL100	340	P	Descending
				340	P	Ascending
	151838(148)	{149}	LPT000-LPT(1)	340		(ASCENDING
P5.12 P5.13	151838(148) 152626(150)	(149) 154121(151)	FL100-FL170 FL170-FL100	340-355	В	Descending

Table 21: Summary of profiles and runs for flight A079

ALLEVIATOR	ALLEVIATOR	HEIGHT	COMMENTS
START	END		
0533	<u> </u>	Ground	Calibration
070002	0701??	FL110	P1
071305	071529	FL197-FL200	P1
085412	085615	FL080	Possibly saturated, R4.1
090459	090659	FL120	R5.1
091528	091733	FL120	R5.1
0935??	0938??	FL230	Transit
094821	095056	FL230	Transit
100250	100455	FL170	Transit
101611	101800	FL150	P3
104500	104700	FL128-FL140	Transit
105907	110150	FL150	R6.1
111233	111426	FL150	Transit
112650	112844	FL150	Transit
113724	113924	FL150	Possibly saturated, R7.1
114826	115035	FL150	Possibly saturated, transit
115920	110122	FL135-FL150	Possibly saturated, P4
121038	121239	FL145	R8.1
121930	122130	FL145	R8.1
123036	- 123309	FL145	Possibly saturated, R9.1
124315	124521	FL145	Possibly saturated, R10.1
125502	125708	FL145	Possibly saturated, R10.1
130725	130925	FL145	Calibration, R11.1
131814	132024	FL145	Calibration, R12.1
133054	133300	FL145	R12.1
134233	134527	FL145	R13.1
· 135753	135949	FL150-FL130	Possibly saturated, P5.1
141535	141718	FL120-FL105	Possibly saturated, P5.4
142608	142700	FL170-FL160	Possibly saturated, P5.5
143607	143723	FL127-FL140	Possibly saturated, P5.6
145007	145126	FL120-FL140	Possibly saturated, P5.8
150324	150423	FL100-FL110	Possibly saturated, P5.10
151533	151642	FL125-FL120	Possibly saturated, P5.11
152409	152628	FL155-FL170	P5.13

Table 22: Summary of CCN counter operations for flight A079

BOTTLE	PURGE	FILL	FILL	HEIGHT	COMMENTS
NO.	START	START	END		
H06	081900	082700	082900	FL050	-
H12	083200	083800	084000	FL080	
R21	084900	084700	085500	FL080	In puff of smoke!, SO2 20, NOx 5, 03 60
SO2	090724	091200	091800	FL120	Run 5.1 SO2 —, NOx B/G, 03 60
R20	113000	113500	113700	FL150	•
SO3	114300	121100	121950	FL145	In plume
R40	122100	122440	122700	FL145	. =
R.27	130500	130937	131232	Fl145	-
R11	140720	141707	141935	FL125-FL100	Sawtooth through plume. 141500 two pumps
R24	142700	142802	142911		In FSSP layer; 4 fills
		143951	144042		
		145345	145840	,	
		145909·	145848		•
					<u> </u>

Table 23: Summary of bottle samples for flight A079

9. Flight A080 GULFEX 7 30th March

Once again the plume was being advected straight down the Gulf and this flight was undertaken to investigate its near field and intermediate field. Shallow saw tooth profiles were carried out through the initial plume rise from Kuwait and across wind runs were done at several heights in the near field and intermediate field. The plume was very thick and had a complex structure due to vertical wind shear. The flight pattern was restricted by the limitations of Iranian airspace.

The synoptic situation showed a weak upper trough moving into the Gulf quite rapidly which was producing a lot of high cloud and the surface winds were from a north westerly direction.

Tables 24, 25, 26 and 27 summarize the CCN counter operations, runs and profiles, MCR configurations and bottle samples respectively for this flight.

	•		
ALLEVIATOR	ALLEVIATOR	HEIGHT	COMMENTS
START	END		
051900	053000	Ground	Calibration with film
064506	064717	FL120-FL130	Transit
065630	065852	FL185-FL195	Transit
070757	070957	FL170	Transit
071911	072111	FL170	Transit
073050	073323	FL170	Transit
075309	075508	FL100-FL080	P1 ·
080348	080549	FL030-FL020	P1
083622	. 083728	FL075	R1.6
. 084250	084402	FL145-FL155	Possibly saturated, R1.6 .
112827	113029	FL140-FL150	P3
114008	114245	FL150	Transit
120214	120430	FL180	Transit
121337	121519	FL180	Transit
122220	122411	FL080	Completely saturated, R4.1
144650	144838	FL070-FL050	Saturated, R6.2
150136	150328	FL080-FL095	Saturated, R6.3
151206	151400	FL080-FL065	Saturated, R6.4
152230	152430	400 - 2000 FT	Saturated, R6.5
153302 .	153459	FL110-FL130	R6.5

Table 24: Summary of CCN counter operations for flight A080

						· · · · · · · · · · · · · · · · · · ·
RUN	START	END	HEIGHT	HEADING	CABIN	COMMENTS
NO	(GMT)	(GMT)	(ft)	(deg)		·
	063225					Take off Bahrain
P1	0764412(10)	080706(19)	FL170-1000ft	215-025	P	Descending profile outside
L			· ·			plume ·
R1.1	082025(21)	082227(25)	FL100-FL080	120	P	Starting sawtooth
		·				profiles through plume rise
						- descending
R1.2	082227(25)	082450(26)	FL080-FL100	120	P·	Ascending, 7/8 Cs and 3/8
						Cu
R1.3	082450(26)	082756(27)	FL100-FL070	100	P	Descending
R1.4	082756(27)	083013(28)	FL070-FL090	100	P	Ascending
R1.5_	083013(28)	083413(29)	FL090-FL055	100	P	Descending
R1.6	083413(29)	084441(30)	FL055-FL160	100	P	Ascending
R1.7	094441(30)	085500	FL160-FL060	100	P	Descending
P2	085717(33)	090322(34)	FL060-50ft	275	В	Descending profile through.
						plume
R2.1	091834(46)	094352(49)	1000ft	195	U	Run. downwind through
	, ,		•			plume
R3.1	094730(54)	095311(55)	250ft	115	. U	MARSS runs
R3.2	095629(57)	100520(60)	250ft	280-315	Ū	MARSS runs
R2.2	101300(64)	103118(66)	FL090-FL085	005	Ū	Run across wind through
	`	, ,				plume
R2.3	103335(67)	105101(71)	FL087	210-200	Ū	Run across wind through
		` ′				plume,7/8 Cs
R2.4	105418(73)	111046(75)	FL060	005	Ū	Run across wind through
		` ,				plume .
P3	111524(78)	-112928(79)	500ft-FL150	285-200	В	Ascending profile through
1	` ,		•	•]	plume
R4.1	122224(86)	123704(87)	FL080	095-110	P	Run close to top of plume
R4.2	123905(88)	124959(91)	FL065	100-130	Ū	Run close to top of plume
R5.1	125036(92)	125318(93)	FL065	025-350	Ū	Run across wind through
	` ,				_	plume
R5.2	125448(94)	130910(96)	FL065	220	U	Run across wind through
l		,			•	plume
P4	131439(98)	132934(102)	500ft-FL080	030	Ü	Ascending profile through
	` '	,		Ť	·	plume
R5.3	133500(104)	135134(105)	4800ft	210-200	Ū	Run across wind through
	`	,			l .	plume
R5.4	135355(106)	141318(113)	2000ft	015-025	Ū	Run close to base of plume
R5.5	141658(117)	143235(118)	FL'070	200-215	P	Run across wind through
	, , ,	,			_	plume, 7/8 CsAc
R6.1	143340(121)	144008(126)	FL070-FL130	105	P	Starting sawtooth profile -
	- ()	, , , , ,	,, _ ,, 		-	ascending
R6.2	144008(126)	145323(129)	F1130-500ft	105	P	Descending
R6.3	145323(129)	150700(132).	500ft-FL130	105	P	Ascending
R6.4	150700(132)	152229(135)	FL130-500ft	105-260	P	Descending
R6.5	152229(135)	153511(136)	500ft-FL130	260	P	Ascending
R6.6	15351(136)	154628(137)	FL130-4000ft	260		Descending
140.0	10001(130)	155504	T DIOC-GOOOT	200		
		100004			<u> </u>	Land Bahrain

Table 25: Summary of profiles and runs for flight A080

RUN NO.	MCR CONFIGURATION
P1	CBB, Zen 074843, Nad 074912
R1.1	CBB, Nad 082111
R1.2	Nad
R1.3	Nad
R1.4	Nad
R1.5	Nad
R1.6	Nad
P2	HBB
R2.1	Nad, Zen 094039, Nad 094151
R3.1	Nad
R3.2	Nad
R2.2	HBB, Nad 101359
R2.3	Nad
R2.4	CBB, HBB 110619 (LW CAL)
P3	CBB
R4.1	CBB
R4.2	CBB, Zen 124749
R4.3	HBB
R5.2	HBB, CBB 125613
P4	HBB -
R5.3	Nad
R5.4	HBB, occasionally to Zen
R5.5	СВВ
R6.1	CBB, HBB 143436 (LW CAL)
R6.2	HBB, Nad 145352
R6.2	Nad
Nad - Nadir	

Zen - Zenith

CBB - Cold Black Body

HBB - Hot Black Body

LW CAL - Long Wave Calibration

Table 26: Summary of MCR configurations for flight A080

	·				
BOTTLE	PURGE	FILL	FILL	HEIGHT	COMMENTS
ΝO.	START	START	END		
R22	102158	102253	102545	FL850	Run 2.2, in plume; point B
R07	103756	104512	101720	FL085	Run 2.3, SO2 50, NOx 2, 03 66 Higher 03 on one side of plume
R.26	125756	123127	123239	FL080	Run 4.1
S01	124344	125106	125500	FL065	Run 5.1, Point C, SO2 230, NOx 6, 03 62, Into Tehran airspace. (point C?)
R10	133900	143445	134647	FL048	Tenuous plume, SO2 100, NOx 5, 03 70
. R.05	145140	145346	145450	FL005-FL010	Profile up
R09	152140	152244	152351	FL005-FL015	SO2 10, NOx 5, 03 60

Table 27: Summary of bottle samples for flight A080

10. Flight A081 GULFEX 8 31st March 1991

The final GULFEX flight was carried out to investigate the plume originating from the sources to the north of Kuwait City and to find how it merged with the southern plume. The surface wind was blowing almost straight down the Saudi Arabian coast from Kuwait and the northern plume could easily be distinguished from the southern plume close to Kuwait. Several transects through this plume were carried out and it was found to be much weaker than the southern plume. The initial rise of the plume took it to 14,000ft. A zig zag track was then flown down the gulf to see how the two plumes merged. Away from the sources the plume was observed to be no higher than 10,000ft.

The synoptic situation showed high pressure to the west of the Gulf and the north westerly flow ahead of it was quite deep.

Tables 28, 29, 30 and 31 summarize the runs and profiles, CCN counter operations, MCR configurations and bottle samples respectively for this flight.

RUN	START	END	HEIGHT	HEADING	CABIN	COMMENTS
NO	(GMT)	(GMT)	· (ft)	(deg)		
	063335				-	Take off Bahrain
P1	075250(15)	081921(18)	FL200-500ft	190-015		Profile upwind of northern plume - descending
P2	083613(21)	084904(22)	FL140-1000ft	130	В	Ascending profile through plume
R1.1	090158(24)	091901(25)	FL085	225	Ū	Run across northern plume
R1.2	092100(27)	093631(32)	FL095	040-025	P	Run across northern plume
R1.3	094018(34)	100028(38)	FL085	220-315	В	Run across northern plume
R2.1	100212(40)	100719(42)	FL085-FL095	105	В	Run below plume
R2.2	100719(42)	102600(43)	FL095	180	Ρ.	Start zig zag through plume, high PCASP values
R.2.3	102717(44)	104414(49)	FL095	065	P	Run through plumes (northern and southern)
R2.4	104537(50)	110133(53)	FL095	205	P	Run through plumes, Ac above
R2.5	110246(54)	111359(55)	FL095	070	P	Run through plumes
R2.6	111541(56)	113001(58)	F1095	205	P	Run through plumes
R2.7	113121(59)	114427(60)	FL095	070	P	Run through plumes
R2.8	114557(61)	120101(66)	FL095	220	P	Run through plumes
		121535				Land Bahrain

Table 28: Summary of profiles and runs for flight A081

ALLEVIATOR	ALLEVIATOR	HEIGHT	COMMENTS
START	END		
0410		Ground	Calibration
064121	064315	FL090-FL105	Transit
065208	065410	FL180-FL190	Transit
070300	070500	FL200	Calibrate, transit
072043	072247	FL200	Transit
073242	073428	FL200	Transit
074305	074513	FL200	Transit
080720	080900	FL080-FL065	P1
081745	081938	FL015-500 FT	P1
092350	092518	FL095	Saturated, R1.2
100608	100819	FL095	Possibly saturated, R2.1
102100	102319	FL095	Completely saturated, R2.2
103758	103958	FL095	Saturated, R2.3
104958	105210	FL095	Saturated, R2.4
112729	112929.	FL095	Saturated, R2.6
113848	114048	FL095	Saturated, R2.7
115050	115238	FL095	Saturated, R2.8
120022	120240	FL095	R2.8

Table 29: Summary of CCN counter operations for flight A081

RUN NO.	MCR CONFIGURATION
P1	CBB
P2	HBB -
R1.1	Nad .
R1.2	Nad, Zen 092738
R1.3	CBB, Nad, Zen 095112
R2.1	HBB, Zen 100322
R2.2	Zen
R2.3	Zen, Nad 103055
R2.4	Nad
R2.5	Nad
R.2.6	Nad, Zen 112144
R2.7	Nad
R.2.8	Zen, HBB 115413 (LW CAL), CBB

Nad - Nadir

Zen - Zenith

CBB - Cold Black Body

HBB - Hot Black Body

LW CAL - Long Wave Calibration

SW Cal - Short Wave Calibration

Table 30: Summary of MCR configurations for flight A081

BOTTLE	PURGE	FILL	FILL	HEIGHT	COMMENTS
NO.	START	START	END	<u> </u>	
R01	090856	090956	091120	FL085	•
R12	092300 ·	092614	092755	FL095	
R28	094316	094500	094650	FL085	•
R25	095430	095530	095723	FL084	•
H04	102147	102200	102340	FL095	
R15	115400	111054	111310	FL095	SO2 40, NOx 5, 03 70

Table 31: Summary of bottle samples for flight A081

11. Bottle samples - flight cross reference table.

BOTTLE	FLIGHT
NUMBER	NUMBER
G01	A077
G02	A077
H03	A077
H04	A081
H05	A077
H06	A079
H12	A079
R01	A081
R02	A077
R03	A076
R04	A077
R.05	A080
R.06	A076
R07	A080
R.08	A077
R09	A080
R10	A080
R11	A079
R12	A081
R14	A077
R.15	A081
R16	A076
R17	A075
R18	A077
R19	A076
R.20	A079
R21	A079
R22	A080
R23	A077
R24	A079
R.25	A081
R26	A080
.R27	A079
R.28	A081
R29	A077
R.30	A077
R31_	A075
R34	A076
R36	A076
R37	A077
R40	A079
R42	A078
S01	A080
S02	A079
S03	A079
200	TO12

Table 32: Summary of bottle samples for each flight.

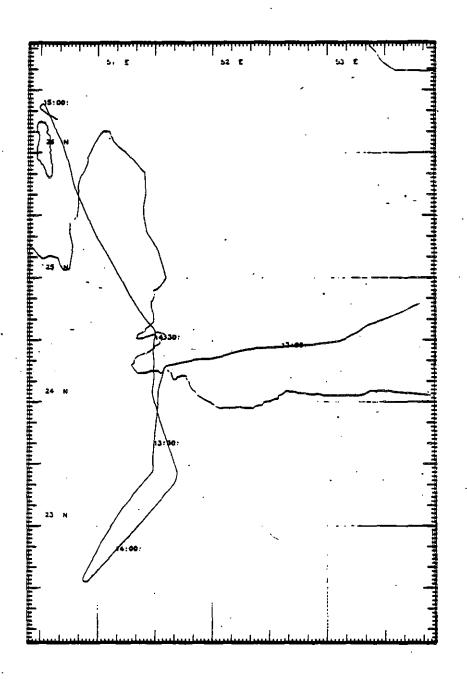
SUMMARY OF FILTERS USED DURING GULFEX

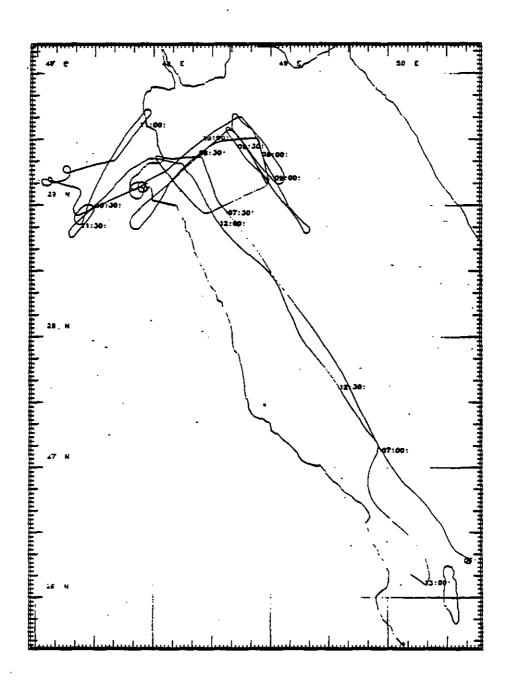
Note - all volumes are as indicated by meter and require a pressure correction.

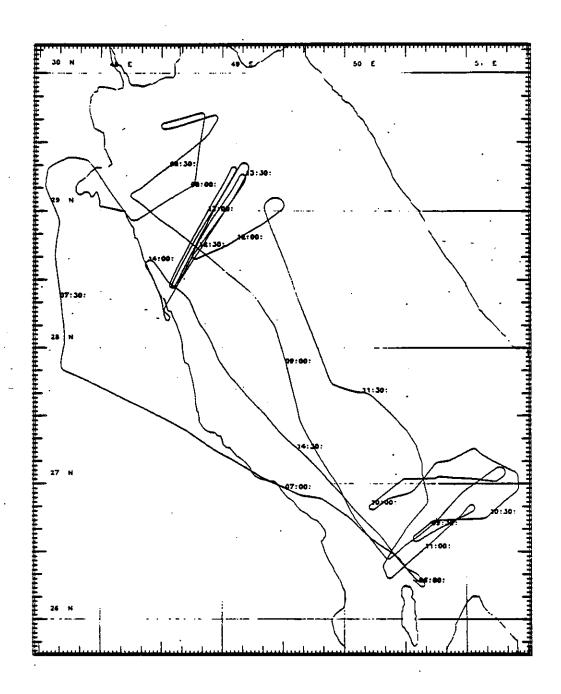
FILTER NO	FLIGHT	HEIGHT FT	TIHES GHT	M3 Noruhe	PUHE RAH		\1 DI		Babs 10-4 m-1	Bscat	Ho 	Dist source		.YSI8
					OP 	TICA	L F1	LTERS						
FILTER NO	*LIGHT	HEIGHT FT	TIHES GHT	NOT THE	PUMP	LDG	/I	_	Babs 10-4 m-1	Bacat	W o	Dist source		.YS15
Opex 6	74		130456-132600	1.01	6 P	L	. 21	0.022	0.2	0.4	0.0	. 700	, _	
Opex 7		Bla										_		
Opex &	75	. 2000	091400-092200					0.022		1.4	0.74	60	-	
Opex 9	75	10,000	100050-100750					0.08		- •	_ `	60	WSI	
Opex10	75	10,000	105130-110130					0.11		-	-	30		(SEM)
Opexii	76	6000	100635-104230					0.173		3.2	0.73	60	WSI	
Opex12	77	4000 7000	100312~101737					0.051		1.3	0.65	300	-	
Opex15	77	7000	123840-125142	1.31				0.111		3.9	0.63	100		well
Opex13	78	5100	142200-143915		•			0.049		2.5	(0.86)	120	-	
Opex16	70	6500	123310-124519	0.56				0.123		3.2	0.6	130	HAF	WELL
Opex14	79	8000	083335-085833					0.018		0.7	(0.44)	500	-	
Opex17	79	12000-17000	113637-121550	3.09	2 P	L	.12	0.019	0.06	-	***	690	-	
Opexid	79	14500	123129-131335	0.63	5 R	Ł	. 03	0.016	0.04		-	700	_	
Opex19	79	14500	123129-131335	3.30	7 2	L	.06	0.017	0.05		-	700		(SEM)
Opex 20	80		143640-153300	3.70	5 P				0.3	••	-	250		
Opex21	0 G	6500	124355-130500	1.04	7 P	M	. 9 3	0.157	1.4	6.5	0.82	100	MARSS+	RYE(C)
Opex22	81	9500	103645-111740	(2.61)	8) R	L	-	0.010	0.05.		-	210		e e
Opex23	• 1	8 500-9500	0902441-093750	2.24	I, P	ĸ	.72	0.016	0.3	0.94	0.76	100	, HAR	WELL
,									•					
			•									•		
2 FILTERS -	MPTECH	•	•					- cı						
						u	gm-3	ug ug	m-3					
						_	_				4.4			
502-1	75	2000	091400-092200		_	6.	_	'			1'0	-	PTECH	
SO2-2	75	10,000	100050-100750	0.469	-	. 60					50		PTECH	
502-3	75	10,000	105130-110130	0.70		. 94					60		PTECH	
502-4	76	6000	100635-104230	1.00		13	_	9.6			70		PTECH	
WHAT-5	77	4000	100312-101737	0.683		11					32	-	PTECH	
so2-7	77	7000	123840-125142	1.31		33					10	-	PTECH	
502- 9	78	6500	123310-124519	0.56		10	_				12		PTECH	
so2-10	79	12000-17000	113637-121550	3.092		1.					65 70		PTECH	
502-11	79	14500	123129-131335	3.30		0.					35		PTECH	
502-12	•0	9500-11000	143640-153300	3.70		15 11					35 20		PTECH PTECH	
502-13	80	6500	124355-130500	1.047							15		PTECH	
502-16	80	9000	101353-110756			72		12.			20	-		
502-15	• 0	4750	133455-135155	0.050		45		•			70		PTECH	
so2-16	#1	8500	095627-102105	1, 19		28 33					70 25		PTECH PTECH	
SQ2-17	81	9500	103645-111740	2.61	8	3 3					. 23	U 11	E18CU	•
BLANK	41								1.02,1.07	ug				/ N

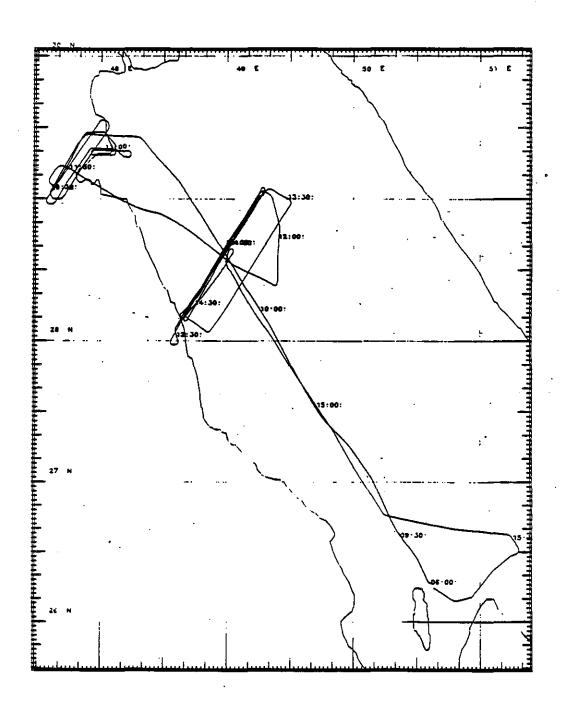
						•			MASS		•				
REF		FLT	HT (ft)	Time (GHT		Vo.	1 3) .		HASS (g) before	after	(+- '50) (nd) FOYDING	DEMSITY {ugm-3}	PCASP (ugm-3) ell/plume	Distance (KH)	COMMENTS
Opex	HW2	74	1500-800	0 130456-	132600	(1	.021	R	0.01550	1560	20	(20.0)		500	
Opex	HW3	75	2000	091400-	092200	(0	. 39)	R	0.01530	1534		•	•	100	_
Opex	NW4	76	6000	100635-	1042330		. 482}	R	0.01571	1574	25	(15.0)		50	WSL
Opex	NW5	81	9500	103645-	111740		2.618		0.01558	1554				160	-
Opex	NW7	75	10,000	100050~	100750	. (1	0.49)	1	0.01553	1547	, .	, •	•	50	_
Opex	HHS	75	12,000	111105-	111635		0.436		0.01587	1507	, .	•		50	_
Opex	NW10	80	9000	101353~	110756		2.452	P	0.01563	1574	11 110	39.0	73/120	100	HARWELL
Opez	HW11	80	4750	133445~	135155		0.850	P	0.01576	1541	50	59.0	29/50	180	WSL
Opex	NW12	80	6500	124355~	130500	()	1.05)	R	0.01524	1524	0 35	(33.0		180	RAE (SEM
Opex	NW15	41	8500	095627-	102105		1.499	P	0.01547	1553	70	47.0	37/75	50	RAE(C)
Blani	k s –	NW NW							0.01565 0.01593	1564		Repeat	table to b	etter than	1 20 ug.
Opex	HW1	77	7000 5500	123840- 125810-			0.071	R	0.09312	9265	-47(+9) •	10	0	WSL
Opez	HW2	79	10000-17000				6.472	P	0.09307	9289	-18(+30) 6.0	70	0	HARWELL
<u>Dlani</u>		HW3 HW4 HW7							0.09335 0.09200 0.09332	9263 9162 9282	-72 -46 -50	HEAN = -	56		<u>-</u>
QUART		DES	ERT RESEARC	H INSTITU	TE				 .	·		V			
c	uert	z 1	78	6500	123310-	124519	(0.	5671	R L				1	20	DRI
	uert		70	5100	142200-			080	P #					20	DRI
	uart		78	•	1453-		**	B L	ANK / CONTI	ROL **			_		
ā			79	8000	083335-	085833	1.	071	P M				5	00	DRI
	uart							0921	R L				.6	00	DRI
q			79 12	000-17000	113637-	121220	(3.	V 7 6							
Q Q	luart Juart Juart	x 5	79 12	000-17000 9000	113637-1 101353-1			1521		•				20	DRI
9	uart uart	z 5 z 6				110756	(2.		R H	•			1		DRI DRI
9	uart	z 5 z 6 z 7	80	9000	101353-	11075 6 135155	(2.	852) 850)	R H	,			1 2	20	

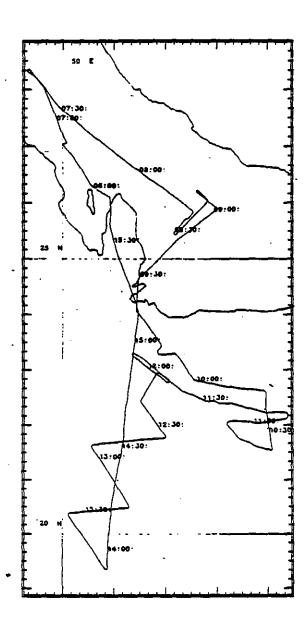
A074 23 March 1991



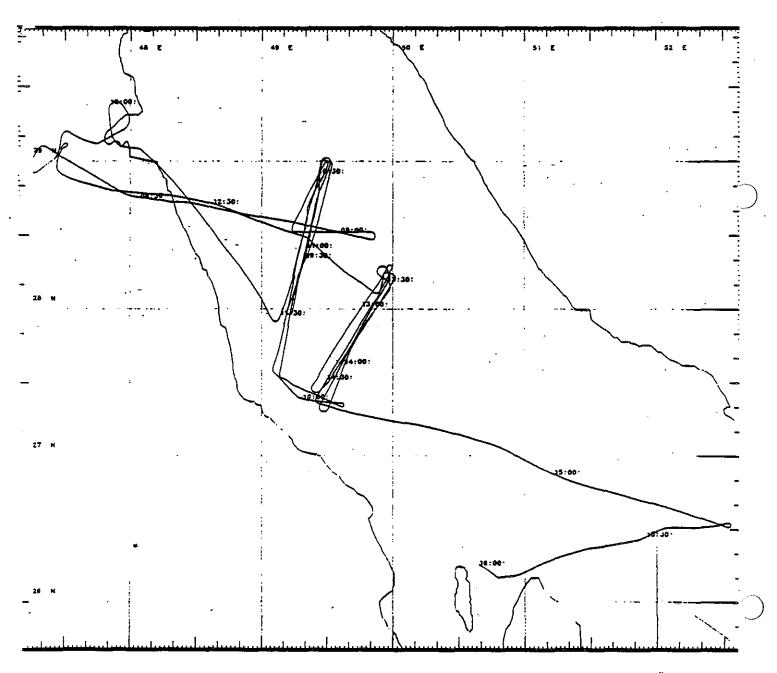




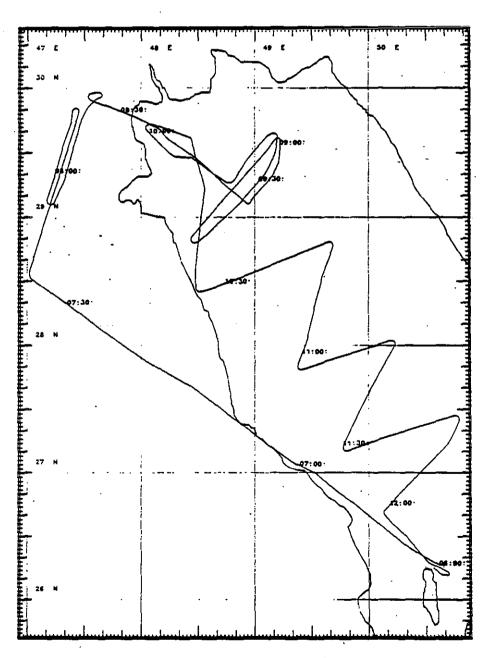


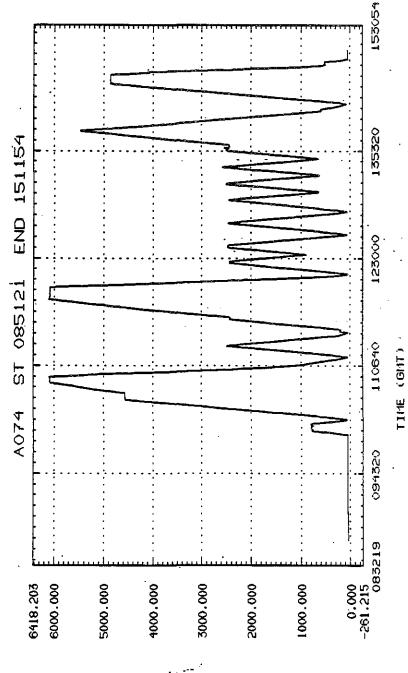


A080 30 March 1991



A081 31 March 1991

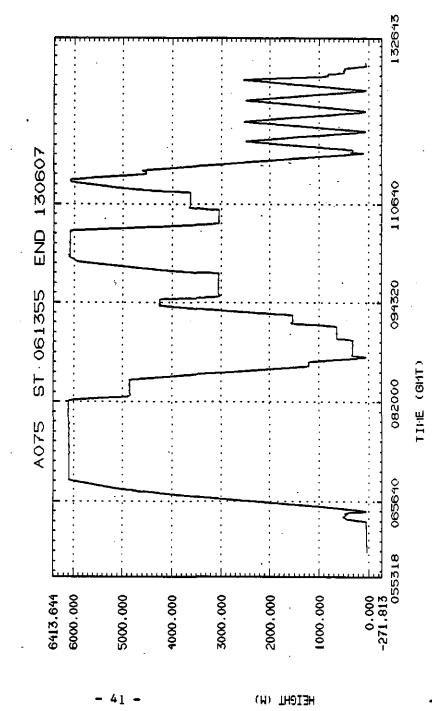




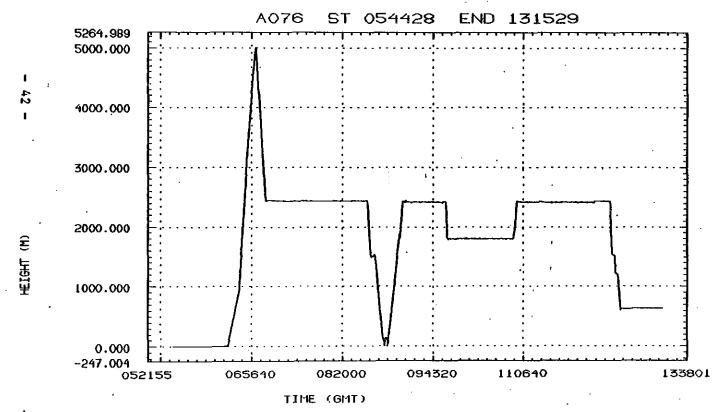
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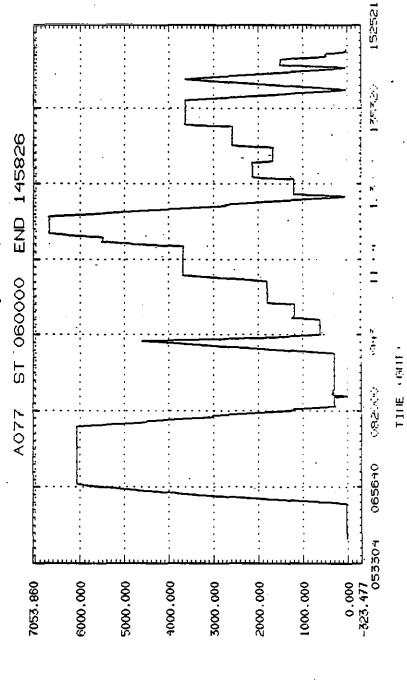
HE164T v 11ME



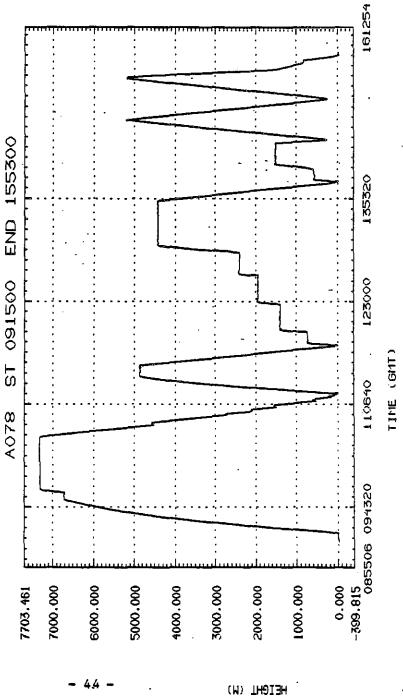
| HEIGHT v 11ME



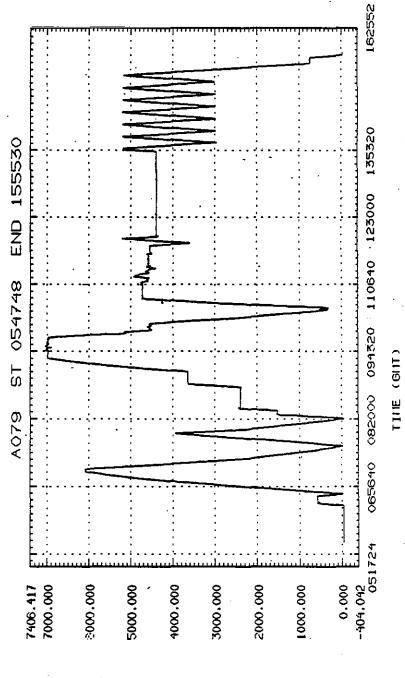
| HEIGHT v TIME



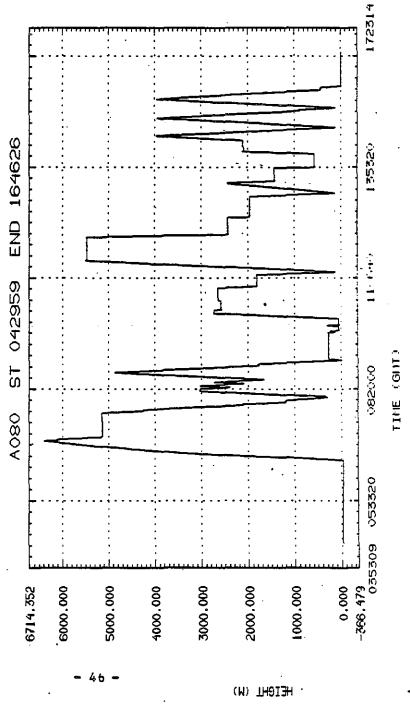
161941 v 119E



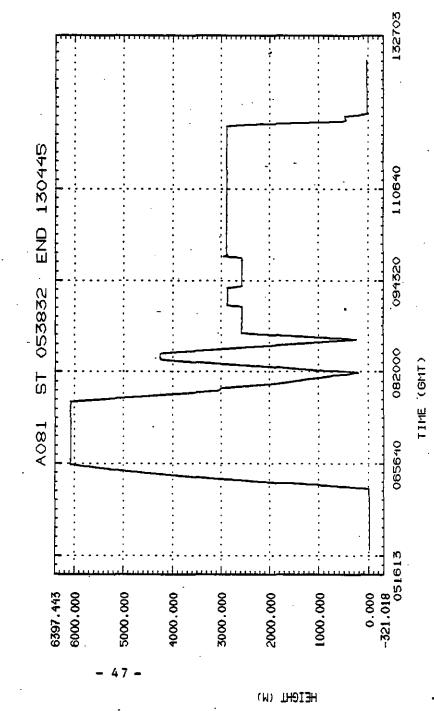
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HEIGHT . THE

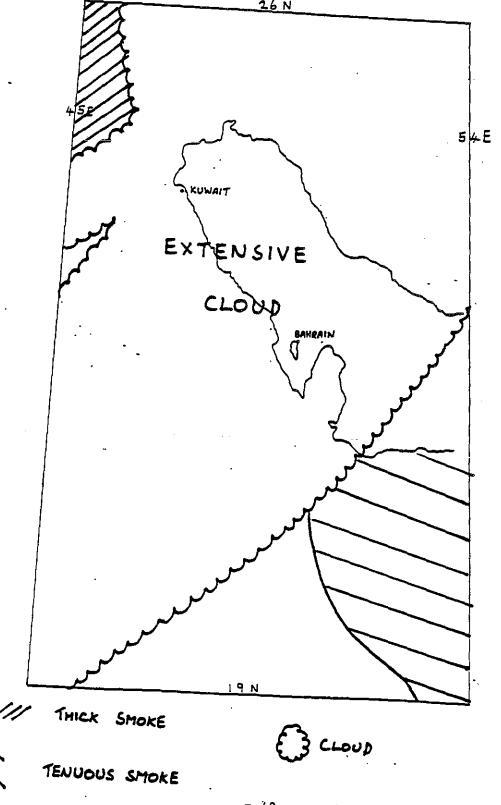


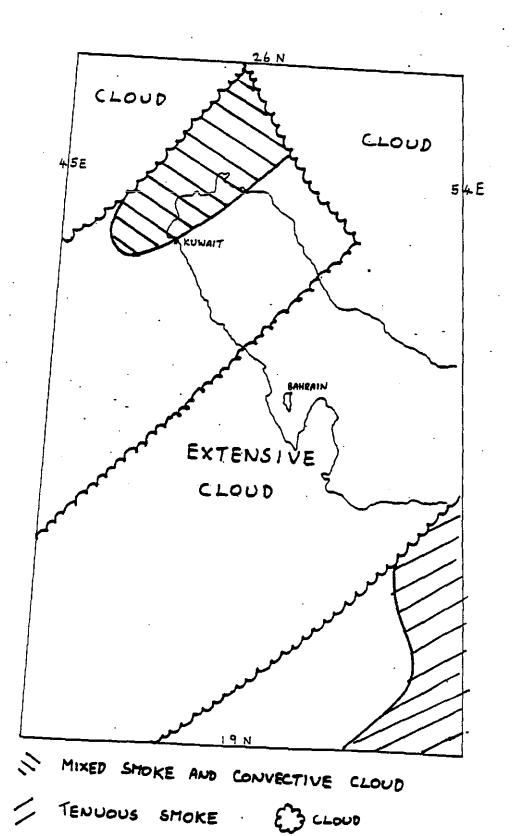
HEIGHT V THE

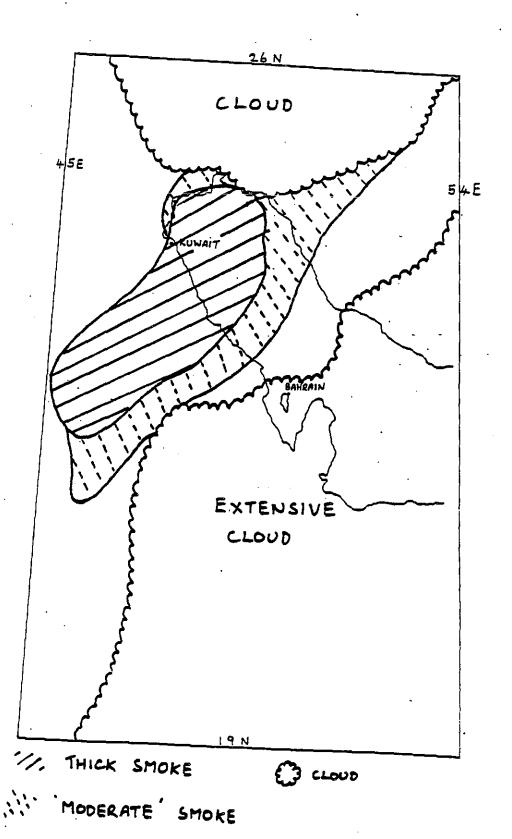


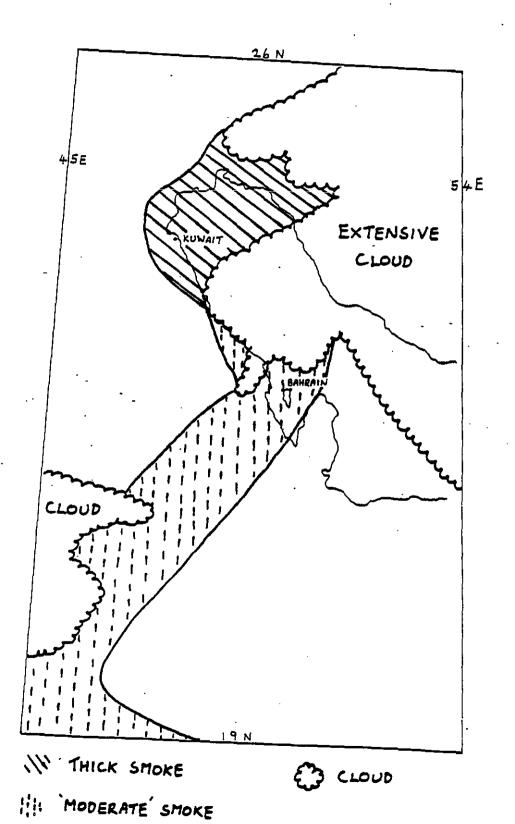
HEIGHT V THE

13:00z 23 March 1991 A074

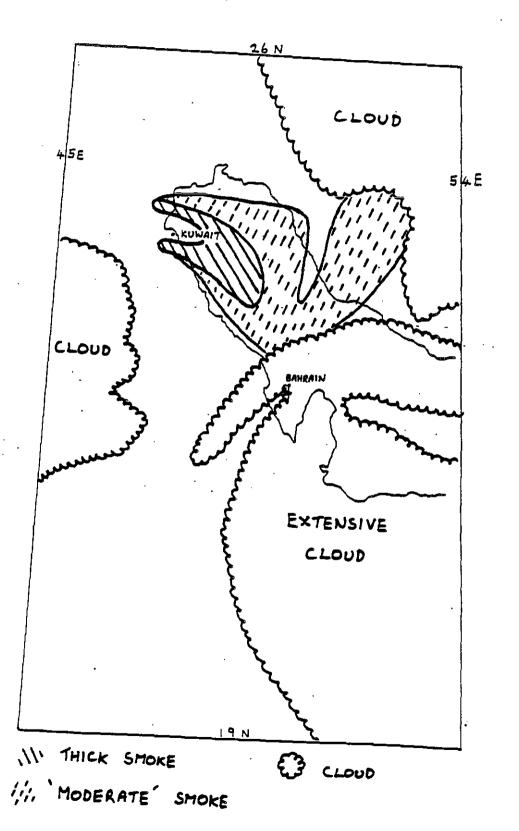


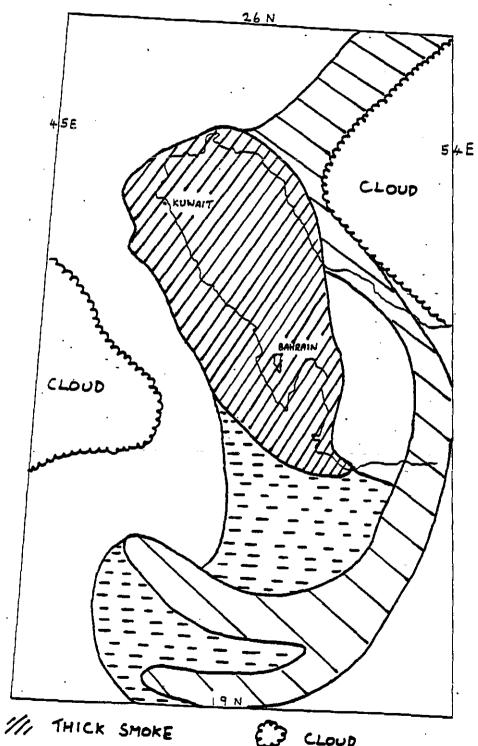






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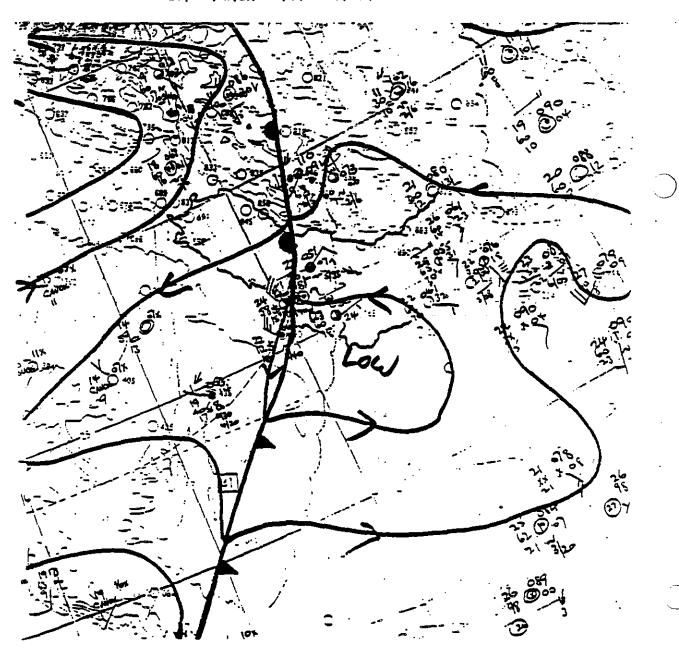




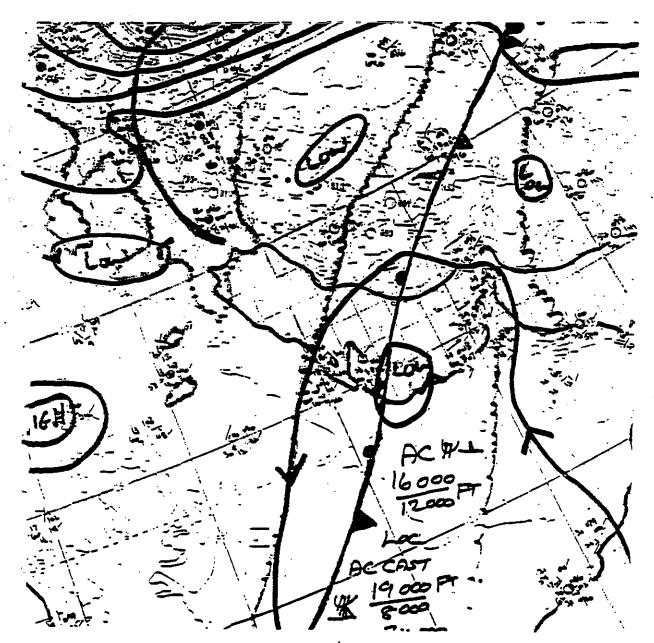
MODERATE' SMOKE --- TENUOUS SMOKE

16. Synoptic charts for each flight.

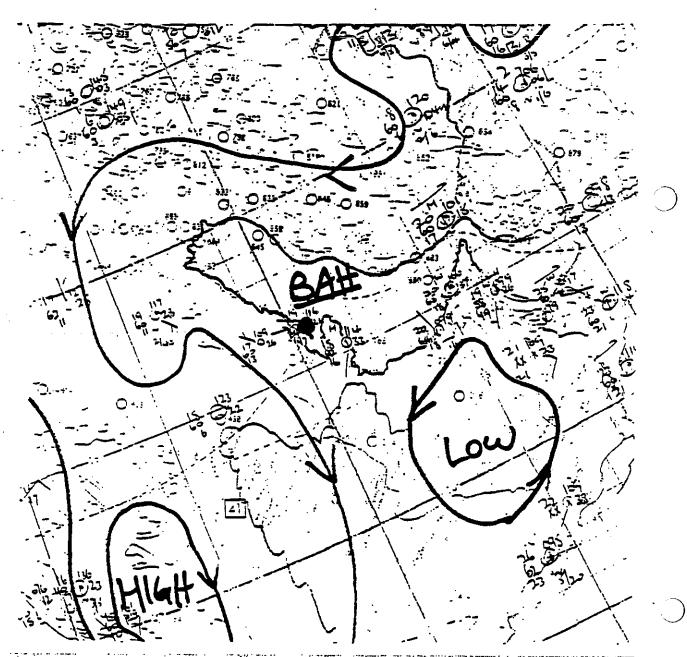
00012 24 MARCH 1991 A074



00012 25 MARCH 1991 ACTS



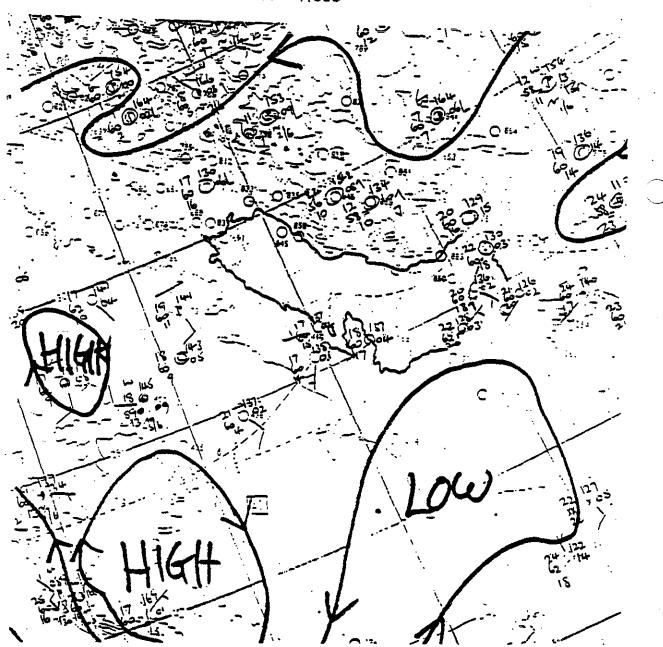
00012 28 MARCH 1991 A078



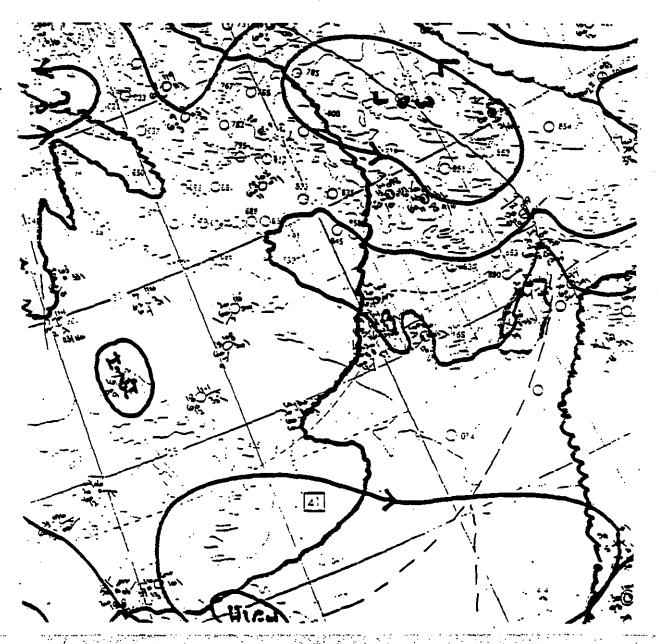
00012 29 MARCH 1991 A079



00012 30 MARCH 1991 AGEG



0001 Z 31 MARCH 1991 AOSI



17. Summary of videos recorded for each flight.

Tables 33 to 53 summarize what is seen on the video tapes from each of the flights. To view one of these tapes contact the aircraft manager on ext 5400.

TAPE COUNTER	TIME GMT	CAMERA	COMMENTS
0000	103040	FFC	
2115	111300	FFC	A/C at low point over sea
2811	113200	FFC	A/C at low point over sea
2839	113248		Left turn, almost into sun
3161	114231		Right turn
3459	1152		Coastline?
3674	115911		Left turn into sun
4198	121730		A/C low point over sea. Occasional ships .
	124700		? Visible to right
4999	124812		Low pass over sandbar - A/C low point
5421	130548		A/C low point over sea - into sun glint
5671	131635		End

Table 33: Summary of tape 105 for flight A074

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0000	131720	FFC	Turning left. Coastline
1601	134711		Low point
1879	135343		Left turn
3038	142517	•	Coastline A/C low
3193	143002		A/C low point. Islands
3270 .	143230		Coastline
4166	150242		Runway lights
4221	150440		Touchdown
4343	150903		End

Table 34: Summary of tape 106 for flight A074

TAPE COUNTER	TIME GMT	CAMERA	COMMENTS
0000	GWI	DFC	No clock set
0981	063944		17/0
1384	064806		A/C reflection - low point
1561	065200	FFC	A/O renection - low point
1922	070036	110	Into Sc.
2166	070645		Clear Sc.
3200	073611		Sharp left
3271	073825	DFC	Sea, broken small Cu.
3390	074210		Right turn. Small Cu surface not clear, Smoke
3501	074506	<u></u>	Fires visible More 074630
3673	075132	<u> </u>	Right turn
3718	075303	FFC	Plume ahead/below
3826	075644		Left turn
3960	080127	<u> </u>	Left turn. Flying above Cu tops. Minor turns
4487 .	082037		Right turn
4772	083139	DFC	Lught van
4814	083314	. 210	Left turn. Smoke below
4851	. 083434		Sea surface?
4876	083545	FFC	5-5-5-6-6-6-6-6-6-6-6-6-6-6-6-6-6-6-6-6
4958	083900	DFC	Sea surface, descending. Oil slick
5114	084522	FFC	Hazy, no horizon
	085030 ish		Left turn
5304	085318	DFC 2 sec	Waves
	0856		Descending
5406	085734		A/C low point
	0908		Heading into plume
	0911		Slow climbing left turn
5873	091751		End. No clear horizon - smoky

Table 35: Summary of tape 107 for flight A075

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
005	091839	FFC	Hazy
0093	091956	DFC	A/c shadow on sea and sun glint
0303	092314		Right turn. Prob 180deg
0603	092821	FFC	Just above cloud tops
0767	093118		Enter smoke/cloud
	0933 ish		Right turn
1030	093625		Horizon
1400	094411		Left turn to gloom below white cloud above dark line
			ahead
1737	095151		Approaching cloud sheet
1811	095337		Left turn
2070	1000		Very hazy. Near plume top
2243	100428	DFC 25secs	Cloud/smoke. Descending
2422	100916		Slow right turn. Smoke/cloud, clear above. Into sun
2634	101510		Climbing 360deg. Into sun again
· 2803	102000		Another 360deg
3248	103257		Turn right
3323	103519		Then left
3489	104040		Left again. Lots of Cu.
3621	104500		Another left
_	104845		Into cloud/plume
3785	105030		Boom just visible.
4026	105852	DFC	Smoke/cloud
4092	110115	FFC	Thick haze
	1110		Much of last 20m - dense smoke or white cloud
	1115		Suggestion of horizon
4516	111649		Climbing into clear
4626	112102		Right turn
4725	112454	DFC	Smoke/cloud still turning
4737	112521	FFC	
4902	113150		Right turn in 180deg then descending
5078	113858		Into plume. Dense smoke and white cloud
5327	114920		Level off-below plume base? then down again
5742	120710	DFC 12secs	Descent to waves low point 120746
5779	120849	· -	End

Table 36: Summary of tape 108 for flight A075

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		•
	120944	FFC	Hazy
0188	121231	DFC	Over sea. White spot on right - Fire/Flare Smoke/plume visible on FFC to right of boom at 1212 - Probable spot visible on DFC at 121320.
0276	121407	FFC	
0881	122446		A/c low point. Climb into haze then smoke
1664	124124		Descend back to smoke base to low point at - climb back to plume. Thick smoke and haze to end.
2326	125800		End

Table 37: Summary of tape 109 for flight A075

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		•
0000			
0124	062700	DFC	
0273	062919	FFC	Unstable picture
	04035		Airbus
1005	064229		Take off
1365	065000	·	Hazy horizon
1803	070000		Nice blue sky above haze
1852	070112		Clock zeroed. Clear horizon
1878		DFC	Waves. Clock setting
1940	070900	FFC	Clock restart. Hazy horizon
2139	071400		Cu and smoke ahead
2440	072200	_	First smoke wisps
2510	072353		Cu base just below
2689	072857	DFC 6sec	Uniform grey. A/c below Cu base
3065	074000		Smoke slowly getting denser
3127	.074152		Right turn. A/c below Cu base
3235	074515		Right turn.
3341	074836		Left turn. A/c below Cu base
3476	075300		Left turn.
3593	075654		Left turn. Some turns earlier - too hazy to time
3774	080300		Descending? Denser smoke. Turn follows - no horizon.
			0808 - Cu above.
3950	080908		Left Turn. 0816 - uniform grey - turn?
4190	081744		Left turn.
4254	082004	DFC 6sec	Streaky smoke
4263	082024		Left turn. Still below Cu base
4372	082427		Right turn.
4426	082630		Left turn. Faint horizon
4468	082805	DFC 23sec	Sea surface. Right turn
4648	083500		Denser, then clearing
4973	084751		Dense at 0845, horizon 0847. Left turn.
5047	085050	·	Exit bottom of plume
5174	085602	DFC	Sea
5237	085839		A/c low point. Shadow 1/3 Ac on screen
5274	090011	FFC	In right turn
5378	090934		Climb to plume base. Into plume 0910.
5663	091657		Plume base right turn
5710	091859		End

Table 38: Summary of tape 110 for flight A076

TAPE COUNTER	TIME GMT	CAMERA	COMMENTS
0004	0922590	FFC	Grey
0006	092257	DFC 14secs	Smoke. Turn about 0925 Right at 0926
0463	093015		Turn right Coastline
0560	093115		Right turn
0757	093529	DFC 50secs	Coastline/sunglint/smoke/turning right
0921	093838		Right
1191	094405	DFC 3secs	Smoke
1573	095228		Right turn
	095403	DFC 3secs	Smoke. Turning right?
1680	095500		Nose down. Left turn, coastline A/c below plume base
2284	101000		Grey - occasional Cu bases
2296	101022	DFC 8secs	Smoke
	101330 ish		Turn (no horizon)
2591	101824	DFC 6secs	Sea - turning?
•	102120	To:- FFC very bad	
2769	102331	DFC 8sec	Grey. FFC featureless and unstable picture
	102700	FFC	A/c in Rt turn.
2980	102946	DFC 32secs	Smoke. FFC picture clear. V. Hazy
3037	103130		Right turn. Just below Cu bases
3196	103621-	DFC 6secs	Grey
3250	103801	DFC 4secs	Grey
3482	104525	DFC	Sea, smoke wisps
3648	105057		Right turn
	1055		More wisps
3854	105800	FFC	Sea had faded on DFC. FFC grey
4183	110934	DFC 4secs	Grey. Blue appearing above
4489	112048	DFC	Sea surface - hazy. Smoke 1122 to
 -	112944	 	Coastline?
4774	113142	FFC	Horizon visible
4788	113216		Right turn above haze
5166	114732	DFC	Desert
5357	115526	FFC	Hazy
5741	121200		End

Table 39: Summary of tape 111 for flight A076

TAPE	TIME	CAMERA	COMMENTS	
COUNTER	GMT			
0000	121300	FFC	Hazy	
0066	121354	DFC	Desert	
0147	121511	FFC	Hazy	
0681	122410	DFC	Desert. Wadis. Descending	
0912	122830	FFC	Hazy ground detail	
	123100	·	Township. Turn right for Riyadh	
	1235		Runway in sight	
1612	124317		End.	

Table 40: Summary of tape 112 for flight A076

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0000	062722		Start
0655	063758		Take off Bahrain
2252	071325	DFC	
2657	072429	to FFC	Plume ahead
2983	073357	DFC	Over fires and smoke
3348	074518		Over coast
			Over plume
. 3810	.080033	FFC	
3934	080453	DFC	Oil slicks
3980	080630 ish		Ships and wakes
			oil slicks
4212	081456	FFC	Plume ahead
4295	081758	DFC	-
4592	082910	FFC	·
4690	083200	DFC	
	083623		Shadow or reflection
5065	084802	FFC	Below plume
5072	084818	DFC	
5161	085156	FFC	Small plume off rig
5176	085233	DFC	
5321	085838	FFC	Plume above
5486	090543	DFC	
5534	090748	FFC	Various ships and oil installations
5793	091910		

Table 41: Summary of tape 113 for flight A077

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0000	092010	FFC	Start recording
0122	092159	DFC	
0132	092207	FFC	
	0931	FFC	Into base plume/cloud
2269	100632	DFC 12secs	Sea
2908	102430	DFC 8secs	
3041	102828	FFC	Rain
3010	102919	DFC 7secs	
3638	104734	DFC	Cumulus below
. 3654	104809	FFC	
3858	105506	DFC	
1	110030		
4193	110657	FFC	Above plume/cumulus
4318	111129	DFC 9secs	Cloud tops
4354	111249	DFC	
4361	111303	FFC	
	1118	FFC	Thro' Cu/CB tops
5568	120140	DFC 46secs	
5736	120856	FFC	Into top of plume
5780	121054	FFC	Out of plume
5887	121542	DFC	Sea
5978	121945	FFC	Plume above
6043	122240	FFC	End tape

Table 42: Summary of tape 114 for flight A077

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT	i	
0005	122338	FFC	În plume - picture breakup. Dense plume
0746	123550		Right turn
0949	123945	DFC 20secs	Smoke tops
1291	124646	DFC 26secs	Grey, then out of plume base
1997	130305	DFC 8sec	Grey
2200	130814	DFC 13sec	Plume tops
2283	131026		Left turn at plume top
2300	131052	DFC	Little detail
2321	131125	FFC	Still turning. Above plume
2436	131433		Into plume, along top
2510	131635	DFC 13sec	Close to tops
2842	132600		Plume base
2892	132731		Right turn below plume base, into plume
3043	133200		Tops. Then above plume
3611	135000		Left turn, then right, thro' sun
3878	135906	•	Right turn, above plume
	140300		Left slightly
4026	140415	DFC 6sec	Little detail
4082 -	140616		Right turn into plume - quickly below plume
. 4277	141322	•	A/c low point. Climb thro' thin plume - thinning fast
4573	142430		Plume thicker, Cu Sc
4701	142924	DFC	peninsula, sea and smoke
4764	143152	FFC	Thickening plume - dusk. Descending
4914	143750		Low point behind a tanker
5284	145304		Right turn after flying thro' plume/cloud
5329	145500		Line-up
5412	145830		End

Table 43: Summary of tape 118 for flight A077

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0000		DFC	Concrete
0657	092140		Rolling concrete
0683	092219		Lift off
0813	092434	FFC	
3027	101852	DFC 25sec	Land
3109	102122	DFC 1min	Oil slick
3168	102314	DFC 1.25min	Oil slick
3226	102503	DFC	Land and oil. Town at 3268
3548	-		Kuwait City. Coastline 3594
3632			Oil slick edge
3760			Harbour
3832	104500		4003 - Fire
4134			Cultivation, town, coastline 4260
4323			Coastline, land A/C low turn
4435			Coastline, sea
4504			A/c shadow
4566	111145	FFC	•
4667			Smoke
4758	111917	DFC 3sec	
4768	·111938	DFC	Oil slicks
4808	•		Coastline, land
5058	1131		Fires
5125			Refinery - coastline, sea
5262	113943	-	Smoke
5283	114036	FFC	Smoke/cloud tops
5347			Enter plume
5434	114700		Increasing gloom, boom fades at 114715
5449	114738	DFC 10sec	Grey
5476	114838	DFC 10sec	Smoke still very thick
5488	114921	DFC 6sec	Clearance visible
5535	115124	DFC 20sec	Fire
5562			A/c below plume/low
5764	120130	DFC 6sec	
5859			Turn to dense bit, reenter plume
6050			Climbing into plume
6066	121506		End

Table 44: Summary of tape 121 for flight A078

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0000	121611	FFC	No boom visible
0029	121640	DFC 10sec	Grey
0061	1217		Boom silhouette. Boom clearly vis. (nice out-of-the-
			clag sequence)
0400	<u> </u>		Still heavy smoke
0505	. 122418	DFC 10sec	Smoke
0624	122624	DFC	Oil slicks
0638		<u></u> _	Coastline, land
0684		_	Army convoy
0688	122742	FFC	Heading back into smoke
1349			Thick, but boom still visible
1806			Plume edge, bank towards sunglint
1950		•	Back to plume
2409	130641	DFC 5sec	
2524			Climbing turn into sun, out of plume
2671	131358	DFC 15sec	Smoke tops
2836	131844	DFC 20sec	Smoke tops
2946			Down into plume - along plume top
3103	132647	DFC 10sec	Grey
3737			Turn thro' sun
3999	135628	DFC 10sec	Tops
4012			Into plume
4067	·	ļ	Very thick
4100	140008	-DFC 49sec	Some surface detail - below plume
4218	140422	DFC 24sec	Sea surface
4293			A/c low point
4338	140845	DFC 4sec	Turn into sun, sunglint
4452	141307	DFC 7sec	
4553			Bright line between sea/plume
4643			Climb to plume
4728			Plume top
4797	142626	DFC 5sec	
5062			Plume bottom
5222			Reenter plume
5440			Plume top
5503	145535	DFC 5sec	
5651			Into plume
5745			Boom just visible
5835			Boom barely visible
5894			Boom not visible, sunset
5932	151435		End

Table 45: Summary of tape 119 for flight A078

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT	[
0000	062332	FFC	taxi
0557	063220		Rolling
1300			Low level - waves!
1495	065100		Into plume
1890	070014		Plume top
1947	070142	DFC 5secs	
2454	071500		Left turn.
2504-2554			Spectacular lens flare
2819	072517		Into plume
2909	072753	DFC 5secs	
3064	073237	DFC 20secs	Sea surface
3107	073355		Leave plume
3305	074007	DFC 23secs	Sea surface
3404	074317	DFC	Sea surface - a/c shadow - sunglint
3499	074623		Shadow more than fills screen - low point
. 3575	074854	FFC	
3819	075706		Plume top
4004	080336		Into plume
4219	081117-		Bottom
4462	082019		Low point
4472	082040		Right turn
4516	082224		Plume base
4545	082327	DFC 17sec	Island visible on FFC - Right turn. Plume not clear
4724	083023		Left turn
4865			Island
5018			Plume visible again
5068	084410		Into plume top
5092	084508		Left turn
5184	084858		Left turn
5304	0854		Into plume.
5410	0854		Right turn.
5822	091634		End.

Table 46: Summary of tape 117 for flight A079

TAPE	COTO CTO	CAMERA	COMMENTS
l	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0005	091728	FFC	
0300	<u> </u>		Plume 'horizon' visible
0797	093040		Left turn
1177	093810		Left turn. Surface visible, blue sky - no smoke??
1580	094654		Right turn
1644	094824		Left turn
1804	095210		Right turn
2081	0959		Left
2415			Clouds getting nearer
2711	1016		A type 2 Cu to the left. A/c turns right
3195	103033	Dunes and rocks	
3348			A/c shadow
3372			Oxbow shapes
. 3400			A/c shadow. Beautiful curves
3629	104444	FFC	
3688	104642		Right turn
3774			Descending
3843	1052		Right turn
4000-4072			A/c drives round Cu
4296	110815		Left turn
4737	1125		Plume ahead? Right turn, then left
4931	113248		End

Table 47: Summary of tape 120 for flight A079

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0000	1215	DFC	Desert - relatively featureless after 120/3195
0548	1		Herringbone pattern
0686	122644	FFC	
0842	122939	DFC 6sec	
1025	123315		Right turn into sun
1158	123558	DFC	Dunes
1450	124214	FFC	Into sun
2006	125520		Turn left
2124	125820	DFC 25secs	Dunes
2650	131239	DFC	Dunes
2773	131610		Right turn
3000			Still dunes
3213	132933	FFC	Into sun
3239	133020	DFC 13secs	Ridges
3388	133506		Left turn
3772 ·	134753	DFC	Ridges/dunes
3949	1354	l	Left turn
3979	135503	FFC	
4652	142004	DFC	Dunes
- 4707	142210	FFC	
4900			Smoke visible
5130	143911	DFC 13sec	Dunes
5284	144537		Sunset
5473	145339	DFC 1min	Dunes
5816	150840		Last of the light - quite pretty
6030	151830		End

Table 48: Summary of tape 124 for flight A079

TAPE	TIME	CAMERA	COMMENTS		
COUNTER	GMT.	<u> </u>			
0000	062626	FFC	take off		
0414			Rolling		
0590			Smoke?		
2431	071714		Right turn		
2476	071825	DFC 11secs	(Land) Smoke on FFC to right		
	0-724		Distant smoke		
2933	073132	DFC	Well used desert track		
3011	073355		Right turn		
3021	073413	FFC 9secs	Smoke plumes bottom right		
	073430	DFC	Fires visible - Desert oil spill?		
3066	073535		Right turn, then left		
3163	073834	FFC	Line of small Cu		
3293	074240	DFC	Desert and tracks, smoke at left side		
3431	074706		Left turn. Odd formation 3480 074845		
3559	075118	FFC	Smoke at altitude above A/c		
3691	075546		Right turn below Cu into hazy smoke.		
3756	075758	DFC	Desert and cloud shadows, A/c descending		
3826	080025		Left turn - A/c shadow - multi tracked desert		
3930	080403	FFC	Fires ahead/right		
4009	080650	DFC	A/c shadow		
4012	0807		Turn right -		
4027	080731	FFC	towards fires		
	080825		Turn left - fires to left. Surface oil spill. Climbing		
	081308		Gentle right		
4296	081713		Right turn just over Cu tops - smoke ahead		
4430	082213	DFC 20sec			
<u>-</u>	0824		Nose down towards plume		
4608	0829		Just over plume		
	083030		Entered outer edges		
4711	0833		In thick bit		
	0835		Plume gloom		
4796	083620		Thickest - boom still visible (just)		
	0838		Plume gloom		
4887	0840		Exiting		
5012	0845		Clear but thick bit shead. Enter at 084620 ish		
	0849		Thickening plume gloom		
5183	0852		Exit below plume		
5252	085454		Left turn		
	0858		Below plume, fire to left. Thick bit ahead		
5432	090229		Enter thick bit. Structure visible - prob near top		
5517	090610	 	Right turn. Still near top. Plume gloom by 0909.		
	-		Between layers 0913-14		
			1-,		
5750	091625		Right turn back to PG. Layered 0923		

Table 49: Summary of tape 115 for flight A080

TAPE	TIME	CAMERA	COMMENTS		
COUNTER	GMT	CAMERICA	·		
0007	092456	FFC	Plume Gloom - close to top (0927)		
0842	093230	110	Left turn		
0624	0935		Layered		
0732	093700		Daycreu		
0750	093720	DFC			
1003	094234				
1005	094450		Turns, a touch of coastline		
1138	094521	 -	Oil spills by 0926.		
1273	094813	FFC	Overcast		
1348	094951	DFC	Shadow/reflection		
1512	095329	DFO	Climbing/turn. Good shadow 095415 to turn		
1564			and descend again		
1304	095440 1000		<u> </u>		
2005 •	100519		Good reflection, shadow wing, oil 1003		
		FFC	Right turn and climb		
2045	100620	FFC			
2313	101320		Into plume		
2508	101836		Into plume		
			Plume gloom by 1022. 1032.5 thick bit and camera		
			flare		
3178	103816	DFC 9secs	Grey		
3400	104520	_	Ac As becoming visible. Odd patch upper right		
			104940		
3575	105102		Right turn. Into plume 1053.5		
	1058		Plume Gloom - upper cloud still just visible, then goes.		
			Dense 1102		
3932	110312	DFC 4secs	White		
4084	110832	DFC 6secs	Light grey		
4184	111050		Right turn		
4220	111327	Video off until	NOT ON TAPE LOG		
4220	122441		71 minutes and its still Plume Gloom		
4455	123326		Upper cloud visible, close to top of plume		
	124011		Small Right turns		
	1243		Upper cloud		
	1250 ish		Left turn		
4963	125315		Left turn, still close to top of plume		
5375	131022		Cloud and sunglint. Left turn		
5554	131806	, 	End		

Table 50: Summary of tape 116 for flight A080

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT		
0003	131849	FFC	Gloomy
			Clear of smoke
0616	132844		Left turn and back in again
0769	133130		Right turns
1683	135030		Coastline
1734	:135142		Left turn Descend, sandband 1352.5
	140000		A/c low - some smoke
2271	140503	DFC 10sec	No detail
2571	141314		Left turns into plume gloom
3227	143237		Left turn over coastline
3409	143820	• .	White gloom for a change. Above cloud by 1440.
·	•		Cumulus
3884	145414	DFC 6sec	Sea surface. Night approacheth
4189	150500		Night
4277	150811		End

Table 51: Summary of tape 122 for flight A080

TAPE	TIME	CAMERA	COMMENTS			
COUNTER	GMT		<u></u>			
0001	062421	FFC	T/O			
	063200		Rolling			
0868	063900	-	Smoke			
1494	065200		Gradually clearing. Coastline just appearing			
	0659 ish		Over coast			
	0705		Getting thicker again			
2519	071732	DFC 14secs	Sand and tracks			
2719	072309	DFC	Sand and tracks			
2874	072740		Crossroads			
3099	073430		Right turn			
3107	44	FFC	Desert hase			
3249	073907	DFC	Much desert many tracks			
3468	074611	FFC	Smoke to right			
3617	0751505		Left turn. Hasy horizon			
3973	080320		Descending then turn left			
4002	080422	•	Fires ahead. Still turning			
4215	081200		Smoke ahead/right A/c descending			
	32 to 38		Patterns (odd) A/c shadow at 081844			
4434	082004 -		5 parallel "tracks"			
	· 14		More			
4491	082214		Fire at right A/c turns and climbs			
4594	082609	FFC	Fires ahead. Approaching plume from upwind			
4815	083446		Staying above plume until			
4908	083830		Enter plume. Hazy			
5113	084648	DFC	Sea, descending. Not very-low point 084910			
5195	085011	FFC	Hazy horizon. Climbing back to smoke			
5438	090027		Left turn			
5559	090540	DFC	Sea, some smoke			
5632	090851	FFC	Hazy			
5848	091824		Thicker bit			
5884	092000		End			

Table 52: Summary of tape XXX for flight A081

TAPE	TIME	CAMERA	COMMENTS
COUNTER	GMT	\	
0000	092033	FFC	Very hazy
0946	093634		Left turn. Thickish band at A/c level - last 5 mins
1346	094446		Getting thicker. Right turn
1424	094630	ļ	Level out - near plume base
1651	095134	DFC	sunglint
1866	095640	FFC	Greyish
2018	100024		Right turn. Straighten between layers cloud/smoke
2252	100627		Right turn
	102125		Denser bit
3526	104415		Right turn into camera flare
4031	110134		Left turn. Unmitigated grey
4370	111356		Right turn
4786	112956	•	Left turn.
	1145		Turning, No horizon - all grey
5535	120104		Left turn. Sea surface - brighter
	1207		Descending
5755	121042		Right turn
	1212		BRN approach and landing
5924	121815		End

Table 53: Summary of tape XXX for flight A081

18. Other Information Available

Standard plots have been produced for each flight and these are stored at MRF. For each run and profile the following parameters have been plotted:

- (a) temperature,
- (b) dew point,
- (c) TWC dew point,
- (d) total water.
- (e) northward wind component,
- (f) eastward wind component,
- (g) uncorrected vertical velocity,
- (h) corrected liquid water content,
- (i) total scattering coefficient,
- (j) ozone,
- (k) pressure height, ·
- (l) upper vis clear,
- (m) upper vis red,
- (n) lower vis clear,
- (o) lower vis red,
- (p) 50_2 ,
- (q) NO,
- (r) NO_x ,
- (s) FSSP concentration and
- (t) PCASP concentration.

Also for each profile a tephigram and hodograph has been plotted. To view and get more information on these contact Doug Johnson Ext 5734.



Meteorological Research Flight

Y46 Building

Dr Peter Hill
NOAA
Office of the Chief Scientist
Arabian Gulf Program Office
Herbert C Hoover Bldg, Room 1617M
14th & Constitution N.W.
Washington, D.C. 20230
U S A

Our Reference M/MRF/9/5/16

Date 10 October 1991

Dear Dr Hill,

Thank you for your fax of 8 October 91.

I enclose two reports:

(a) Our preliminary report of June 91 (which you already have a fax of)
(b) Our paper submitted to Nature.

They are essentially the same, although our estimates of emissions have been updated slightly in (b), which is also slightly shorter because of the page limitations in Nature.

I hope these are useful; I look forward to receiving a copy of the completed folder.

Yours sincerely,

Cest Jenkins

Dr G J Jenkins Head, Meteorological Research Flight

Royal Aerospace Establishment FARNBOROUGH Hants GU14 6TD UK Direct tel: 0252 370019 International: +44 252 370019 Fax: 0252 376588



Meteorological Office Meteorological Research Flight

Observations in March 1991 of the oil smoke plume from Kuwait by the UK Meteorological Office C-130 aircraft

Preliminary Report

June 1991

Meteorological Office Meteorological Research Flight RAE FARNBOROUGH GU14 6TD

Introduction

About 600 naturally pressurised oil wells were set alight in Kuwait in late February 1991, injecting massive quantities of smoke, sulphur dioxide (SO₂), unburnt hydrocarbons and nitrogen oxides (NO_x=NO+NO₂) into the atmosphere; estimates for the burning rate vary from 2 to 6 Mbarrels per day (MBd⁻¹). The main source areas, as indicated by ground surveys and infrared satellite images, are shown in figure 1. Assessments of the impact of the pollution from Kuwait have been made (those from the UK Meteorological Office and from the Hamburg group were reported in Nature, 30 May 1991) but there are large uncertainties due to the lack of information on the magnitude and the characteristics of the emissions and the resulting plume.

In order to investigate the nature of the plume, the chemical and particulate composition of the smoke, and its effect on visible and thermal radiation, the C-130 aircraft of the Meteorological Office Research Flight (MRF) was based in Bahrain during late March 1991 and from there made a total of 57h of observations in eight flights into and around the plume. This is a preliminary report of the the first airborne measurements of the plume both close to source (up to 200km) and in the far field (1000km from source).

Meteorology and plume behaviour

Based on a mixture of visual, photographic and in situ measurements over the period of the investigation, the typical appearance of the plume can be summarised as follows. Smoke from individual oil wells combined and continued to rise so that the plume top reached about 5000m; shallow convective clouds were observed to form on the windward edge of the plume on many

occasions. On the majority of days there was a marked directional wind shear in the vertical leading to differential advection of the plume with, for example, the lower part of the plume being transported southeastwards down the Gulf, with the upper part heading across the Gulf towards Iran.

There has been speculation that, as a result of radiative self heating aerosol may be carried upwards (often referred to as self-lofting) into the stratosphere, where its long lifetime would allow transport over considerable distances. Visual observations showed the plume top to be relatively well defined on most occasions, although sometimes with an uneven structure on the upper surface. On one or two occasions only a detached smoke layer was seen a few tens of metres above the main top. Over the eight days of measurements, the maximum height at which substantial aerosol enhancement was seen was 5km; at a distance of 120km from source. Therefore, based on these observations over a limited period we deduce that significant amounts of aerosol were not being lofted into the stratosphere, in agreement with recent assessments.

Near field measurements of particulates and chemistry

On 28 March 1991 a flight was undertaken to investigate the smoke plume in the near field of the source region in order to quantify the magnitude and character of the emissions from the southern oil well fires. Multiple vertical profiles and cross wind horizontal runs through the plume were executed approximately 120km downwind of the source (defined for the purposes of this report as 29°N, 48°E.) as shown in figure 1.

A laser scattering probe was used to measure smoke particle concentrations and deduce the

mass of smoke particles per unit volume (smoke density). Continuous measurements of SO₂, NO_x and ozone (O₃) were made from the C-130 and in addition, samples of polluted air were pumped into stainless steel flasks, which have subsequently been analysed for C₂-C₈ hydrocarbons.

Figure 2 shows data from a descending profile carried out alongwind through the centre of the plume. A significant vertical wind shear was present and the plume as indicated by the particulate and gaseous pollutants had a complex vertical structure, on this occasion made up of two main layers; an upper one with a top at 4,600m and base 3,600m and a much deeper and denser lower layer with a top at 3,200m and base 1,000m. The lower layer was capped by thin altocumulus cloud. Figure 2 a-d show the smoke density, the liquid water content and the wind speed and direction respectively. Figure 3 a-c show the SO_2 , O_3 and NO_x mixing ratios and the sum of the O_3 and the NO_x mixing ratios. From the close correspondence between the sum of NO_x and O_3 within the plume, and the O_3 profile obtained earlier in the flight outside the plume (figure 3d), it can be seen that $NO_x + O_3$ is better conserved than either NO_x or O_3 separately.

Seven horizontal, cross wind runs through the plume were carried out at heights between 1,420m, and 4,420m. Each run was over the same ground position as shown in figure 1. Figures 4 add show measurements from the run at 2,440m (near the centre of the lower plume) of smoke density, total scattering coefficient as measured by the integrating nephelometer, SO_2 , NO_x , and O_3 and the sum of NO_x and O_3 . A clearly defined plume 50km wide is seen. The highest concentrations found during this horizontal run were $500\mu \text{gm}^{-3}$ of smoke, 400ppbv of SO_2 and 40ppbv of NO_x . In both the vertical profiles and horizontal runs all the plume indicators (SO_2 ,

 NO_x , particulates, scattering coefficient) were highly correlated; this behaviour was consistently exhibited over several days of measurements close to the source, with the correlation coefficient between SO_2 and smoke density, for example, typically greater than 90%. (For comparison, maximum hourly concentrations in Central London are typically 300 ppbv for SO_2 and NO_x , and $100\mu gm^{-3}$ of black smoke. UK maximum ozone concentrations usually reach 150 ppb at some period in summertime.)

In the lower layer as seen in the profile and horizontal runs, NO_x and O_3 mixing ratios are negatively correlated while their sum shows little horizontal variation (figure 4d). The negative correlation between O_3 and NO_x is indicative of the reaction between O_3 and NO. This lack of horizontal variation indicates that there has been no detectable loss of O_3 either by reactions with smoke particles or in the conversion of SO_2 to sulphate. In the upper layer shown in figure 3c (also evident from higher level horizontal runs) it is clear that the negative correlation between NO_x and O_3 no longer exists, indicating that some degree of photochemical oxidant production has already been initiated by the ambient solar radiation.

Results of the hydrocarbon analysis of three flasks (out of a total of 44) filled in different parts of the plume are summarised in table 1. The maximum mixing ratios of benzene and toluene determined from the samples are lower than the corresponding mixing ratios in a sample of air taken beside a busy road in Bracknell, U.K. However, n-hexane mixing ratios in the flasks filled in the plume were substantially greater than in the Bracknell sample.

The flask which showed the highest mixing ratios of hydrocarbons of any of the flasks analysed (sample A) was filled at an altitude of 2600m as the C-130 penetrated the densest part of a

Species	Table 1: Species Sample A Sample B Sample C						
obectes	30 Ma			30 March 91		29 March 91	
	Mixing ethane		Mixing ethane		Mixing	ethane	
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	
·	(ppbv)		(ppbv)		(ppbv)		
ethane	25.111	1.000	5.440	1.000	1.330	1.000	
ethene	13.030	0.519	1.851	0.340	0.034	0.026	
propane	19.952	0.794	2.345	0.431	0.453	0.340	
propene	1.637	0.065	0.220	0.040	0.026	0.020	
benzene	1.057	0.042	0.215	0.040	0.044	0.033	
toluene	1.309	0.052	0.203	0.037	0.025	0.019	
n-hexane	5.052	0.201	0.409	0.075	0.013	0.010	
NMHC(T)	339.6	13.53	45.92	8.44	6.266	4.71	

smoke plume on the 30 March 1991, 120km from the source. A second flask filled on the same day (sample B) at an altitude of 1500m near the bottom of the plume was more typical of several of the polluted flask samples. Since hydrocarbons with very different life times, such as ethane and ethene, are found in similar proportions in both sample A and B it is likely that the lower mixing ratios in sample B are due to a dilution through turbulent mixing rather than chemical loss.

Far field measurements of particulates and chemistry

For several days at the end of March a low pressure system was present in the upper air to the north west of Kuwait. On 29 March 1991 satellite images showed smoke over the central deserts of Saudi Arabia some distance from Kuwait oriented roughly southwest-northeast and being advected to the northeast. The C-130 was deployed to make measurements in this area of smoke; its flight track is shown in figure 1. The O₃ mixing ratios and particle concentrations observed in a horizontal run through the area of smoke are shown in figure 5 a and b; smoke particle concentrations are enhanced by several hundred particles per cm³ and O₃ mixing ratios

are enhanced by 40-60ppby over the already high values in adjacent clear air.

It is likely that the enhanced ozone in this more distant plume is formed from ozone precursors released from the oil fires. In contrast to the hydrocarbon samples collected near the fires, the contents of a flask (sample C, table 1) filled in the smoke shows a different distribution of hydrocarbons. This sample still has relatively high mixing ratios of many of the longer lived hydrocarbons, such as ethane and propane, while the mixing ratios of the short lived hydrocarbons such as ethene and propene are substantially reduced. The mixing ratio of ethane in this sample compared with that in sample B, 120km from source, indicates that the plume dispersion has not been very efficient. The very low mixing ratios of the shorter lived species suggest that significant degradation through OH attack has taken place consistent with the enhanced ozone within the plume. Although the NO_x mixing ratios in the plume were below the limit of detection (5ppbv), the potential for further ozone production cannot be ruled out because mixing ratios of only several pptv are required to generate ozone. However the absence of many of the more reactive and therefore short lived hydrocarbons from the plume at this time means that any further ozone production will proceed at a much slower rate.

The observations of this mature area of smoke on 29 March suggests an interpretation of some of the clear air observations in the near field. During many of the vertical profiles made near the source region but out of the visible plume, ozone mixing ratios much greater than the normal free tropospheric background (30-40 ppbv) were encountered (e.g. figure 3d), associated with somewhat increased particle density. It is likely that the enhanced ozone mixing ratios observed in the clear air are due to precursor emissions several days earlier which have remained near, or returned to, the source area.

Morphology of smoke particles

Ambient air was passed through Nuclepore polycarbonate filters with a $0.4\mu m$ pore size projected about 0.4m from the aircraft skin on an extendable boom. Some of these filter samples were studied with a scanning electron microscope to determine the smoke particle morphology. Figure 6a shows a typical smoke particle from a filter exposed 180km from the source, on 30 March 1991. The smoke particles are composed of spherules having a mass mode diameter of approximately $0.1\mu m$ which form chains of hundreds in number and several microns in length. These chains are common features of oil smoke.

Particles on filters exposed over 1000km from Kuwait (figure 6b) have a different appearance to those from the near field; although the spherule size is similar in both cases the spherules in the far field are more likely to be closely packed into near-spherical clusters. This behaviour has been noted in laboratory experiments, in air aged at high humidity.

Estimates of the magnitude of emissions from the fires

Although it was not the original intention of the measurements to estimate the emissions from the fires, the series of multiple horizontal runs and vertical profiles through the plume carried out on two of the days allow such an estimate to be attempted. The magnitude of sulphur emissions was estimated by determining the flux of sulphur in the plume, calculated from the product of the sulphur concentration across a vertical crosswind plane through the plume and the wind component perpendicular to this plane. SO₂ measurements were used, together with

the winds measured by the aircraft.

For 28 March 1991, when the aircraft measurements captured essentially the entirety of the plume about 120km from the southern oilfields, we estimate the source strength of these fields to be 6 Mt yr⁻¹ of sulphur. As the oil has a known sulphur mass fraction an estimate of sulphur emissions will allow the total emissions from the oil well fires to be deduced. Assuming a value of 3.3% for the southern oilfields, this corresponds to an oil burning rate of 182 Mt yr⁻¹. We assume, based on previous estimates, that the southern oilfields account for 85% of the total burning rate; this implies a total rate of 214 Mt yr⁻¹ or 4.1 MBd⁻¹. A flux calculation on 30 March 1991 gives a similar burning rate. Because of the motion of the plume, and time taken to make the multiple passes through it (typically 3 hours), the plume sampling will not be instantaneous; it is considered subjectively that this and the complex structure of the plume will lead to errors in estimating the source strength of \pm 40%. Thus the range of uncertainty for the burning rate is 2.5-5.7 MBd⁻¹. A far larger number of passes through the plume, or the use of a lidar system able to make a two dimensional scan of the plume cross section, would be needed in order to narrow the uncertainties in this estimate.

Using the relationships between concentrations of various pollutants measured by the C-130, we can directly estimate the source strength of other constituents; these are shown in table 2. Carbon gas (le the sum of $CO + CO_2 + CH_4 + NMHC$) is the residual when calculated emissions of S, NO_x , and particulate carbon are subtracted from the total. Also shown in the table are estimates of emissions from three recently published assessments.

		Tabie 2:		
	This Study	Browning et al.4	Small ³	Bakan et al. ⁵
Component	Mt yr-1	Mt yr-1	Mt yr ⁻¹	Mt yr-1
Total Burn Rate	214	80	63	161
Carbon Gas	203	60	63	-
Fine Particulate Carbon	4.6†	5	5.8	16.1
Sulphur	6.1*	2	-	-
Nitrogen Oxides	0.24†	0.5	-	•

[†] Assuming the same emission factors for the southern and northern fires.

Effect of the smoke on radiation

The effect of the smoke plume on radiation is illustrated in figure 7, showing measurements taken during a horizontal run on 31 March 1991 through the centre of the plume at 2900m about 65km from source. The plume, with a top at 3600m and a base at 1700m, was being blown down the Gulf by winds at all levels from the northwest. The plume was well defined by the smoke density, and the aircraft flew just beyond the densest region before turning. The total shortwave (0.3-3 μ m) downwelling flux was reduced from its clear sky value of 800 Wm⁻² outside the plume to essentially zero in the centre, and associated changes were seen in the infrared and microwave regions.

Figure 7c shows the downward hemispheric infrared (4-50 μ m) fluxes measured by a pyrgeometer to be increased by 45 W m⁻² in the centre of the plume compared with that in clear air due to the increased emission from the smoke particles. At infrared wavelengths scattering due to the individual spherules will be negligible although the carbon chains may still scatter a significant amount of radiation.

Also plotted in figure 7c is the vertical downward radiance at 11.1 \(\mu \) measured by a multi-

^{*} Assuming a 1.5% sulphur content for the northern fields which contribute 15% overall to the emissions.

channel, narrow field of view (1.5°) radiometer mounted on the aircraft. The radiance in this atmospheric window channel was closely correlated with the variation in broadband infrared flux, with an increase in radiance of 20 mW m⁻² ster⁻¹ (cm⁻¹)⁻¹ in the plume, except for the peak at 45 km along the run which is thought to be due to a small cloud at the top of the plume, also seen in the microwave measurements (figure 7d).

Figure 7d shows the effect the plume had on downward radiances (or brightness temperatures) at 89 and 157GHz measured by a microwave radiometer. Atmospheric emission at these frequencies is principally controlled by water vapour absorption and liquid water. The increase in brightness temperature in the plume at 157 GHz (22K) is three times the increase at 89 GHz (8K) but both are well correlated with the infrared radiance. The close correlation between the infrared fluxes and microwave radiances was seen on several occasions when there was no trace of liquid water in the plume.

Discussion

The observation that significant amounts of smoke were not present above 5km bears out previous predictions by the UK Meteorological Office and others. Our best estimate of oil burning rate is greater than those previously assumed, but the greater CO₂ emissions that this implies would still have a negligible effect on global climate through the greenhouse effect. Our best estimate of particulate emissions is similar to that assumed in the Meteorological Office study; the greater burning rate which we deduce is offset by a lower smoke emission factor. The sulphur emissions calculated from airborne measurements are considerably higher than those taken in the Meteorological Office assessment and, although we would expect the acidity of

rainfall episodes to be no higher than previously predicted, these episodes would extend further downwind across Southern Asia. As predicted, increased photochemical oxidant concentrations were observed both close to the source and further afield. The emissions of nitrogen oxides are smaller than those assumed in the Meteorological Office study; for this reason and because they are rapidly removed, they are unlikely to influence the global NO_x background and therefore will have little impact on global tropospheric ozone. Our measurements thus support the conclusions of several recent assessments that, whilst effects on a global scale, including those on the Asian summer monsoon, are likely to be insignificant, they may be significant on a regional scale.

Acknowledgements

We would like to acknowledge a great number of people without whose assistance these measurements would not have been possible, in particular the Royal Air Force MRF C-130 aircrew and RAF Muharraq for aircraft facilities. The co-operation of Sheik Essa bin Abdulla Alkhalifa and the State of Bahrain Ministry of Development and Industry, and that of the many Gulf states who speedily granted permission for the aircraft to operate with maximum flexibility in the area, was essential to the success of the study.

Figures

- 1. The location of aircraft tracks for the near and far field flights.
- 2. A vertical cross section of the plume made in a descending profile on 28 March 1991, 120km from the source, (a) smoke density, (b) liquid water content, (c) wind direction, (d) wind speed. The large apparent smoke density values at 3km are due to the liquid water cloud.
- 3. As figure 2, for (a) SO₂, (b) O₃, (c) NO_x, O₃+NO_x (thick line). (d) O₃ outside the plume,

upwind of the source.

- 4. A horizontal cross section through the plume at 2,440m on 28 March 1991 of (a) smoke density, (b) total scattering coefficient, (c) SO₂, (d) O₃ (solid line), NO_x (dashed line) and O₃+NO_x (dotted line).
- Horizontal run through the area of smoke (about 1000km from Kuwait) on 29 March 1991 showing (a) O₃ (b) smoke concentrations at an altitude of 4400m.
- 6. Scanning electron micrographs of smoke particles collected on filters exposed in the plume on (a) 30 March 1991, 180km from the source and (b) 29 March 1991, about 1000km from the source.
- 7. An illustration of the effect of the smoke on downwelling radiation during a crosswind run through the centre of the plume. a smoke density, b shortwave flux, c infrared flux and 11 μm radiance (in units of mW m⁻² ster⁻¹ (cm⁻¹)⁻¹) and d the microwave brightness temperatures at 89 and 157 GHz.

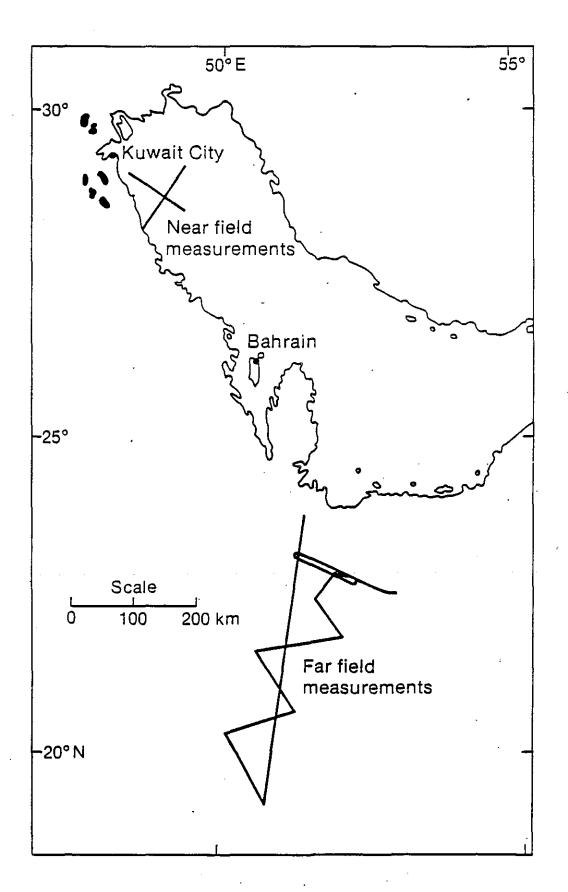
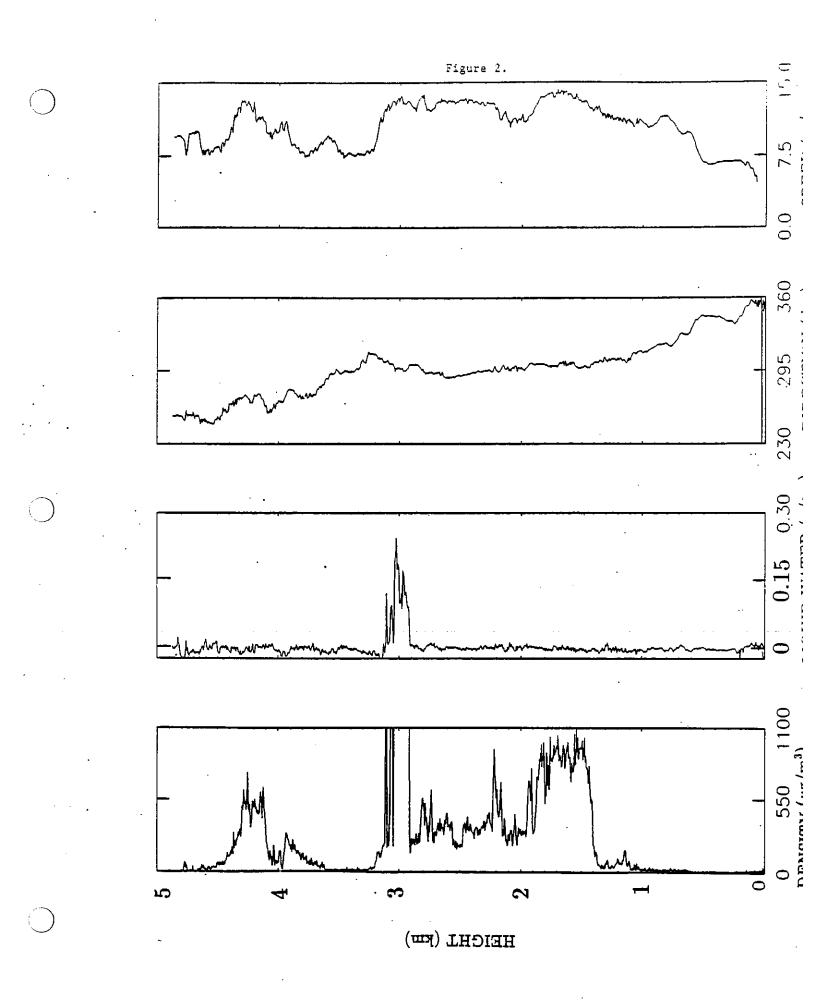
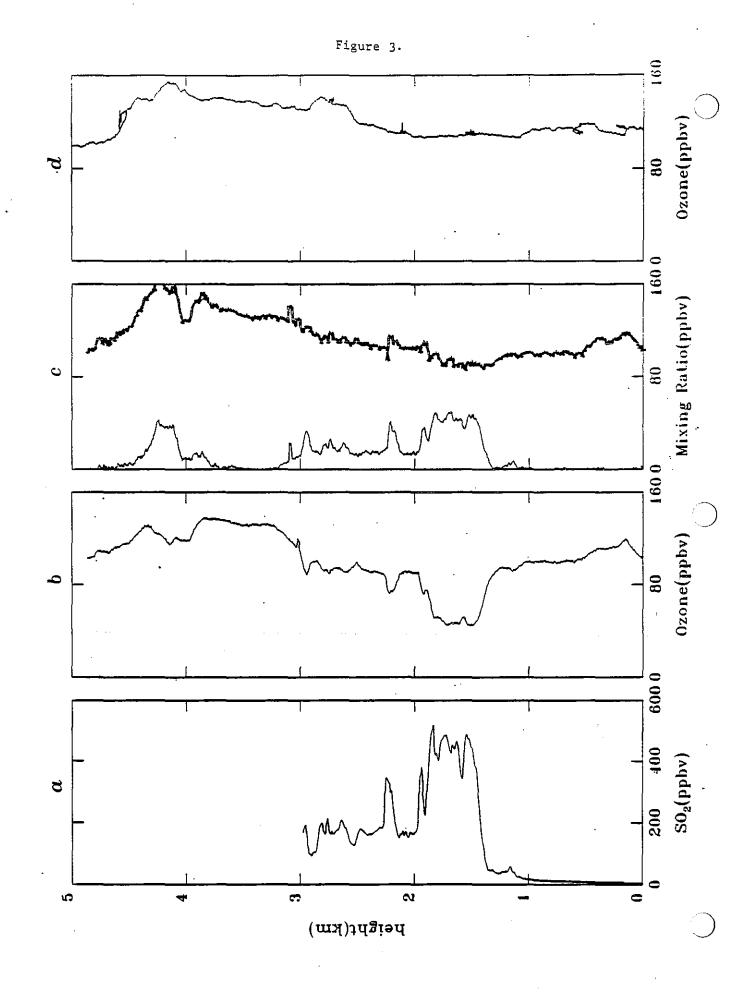
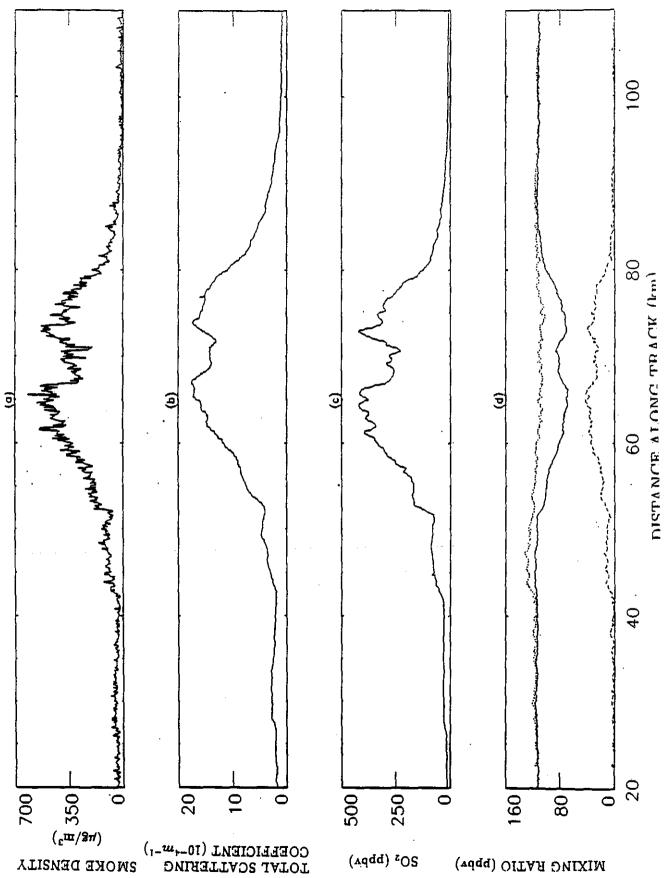
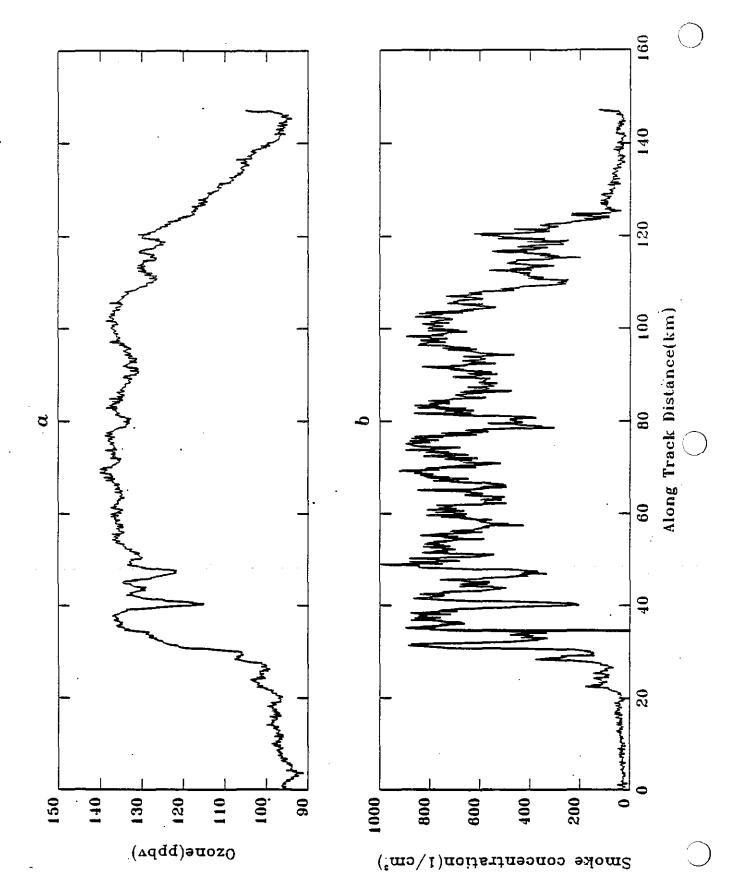


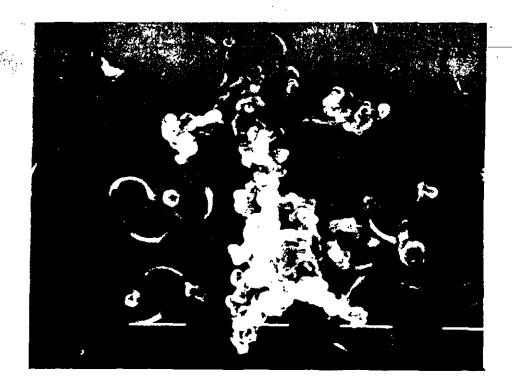
Figure 1.









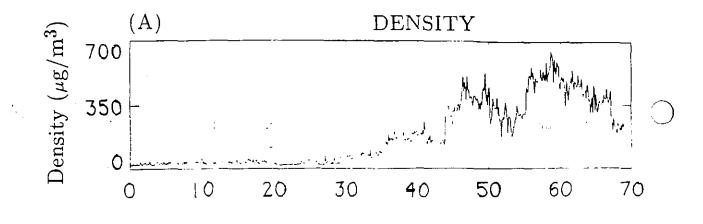


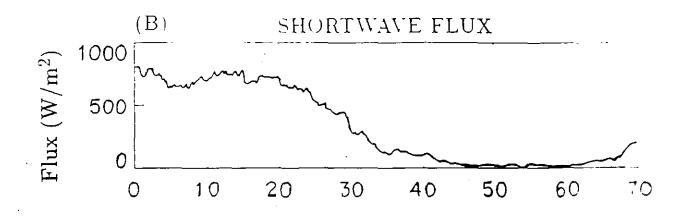
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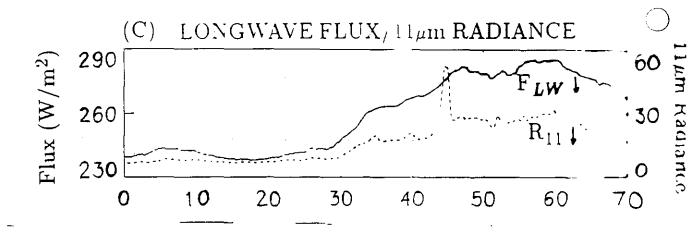
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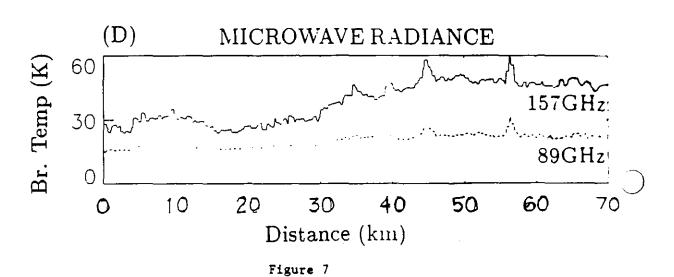


Figure 6.











Y46 Building

Dr Peter Hill
NOAA
Office of the Chief Scientist
Arabian Gulf Program Office
Herbert C Hoover Bldg, Room 1617M
14th & Constitution N.W.
Washington, D.C. 20230
U S A

Our Reference M/MRF/9/5/16

Date 10 October 1991

Dear Dr Hill,

Thank you for your fax of 8 October 91.

I enclose two reports:

(a) Our preliminary report of June 91 (which you already have a fax of) .

(b) Our paper submitted to Nature.

They are essentially the same, although our estimates of emissions have been updated slightly in (b), which is also slightly shorter because of the page limitations in Nature.

I hope these are useful; I look forward to receiving a copy of the completed folder.

Yours sincerely,

Jest Jenkins

Dr G J Jenkins Head, Meteorological Research Flight

Royal Aerospace Establishment FARNBOROUGH Hants GU14 6TD UK Direct tel: 0252 370019 International: +44 252 370019 Fax: 0252 376588

Airborne observations of the physical and chemical characteristics of the Kuwait oil smoke plume

by

D.W. JOHNSON¹, C.G. KILSBY¹, D.S. McKENNA¹, R.W. SAUNDERS¹, G.J. JENKINS¹, F.B. SMITH², and J.S. FOOT³.

1
Meteorological Office
Meteorological Research Flight
Royal Aerospace Establishment
Farnborough
Hampshire GU14 6TD
U.K.

2
Meteorological Office
London Road,
Bracknell,
Berkshire RG12 2SZ
U.K.

3
Meteorological Office
Remote Sensing Instrumentation
Royal Aerospace Establishment
Farnborough
Hampshire GU14 6TD
U.K.

September 1991

Airborne observations of the physical and chemical characteristics of the Kuwait oil smoke plume

Abstract

Airborne measurements in the densest part of the smoke plume at about 120km from the burning wells in Kuwait in late March 1991 showed typical particulate mass densities of $500-1000\mu gm^{-3}$, mixing ratios of 500-1000 ppbv of sulphur dioxide and 30-60 ppbv of nitrogen oxides. 1000 km from Kuwait, ozone was enhanced by about 50 ppbv within the area of smoke. The oil burn rate was estimated from sulphur fluxes to be 3.9 ± 1.6 Mbarrels d⁻¹. Significant amounts of smoke were observed only below 5000m and the measured attenuation of solar radiation by the smoke was similar to those assumed in recent assessments.

Introduction

About 600 naturally pressurised oil wells were set alight in Kuwait in late February 1991, injecting massive quantities of smoke, sulphur dioxide (SO_2), unburnt hydrocarbons and nitrogen oxides ($NO_x=NO+NO_2$) into the atmosphere. Assessments ^{1,2,3} of the impact of these pollutants are subject to large uncertainties in the magnitude and the characteristics of the emissions and the resulting plume.

To investigate the chemical and particulate composition of the smoke, and its effect on visible and thermal radiation, the C-130 aircraft of the Meteorological Office Research Flight made 57h of observations in eight flights into and around the plume in March 1991. This paper reports the first airborne measurements of the plume both close to source (up to 200km) and in the far field (1000km from source).

Meteorology and plume behaviour

Typically the smoke from individual oil well fires combined and rose so that the plume top reached about 4,500m with, on many occasions, shallow convective clouds forming on the windward edge of the plume. There was a marked vertical wind shear leading to differential advection of the plume, e.g. the lower part of the plume being transported southeastwards down the Gulf, with the upper part moving over Iran.

There has been speculation that, due to radiative self heating, aerosol may be lofted 1 into the stratosphere, where its long lifetime would allow transport over considerable distances. Vi-

sual observations showed the plume top to be well defined with a maximum height of 5000m. On one or two occasions a detached smoke layer was seen a few tens of metres above the main top. These observations in springtime show that the smoke was confined to the lower half of the troposphere and significant amounts were not being lofted into the stratosphere, in agreement with recent assessments ^{2,3}.

Near field measurements of particulates and chemistry

Vertical profiles and cross wind horizontal runs through the plume were executed on 28 March 1991, 120km downwind of the source (defined as 29°N, 48°E) south of Kuwait City. This distance was chosen as it was close enough to the source areas that the totality of the emissions could be measured while not so close that the inhomogeneity of the individual sources rendered the measurements unrepresentative.

A Passive Cavity Aerosol Spectrometer Probe (PCASP) was used to measure smoke particle concentrations and deduce the mass of smoke particles per unit volume (smoke density). Continuous measurements were made of SO_2 , NO_x and ozone (O_3) with accuracies⁵ of \pm 5%, \pm 10% and \pm 5% respectively. Stainless steel flasks were pressurised with ambient air and subsequently analysed for C_2 - C_8 hydrocarbons.

Figure 1 shows pollutant concentrations, together with the sum of O_3 and NO_x mixing ratios, from a descending profile carried out alongwind through the centre of the plume. Also shown is an O_3 profile obtained earlier outside the plume. The plume had a complex vertical structure, made up of two main layers; an upper one with a top at 4,600m and base 3,600m and

a deeper, denser lower layer with a top at 3,200m and base 1,000m. The lower layer was capped by thin (200m) altocumulus with droplets of high concentration (270 cm⁻³) and small effective radius (2.5 μ m). The upper layer was advected eastwards while the lower layer was advected southeastwards down the Gulf, trapped by a weak temperature inversion at the top of the liquid water cloud.

Seven horizontal, cross wind runs over the same ground position were carried out at 1,420m, 1,520m (twice),1980m, 2,440m and 4,420m (twice). Figures 2 a-d show measurements from a run through a 50km wide plume (near the centre of the lower layer at 2,440m) of pollutants, total scattering coefficient and NO_x+O_3 . In both the vertical profiles and horizontal runs all the plume indicators (SO_2 , NO_x , particulates, scattering coefficient) were highly correlated; this correlation was observed over several days of measurements close to the source.

In the lower layer NO_x and O_3 mixing ratios were negatively correlated, indicative of the gas phase titration of O_3 by NO, while their sum showed little horizontal variation (figure 2d) indicating little loss of O_3 either by reactions with smoke particles or in the oxidation of SO_2 to sulphate. In the upper layer the observed correlation between NO_x and O_3 was zero or positive, indicating that photochemical oxidant production had already been initiated.

Analyses of hydrocarbon samples taken in different parts of the plume are summarised in table

1. The flask which showed the highest mixing ratios of hydrocarbons (sample A) was filled at an altitude of 2600m in the densest part of a smoke plume on 30 March 1991, 120km from source.

The aggregate of the carbon contained in all of the non-methane hydrocarbons (NMHC) which can be identified, implies the presence of at least 340 ppbv of carbon as unburnt hydrocarbons.

Assuming unidentified species having a flame ionization response are hydrocarbons implies a carbon content of over 460ppbv. A second flask filled on the same day (sample B) at an altitude of 1500m near the bottom of the plume was a more typical sample; when compared with a UK urban air sample the maximum mixing ratios of benzene and toluene in the plume sample were lower but that of n-hexane was substantially greater.

Two supersaturation cloud condensation nuclei (CCN) spectra taken on 28 March 1991, one just below the top of the upper smoke layer at 4,500m and the other in clear air at 5,200m, indicate the plume contains an order of magnitude more CCN for a given supersaturation. For example at 0.6% supersaturation CCN concentration increased from 140cm⁻³ to 2000cm⁻³. In the thicker parts of the plume, CCN were so numerous (>4000cm⁻³) that the counter became overloaded.

Far field measurements

On 29 March 1991 satellite images showed smoke over central Saudi Arabia some distance from Kuwait oriented southwest-northeast and being advected to the northeast. The O₃ mixing ratios and particle concentrations observed in a horizontal run through this area of smoke are shown in figure 3 a and b.

In this more distant plume, it is likely that the ozone, enhanced by 40-60ppbv over the already high values in the adjacent clear air, is formed from ozone precursors (NO_x and NMHC) released from the oil fires. In contrast to the hydrocarbon samples collected near the fires, sample C (table 1), taken in this distant plume, has a different distribution of hydrocarbons. It still

has relatively high mixing ratios of the longer lived hydrocarbons, such as ethane and propane. but short lived hydrocarbons such as ethene and propene are substantially reduced. The low mixing ratios of shorter lived species suggest that significant OH degradation has occurred consistent with the enhanced ozone. Although the NO_x mixing ratios in the plume were below the limit of detection (5ppbv), the potential for further ozone production remains because mixing ratios of only several pptv are required to generate ozone ⁶. However the absence of many of the more reactive and therefore short lived hydrocarbons means that further ozone production will proceed at a slower rate:

The observations of this mature area of smoke suggests an interpretation of some of the clear air observations in the near field. During many of the vertical profiles made near the source region but outside the visible plume, ozone mixing ratios much greater than the normal free tropospheric background (30-40 ppbv) were encountered (e.g. figure 1d), associated with somewhat increased particle density. The enhanced ozone mixing ratios observed in the clear air were probably formed from NO_x and NMHC in smoke emitted several days earlier which remained near, or returned to, the source area.

Morphology of smoke particles

During flights in the smoke plume ambient air was drawn through polycarbonate filters which were subsequently studied with a scanning electron microscope (SEM). Figure 4a shows a typical smoke particle from a filter exposed 180km from the source, on 30 March 1991. The smoke particles are composed of spherules of diameter approximately $0.1\mu m$ which form chains of hundreds in number and several microns in length, as observed in other studies ^{1.7}.

Particles on filters exposed over 1000km from Kuwait (figure 4b) have a different appearance to those from the near field; although the spherule size is similar in both cases, the spherules in the far field are more likely to be closely packed into near-spherical clusters. Similar behaviour has been noted ⁸ in laboratory experiments, in air aged at high humidity.

The PCASP determines the number and size distribution of particles by passing them through a laser beam and measuring the scattered light intensity, using a relationship between intensity and size derived using latex spheres of known radius. The smoke density is calculated by integrating the size distribution assuming (a) 100% collection efficiency, (b) the non-spherical particles in the plume scatter the same amount of light as spheres of the same mass (we conclude from previous laboratory⁷ and theoretical⁹ work that, for the shape of the particle encountered, this assumption is reasonable) and (c) the density of the smoke particles is 1gcm⁻³, in line with Sokolik¹⁰. Support for this approach comes from the mass loading of the filter samples, which suggest that the absolute determination of smoke density from the PCASP is not grossly in error, and the linear relationship between SO₂ concentrations and smoke density (see below) which confirms the instrumental response to smoke density is linear. Nevertheless, the uncertainties in these assumptions lead us to believe that the absolute values of smoke density could be up to 2-3 times higher than those shown. The relative variations in the plots are still valid.

Emission estimates

The magnitude of sulphur emissions was estimated from the flux of sulphur through a crosswind plane determined from the product of sulphur concentration and the wind component perpen-

dicular to the plane. SO₂ measurements from the horizontal runs and vertical profiles through the plume were used, together with the winds measured by the aircraft. Above 3000m where the SO₂ monitor will not operate, PCASP measurements were used to derive proxy SO₂ values through the linear relationship evident in figures 1 and 2.

On 28 March 1991, when virtually all of the plume about 120km from the southern oilfields was sampled, the estimated sulphur emissions were 5.7Mt yr⁻¹. Assuming a value of 3.3% for the sulphur content of the southern oilfields ¹¹, this source strength corresponds to an oil burning rate of 172.1Mt yr⁻¹. We assume, based on previous estimates ^{12,13} that the southern oilfields account for 85% of the total burning rate; implying a total rate of 202.5Mt yr⁻¹ or 3.9MBd⁻¹. An estimate for 30 March 1991 gives a similar burning rate. A subjective estimate of the error in this source strength is ±40% based on the temporal evolution and spatial variability over the 3h measurement period.

Using the relationships between concentrations of SO_2 , NO_x and particulates, we estimate the source strength of NO_x and particulates from the sulphur source strength (table 2). Carbon as gas (ie the mass of carbon contained in CO, CO_2 , CH_4 and NMHC) is estimated from the residual mass after the mass emissions of sulphur, nitrogen and particulate carbon are subtracted from the total mass emitted and an allowance is made for the hydrogen content.

Effect of the smoke on radiation.

Figure 5 shows the effect of the smoke on the radiation during a horizontal run on 31 March 1991 through the centre of the plume 700m below its top about 65km from source. The total

shortwave $(0.3-3\mu\text{m})$ downwelling flux was reduced from its clear sky value of 800 W m⁻² outside the plume to zero in the centre, and corresponding changes were seen in the infrared and microwave regions.

The single scattering albedo, ω_0 , of the smoke was estimated in two independent ways. Firstly, hemispheric reflectances of the plume top were measured, using upward and downward looking pyranometers, to be between 5-8% over a range of solar zenith angles (25°-48°). The Ginzburg and Sokolik ¹⁴ method shows that these reflectances correspond to a value of ω_0 in the range 0.5 to 0.55, but with an uncertainty of ± 0.1 due to assumptions made about the scattering properties of oil smoke. Secondly, volume absorption coefficients were measured from filters exposed in the plume using the integrating sandwich technique ¹⁵ and these, when combined with the nephelometer scattering coefficients give values for ω_0 in the range 0.55-0.70(\pm 0.1). Thus the likely range of ω_0 is 0.50-0.65 which is higher than previously published values for oil smoke ^{4,7,10} but lower than that of 0.8-1:0 measured in non-carbonaceous aerosols ¹⁴.

The broadband optical depth of the smoke was estimated from the change in downwelling shortwave flux as the aircraft ascended or descended through the plume. Figure 6 shows the derived optical depth as a function of smoke column density for three profiles through the plume top.

Solar heating rates in the plume were calculated from shortwave flux divergences in a profile at local noon on 30 March 1991, 140 km from the source. The heating rate was typically of the order 50 K d⁻¹ throughout the depth (2300m) of the smoke. It was nearly constant in the plume because the smoke density increased from the top to the base. At a distance of 250km from the source the smoke density was a factor of four lower and the heating rates were 20 K d⁻¹. This compares with typical clear sky values of 1 K d⁻¹.

Figure 5c shows the downward hemispheric infrared $(4-50\mu\text{m})$ fluxes to be greater in the centre of the plume relative to clear air by 45 W m⁻² and the vertical downward radiance at 11.1 μ m to be increased by 20 mW m⁻² ster⁻¹ (cm⁻¹)⁻¹. These were measured by a pyrgeometer¹⁶ and a narrow field of view (1.5°) radiometer¹⁷ respectively. The peak in radiance at 45 km along the run is probably due to cloud above and is also seen in the microwave measurements (figure 5d). The broadband infrared optical depth for a vertical path through the smoke was calculated in a similar manner to the visible optical depth. It was estimated to be 0.34 ± 0.05 for the profile on 30 March 1991. The 11.1μ m radiometer was not operated in this profile but the maximum vertical optical depth calculated from the horizontal run in figure 5c was 0.30 ± 0.02 which was 75% of the corresponding broadband optical depth. Infrared cooling rates in the plume were calculated from the flux divergences to be 2.1 K d⁻¹ which is 1.0 K d⁻¹ greater than that in adjacent clear air. Assuming smoke densities based on the PCASP measurements, the visible extinction coefficient was deduced from the optical depth to be 7-13m²g⁻¹ which is in broad agreement with other measurements of oil smoke^{7,18} The 11.1 μ m infrared absorption coefficient was deduced to be 0.7-1.3m²g⁻¹ in agreement with laboratory measurements¹⁹.

Figure 5d shows the effect the plume had on downward radiances (or brightness temperatures) at 89 and 157GHz measured by a microwave radiometer. Atmospheric emission at these frequencies is principally controlled by water vapour and liquid water. The increase in brightness temperature in the plume at 157 GHz (22K) is three times the increase at 89 GHz (8K) but both are well correlated with the infrared radiance. This correlation was seen on several occasions when there was no trace of liquid water in the plume. The microwave radiance increase is surprisingly high and cannot be explained by variation in water vapour within the plume nor

by the observed levels of SO₂. Bruce et al ²⁰ present measurements of the absorption coefficient of diesel soot at 94GHz which are over an order of magnitude too small to account for our results.

Discussion

Our best estimate of oil burning rate is greater than those previously assumed 1,2,3 . However the greater CO_2 emissions that this implies represents only 3% of total annual fossil fuel emissions and would still have a negligible effect on global climate through the greenhouse effect. The sulphur emissions calculated are considerably higher than those taken by Browning et al.², and although we would expect the acidity of rainfall episodes to be no higher than previously predicted because this is limited by droplet saturation, these episodes will extend further downwind across Southern Asia. As predicted², increased photochemical oxidant concentrations were observed both close to the source and further afield. However the emissions of NO_x are smaller than those previously assumed²; for this reason and because they are rapidly removed, they are unlikely to influence the global NO_x background or global tropospheric ozone.

The estimated smoke emission rate, even with our large uncertainties, is similar to the range used in previous assessments^{1,2,3}. Furthermore, the product of our derived visible extinction coefficient and smoke emission rate (the factor which determines the radiative impact of the plume for a given meteorological situation) is independent of the uncertainties in our estimate of smoke density and is similar to that inferred from Browning et al². Previous assessments^{2,3} assume that the smoke did not scatter radiation; the scattering which we observed would be insufficient to significantly alter their conclusions. The observed infrared effects, though previously ignored, will only very slightly ameliorate the predicted daytime surface cooling. Our

measurements thus confirm the assumptions used in recent assessments^{1,2,3} and the observations that significant amounts of smoke were not present above 5000m bears out their predictions. This study provides strong support for their conclusions that, whilst there may be significant effects on a regional scale, those on a global scale, including the Asian summer monsoon, are likely to be insignificant.

Acknowledgements

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References

- 1. Small, R.D. Nature, 350, 11-12 (1991).
- 2. Browning, K.A., et al. Nature 351 363-367 (1991)
- 3. Bakan, S. et al. Nature 351 367-371 (1991)
- Radke, L.F., Lyons, J.H., Hobbs P.V. and Weiss R.E. J Geophys Res 95, 14071-14076 (1990).
- Marsh, A.R.W., Crabtree, J. Hatton D.B. CERL RD/L/2092N81, Central Electricity
 Research Laboratories, Leatherhead U.K. (1982)
- 6. Crutzen, P.J. Tropospheric Ozone, (3-32), D. Reidel Publishing Company, Dordrecht, Holland, (1988).
- Colbeck, I., Hardman E.J. and Harrison R.M. J Aerosol Sci. 20, 765-774 (1989)
- 8. Colbeck, I., Appleby, L. Hardman E.J. and Harrison R.M. J. Aerosol Sci. 21, 527-538 (1990).
- 9. Berry, M.V. and Percival I.C. Optica Acta 33 577-591 (1986)
- 10. Sokolik I.N. Izvestiya, Atmospheric and Oceanic Physics 24 200-204 (1988).
- 11. Small, R.D., Personal Communication.
- 12. World Meteorological Organisation Report of the meeting of experts on the atmospheric part of the joint UN response to the Kuwait oil field fires, 27-30 April 1991; WMO Geneva.
- 13. King Fahd University of Petroleum and Minerals: Environmental impact of oil burning in the Kuwaiti oilfields; a preliminary evaluation. Dhahran April 1991.
- Ginzburg A.S. and Sokolik I.N. Izvestiya, Atmospheric and Oceanic Physics 25, 700-704
 (1989).

- 15. Kilsby C.G. Quart. J. Roy. Meteor. Soc., 116, 1173-1192 (1990).
- 16. Foot, J.S. J. Atmos. Oceanic Technol. 3, 363-370 (1986).
- 17. Rawlins, F. and Foot J.S. J. Atmos. Sci. 47, 2488-2503 (1990).
- Golitsyn G.S., Shukurov A.Kh., Ginzburg A.S., Sutugin A.G. and Andronova A.V. Izvestiya, Atmospheric and Oceanic Physics, 24, 163-168 (1988).
- 19. Roessler, D.M. and Faxvog F.R. J. Opt. Soc. Am., 69 1699-1704 (1979).
- Bruce, C.W., Stromberg, T.F., Gurton K.F. and Mozer J.B. Appl. Optics 30, 1537-1546
 (1991).

Figures

- A vertical cross section of the plume made in a descending profile on 28 March 1991, 120km from the source, (a)smoke density(μg/m³), (b) SO₂(ppbv), (c) O₃ (solid line) and NO_x (dotted line), (d) O₃ outside the plume (solid line) and O₃+NO_x in the plume. (dotted line).
- A horizontal cross section through the plume at 2,440m on 28 March 1991 of (a) smoke density, (b) total scattering coefficient at 0.48 μm as measured by an integrating nephelometer,
 (c) SO₂, (d) O₃ (solid line), NO_x (dashed line) and O₃+NO_x (dotted line).
- Horizontal run at an altitude of 4400m through the area of smoke (about 1000km from Kuwait) on 29 March 1991 showing (a) O₃ (b) smoke concentrations.
- 4. Scanning electron micrographs of smoke particles collected on filters exposed in the plume on (a) 30 March 1991, 180km from the source and (b) 29 March 1991, about 1000km from the source. The filters were mounted on an extendable boom 0.4m from the aircraft skin

and the air drawn over the filters isokinetically 15. The dark holes in the photograph are the pores in the filter.

- 5. An illustration of the effect of the smoke on downwelling radiation during a crosswind run through the centre of the plume. (a) smoke density, (b) shortwave flux, (c) infrared flux, F_{LiV}, and 11 μm, R₁₁, radiance (in units of mW m⁻² ster⁻¹ (cm⁻¹)⁻¹) and (d) the zenith microwave brightness temperatures at 89 and 157 GHz.
- 6. Broad-band shortwave optical depths of the plume from three different ascending or descending profiles flown through the plume as a function of the total column density of smoke in the path. The profile on 29 March 1991 was further away from the source and lower smoke densities were encountered.

Tables

Table 1. Hydrocarbon analyses of 1.6 litre stainless steel flasks, by Gas Chromatography-Flame Ionisation Detection. Sample A: most polluted sample 120km from source, Sample B: typical polluted sample at a similar distance, Sample C: typical far field sample (1000km from source).

Table 2. Estimates of oil well source strengths derived from observations and for comparison those assumed by recent assessments^{1,2,3}. The mass of hydrogen contained in H₂S and hydrocarbons in the fuel has been taken into account when determining the different components of the emissions.

Table 1:								
Species	Sample A 30 March 91		Sample B 30 March 91		Sample C 29 March 91			
	Mixing	ethane	Mixing	ethane	Mixing	ethane		
_	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio		
l	(ppbv)	_	(ppbv)		(ppbv)			
ethane	25.111	1.000	5.440	1.000	1.330	1.000		
ethene	13.030	0.519	1.851	0.340	0.034	0.026		
propane	19.952	0.794	2.345	0.431	0.453	0.340		
propene	1.637	0.065	0.220	0.040	0.026	0.020		
benzene	1.057	0.042	0.215	0.040	0.044	0.033		
toluene	1.309	0.052	0.203	0.037	0.025	0.019		
n-hexane	5.052	0.201	0.409	. 0.075	0.013	0.010		
NMHC	339.6	13.53	45.92	8,44	6.266	4.71		

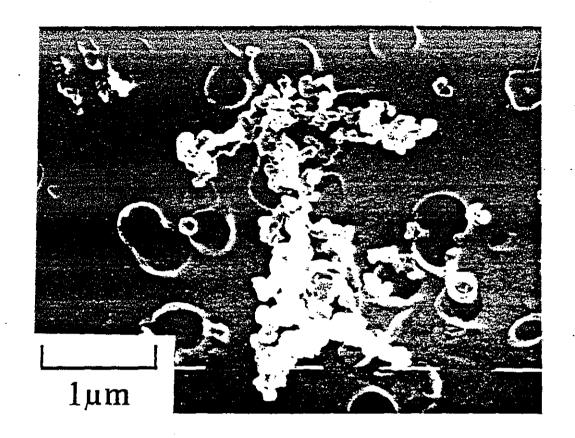
	•	Table 2:		
	This Study	Browning et al. ²	Small ¹	Bakan et al. 3
Component	Mt yr-1	Mt yr ⁻¹	Mt yr-1	Mt yr-1
Total Burn Rate	202.5	80	63	161
Carbon as gas	161.2§	60	63	
Fine Particulate Carbon	6.4†‡	5	5.8	16.1
Sulphur	6.1*	2	•	•
Nitrogen in Oxides	0.42	0.5	•	•

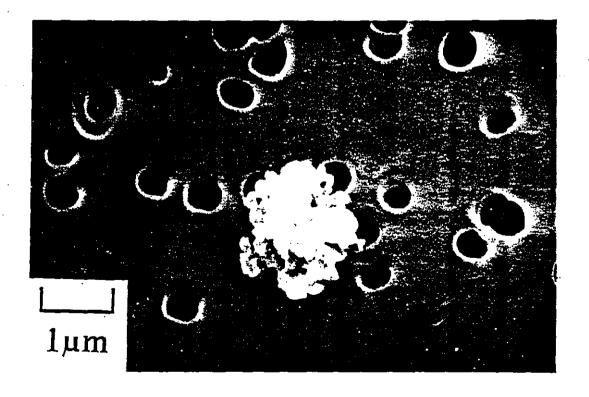
[†] Assuming the same emission factors for the southern and northern fires.

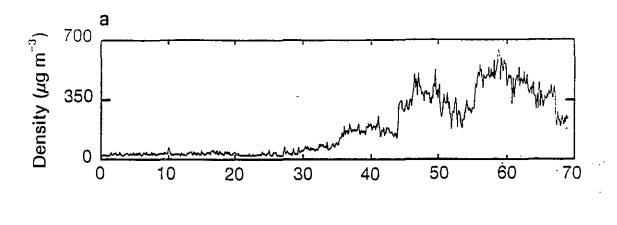
^{*} Assuming a 1.5% sulphur content for the northern fields which contribute 15% overall to the emissions.

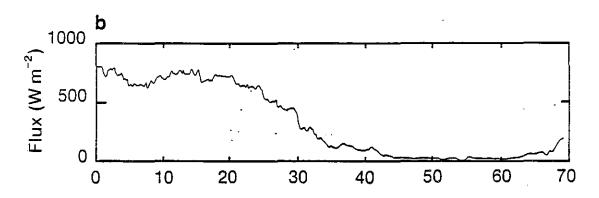
[§] Deposits from large partially burned oil droplets near the well heads may reduce this total.

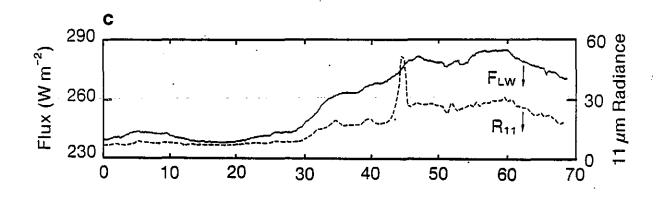
[‡] This quantity could be up to 2-3 times higher with a commensurate reduction in carbon as gas.

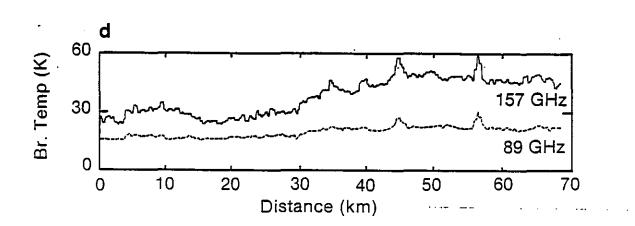


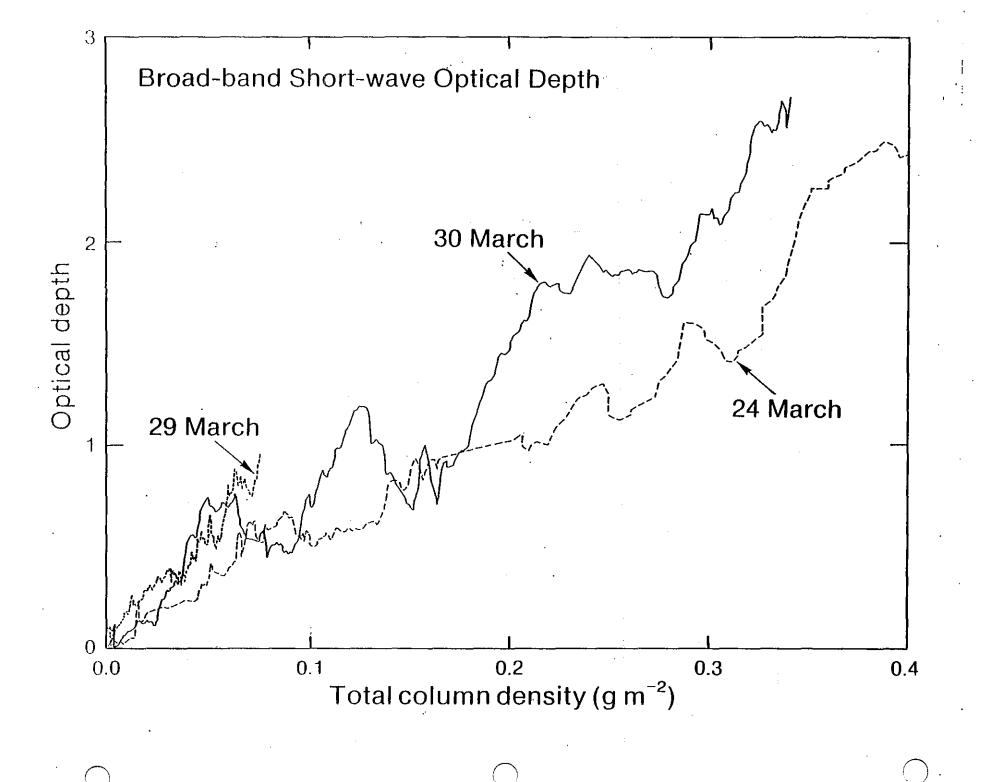


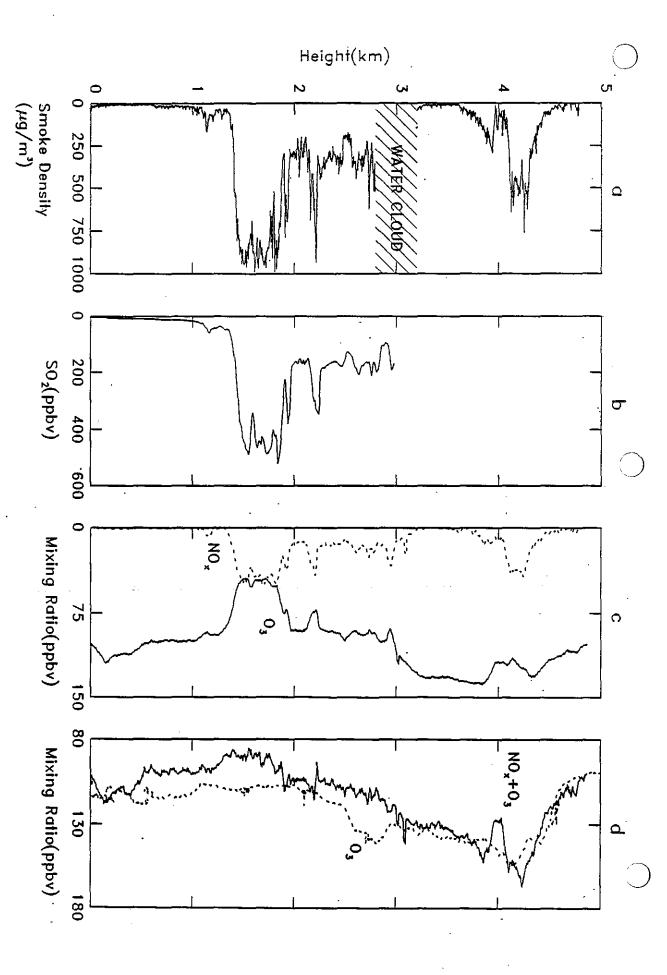


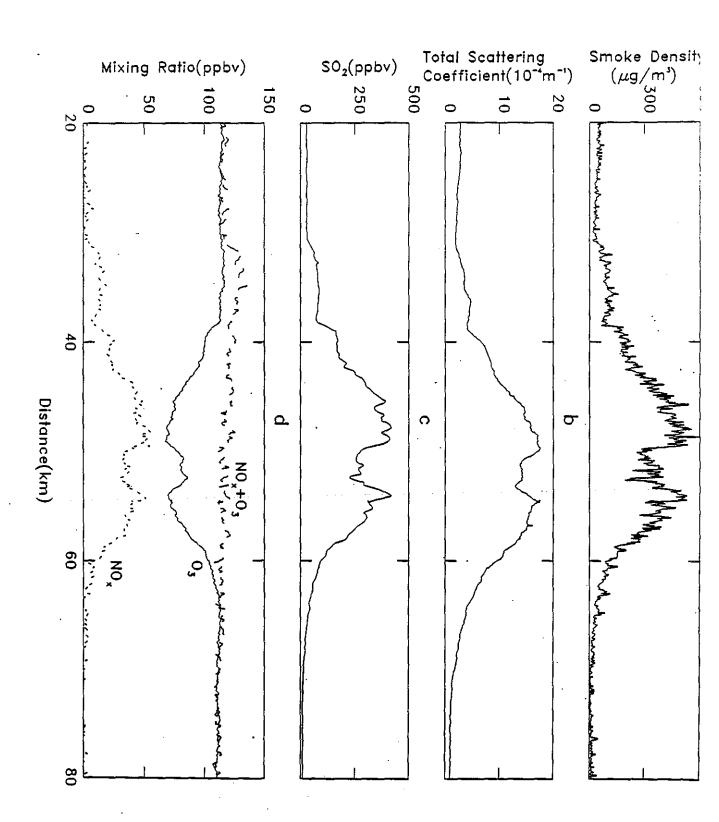


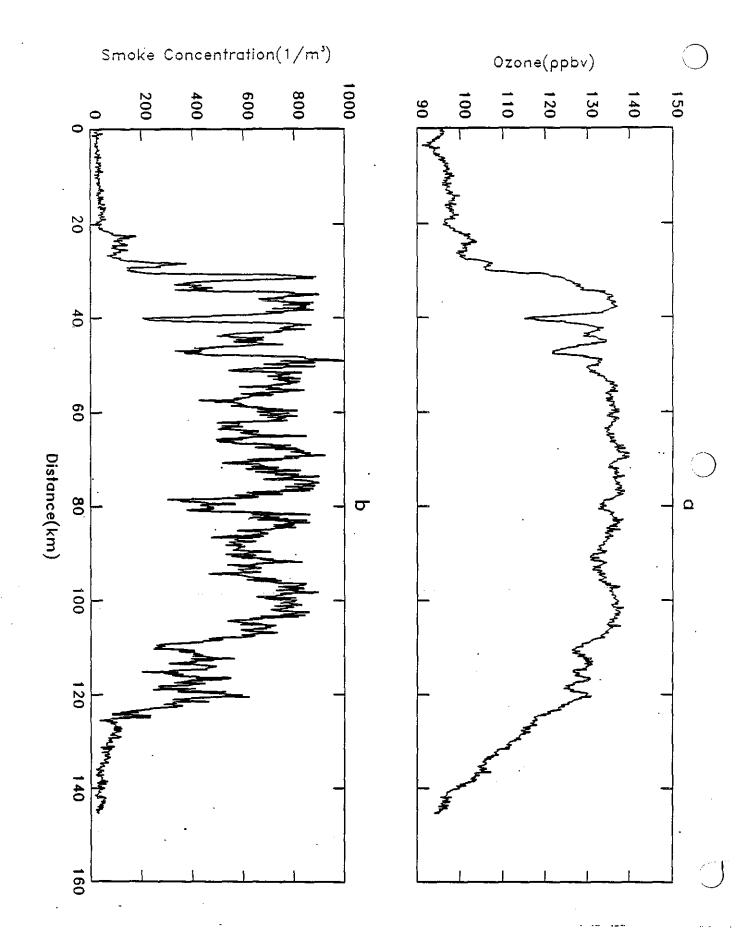












Aircraft Research Instrumentation Electra N308D Kuwait Oil Fire Project May 6, 1991

RAF-Supplied Instrumentation:

- I. Airborne Data System
 - A. Acquisition: ADS
 - B. Display: New Sparc-based System
- II. Aircraft Position, Velocity and Attitude
 - A. Honeywell Inertial Navigation System
 - B. Litton INS, LTN-51
 - C. Loran C, Advanced Navigation Inc., ANI-7000
 - D. GPS
- III. Static Pressures
- IV. Dynamic Pressures
- V. Temperatures
- VI. Dew Point and Rumidity
- VII. Flow Angle Sensors, Radome
 - A. Attack Rosemount Model 1221F1VL Differential Pressure Transducer (ADIFR)
 - B. Sideslip Rosemount Model 1221F1VL Differential Pressure Transducer (BDIFR)
- VIII. Cloud/Aerosol Physics
 - A. Particle Measuring Systems Model PCASP Window Mount Aerosol Size Distribution, 0.12 to 3.12 μm
 - B. Particle Measuring Systems Model FSSP-300 Window Mount Aerosol Size Distribution, 0.30 to 20.0 μm
 - C. Particle Measuring Systems Model FSSP-100 Right Pylon Droplet Size Distribution, 2 to 47 µm
 - D. Particle Measuring Systems Model 260X Left Pylon Droplet Size Distribution, 40 to 600 µm
 - E. Particle Measuring Systems Model KLWC-1 Left Pylon Liquid Water Content 0 3 g m⁻³
 - F. Counter Flow Virtual Impactor (CVI) Top Front Right Mounting Plate. Droplet Composition (XCVF1, XCVF2, XCVTT, XCVST, XCVFH)

NCARZ

G. TSI Model 3760 CN Counter - Forward Cabin Mount plumbed with CVI - (XCNTS, XPCN, XFCN, FCBADS, TCBADS)

IX. Radiation Fluxes

- A. Visible Radiation RAF Modified Eppley Model PSP Pyranometers 2 units: Upward looking (SWT), Downward looking (SWB)
- B. Infrared Radiation RAF Modified Eppley Model PIR Pyrageometers - 2 units: Upward looking (IRT), Downward looking (IRB)
- C. Ultraviolet Radiation RAF Modified Eppley Model TUV Pyranometers - 2 units: Upward looking (UVT), Downward looking (UVB)
- D. Remote Surface Temperature Barnes PRT-5, 2 units, Upward looking (RSTT), Downward looking (RSTB)

X. Geometric Altitude

XI. Air Chemistry

- A. NCAR Modified TECO Model 49 Ozone Analyzer (TEO3, TET, TEP)
- B. U. of Maryland Modified TECO Model 48 Carbon Monoxide Analyzer (CMODE, XCO)
- C. NCAR modified TECO Model 42 Nitrogen Oxides Analyzer -(XNO, XNOX, XSTAT, XO2F, XNOF)
- D. TECO Model 43A Sulfur Dioxide Analyzer (XSO2)
- E. NCAR Fast Ozone (NO) (O3FS, O3FF, O3FT, O3FP, O3FN)
- F. RAF Chemical Ozone (dye) (O3CS, O3CP, O3CT, O3CF)
- G. Continuous Peroxides (PERSA, PERSB, PERFA, PERFB, PERST)
- H. Speciated Peroxides (PEROF)
- I. Formaldehyde (XFORS, XFORF)

XII. NAILS (Back-scatter mode only)

XIII. Photography

Forward, Left, and Down-looking Video

<u>User-Supplied Instrumentation</u>

- I. SRI Nd:YAG Lidar (1 μm)
- II. U. of Hawaii Aerosol Ensemble (Tony Clarke)
 - A. TSI Model 3760 CN Counter Forward Cabin Mount plumbed into separate inlet (CNTS2)
 - B. Aethelemeter Aerosol Elemental Carbon Forward Cabin Closet - (XTH01, XTH02)
- III. Drexel University (Alan Bandy)

Gas Chromategraph with flame photometric detection - Measurements of H_2S , SO_2 , OCS, and CS_2 - (XDET, XDET5, XDETT, XDT10)

IV. NOAA/ERL/CIRES (Barry Bodhaine, Russ Schnell)

Aerosol Nephelometer - Aerosol Scattering Coefficient - (X449, X536, X690, XNPBG, XNPMF, XNPT, XNPP)

Aethelometer - Aerosol Elemental Carbon (XATH1, XATH2, XATH3, XFILF)

V. Desert Research Institute (Jim Hudson)

CCN Counter (XCNEX, XCNCF)

VI. NIST (George Mulholland)

Transmission Cell Reciprocal Nephelometer (TCRN) - Aerosol optical scattering, extinction and absorption at 0.5 μm - (XRAT, XPMTB, XIO)

VII. NCAR/SSSF

L2D2 Drop Sondes

VIII.University of North Dakota

SF-6 Analyzer (XSF6)

```
lat?, lon9 = Latitude, Longitude of starting point
lati, loni = Latitude, Longitude of ending point
           Altitude in metersAircraft heading
Palt
Hdg
           = Distance of mid-point of flight leg from Kuwait
Cist
Width
           = Length of flight leg
Temp
           = Temperature
IDP
           = Dew Point temperature
WS, WD
           - Wind velocity and direction
IK
           - Not presently used
TEO3C
           = Maximum Ozone concentration during pass
S02
           - Maximum SO; concentration during pass
CN
           - Maximum counts measured by fine CN counter during pass
              (not a concentration)
CMC.3
           = maximum concentration of particles > 0.3 µm diameter
Flt 1 May 19, 1991
Flight Leg Statistics
         Stop
                lat0
                       lon0
                              latl
                                      lon1 Palt (m)
                                                      Hdg Dist Width
                              WS
                                    WD
                                          WI TEO3C
                                                      502
                                                              CN CNC.3
               Temp
                      TDP
063500 070900 27.690 49.606 29.160 48.013 5490.4 312.3
                                                            4.2 122.8
                -5.6 -27.8 32.7 286.1 0.0 66.3
                                                      9.2
                                                              1. 1.45
                                                           15.1 17.2
071830 072200 29.529 47.988 29.325 48.214 3676.7 143.7
                5.9 -26.5 22.8 289.6 0.0 83.8
                                                      7.2
                                                              О.
073100 075050 29.097 48.400 27.929 49.500 3991.3 140.1 114.5 90.5
                6.5 -14.3 27.5 280.0 0.0 85.1 7.5
                                                              0. 0.00
075730 080810 28.066 49.900 27.699 49.318 2471.7 240.9 114.3 40.0
               15.7 -18.6 19.6 289.3 0.0 97.9 39.3
                                                              0.00
081200 082200 27.709 49.423 27.323 48.906 2773.4 237.0 115.9 37.3
               14.5 -13.6 22.4 280.9 0.0 89.5
                                                    6,3
                                                              0.00
082500 093000 27.330 48.983 27.161 48.722 2778.1 241.2 119.1 18.1
               14.3 -13.9 21.0 289.3 0.0 77.1 6.4
                                                              0. 0.00
083110 085020 27.116 48.745 27.708 50.173 2765.7 52.3 154.6 91.3 14.3 -19.3 25.2 293.7 0.0 104.6 97.6 1. 0.00 085110 091510 27.740 50.186 27.219 48.775 2329.2 253.2 117.5 89.1
                                                                  0.00
               15.4 -11.8 22.7 295.9 0.0 101.2 76.2
                                                              c. 0.00
091700 093700 27.261 48.766 27.909 50.080 1976.9 52.2 144.3 86.0
               20.6 -15.5 23.5 292.0
                                        0.0 101.6 127.2
                                                              C. 0.00
093800 095800 27.944 50.077 27.359 48.978 1515.1 245.5 116.4 72.9
               19.7 -4.5 24.6 306.2 0.0 93.6 110.1
                                                              0.00
105100 105340 25.365 49.346 25.258 49.500 1950.4 127.6 234.1 10.9
                                ECT.1
                                         0.0
105700 110220 25.208 49.650 25.303 49.333 2278.4 284.8 228.0 19.7
               21.6 -1.9 11.8 242.9 0.0 49.2 7.7
                                                              3. 0.93
110400 111750 25.266 49.330 25.788 50.164  2340.2  38.4 227.5  57.4
19.3 -1.7 15.6 269.1 0.0 51.1 8.8 8. 0.00 111990 112310 25.855 50.197 26.117 50.176 2735.0 339.5 213.3 14.2
               17.5 -1.8 25.4 262.3 0.0 38.5
                                                     6.3
                                                              3. 0.00
112890 113240 26.231 50.444 26.252 50.736 1117.4
                                                     72.4 230.4 17.6
               25.6 -9.4 23.1 320.6 0.0 85.4 38.5
```

Flt 3 May 21,1991 Flight Leg Statistics Stop latC lonC latl lond Falt (m) Hdg Dist Width WD NI TEO3C TDP 502 CN CNC.3 Temp WS 085200 085630 27.639 49.070 27.484 48.810 3640.6 242.1 105.5 17.7 7.3 -6.8 17.2 286.9 0.0 46.1 25.9 1400. 7.42 094000 095600 27.493 48.837 28.111 49.890 2735.7 54.5 129.2 71.2 13.9 -4.3 14.1 276.1 0.0 63.4 35.1 13200. 26.53 095850 101800 28.157 49.960 27.532 48.907 2429.4 240.8 106.1 71.4 17.8 +3.0 15.2 283.8 0.01709.3 143.5 16400. 28.20 7.513 48.862 28.096 49.899 2130.2 52.4 130.0 69.5 19.8 -3.5 15.2 274.3 C.O 65.2 60.7 14000. 12.69 102050 103700 27.513 48.862 28.096 49.899 2130.2 104000 105840 28.113 49.975 27.541 48.930 1824.6 236.2 106.4 69.7 23.9 -2.2 15.6 281.2 0.0 74.0 77.9 14700. 23.61 110300 111830 27.558 48.974 28.110 49.900 902.1 55.1 129.7 62.8 27.8 -1.6 10.8 357.9 0.0 63.3 70.9 20000. 31.29 114300 121400 27.425 50.242 26.153 52.251 1805.1 118.9 305.3 138.6 23.4 -3.1 18.9 306.3 0.0 66.2 60.8 9700, 19,73 123400 124710 25.799 52.961 25.024 52.469 3033.6 216.6 353.4 51.4 14.6 -8.6 17.3 312.9 0.01852.5 36.5 4800, 21.50 125400 130800 25.200 52.626 25.985 53.115 2595.8 22.3 354.5 51.5 . 18.9 -10.0 17.5 296.7 0.0 58.6 45.3 4900. 20.15 131300 132630 25.806 52.995 25.053 52.541 2120.4 213.0 355.7 49.2 21.6 -1.1 18.6 307.0 0.0 65.3 8100. 19.56 70.8 132900 134740 25.107 52.557 26.009 53.171 908.4 22.7 356.8 61.0 30.9 -1.9 16.3 327.7 0.0 58.8 43.1 6100. 20.19

Fit 6 May 26, 1991 Flight Lea Statistics lat0lonC . latl lon1 Palt (m) Hig Dist Width Start Stop Temp TDP WS WD WI TEO3C SQ2 CN CNC.3 082421 083040 28.109 49.395 28.350 49.837 4842.5 30.8 120.9 29.4 -1.1 -20.0 73.1 299.9 0.0 87.7 53.7 12900.549.86 093201 085200 28.364 49.808 27.386 48.779 4317.2 255.3 109.3 '80.8 1.8 -8.2 73.9 324.7 0.0 83.1 7.8 6200.489.87 085320 091150 27.430 48.766 28.250 49.962 4253.7 30.8 129.9 83.8 3.6 -15.9 73.4 299.7 0.0 89.7 49.2 19800.357.88 091501 093830 28.247 49.828 27.484 48.415 3290.5 255.1 96.5 94.0 8.7 -3.5 50.2 316.9 0.0 76.8 128.T 4650C.429.09 094010 100200 27.526 48.417 28.332 49.849 3037.8 30.8 121.9 95.9 10.5 -2.5 67.4 304.0 0.0 73.2 98.1 44800.568.92 100300 102700 28.361 49.838 27.440 48.480 2732.1 255.2 99.9 95.1 -3.0 65.6 333.3 0.0 72.0 69.9 31800.576.45 12.4 103021 105330 27.405 48.457 28.343 49.835 2738.3 30.8 120.9 96.4 13.3 -2.5 54.8 307.1 0.0 69.8 64.0 48400.582.04 105620 110600 28.361 49.888 27.997 49.341 2749.5 255.€ 104.7 38.0 13.3 -3.7 53.4 320.3 0.0 71.4 41.8 25930.578.87 112730 114000 26.752 50.376 26.175 49.764 2742.0 210.8 196.3 48.1 14.1. -3.3 64.0 124.0 0.0 79.0 118., 20100.5/3.85 114131 120020 26.201 49.727 27.029 50.717 2590.7 31.2 202.1 74.1 14.1 -4.0 62.1 323.9 0.0 81.0 92.3112500.600.06 120140 121530 27.036 50.685 26.267 50.143 3039.6 210.9 205.6 52.6 12.1 -0.8 33.5 108.1 0.0 72.6 52.0 14200.625.87 121700 122750 26.233 50.052 26.249 49.337 3036.0 300.6 179.9 42.9 6.6 2300.515.35 12.1 -2.4 56.9 358.5 0.0 50.2 122903 123400 26.289 49.349 26.244 49.758 3938.9 75.8 193.0 24.7 5.6 -10.1 67.9 247.0 0.0 69.5 7.3 2000.598.41 123600 125500 26.333 49.874 26.910 50.581 3646.2 211.1 199.5 52.5 0.0 81.7 8.8 -13.5 75.6 46.5 7.0 2600.557.58 125400 130540 26.970 50.622 26.253 50.150 3641.3 210.9 206.5 47.9 9.2 19.0 0.0 76.5 22.9 7400.528156 8.8 -10.7 130700 131830 26.226 50.070 26.208 49.282 3039.9 255.5 180.5 47.3 3200.514.45 12.1 -2.5 63.0 197.3 0.0 64.8 6.5 132007 133700 26.248 49.301 26.227 50.670 2741.9 76.2 228.5 82.2 0.0 69.4 27.4 7400.520.99 14.8 -1.8, 46.8 321.9 194000 198540 26.252 50.009 25.200 51.574 2735.6 166.6 306.5 69.5 15.8 -0.2 55.1 303.8 0.0 75.7 63.0 12200.572.23 140000 140400 25.396 51.618 25.621 51.696 2736.8 31.6 296.5 13.1 0.2 65.7 85.7 0.03981.4 91.9 14200.551.95 15.6 141300 142030 26.109 51.730 26.314 51.327 2738.0 301.4 254.9 26.6 15.2 -1.1 22.5 305.9 0.01721.6 46.5 1530C.568.68

7 May 27,1991 Flt Flight Leg Statistics lon0 lati loni Falt (m) Hda Dist Width Stop la+0 SC2 WD CN CNC.3 Temp TDF WS WI TEO3C 094850 095020 27.997 49.790 27.927 49.896 5460.5 112.1 134.3 7.4 -5.9 -13.0 61.6 358.9 0.0 26.0 8.3 15700.432.54 095230 095530 27.865 49.977 27.898 49.822 5461.1 306.5 131.3 9.5 -6.1 -13.3 57.4 352.8 0.0 28.4 8.3 17800.460.56 102130 104140 27.974 49.791 28.088 48.650 5462.9 103.4 72.7 68.7 -5.6 -13.6 66.8 243.6 0.0 27.9 8.3 52000. 30.95 104300 105520 28.074 48.778 28.120 49.997 5448.4 104.5 134.7 73.2 -5.6 -13.1 77.7 215.8 8.4104300.366.31 0.0 23.3 105820 112000 28.107 49.949 28.125 48.484 4867.8 282.2 65.8 87.9 -1.6 -9.0 56.1 327.9 0.0 39.6 24.3 33000.128.68 112300 114000 20.110 40.465 28.126 50.004 4266.8 96.2 134.9 92.4 3.0 -4.1 64.4 213.6 0.0 38.2 21.9 38400. 84.68 114120 120300 28.190 50.015 28.251 48.593 3679.2 282.5 63.5 85.4 5.6 -1.5 50.1 320.4 0.0 38.7 29.3 49700, 55.4C 120540 122130 28.239 48.546 28.232 49.835 2735.5 105.0 123.4 77.4 13.5 -2.4 54.1 213.3 0.0 39.2 20.6 42400. 74.67 122400 124500 28.213 49.927 28.232 48.613 1809.6 282.8 65.1 78.9 124740 130540 28.223 48.566 28.209 49.826 913.5 95.7 123.4 75.6 28.7 -0.9 46.9 199.4 0.0 28.7 7.7 51300. 21.25 130840 131220 28.295 49.735 28.496 49.708 615.4 326.3 110.8 10.7 31.4 -1.7 44.2 250.7 0.0 26.6 4.5 42600. 79.96 131330 132030 28.510 49.651 28.184 49.395 921.4 336.7 101.5 23.1 29.9 0.9 55.3 30.6 0.0 26.6 5.4 6300. 42.74 132300 132920 28.163 49.425 28.489 49.654 1799.4 13.5 108.0 22.0 21.2 -1.2 50.1 300.9 0.0 29.4 14.4 42300. 61.31 133330 133910 28.481 49.653 28.183 49.429 2727.4 238.6 103.2 20.7 13.5 -1.7 57.0 311.6 0.0 38.1 36.3 58600.123.66 134200 134850 28.104 49.433 28.514 49.666 3643.6 12.2 108.2 25.7 6.5 -2.6 55.7 292.5 0.0 35.6 47.0 64200,147.38 135340 140100 28.549 49.704 28.115 49.415 4857.6 193.5 104.5 28.8 -2.2 -7.9 74.0 112.9 0.0 32.8 11.5103800.173.86 140200 140700 28.056 49.456 27.933 49.919 4859.3 102.9 135.3 28.5 -2.3 -7.6 52.7 351.2 0.0 30.8 13.7 23100.189.57 141300 142200 27.681 52.041 27.072 50.298 2734.8 147.3 180.8 36.0 14.4 -0.7 61.7 30.2 0.0 400.3 16.7 27400.127.40

Flt 8 May 28,1991 Flight Leg Statistics loni Palt(m) Hdg Cist Width Start Stop lat0 lon0 latl WD WI TEO3C SQ2 CN CNC.3 IDP WS Temp 072200 074300 26.651 51.430 26.127 53.093 4564.6 107.7 349.5 103.7 2.2 +8.6 24.1 308.5 0.01877.1 7.4 1500. 96.30 2.2 -8.6 24.1 308.5 0.01877.1 074400 075920 26.072 53.148 25.087 52.543 4560.3 213.1 354.6 64.6 2.9 -10.5 27.6 319.0 0.0 33.2 7.4 13700. 63.63 33.3 357.4 33.8 7.4 4300. 42.54 080500 081300 25.236 52.627 25.694 53.009 4560.4 2.4 **-9.4** 18.8 312.7 C.O 33.0 081500 082130 25.792 52.964 25.957 52.554 4556.6 297.1 326.5 26.1 7,4 2900. 45.08 2.4 -9.8 20.9 313.6 0.0 34.8 082900 084300 26.132 52.132 26.432 51.376 1813.7 294.8 253.4 48.1 22.5 -10.3 20.5 299.2 0.0 67.4 14.4 14300. 74.69 084400 091800 26.434 51.317 26.250 49.292 1813.3 274.0 178.6 121.9 21.4 -2.4 22.8 295.1 0.0 74.8 21.7 37800. 81.03 092320 095020 26.326 49.094 27.128 50.695 1132.1 58.8 198.0 105.2 23.4 -12.1 16.1 327.2 0.0 67.9 21.5 33900.114.91 095200 101820 27.154 50.657 26.536 49.108 1811.1 251.4 159.7 98.7 21.8 -9.0 19.5 298.8 0.0 71.8 15.0 27700.117.23 102000 104210 26.485 49.136 27.098 50.680 2132.6 58.5 198.2 98.2 19.9 -12.9 21.0 306.5 0.0 73.6 16.6 80000.154.51 104400 110200 27.114 50.643 26.690 49.569 3255.7 249.2 166.3 68.3 11.5 0.0 27.4 282.0 0.0 63.0 17.7 21700.138.14 110400 111730 26.672 49.655 27.116 50.681 3346.4 57.3 197.7 66.0 10.6 -7.4 23.8 307.7 0.0 54.0 6.3 11000.136.46 112100 115400 27.112 50.565 26.231 48.484 3961.6 250.1 164.2 133.5 6.3 -7.7 26.0 302.0 0.0 34.5 6.9 1800.141.62 122200 123700 26.396 49.232 26.234 50.343 1841.1 95.0 214.8 67.2 22.5 0.7 16.2 318.4 0.0 52.8 5.2 3900.156.96

Fit 9 May 29,1991 Flight Leg Statistics lomi Palt(m) latC lon0 lat1 Hdg Dist Width Stop WD WI TEO3C CN CNC.3 IDP WS SC2 Temp 190000 082300 26.852 50.242 27.993 49.399 4252.1 323.7 107.5 78.8 5.3 -23.4 22.4 282.9 C.C 36.2 4.2 25000. 15.81 083200 083900 27.927 49.489 28.228 49.827 3679.4 33.3 123.0 25.8 9.7 -13.4 18.0 288.5 0.0 29.7 4.2 72400. 15.51 084100 085910 28.233 49.872 27.680 48.789 3650.9 243.8 95.6 71.4 9.1 -16.6 19.2 279.6 0.0 29.5 4.2 84600. 20.96 53.8 123.3 67.7 14.9 76500. 44.92 090500 092400 27.672 48.811 28.223 49.830 474.2 24.3 1.5 18.2 340.9 0.0 44.6 093100 095100 28.228 49.922 27.677 48.766 2122.4 246.6 95.0 75.3 53.2 53600. 82.42 18.7 -3.2 23.8 296.4 C.C 61.5 095600 100800 27.648 48.727 28.036 49.363 465.3 45.3 104.5 43.3 24.4 0.7 16.1 345.0 0.0 53.1 24.5 39800. 32.37 79.3 24.1 100900 101700 28.074 49.366 28.385 49.070 459.3 336.6 C.C 15.0 6.2 0.0 38.8 5.0 9000. 13.06 25.2 101800 102430 28.419 49.103 28.584 49.473 470.0 53.8 96.0 23.8 0.0 15.2 341.9 0.0 36.5 4.1 16800. 9.28 25.2 102700 104300 28:599 49.517 28.301 48.531 472.1 255.1 59.2 61.2 28.5 -2.2 16.9 335.8 C.0 41.3 20.1 44300. 27.03 20.1 44300. 27.02 104630 110110 28.268 48.535 28.592 49.482 1051.8 59.7 96.4 59.4 25.2 -11.0 18.1, 325.4 0.0 58.2 48.1 67200. 70.65 110500 112440 28.588 49.500 28.198 48.310 2121.9 249.4 58.0 74.4 18.5 -2.8 20.5 297.1 0.0 56.8 50.2 74200. 85.57 112730 114300 28.183 48.296 28.599 49.481 2586.1 63.6 96.2 74.4 15.2 -2.4 22.3 295.6 0.01194.6 28.1 48500. 58.26 114600 120540 28.615 49.557 28.223 48.369 3040.6 253.7 58.1 74.2 12.3 -3.0 22.1 284.3 0.0 29.3 4.1 20000. 37.29 120840 122310 28.227 48.332 28.606 49.525 3651.4 65.3 98.6 74.3 8.4 -11.5 21.6 288.9 0.0 30.5 7500. 45.81 4.9 122500 125420 28.640 49.495 28.195 48.244 1052.6 255.2 56.9 78.7 25.6 -3.5 30.8 334.4 0.0 54.4 49.0 68200. 48.56 125700 131200 28.168 48.200 28.426 49.080 512.6 68.0 78.6 54.5 28.0 -4.7 17.5 344.C 0.0 44.6 24.3 38700. 37.42 131800 132800 28.148 49.318 27.806 49.844 511.9 85.3 135.1 36.4 27.8 -9.6 22.9 341.3 0.0 43.1 4.1 15300. 6.67 133420 135200 27.728 50.283 26.555 50.673 1477.7 158.1 216.3 67.2 26.5 -0.4 20.7 321.0 0.0 55.3 23.4 25400. 35.42 Fit 10 May 30,1991 Flight Leg Statistics lon1 Palt(m) Hdg Dist Width Stop lat0 lon0 latl WD WI TEOSC SO2 CN CNC.3 WS Temp TDP 045500 050400 26.895 50.203 27.318 49.890 3035.8 322.0 153.5 29.3 13.6 -7.0 21.3 285.5 0.0 45.3 2900. 43.64 6.4 050900 054800 27.540 49.723 29.250 47.943 3827.6 310.4 2.3 139.3 5.2 -11.3 21.4 266.6 0.0 80.9 7.1 3800. 60.29 060600 061400 28.644 48.012 28.799 48.518 1091.0 39.6 31.5 63.7 U.U 68.6 747.5119700.248.33 -6.4 17.8 344.4 24.5 061700 062700 28.805 48.580 28.608 47.933 1381.2 259.0 32.7 40.2 -3.1 16.7 331.0 0.0 68.3 508.2117100.264.10 23.3 062940 06423C 28.581 47.899 28.893 48.755 1681.0 62.8 49.9 -8.1 15.1 317.8 0.0 70.9 237.0117400.235.54 20.2 727.9 294.7 32.2 54.7 064520 065900 28.904 48.808 28.619 47.932 27.6 -3.2 20.8 350.9 0.0 75.9 312.9116500.158.17 070200 071400 28.619 47.966 28.868 48.693 548.0 62.2 47.0 45.5 0.6 67.7 180.3110100.114.36 28.0 2.2 10.2 044.9 071900 07215C 28.865 48.755 28.823 48.580 1966.4 259.8 42.0 10.7 20.0 -11.4 14.2 303.4 0.0 78.3 5.5 2000. 29.67 074400 075100 28.396 48.159 28.089 48.538 2535.3 136.3 69.1 27.9 16.2 -5.6 15.4 302.4 0.0 77.0 137.3 57700. 90.18 075730 080800 28.111 48.837 27.779 48.207 1987.4 242.3 78.2 41.7 18.7 -7.2 17.1 344.6 0.0 82.5 319.7 92800.147.45 081100 082540 27.749 48.149 28.264 49.064 2273.1 51.7 82.8 61.3 17.5 -3.9 16.6 303.1 0.0 81.8 134.5 54000. 92.19 082900 084800 28.304 49.108 27.702 47.987 1093.0 247.5 81.1 74.4 25.9 -2.9 14.5 337.9 0.0 70.6 150.9 71300. 92.51 085100 091400 27.661 47.924 28.319 49.308 1381.9 59.2 93.2 90.0 23.4 -8.9 15.8 332.6 0.0 72.9 180.2 80900.111.40 092300 093600 28.217 49.123 27.853 48.311 3792.0 244.3 75.7 52.4 0.0 71.1 7.8 -21.0 17.1 269.5 7.0 2300. 91.03 093900 100440 27.687 48.380 27.383 50.302 4096.9 69.7 170.7 116.5 6.4 -24.4 24.7 299.9 0.0 65.3 7.3 2300, 50.23 100900 104530 27.286 50.183 27.276 50.269 2280.8 79.8 172.5 5.2 21.7 -4.1 16.6 289.3 0.0 86.4 89.1 26100. 82.33 105240 105900 26.824 50.468 26.418 50.600 806.2 162.7 218.2 23.2 28.1 -5.9 16.1 348.7 0.0 57.5 4.8 2400, 52.60

Flt 11 May 31,1391 Flight Leg Statistics lar I lon1 Falt (m) lon0 Hdg Dist Width Stop latO qmeTMT. WI TEO3C 302 CM CMC.3 TDP WΞ 0.000 0.000 0.000 0.000 3641.7 339.73370.7 045900 051400 8.6 -8.5 13C.1 339.8 C.0 60.6 6.9 1700, 46.65 051700 054330 0.000 0.000 0.000 0.000 3796.9 349.63370.7 7.1 2600, 96.36 7.6 -14.7 131.4 349.8 0.0 62.6 0.000 0.000 0.000 0.000 3802.5 345.43370.7 0.0 054500 055600 7.5 -17.9 132.6 345.6 0.0 56.5 7.1 34100. 45.64 055800 060900 0.000 0.000 0.007 0.000 3799.2 344.73370.7 0.0 7.6 -14.5 128.3 344.9 0.0 62.3 7.1 17900. 57.60 062800 063500 27.556 48.634 27.113 48.546 2585.3 205.1 118.0 24.3 17.5 -3.0 13.3 268.5 0.0 63.1 7.5 8800. 66.33 063600 064400 27.084 48.502 27.264 47.999 2588.3 290.5 104.8 16.2 -4.6 12.6 262.8 0.0 70.1 75.7 40800. 73.69 064530 065800 27.227 47.970 26.772 48.796 2589.7 137.0 140.4 55.2 18.2 -2.6 15.4 286.9 0.0 72.1 68.8 31400, 83.51 065940 070950 26.785 48.858 27.172 48.338 2582.5 299.0 111.9 37.4 17.2 -3.8 15.1 267.4 0.0 72.0 53.9 34600, 71.62 971109 072300 27.135 48.282 26.437 47.873 2583.0 211.2 150.1 44.8 -3.7 13.9 277.5 0.0 75.1 129.6 31900, 85.07 18.2 072400 073540 26.408 47.909 27.000 48.384 2273.5 33.7 121.6 42.6 20.6 -3.1 13.6 317.6 0.0 80.2 131.2 21000, 99.45 073730 074900 26.963 48.440 26.301 48.038 2279.6 212.5 157.5 43.0 19.9 -2.9 10.1 276.6 0.0 77.2 79.7 16900. 87.87 075030 080720 26.277 48.091 27.272 48.602 2617.8 17.5 110.9 61.3 17.5 -3.5 17.4 294.3 0.0 82.3 106.0 25500. 85.56 080830 082000 27.285 48.560 26.624 48.161 2883.3 213.2 140.1 42.7 15.7 -4.0 13.2 294.9 0.0 75.1 70.8 23400. 70.22 082200 083420 26.573 48.208 27.316 48.632 3202.8 22.9 109.3 47.1 12.5 -5.3 14.8 298.7 0.0 76.1 50.6 16400. 86.74 983600 085630 27.341 48.594 25.979 48.205 3495.4 202.4 175.8° 77.1 11.3 -9.4 17.5 296.1 0.0 65.6 36.6 14100, 91.40 085800 092200 25.963 48.273 27.287 48.858 1669.5 33.8 116.2 78.8 9.7 5400. 73.75 22.8 -4.0 12.7 18.7 0.0 62.3



National Center for Atmospheric Research

P.O. Box 3000, Boulder, CO 80307-3000

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Contact:

Joan Vandiver Frisch

Manager, NCAR Media Relations

(303) 497-8607

NCAR Scientists Release Preliminary Results from Kuwait Oil Fires Study

BOULDER, CO—Two research aircraft, one from the National Center for Atmospheric Research (NCAR) and one from the University of Washington, as well as a team of scientists from NCAR and other institutions have just returned from a month-long study of smoke plumes blackening the skies over the burning Kuwaiti oil fields. Lawrence Radke, co—project leader from NCAR, along with Peter Hobbs of the University of Washington, said the scientists studied the smoke because of effects on clouds, precipitation processes, radiation, and atmospheric chemistry and because this unprecedented air pollution event, by its very magnitude, can provide insights into controversies over atmospheric responses which could be caused by more subtle pollution sources.

The potential for environmental havoc, regional weather modification (especially in reference to the Indian monsoon and precipitation processes), and poisonous clouds and rains have all received considerable attention. The purpose of this on-site project was to provide the quantitative detail to either support or refute these speculations. Some preliminary results are now becoming available.

For example, according to Radke, for catastrophic environmental effects to occur, the smoke had to fulfill several conditions: it had to be very black, not absorb water, and loft itself into the stratosphere. The smoke turned out to be only half as black as predicted, with individual wells producing smokes ranging from white to black.

Also the smoke proved to be hydroscopic, rather than hydrophobic, as predicted. Thus the smoke will interact with clouds and precipitation and thereby be comparatively quickly removed from the atmosphere.

Self-lofting held up no better than the first two conditions. Although the smoke became more buoyant in the midday heat, rising higher into the atmosphere, these very dynamics diluted the plumes and ultimately halted the self-lofting. The highest altitude at which the smoke was observed was 18,000 feet (5,500 meters) after two days in the air. No further significant rise was expected because of the then diluted nature of the smoke cloud. If the particles had reached the stratosphere, where they could remain for months, they could have damaged the environment much more than they would in the troposphere, where they are removed within days.

Another important concern was the effect of smoke on regional precipitation.

Theoretically, injecting cloud-active aerosols into clouds would decrease rainfall by spreading the cloud moisture among a larger number of cloud condensation nuclei, thus producing a greater number of droplets too small to fall out as rain. In reality, the aerosols vary greatly in size, so the larger smoke particles may facilitate precipitation formation. Another hypothesis suggests that the injection of black carbon particles into white clouds would increase rainfall by causing the clouds to absorb (rather than reflect) a significant amount of solar radiation. The warmer clouds would rise to higher, cooler altitudes, where condensation and rainfall would be enhanced. In addition, this change in cloud reflectivity, if large-scale, could ultimately affect the earth's radiation balance by increasing surface temperature. Because there were few clouds in the Kuwaiti sky during May (the team encountered only one region of altocumulus, and the data from this encounter are awaiting analysis), these questions have not yet been answered.

The scientists also searched for the poisonous hydrogen sulfide gas and the main acid rain constituent, sulfur dioxide. Evidently, because the hydrogen sulfide was burned quickly by the fires and readily oxidized to sulfur dioxide, it was not a threat. As for acid rain, the fires produced approximately 65 pounds (30 kilograms) of sulfur dioxide per second, an amount equivalent to 6–12 power plants or one recently erupted volcano. "Although a big source," says

Radke, "its effects would be local and moderate," somewhat increasing acid rain downwind of the plume.

But, he adds, "We're certainly going to have some regional weather modification near the fires." For example, the Kuwaiti ground is gradually getting blacker from incompletely burned oil and carbon falling out of the atmosphere. This will change the local reflectivity, since the desert is originally rather bright but oil on the surface will cause it to be less so.

Radke describes the smoke and the difficulty of comprehending the plume's scale: "When we flew over it in the plane, the black plume stretched from horizon to horizon, covering thousands of square miles. Inside of the plume at 3,000 feet (about 900 meters) altitude and 20 miles (about 30 kilometers) downwind of the fire, all sunlight was gone; it was completely dark in the airplane. But when we looked at satellite pictures, we saw that the plume is very small globally."

In Kuwait, the research team found some surprises: models of the smoke plume dynamics were inaccurate, the importance of the effects of blowing sand on the plume hadn't been accounted for, and the plumes were affected by unexpected wave activity created by complicated small-scale airflow patterns.

Using multiple-wavelength lidars aboard NCAR's Electra to measure molecular and particle scattering, observers could detect both the sensitivity and distribution of smoke within the plumes. They obtained strong circumstantial evidence that the particles grew in size more rapidly than expected as the plume dispersed and aged.

To get an overview of the gas phase species emitted from the fires, chemists on the project measured emission fluxes and their photochemical reactivity. According to NCAR chemist Gregory Kok, they found the photochemical reactivity (measured in terms of excess ozone) was 20 to 30 parts per billion (ppb), compared to over 100 ppb in Los Angeles on a sunny day.

Says Radke, "These fires provide an exaggerated example of air pollution. There's never been this much oil burned in such a primitive fashion over such a long period."

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Measurements of Formaldehyde and Hydroperoxides in the Kuwait Oil Fire Plume

1. 1991 Fall Meeting

GL Kok, WT Luke, and RD Schillawski (Research Aviation Facility, National Center for Atmospheric Research, Post Office Box 3000, Boulder, CO 80307-3000; 303-497-1070)

As part of the airborne measurements in the Kuwait oil fire smoke plumes, analysis for formaldehyde (HCHO) and hydroperoxides (H_2O_2 and ROOH) were conducted. The HCHO measurements were made using a continuous wet chemical technique based on the Hantzsch reaction. The continuous dualenzyme technique was used to determine H_2O_2 and a lower limit on the organic hydroperoxides. HCHO concentrations were typically 5-10 ppbv at 80 nm downwind. At the head of the plume from the southern field, the HCHO concentration was in excess of 50 ppbv. On some flights, a close correlation between SO_2 and HCHO was observed. No significant changes in the concentrations of hydroperoxides were observed. Increases of H_2O_2 from 1-2 ppbv were observed within the plume.

*The National Center for Atmospheric Research is sponsored by the National Science Foundation

Some Dynamical Influences on the Smoke Plumes from the Oil Fires of Kuwait

1. 1991 Fall Meeting

W A Cooper, L F Radke, and D H Lenschow (Research Aviation Facility, National Center for Atmospheric Research, Post Office Box 3000, Boulder, CO 80307-3000; 303-497-1038; OMNET: NCAR.RAF) (sponsor: P V Hobbs)

When the smoke plumes from the oil fires of Kuwait moved along the coast of Saudi Arabia, complicated interactions occurred involving the redistribution of absorbed energy by the smoke, land-sea-breeze circulations, and the regional mesoscale airflow. An instrumented research aircraft was used to observe the air motions and radiation fields within and near the smoke plumes during May and June 1991.

During these flights, a common observation was strong horizontal convergence of the wind field into the plume, even at low levels where a cooler outflow might have been expected. Absorption of solar energy at the top of the smoke layer, and shielding of lower layers, led to differential heating and hence to local circulation patterns. However, the strong static stability of the atmosphere limited the effects of the changes in buoyancy, and hence limited the degree to which the smoke rose in the atmosphere in response to solar heating.

In addition, the large (100 km) widths of the smoke plumes permitted unusually good characterization of the turbulent wind fluctuations responsible for spreading of the smoke. Examples of measured variance spectra and deduced characteristic time scales for the turbulent air motions will be presented. These are used to relate the observed plume dimensions to predictions of simple models of turbulent diffusion.

*The National Center for Atmospheric Research is sponsored by the National Science Foundation

Ozone and Sulfur Dioxide Measurements in the Kuwait Oil Fire Plume

1. 1991 Fall Meeting

R D Schillawski, G L Kok, and W T Luke (Research Aviation Facility, National Center for Atmospheric Research, Post Office Box 3000, Boulder, CO 80307-3000; 303-497-1042)

In-plume and background measurements of ozone (O₃) and sulfur dioxide (SO₂) were made during May and early June of 1991 from the NCAR Electra. Three different techniques were used for O₃ measurements, ultraviolet absorption, nitric oxide chemiluminescence, and Rhodamine 6G dye chemiluminescence. SO₂ levels were made using the pulsed florescence technique. This presentation will compare the performance of the O₃ instruments, show the results of the O₃ and SO₂ measurements, and discuss these results as compared with those of other species, or made by other investigators.

The National Center for Atmospheric Research is sponsored by the National Science Foundation

Reactive Trace Gas Measurements and Photochemistry in the Kuwait Oil Fire Smoke Plume

1. 1991 Fall Meeting

WT Luke, GL Kok, and RD Schillawski (Research Aviation Facility, National Center for Atmospheric Research*, Post Office Box 3000, Boulder, CO 80307-3000; 303-497-1018)

A variety of reactive trace gases (O₃, CO, NO, NOy, SO₂) were measured from the NCAR Electra both inside and outside the Kuwait oil fire smoke plume in May and June, 1991. At a range of 80 km from the fires, NOy concentrations varied from less than 0.5 ppbv outside the plume to almost 70 ppbv at an altitude of 1100 m; nitric oxide (NO) typically comprised only 5-10% of total NOy inside the plume. Sulfur dioxide levels reached a maximum of over 700 ppbv, while CO peaked at over 500 ppbv at the same location. Close to the fires, high NOx and low UV levels allowed a significant fraction of the ambient ozone to be titrated. At a distance of 160 km downwind, however, net photochemical ozone production was observed, and averaged less than 2 ppbv per hour throughout the plume. The trace gas data will be discussed in terms of regional photochemistry and emission budgets, and will be used to infer combustion characteristics at the blazing well heads.

The National Center for Atmospheric Research is sponsored by the National Science Foundation

A Review of the United States Interagency Airborne Study of the Smokes From the 1991 Kuwait Oil Fires

- L F Radke (Research Aviation Facility, National Center for Atmospheric Research, Post Office Box 3000, Boulder, CO 80307-3000; 303-497-1032)
- P V Hobbs (Atmospheric Sciences Department, AK-40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)

As the Iraqi army fled Kuwait in March 1991, they damaged or destroyed 749 oil wells, most of which were ignited. The resulting fires produced an extraordinary large plume of black smoke that had both local and regional effects on the Gulf States and the potential for global effects.

As part of the interagency United States effort (coordinated by the National Science Foundation) to assess the impacts of the fires on the atmosphere, the University of Washington (UW) and the National Center for Atmospheric Research (NCAR) mounted an airborne study of the smoke from the Kuwait fires utilizing the UW Convair and the NCAR Electra research aircraft.

During the period 16 May through 12 June 1991, some 200 research flying hours were flown to study the smoke form the Kuwait oil fires. The primary goals of the studies were to determine the chemical and physical nature and the radiative properties of the smoke, the fluxes of various materials in the smoke, and the potential effects of the smoke on weather, climate and air quality.

The key result of our preliminary analysis is that predictions of very large scale, even global scale climate modification are not supported. These predictions had been predicated on an optically very dark smoke being solar self-lofted to the tropopause where cloud and precipitation scavenging would be minimized by both elevation and expected particle hydrophobicity. This would lead to a long atmospheric residence time for the smoke particles. To the contrary, we found the smokes to be substantially "whiter" than expected (single scattering albedo at visible wavelengths ~0.6). While solar heating of the smokes introduced interesting dynamics in the plume, self-lofting was found to have limited effectiveness (the smoke plume top was never observed above 6 km after travel times of up to two days). Finally because of water soluble salts in the fuel and oxidation of SO₂ to sulfate, the smoke particles were hygroscopic rather than hydrophobic and thus have a rather limited tropospheric residence time.

*The National Center for Atmopsheric Reserach is sponsored by the Natinoal Science Foundation

1. Ocean Sciences Meeting

Solar Heating of the Kuwaiti Oil Fire Plume and Induced Self-Lofting and Dynamics

1. 1991 Fall Meeting

LF Radke, D Baumgardner, R L Schwiesow and W A Cooper (Research Aviation Facility, National Center for Atmospheric Research, Post Office Box 3000, Boulder, CO 80307-3000; 303-497-1032)

The optically black smoke plume from the hundreds of burning oil wells in Kuwait was initially forecast to have a potentially significant regional and global climatic effect by virtue of the smoke's expected optical properties and long atmospheric residence times. An important factor in long residence times is the mechanism of solar self-lofting, where much of the smoke would rise high in the troposphere and perhaps into the lower stratosphere and thus largely escape cloud and precipitation scavenging. The role of solar self-lofting of the soot particles, whereby optically black particles absorb solar radiation, heat the surrounding air and through increased buoyancy rise to high altitudes was strongly supported by recent large-scale test fires of aviation fuel (JP-4) which produces a dense, dark, smoke (visible wavelength single scattering albedo of ~0.3). Airborne observations showed that the JP-4 smoke plume rose through a strong planetary boundary layer capping inversion in a few hours. However, both direct sampling and visual observations together with multi-wavelength lidar observations (0.5, 1, and 10 μ m) from the NCAR Electra, showed that while the Kuwaiti plume was significantly modified by solar heating, self-lofting was comparatively ineffective in transporting the soot particles to higher altitudes. The maximum altitude where particle concentrations appeared above the normal background levels never exceeded about 6 km. However, self-lofting in the form of small convective elements within the larger plume were frequently observed by lidar.

The reasons for this limited role for self-lofting is evidently due to a combination of a much "whiter" than expected smoke plume (single scattering albedo -0.6), a comparatively stable atmosphere and rather rapid dilution of the smokes. This latter effect was caused by both strong winds and solar induced plume dynamics. Plume dynamical effects were observed on a variety of scales including strong low level convergence along the length of the smoke plume.

^{*}The National Center for Atmospheric Research is sponsored by the National Science Foundation

FLT 1491 (SOUTH FIELD SOURCE STUDY) EMISSION FACTORS (in g C/kg) University of Washington

Fuel Carbon Fraction (Cf) = 0.85

Sample Time	Particle*	Soot T	OC(a)**	CO	CO2	CH4	TOC(v)	SO2*	Comments
0536	12.1	3.3	4.4	5.2	827.8	1.2	8.1	33.8	6.5 K ft CS sample*** 5.5 K ft CS sample 4.5 K ft CS sample 3.5 K ft CS sample 2.5 K ft CS sample
0549	15.0	3.5	5.7	6.0	818.4	1.8	14.5	31.8	
0604	20.5	4.3	8.1	7.2	809.5	2.1	18.8	36.8	
0616	25.2	5.7	9.7	7.9	791.5	3.4	31.7	35.3	
0629	29.2	5.6	11.8	7.7	791.2	3.1	30.6	29.7	
0717	42.2	9.5	16.3	5.5	816.0	0.7	1.9	69.0	Minagish pool fire sample
0757	51.5	16.5	17.5	9.5	802.0	1.8	2.8	31.7	Magwa pool fire sample
CS Average:	20.4	4.5	7.9	6.8	807.7	2.3	20.8	33.5	
CS Std Dev:	7.0	1.1	3.0	1.2	16.2	0.9	10.2	2.8	

^{*} Particle and SO2 emission factors in g/kg

^{**} TOC(a) = Total organic carbon in aerosol Estimated as (Particle mass conc. - Soot conc.)/2

^{***} CS = Cross section of Magwa/Burgan aggregate plume

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FLT 1491 (SOUTH FIELD SOURCE STUDY) CARBON BUDGET DATA University of Washington

RESULTS FOR MINAGISH AND MAGWA POOL FIRE SAMPLES

All concentrations in ug C/m3
Values in parentheses are percent of total carbon

Sample Time	Soot	TOC(a)*	CO-C	CO2-C	CH4-C	TOC(v)	Total C
0717 (Minagish)	181.4 (1.1)	311.3 (1.9)	105.5 (0.7)	15535.7 (96.0)	12.9 (0.1)	37.0 (0.2)	16183.8
0757 (Magwa)	165.4 (1.9)	175.3 (2.1)	94.8 (1.1)	8035.7 (94.4)	17.7 (0.2)	28.0 (0.3)	8516.9

^{*} TOC(a) = Total organic carbon in aerosol



FLT 1491 (SOUTH FIELD SOURCE STUDY) CARBON BUDGET DATA University of Washington

RESULTS FOR MAGWA/BURGAN AGGREGATE PLUME CROSS SECTION STUDY

All concentrations in ug C/m3 Values in parentheses are percent of total carbon

Sample Time	Soot	TOC(a)*	CO-C	CO2-C	СН4-С	TOC(v)	Total C
0536	63.6 (0.4)	85.2 (0.5)	101.3 (0.6)	16071.4 (97.4)	23.0 (0.1)	158.0 (1.0)	16502.5
0549	80.3 (0.4)	131.4 (0.7)	137.1 (0.7)	18750.0 (96.3)	41.8 (0.2)	333.0 (1.7)	19473.6
0604	94.3 (0.5)	176.4 (1.0)	157.0 (0.8)	17678.6 (95.2)	46.6 (0.3)	411.0 (2.2)	18563.8
0616	358.2 (0.7)	612.9 (1.1)	498.8 (0.9)	49821.4 (93.1)	213.2 (0.4)	1996.0 (3.7)	53500.5
0629	309.1 (0.7)	645.0 (1.4)	424.3 (0.9)	43392.9 (93.1)	171.4 (0.4)	1677.0 (3.6)	46619.6
Avg % of Total C:	0.5	0.9	0.8	95.0	0.3	2.4	
Std Dev:	0.2	0.4	0.1	1.9	0.1	1.2	

^{*} TOC(a) = Total organic carbon in aerosol

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FLT 1488 (NORTH FIELD SOURCE STUDY) EMISSION FACTORS (in g C/kg) University of Washington

Fuel Carbon Fraction (Cf) = 0.85

Sample Time	Particle*	Soot	TOC(a)**	СО	CO2	CH4	TOC(v)	SO2*	Comments
0413	33.3	8.5	12.4	4.9	820.5	0.6	3.1	31.2	Black plume sample
0445	25.8	0.9	12.4	3.2	830.4	0.3	2.7	24.1	White plume sample
0524 0620	15.2 20.1	3.1 2.8	6.1 8.7	18.5 4.8	786.6 824.2	4.7 0.9	31.0 8.7	18.9 17.2	3 K ft CS sample*** 2 K ft CS sample
CS Average:	17.7	2.9	7.4	11.6	805.4	2.8	19.8	18.0	· · · · · · · · · · · · · · · · · · ·
CS Std Dev:	3.5	0.2	1.8	9.7	26.6	2.7	15.8	1.2	

^{*} Particle and SO2 emission factors in g/kg

^{**} TOC(a) = Total organic carbon in aerosol Estimated as (Particle mass conc. - Soot conc.)/2

^{***} CS = Cross section of North field plume

FLT 1488 (NORTH FIELD SOURCE STUDY) CARBON BUDGET DATA University of Washington

RESULTS FOR BLACK AND WHITE INDIVIDUAL PLUME SAMPLES

All concentrations in ug C/m3 Values in parentheses are percent of total carbon

Sample Time	Soot	TOC(a)*	CO-C	CO2-C	CH4-C	TOC(v)	Total C
0413 (Black plume)	172.1 (1.0)	250.4 (1.5)	99.6 (0.6)	16607.1 (96.5)	11.3 (0.1)	63.0 (0.4)	17203.6
0445 (White plume)	39.8 (0.1)	537.6 (1.5)	137.1 (0.4)	35892.9 (97.7)	14.5 (0.04)	118.0 (0.3)	36739.9

^{*} TOC(a) = Total organic carbon in aerosol

FLT 1488 (NORTH FIELD SOURCE STUDY) CARBON BUDGET DATA University of Washington

RESULTS FOR NORTH FIELD PLUME CROSS SECTION STUDY

All concentrations in ug C/m3 Values in parentheses are percent of total carbon

Sample Time	Soot	TOC(a)*	CO-C	CO2-C	CH4-C	TOC(v)	Total C
0524	16.8 (0.4)	33.1 (0.7)	100.7 (2.2)	4285.7 (92.5)	25.7 (0.6)	169.0 (3.6)	4631.0
0620	19.9 (0.3)	62.0 (1.0)	34.3 (0.6)	5892.9 (97.0)	6.4 (0.1)	62.0 (1.0)	6077.5
Avg % of Total C:	0.4	0.9	1.4	94.8	0.4	2.3	
Std Dev:	0.1	0.2	1.1	3.2	0.4	1.8	

^{*} TOC(a) = Total organic carbon in aerosol

Sample No.	Can S/H	Date	Time	Altitude ft.	Comments	H2 ppbv	ppbv CO	bbp n CO	CN4 ppbv	CO2	TO-12 g/m-3	bbpa N50
Flight 1	1477 RF?	16-Nay-91	724	16,500	Clear (background sample	533 52 6	79 79	92	1749	367	334.0	342.7 343.1
2	res	16-May-91	823	10,500	Maze, top of smoke layer over Kuwmit	54 1 563	132 133	149	1762	428	881.5	
Flight 3	1480 RP5	22-May-91	1032	5,090	Haze, smoke over Kuwait	572 575 564 587	260 263 261 264	284	1841	387	650.1	342.2
4	RF6	22-May-91	1053	4,700	haze, smoke over Arabian gulf.	527 536	137 137	154	1797	368	106.3	343. J
5	RF13	22-May-91	1124	4, 000	Clear, background sample			123	1792	362	77.6	343.6
light 6	1481 RF14	27-Hay-91	703	8,000	Haze; plume sample at			152	1782	381	259. <i>7</i>	340. ó

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Sample No.	Can S/R	Date	Time	Altitude ft.	Comments	H2 ppbv	ррьи	Ppbv CO	CH4 ppbv	PPMv CO3	TJ-12 ug/m+3	N20 ppbv
		(continued) 27-May-51	814	4,000	Haze, plume sample			240	1524	378	283.4	342 4
9	RFI	2?-Hay-91	914	2,500	Haze, smoke from Kuwait oil fires	716 548 512 515	206 208 208 208	231	1806	375	308.9	340.7# 343.0
10	RF2	27- May-91	1118	11,500	Haze, smoke sample; sample in plume ESE of Bahrain	575 542 530 530	106 106 106 106	119	1758	366	53.3	341.6 342.9
Flight 11	1482 RF3	28-Nay-91	1130	12,000	Clear; ambient sample above plume.	555 535 526 530	79 79 79 80	84	1757	362	76.3	342.6
12	RF4	28-Hay-91	1206	10,100	Haze smoke sample,	5 14 54 1 524 532 520 516	151 151 152 152 152	163	17/8	373	104.2	341.4
	RFS1	28-Hay-91	1248	8,100	Haze, snoke sample; measurements at time sample: CO 0.1 ppm, CO2 392 ppm	546 528	133 133	148	1777	369	83 4	343.6
14	RF92	28-May-91	1329	6,100	Haze, smake sample;	511 521 554 555	280 281 284 285	310	1807	384	231.6	334.4

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ample lo.	Gan S/K	Date	Time	Altitude ft.	Commen	125		ррћи Н2	cu ppbv	C0 ppbv	CH4 ppbv	СО2 РРМV	TO-12 ug/m-3	N20 ppbv
		(continued) 28-May-91		4,100	Haze,	smoke	sample;	524 517	190 190	213	1816	372	255.6	342.1
light 16		31-Hay-91	828		Baze.	smoke	sample;	524 517	350 352	3 81 374	1809 1810	394 394	238.4	343.0
17	RF33	31-May-91	843				sample (same r can RF 84)			396	1815	399	245.6	346.0 345.3
18	RF≯⊾	31-May-51	920		Maze,	sneke	sample,			151	1791	365	62 0	341.5 341.1
19	RF35	31-May-91	932				sample (same r can RF 34)			144	1793	364	53.6	342.0 342.0
26	RF36	- 31-May-91	10 06		Haze, plume)		sample (white			210	1789	368	134.9	342.6
21	RF41	31-May-91	1038	3,500	Haze,	r luze	sample	531 55?	292 294	313	1848	384	538-0	341 4

KUWAIT - SUMMER 1991	University of Washington
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Sample No.	Can S/N	Date	Time	Altitude ft.	Comments	Н2 р рбу	CO ppbv	ppbv CO	CH4 ppbv	D Dama COS	TO-12	н20 рр b v
		(continued) 31-May-91	1053	3,500	Maze, main plume sample.	558 557	313 315	334	1848	381	565.1	
23	R <i>?</i> 43	31-Hmy-91	1111	5,000	Haze. plume sample 20 mi. from fire at 5000 ft.	540 559	446 446	470	1817	402	475.4	343.4
Flight 24	1485 R P44	02-Jun-91	716	8,000	Maze, plume sample at 8000 ft.	531 526	121 121	.140	1780	379	206.5	344 . 0
25 1	RF45	02-Jun-91	809		Faze, plume sample at 5600 ft.	564 548	301 303	332	1802	405	298.7	344.9 342. 8 *
Fli ght 25	1486 RF46	03-Jun-91	842 -		Haze, plume sample at 3000 ft	525 528	278 280	296	1811	378	275.9	343.6
27 1	RF4)	03-Jun-91	923		Haze, plume sample at 3500 ft	524 536	428 432	448	1829	398	462.1	344.2
28 1	RF49	03-Jun-91	939	3,500	Haze, plume sample	517 523	263 284	297	1828	380	365 6	344.2 340.92 359.8

^{*} calibrated just before run

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Sample Can No. S/N	bate	Time Al	titude ft.	Comen	ts		H2 ppbv	CO ppbv	ppbv CO	CH4 ppbv	CO2 թթեv	70-12 ug/m-3	N20 ppbv
Flight 1486 (29 RF89	continued) 03-Jun-91	959	3,500	Haze,	p lume	sample	543 542	270 271	288	1818	37 8	265.7	342 B 342.4
30 RF90	03-Jun-91	1021	3,500	Haze, ;	plume	sample	541 536	303 3 05	314	1823	379	353.8	342 2*
31 RF91	03-Jun-91	1640	3,500	Baze, j	plume	sample	536 547 527 520	187 188 185 186	202	1/84	369	177.4	342.5*
32 EF92	03-Jup-91	1101	3,500	Kaze,	plume	sample	534 528	224 225	246	1802	377	249.5	341.3
33 RF9	03-Jun-9 1	1119	3,500	Hase,	plume	sample .	516 526	197 198	218	1794	369	189.8	340.2
34 RF)O	03-Jun-91	1145	3,500	Kaze,	pi ca e	sample	533 5 30	176 177	194	1787	366	191 3	340.6 342.3
35 RF11 (03-Jun-91	1205	3,500	Haze, (r lune	sample	578 574	190 190	209	1805	370	260.4	343.3
3r- RF12	03-Jun 91	1312		Clear,	backg	round sample	528 520	71 77	83	1257	153	.15 5	342.9

^{*} calibrated just before inc.

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Sample No.	Can S/N	Date	Time Altitude ft.	: Comments	H2 ppbv	CO ppbv	ъррл СО	СН4 рр Ь v	₽ ₽™∧ CΩ3	TO-12 ug/m·3	N2O ppb v
Flight 37	1487 BF69	05-Jun- 91	801 2,500	Haze, plume sample at 2500 ft.			277	1813	405	315.4	33 5 5
38	RF70	05-Jun-91	818 2,700	Haze, plume sample at 2700 ft.			158	1793	366	111.2	340.5
39	RF71	05-Jun-91	83 0 2,70 0	Haze, plume sample at 2700 ft.			149	1803	363	122.2	340.6 346.4
Flight 40		08-Jun-91	413	Haze, black plume sample	•		280	1780	3 9 0	107.9	341.1 344.6
41	RF49	08 - Jun - 91	424 _.	Haze, black plume sample	•		255	1781	388	140.2	
42	RFSO :	08-Jun-91	445	Haze, white plume sample	•		350·	1786	423	162.7	341.2 343.9
43	RESI	08-Jun-91	457	Haza, white plume sample	s		565	1791	416	244.3	

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KUWAIT - SUNCHER 1991 University of Washington													
Sample Can No. S/N	Date	Time Altitude ft.	Convence	H2 ppbv	CO ppbv	co ppb v	CII4 ppbv	605 CO5	TO-12	N20 ppbv			
	(continued) (08-Jun-9)		Mase, pluse sample 20 mi, downwind at 3000 ft.			282	1867	388	213 9	344.9× 347.5			
45 RF93	08-Jum-91	553 2,500	Haze, plume sample;	1037 610 549 554	193 195 195 195	217	1793	384	158.4	341.7			
46 RF94	0\$-Jun-91	620 2, 00 0	Haze, plume sample;	1017 640 562 556	141 141 141 141	158	1771	368	106.9	341.2			
47 RF95	08-Jun-91	637 2,000	Faze, plume sample;	856 556 528	139 139 139	157	1775	368	78.7	342.0			
48 RF96	08-Jun - 92)17	Clear, background sample below snoke;	875 805 806	80 81 80	94	1759	361	45.4	338.6			
49 RF29	08-Jun-91	736	Clear, background sample East of smoke;	771 572 551	84 84 84	9 8 55	1755 1757	359 358	37.7	340.9			
Flight 1489 50 RF30	09-Jun-91	635 1,000	Haze, black plume sample			115	1778	371	34 9	342.5*			
51 RF31	09-Jun-91	645 1,000	Haze, black plume sample	537 528 524	116 117 117	130	1776	183	41,4	340.8*			

KUWAIT	- SUM	MER 1991	Universi	ty of i	Washingtor							
Sample No.	Can S/K	Date	Time Al	titude ft	Comments	H2 ppbv	CC ppbv	bl·p∧ CO	CH4 ppbv	CO2	70-12 ug/m-3	N20 pp bv
		(continued) 09-Jun-91	710	1,000	Haze, black plume sample			198 195	1784 1786	376 376	151 4	341.6
53	RF21	09-Jun-91	723	1,000	Baze, white plume sample	546 548	207 208	208	1789	396	406.2	
54	RP22	09-Jun-91	747	1,000	Haze, large black plume	568 555	363 366	380	1790	376	637.7	338.5 338.4
55	RF23	09-Jun-91	759	-	Naze, main plume sample at 5000 ft.	575 558	440 443	461	1784	404	347.4	342 4 341.9
56	RF 24	09-Jun-91	816		Haze, main plume sample	546 532 535		197	1786	373	116.0	343 0
Flight 57		11-Jun-91	927	4,500	Haze, plume sample			118	1778	362	50.7	340.8
58	RF53	11-Jun-91	540		Background, West of plume.			105	1769	360	72.:	340.0

59 RF54 11-Jun 91

601

4,000 Plume sample

252

1787

370

166 0 342 8

ŔWAIT	- SUM	MER 1591	Universi	cy of l	<i>l</i> ashington							
Sample No.	Can S/N	Dace	Time Al	titude ft.	Conments	H2 pphv	co pph v	<i>С</i> 0 ррву	CH4 p pb v	СО2 ррш у	TO-12	N2 G p pbv
		(conti nued) 11-Jun- 91	621	4,50C	Flume sample			288	1/81	380	160.6	343.9
61	RF56	11-Jun-91	640	4,500	Plume sample			377	1822	392	355.7	339.4 342.1
62	RF6 5	11-J.m-91	704	4,500	Plume sample;	545 56?	221 222	238	1787	3 75	181.7	341.0
63	RF66	11-Jաը-91	729	4,500	Plume sample;	537 539	163 163	182 177	1785 1785	370 370	131.5	342.9
64	RP6?	11-Jun-91	806	4 , 5 0 0	Plume sample;	820 819	175 176	192	1860	374	318.4	344.2
65	RF68	11-Jun-91	840	4,500	Plume sample;	583 583	117 112	132 123	1783 1775	364 363	48.8	341.9
Flight 69		12-Jur91	536	6,500	Haze, plume sample at 6500 ft.			287	1798	388	22 0.7	342.3
70	RF/9	12-Jun-91	549	5,500	Haze, plume sample at 5500 ft.			354	1833	345	396-2	342 2

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KUWAIT	· Sum	MER 1991	Unive	rsity of \	dauh ingcon							
Sample No.	Can S/N	Date	Time	Altitude ft.	Commencs	H2 ppbv	CO ppbv	CO ppbv	CH4 ppbv	CO? ppmw	TO-12 ug/m-3	R20 ppbv
		(continued) 12-Jun-91	604	4,500	Haze, plume sample at 4500 ft.			391	1842	39:	474 0	*343.8
72	RF97	12-Jun-91	616	3,500	Haze, plume sample at 3500 ft.	614 (3		1029	2153	465	2058.8	358,4
73	rf¢s	12-Jun-91	629	2,500	Haze, plume sample at 2500 ft.	596 (3 614 (3		890	2075	4 50	1739.6	342.7 343.9
	R ₽9 9	12-Jun-91	642	1,500	Haze below plume sample at 1500 ft.	500 515	98 98	113	1780	359	62.7	340.9
75	RF100	12-Jun-91	717		Haze, pool fire plume sample;	532 517 757 614	271 272 270 269	296 293	1781 1777	387 386	99.9	
76	RF85	12-Jun-91	757	900	Haze, Magwa plume sample	862 613	247 249	275	1788	372	96.7	

^{*} calibrated just before rin

SUMMARY OF "GRAB BAG" CHEMICAL SAMPLES OBTAINED BY UNIVERSITY OF WASHINGTON IN THE KUWAIT OIL FIRE STUDY (16 MAY - 12 JUNE 1991)

Date, 1991	UW Flight #	Samples Collected†*	Time of Sample (UTC)	Notes
May 16	1477	37	0704	Background above smoke
		С	0724	Background above smoke
		H,37,G,47,C	0823	Smoke from South Fires at 10,500 ft
•		H,37,G,47	0846	Smoke at 9,000 ft
	•	37,G	0859	Smoke at 9,000 ft
		37,G,47	0924	Mid-plume at 8,000 ft
		37,47	0938	Smoke at 7,000 ft
		37,47,H,G	1020	Power failure, short sample
May 18	1478	37	0621	Background above smoke
		37	0643	Background above smoke
		37,H,G	0732	Background below smoke
		37,H,G	0757	Thickest smoke from South Fires, 4,000 ft
		37,H,G	0806	Thickest smoke from South Fires, 4,000 ft

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons

Q = Quartz filters for organic aerosols

^{37 = 37} mm Teflon filters for soot, mass, elemental analysis, inorganic ions

^{47 = 47} mm Teflon filters for inorganic ions

H = Impregnated filters for H₂S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

Date, 1991	UW Flight #	Samples Collected [†] *	Time of Sample (UTC)	Notes
May 22	1480	G	0719	Old smoke near Qatar
		37,G	1019	Point A, 3,500 ft, between Kuwait and Bahrain
	•	37,G,C	1032	Point B smoke, 5,000 ft, between Kuwait and Bahrain
		37,G,C	1053	Point C smoke, 4,700 ft, between Kuwait and Bahrain
	· :·	37,C	1124	Background, 4,000 ft
May 27	1481	37,G,C	0703	Point C, 8,000 ft, (No "D")
:		37,C	0738	Point E, 4,000 ft, cross section ~30 miles south of Al Burgan

^{*} C = Rasmussen "cans" – for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions
47 = 47 mm Teflon filters for inorganic ions

 $H = Impregnated filters for H_2S$

G = Electron microscope grids for morphological and elemental analysis of individual particles N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

Date, 1991	UW Flight #	Samples Collected [†] *	Time of Sample (UTC)	Notes
May 27	1481	37,H	0755	Point F, 4,000 ft, cross section ~30 miles south of Al Burgan
•		C,Q,H,G	0814	Point G, 4,200 ft, cross section ~30 miles south of Al Burgan
		37,C	0914	Point H, 2,500 ft, cross section ~30 miles south of Al Burgan
		37,G	0934	Point D, 4,000 ft, on return from Kuwait to Manama
•		37,H	1011	Point C, 8,900 ft, on return from Kuwait to Manama
		37,G	1031	Point B, 12,000 ft, on return from Kuwait to Manama
		37,G	1045	Point A, 12,000 ft, on return from Kuwait to Manama
		37,C	1118	Point X, Background?, 11,500 feet, south of Bahrain (Plume accord to PVH)

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons

Q = Quartz filters for organic aerosols

^{37 = 37} mm Teflon filters for soot, mass, elemental analysis, inorganic ions

^{47 = 47} mm Teflon filters for inorganic ions

 $H = Impregnated filters for H_2S$

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

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Date, 1991	UW Flight #	Samples Collected†*	Time of Sample (UTC)	Notes
May 28	1482 ·	37,C	1130	Background, above smoke
		37,C	1206	Smoke, 10,100 ft, cross section near Selig
		37,C	1248	Smoke, 8,100 ft, cross section near Selig
		37,C	1329	Smoke, 6,100 ft, cross section near Selig
		37,C	1401	Smoke, 4,100 ft, cross section near Selig
	•	37	1452	Background below smoke
May 29	1483			(Wing-tip inter- comparison with NCAR Electra at 085201 UTC on Convair Systron)
		37,G	0941	Background below smoke
		37,G	1028	Mid-plume, 7,000 ft

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons

Q = Quartz filters for organic aerosols 37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions

^{47 = 47} mm Teflon filters for inorganic ions

H = Impregnated filters for H₂S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

	·			
Date, 1991	UW Flight #	Samples Collected [†] *	Time of Sample (UTC)	Notes
May 31	1484	37,C,G	0828	Point C (black, or dark gray plume(s)), Al Burgan Area
		Q,C,H,G	0843	Point C', 2nd sample of above
·		37,C	0920	Point D, (Isolated black plume), Al Burgan Area
·		Q,C	0932	Point D (2nd sample of same isolated black plume)
	·	37,C,G	1006	Point E (White plume), Al Burgan Area
	· · · · · · · · · · · · · · · · · · ·	37,C,G	1038	Point F, 3,500 ft (Composite Burgan plume)
·		Q,G,H,C	1051	Point F, 2nd sample (Composite Burgan plume)
·m ·		37,C	1111	Point G, 5,000 ft, (Composite Burgan plume)
		37,G	1125	Smoke, 5,000 ft

H = Impregnated filters for H₂S

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons

Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions
47 = 47 mm Teflon filters for inorganic ions

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

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Date, 1991	UW Flight #	Samples Collected [†] *	Time of Sample (UTC)	Notes
June 2	1485	37	0655	8,000 ft, Composite Plume South of Al Burgan
		Q,C	0716	8,000 ft, 2nd sample of above, Composite Plume South of Al Burgan
	·	37	0746	5,600 ft, Composite Plume South of Al Burgan
·		Q,C	0809	5,600 ft, 2nd sample of above, Composite Plume South of Al Burgan
June 3	1486	Q,C	0842	Smoke, center of plume, 3,000 ft
		37,C,G	0923	Lagranian drift measurements in composite plume. Point A, 3,500 ft
		37,C	0939	Lagranian drift measurements in composite plume. Point B, 3,500 ft
				(Cont.)

^{*} C = Rasmussen "cans" – for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons Q = Quartz filters for organic aerosols 37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions

^{47 = 47} mm Teflon filters for inorganic ions

H = Impregnated filters for H2S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

				- —
Date, 1991	UW Flight#	Samples Collected† *	Time of Sample (UTC)	Notes
June 3	1486	37,C,G	0959	Lagranian drift measurements in composite plume. Point C, 3,500 ft
		37,C	1021	Lagranian drift measurements in composite plume. Point D, 3,500 ft
		37,C,G	1040	Lagranian drift measurements in composite plume. Point E, 3,500 ft
		37	1101	Lagranian drift measurements in composite plume. Point F, 3,500 ft
		37,C,G	1119	Lagranian drift measurements in composite plume. Point G, 3,500 ft
-	-	37,C	1146	Point H, 3,500 ft (100 miles from A), Lagranian measurements in composite plume.
		Q,C,G	1205	Point I, Ht?, Lagranian measurements in composite plume.

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons

Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions
47 = 47 mm Teflon filters for inorganic ions

H = Impregnated filters for H₂S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

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Date, 1991	UW Flight #	Samples Collected [†] *	Time of Sample (UTC)	Notes
June 3	1486	37,G	1234	Point J, 2,700 ft (near base), Lagranian measurements in composite plume.
		37,G	1251	Point K, 3,500 ft, Lagranian measurements in composite plume.
		37,C	1312	Background
June 5	1487	37,C,G	0801	Smoke from composite North Plume (exploration measurements) 2,500 ft
		37,C,G	0818	Smoke from composite North Plume (1st proper sample at mid- point) 2,700 ft
		Q,G,C,H	0830	Smoke from composite North Plume (2nd sample, mid-point) 2,700 ft
	·			Flight cut short due to generator failure

^{*} C = Rasmussen "cans" – for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions
47 = 47 mm Teflon filters for inorganic ions

H = Impregnated filters for H2S

G = Electron microscope grids for morphological and elemental analysis of individual particles N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

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Date, 1991	UW Flight #	Samples Collected†*	Time of Sample (UTC)	Notes
June 8	1488	37,C,G	0413	Subiriyah (North Field), A-1, Isolated black plume
		Q,C,H	0424	Subiriyah (North Field), A-2, Same plume
		37,C,G	0445	Subiriyah (North Field), B-1, White plume (black behind)
		Q,C,G,H	0457	Subiriyah (North Field), B-2, same plume
		37,C	0524	Smoke from composite North Plume, Point C, 3,000 ft (top of plume), cross section 20 miles from upwind edge of fires
		37,C,G	0541	Smoke from composite North Plume, Point D, 2,200 ft (middle plume), cross section 20 miles from upwind edge of fires

^{*} C = Rasmussen "cans" – for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions
47 = 47 mm Teflon filters for inorganic ions

H = Impregnated filters for H₂S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

 $[\]dagger$ In addition to the "grab" samples listed here continuous measurements of NO, NO₂, SO₂, CO, CO₂, O₃ were made aboard the aircraft.

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Date, 1991	UW Flight #	Samples Collected [†] *	Time of Sample (UTC)	Notes
June 8	1488	Q,C,H,G	0553	Smoke from composite North Plume, D-2, 2nd sample, cross section 20 miles from upwind edge of fires
		37,C	0620	Smoke from composite North Plume, E-1 (lower plume), cross section 20 miles from upwind edge of fires
		Q,C,H,G	0637	Smoke from composite North Plume, E-2, 2nd sample, cross section 20 miles from upwind edge of fires
		37,C	0717	Background below sample
		37,C	0736	Background east of smoke
June 9	1489	37,C,G	0635	A, individual, black plume, (Minagish)
		Q,C,H,N	0645	A-2, same plume
		37,C,G,N	0710	B, white plume (Minagish?)

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO2, N2O, CH4, and Freons

Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions
47 = 47 mm Teflon filters for inorganic ions

H = Impregnated filters for H₂S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

 $[\]dagger$ In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

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Date, 1991	UW Flight #	Samples Collected† *	Time of Sample (UTC)	Notes
June 9	1489	Q,C,G,N,H	0723	B-2, same plume
		37,C,G	0747	C, large black plume (Umm Gadair)
		37,C	0759	Composite plume from North Field(?), 5,000 ft, Enroute from Kuwait to Bahrain
	•	Q,C	0816	Composite plume from North Field(?), Enroute from Kuwait to Bahrain
	~	37,G	0842	Composite plume from North Field(?), 3,500 ft, Enroute from Kuwait to Bahrain
June 11	1490	37,Ç,H	0540	Background, West of plume, 4,500 ft
		37,C,G,H	0601	Point B
		37,C,G,H	0621	Point 1, (~25 n. miles from South fields), 4,500 ft
		Q,C,G,H	0640	Point 2, 4,500 ft. Lagrangian drift measurements in composite plume
	•		·	(Cont.)

* C = Rasmussen "cans" – for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions

H = Impregnated filters for H₂S

^{47 = 47} mm Teflon filters for inorganic ions

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

Date, 1991	UW Flight #	Samples Collected† *	Time of Sample (UTC)	Notes
June 11	1490	37,C	0704	Point 3, 4,500 ft. Lagrangian drift measurements in composite plume
		Q,C,G	0729	Point 4, 4,500 ft. Lagrangian drift measurements in composite plume
		37	0751	Point 5, 4,500 ft. Lagrangian drift measurements in composite plume
		Q,C,G	0806	Point 6, 4,500 ft. Lagrangian drift measurements in composite plume
		37	0826	Point 7, 4,500 ft. Lagrangian drift measurements in composite plume
		Q,C,G	0840	Point 8, 4,500 ft. Lagrangian drift measurements in composite plume
		37	0903	Point 9, 4,500 ft. Lagrangian drift measurements in composite plume
		Q,C,G	0927	Point 10, 4,500 ft. Lagrangian drift measurements in composite plume (~126 miles from Bahrain)

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO2; N2O, CH4, and Freons

Q = Quartz filters for organic aerosols
37 = 37 mm Teflon filters for soot, mass, elemental analysis, inorganic ions
47 = 47 mm Teflon filters for inorganic ions

H = Impregnated filters for H2S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

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Date, 1991	UW Flight #	Samples Collected [†] *	Time of Sample (UTC)	Notes
June 12	1491	37,C,G,H	0536	Top of plume, 6,500 ft. Cross section of south plume
		37,C,G,H	0549	5,500 ft. Cross section of south plume
•		37,C,G,H	0604	4,500 ft. Cross section of south plume
	,	37,C,G,H	0616	3,500 ft. Cross section of south plume
		37,C	0629	2,500 ft. Cross section of south plume
		37,C	0642	Below smoke, 1,500 ft. Cross section of south plume
	• .	37,G,H	0707	Individual pool fire plume (Minagish)
		Q,C,G,H	0717	Same plume, 2nd sample
		37,G,H	0747	Individual pool fire (Al Magwa)
•		Q,C,G,H	0757	Same plume, 2nd sample

Q = Quartz filters for organic aerosols

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons

^{37 = 37} mm Teflon filters for soot, mass, elemental analysis, inorganic ions

^{47 = 47} mm Teflon filters for inorganic ions

H = Impregnated filters for H₂S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.

Date, 1991	UW Flight #	Samples Collected† *	Time of Sample (UTC)	Notes
June 12	1491	G,H	0823	Old smoke, 10,000 ft
		37,G	0828	Old smoke, 10,000 ft

Analyses completed as of July 30, 1991

C-N₂O, CO, CO₂, THC, CH₄, Freons, HC speciation approximately 30% complete

37's - mass, soot approximately 20% complete

N – to be analyzed this week

H,Q - sent to Saltzman and Kalman for analyses

47,G – to be analyzed this fall at University of Washington

37's – elemental and ionic composition to be analyzed this fall at FSU and University of Washington

^{*} C = Rasmussen "cans" - for gaseous organics, THC, CO, CO₂, N₂O, CH₄, and Freons

Q = Quartz filters for organic aerosols

^{37 = 37} mm Teflon filters for soot, mass, elemental analysis, inorganic ions

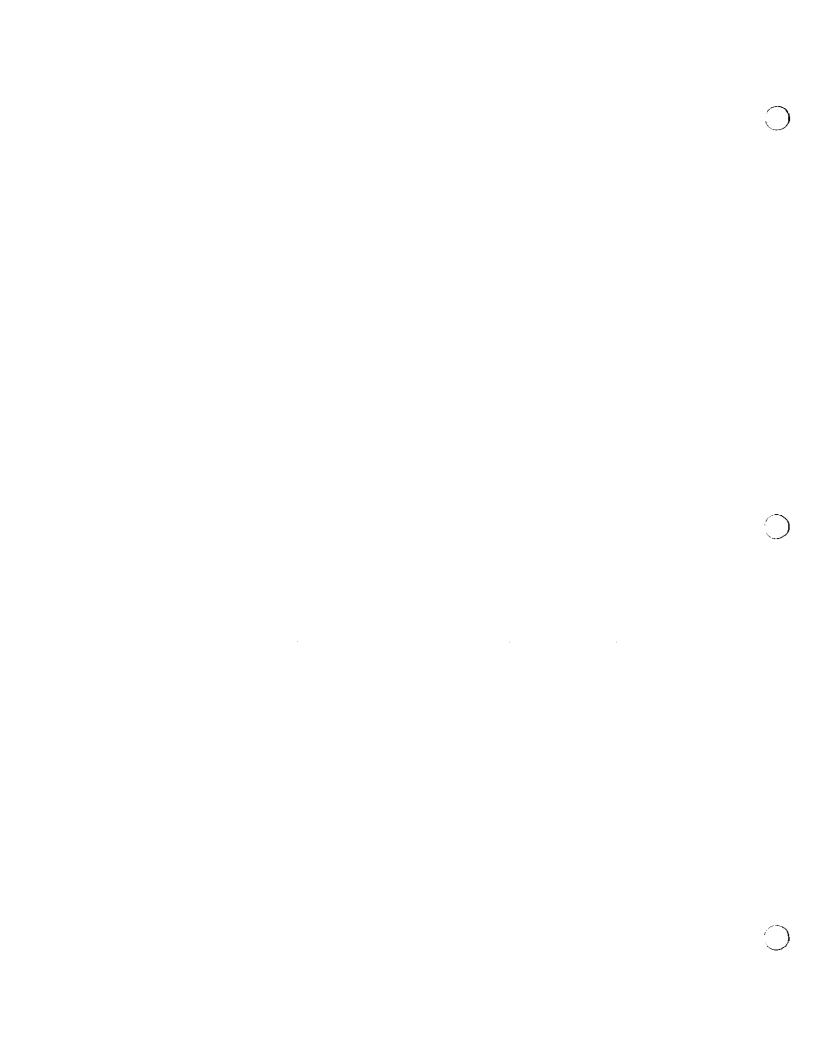
^{47 = 47} mm Teflon filters for inorganic ions

H = Impregnated filters for H2S

G = Electron microscope grids for morphological and elemental analysis of individual particles

N = Nucleopore filters for SEM analysis

[†] In addition to the "grab" samples listed here continuous measurements of NO, NO2, SO2, CO, CO2, O3 were made aboard the aircraft.



University of Washington Kuwait Filter Data (odd #'s w/3.0 μ m cyclone, even #'s w/o)

37 mm Teflon - Mass Concentration, Optical Absorption

Filter No.	Flight, Date 1991	Bag Fill Time	I/Io	Black Carbon (µg / m³)	Mass Conc. (μg / m³)	Comments	
1	1477	0704	0.998	0.2	26	Bkgd	
2	5/16	0704	0.992	0.7	58	Bkgd	
3	5/10	0823	0.883	17.9	143	DREG	
4		0823	0.871	17.4	235		
5		0846	0.965	4.0	88		
6		0846	0.971	3.3	48		
7		0859	0.944	4.8	56		
8		0859	0.950	4.0	84		
9		0924	0.732	31.1	235		
10		0924	0.723	30.9	995	•	
11		0938	0.831	20.2	149		
12		0938	0.839	17.9	139		
13		1020	0.741	76.7	656		
14		1020	0.723	79.7	433		
17	1478	0621	0.989	1.0	36	Bkgd	
18	5/18	0621	0.984	1.3	51	Bkgd	
19		0732	0.985	1.4	67	Bkgd	
20		0732	0.989	0.9	46	Bkgd	
21		0757	0.583	70.8	521	-	
22		0757	0.511	76.6	491		
23		0806	0.481	90.5	551		
24		0806	0.493	79.7	580	•	
25	•	0837	0.584	51.7	327		
26		0837	0.583	45.6	525		
29	1480	1019	0.702	40.3	309		
30	5/22	1019	0.619	48.9	805		
31		1032	0.581	63.4	448		
32		1032	0.510	63.0	890		
33		1053	0.815	20.9	142		
34		1053	0.805	19.6	360		
35		1124	0.973	3.6	50		
36		1124	0.945	6.5	94	-	

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<u></u>	Comments	Mass Conc. (μg / m³)	Black Carbon (µg / m³)	I/Io	Bag Fill Time	Flight, Date 1991	Filter No.
		155	27.8	0.745	0703	1481	41
		167	24.3	0.762	0703	5/27	42
		272	49.6	0.593	0738		43
		365	52.1	0.553	0738		44
		175	30.8	0.710	0755	•	45
		260	27.5	0.711	0755		46
		226	32.4	0.663	0914		47
		260	32.9	0.660	0914		48
		204	36.1	0.644	0943		49
		135	37.3	0.667	0943		50
		93	24.9	0.718	1011		51
		150	21.3	0.741	1011		52
		38	9.3	0.890	1031		53
		42	11.6	0.872	1031		54
		157	*	*	1045		55
		· 61	24.6	0.755	1045		56
	-	97	10.6	0.843	1118		57
		143	11.3	0.843	1118	1482	58
	Bkgd	10	0.7	0.990	 1130	5/28	59
	Bkgd	33	0.8	0.988	1130		60
		276	20.6	0.780	1206	•	61
•		188	21.4	0.786	1206		62
		169	17.6	0.807	1248		63
		109	15.6	0.841	1248		64
		410	60.5	0.494	1329		65
	•	391	52.0	0.576	1329		66
		198	27.6	0.707	1401		67
		117	31.7	0.695	1401		68
		**	14.4	0.847	1452		69
		205	13.6	0.863	1452		70
	Bkgd	12	0.4	0.993	0941	1483	73
	Bkgd	22	0.6	0.990	0941	5/29	74
		111	19.5	0.770	1028		75
	•	121	18.8	0.766	1028	1.40.4	76
		872	60.3	0.511	0828	1484	79
		936	64.3	0.496	0828	5/31	80
		90	15.0	0.843	0920		81
		145	14.3	0.856	0920		82

Filter No.	Flight, Date 1991	Bag Fill Time	I/Io	Black Carbon (µg / m³)	Mass Conc. (μg / m³)	Comments	
83		1006	0.780	21.3	190		
84		1006	0.795	20.2	120		
85		1038	0.495	61.0	505	•	
86	•	1038	0.479	66.3	448		
87		1111	0.249	109.6	708		
88		1111	0.300	101.2	841		
89		1125	0.908	7.1	144		
90		1125	0.915	7.2	70		
93	1485	0655	0.901	8.8	55		
94	6/02	0655	0.909	8.7	88		
95		0746	0.828	16.6	113		
96		0746	0.863	13.1	139		
99	1486	0923	0.324	110.6	732		
100	6/03	0923	0.363	92.5	719		
101		0939	0.516	60.0	363		
102		0939	0.589	45.1	314		
103		0959	0.532	44.7	303		
104		0959	0.517	48.0	344		
105		1021	0.443	57.2	335		
106	•	1021	0.468	56.1	385		
107		1040	0.673	31.8	212		
108		1040	0.681	31.9	163		
109		1101	0.623	32.1	233		
110		1101	0.625	36.2	282		
111		1119	0.602	33.3	225		
112		1119	0.643	29.6	236		
113		1146	0.632	26.5	234		
114		1146	0.703	21.7	1 5 0		
115		1234	0.838	11.9	107		
116		1234	0.842	12.4	130		
117		1251	0.725	23.1	102		
118		1251	0.760	21.6	202		
119		1312	0.959	2.9	12	Bkgd	
120		1312	0.963	2.7	. 14	Bkgd	
123	1487	0801	0.796	18.4	100		
124	6/05	0801	0.825	14.8	129		
125	•	0818	0.800	17.9	66		
126		0818	0.792	20.0	156		

Filter No.	Flight, Date 1991	Bag Fill Time	I/Io	Black Carbon (µg / m³)	Mass Conc. (μg / m³)	Comments
129	1488	0413	0.127	156.7	606	Black Plume
130	6/08	0413	0.102	190.4	760	Black Plume
131	5, 5, 5	0445	0.649	42.3	1105	White Plume
132		0445	0.679	40.2	1145	White Plume
133		0524	0.837	15.8	68	*******
134		0524	0.801	20.7.	118	
135		0541	0.451	73.4	459	
136		0541	0.517	66.2	446	
137		0620	0.762	23.3	194	
138		0620	0.810	19.4	114	
139		0717	0.987	1.2	9	Bkgd
140		0717	0.983	1.7	10	Bkgd
141		0736	0.992	0.5	12	Bkgd
142		0736	0.989	0.8	18	Bkgd
145	1489	0635	0.871	12.6	84	Black Plume
146	6/09	0635	0.891	11.3	41	Black Plume
147		0710	0.873	11.4	203	White Plume
148		0710	0.931	6.7	168	White Plume
149		0747	0.638	35.4	186	Black Plume
150		0747	0.661	34.5	199	Black Plume
151		0759	0.344	98.4	617	
152		0759	0.330	104.7	615	
153		0842	0.494	49.0	254	
154		0842	0.485	53.0	. 264	•
157	1490	0540	0.970	2.0	28	Bkgd
158	6/11	0540	0.985	1.0	31	Bkgd
159	•	0601	0.513	60.9	410	•
160		0601	0.582	53.5	405	
161		0621	0.579	45.2	313	
162		0621	0.673	35.0	257	
163		0704	0.476	59.0	267	
164		0704	0.485	61.7	166	
165		0751	0.738	23.7	120	
166		0751	0.752	22.7	127	
167		0826	0.775	19.5	120	
168		0826	0.759	21.6	145	
169		0903	0.881	9.5	75	
170		0903	0.882	10.2	143	

Filter No.	Flight, Date 1991	Bag Fill Time	I/Io	Black Carbon (µg / m³)	Mass Conc. (μg / m³)	Comments
.73	1491	0536	0.498	67.0	296	* ***
174	6/12	0536	0.509	67.3	340	
175		0549	0.403	79.6	442	
176		0549	.0.383	88.2	411	
177	•	0604	0.362	98.0	511	
178	•	0604	0.375	97.8	551	
179		0616	0.032	361.6	1702	
180		0616	0.037	362.0	1634	
181		0629	0.091	291.9	1745	
182	•	0629	0.073	333.5	1620	
183		0642	0.925	5.0	76	
184		0642	0.969	2.1	92	
185		0707	0.228	188.6	819	Pool Fire
186		0707	0.255	181.4	957	Pool Fire
187		0747	0.203	171.0	613	Pool Fire
188		0747	0.228	166.9	587	Pool Fire
189		0828	0.863	9.9	55	
190		0828	0.870	9.7	74	

Notes:

Black carbon is inferred assuming a specific absorption of 10 m²/g I / Io is optical transmittance of the filtrate

* Ring torn, no optical measurement

** Hole in filter, no mass measurement

Emissions Factors for Particles, Elemental Carbon and Trace Gases From the Kuwait Oil Fires

1. 1991 Fall Meeting

K K Laursen, R J Ferek and PV Hobbs (Atmospheric Sciences Department, AK-40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)

Emission factors (i.e. mass of a species emitted into the atmosphere per unit mass of fuel burned) have been determined for particles, soot, total organic carbon in particles and vapor, CO, CO2, CH4, SO2 and NO_x for the Kuwait oil fires. Particle emission factors are about 2%, which is only about one-third of the value used in previous "nuclear winter" calculations. This, in conjunction with the low soot emission factors for the Kuwait fires, substantially reduces the amount of cooling expected to occur at the earth's surface as a result of smoke from a nuclear war. Emission factors for several of the individual Kuwait oil fires are presented and differences between black and white plumes and the plumes from pool fires are discussed. Carbon budget data for the plumes are presented; the majority of the burned carbon is present as CO2. Fluxes for several combustion products in the plume will be presented and compared with fluxes from other sources.

Ozone Chemistry in the Plume From the Kuwait Oil Fires

1. 1991 Fall Meeting

JA Herring and P V Hobbs (Atmospheric Sciences Department, AK 40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)

Ozone depletion was observed in the core of the plume from the Kuwait oil fires. Most of this depletion occurred within 1 km of the fires and was due to the reaction of ozone with NO. At 40 km from the fires, ozone was found to be further depleted, probably due to reactions with alkenes. Heterogeneous processes, such as the reaction of ozone on soot particles, may have also contributed to the ozone depletion.

As expected, ozone was produced in diffuse regions of the plume where ultraviolet flux was higher than in the core. However, due to the relatively low concentrations of NO_x , ozone production was slow. Nevertheless, since ozone was produced in a much larger volume than it was depleted, the plume as a whole was a significant source of ozone on a regional scale. Up to a distance of about 400 km from the fires, we calculate that the plume contained about 0.2 million kilograms of ozone in excess of ambient values.

Chain-Aggregate Aerosols in the Smoke From the Kuwait Oil Fires

1. 1991 Fall Meeting

V N Kapustin (Institute of Atmospheric Physics, USSR Academy of Science, Moscow, USSR)

R E Weiss (Radiance Research, 12202 9th Ave NW, Seattle, WA 98177; 206-363-6610)

P V Hobbs (Atmospheric Sciences Department, AK-40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)

Airborne in situ measurements have been obtained of the non-sphericity of the smoke particles from the Kuwait fires. An electro-optical scattering (EO) technique was used in which changes in light scattering are measured when smoke particles are subjected to a pulsed electric field (2 kV cm⁻¹). Non-spherical particles align with the field, thus increasing their scattering cross section relative to random orientations. With the field removed, the particles orient randomly; the time required for random orientation (τ) is related to the chain length of the aggregates. Smoke samples were analyzed from continuous flow through an isokinetic port at 8 Hz and averaged over 4 seconds (~320 m of aircraft travel).

Measurements were taken in the plumes from individual oil fires, composite smoke from groups of burning oil wells, and in aged smoke. Chained aggregates of black carbon were the principal non-spherical component of the smoke and were responsible for about one-half of the short-wave optical depth. Smoke from individual wells varied considerably in appearance; some fires produced notably white smoke and others very black smoke. Smoke from burning pooled oil tended to appear black. EO measurements in the individual black plumes indicated that substantial soot aggregates formed within seconds of combustion and EO enhancement in scattering was typically 40 percent, with t between 2 to 4 ms. Very little chain aggregate formation was detected in the white plumes. Typical EO enhancement in the white smoke was less than 5 percent, which is typical of biomass smoke or sea salt. Aged smoke exhibited significant but reduced EO enhancement compared with the black smoke, typically 20 to 30 percent. Most of the aggregate growth appears to have occurred very near the fires; rather small changes in EO properties were detected with time in the aged smoke.

Fluxes and Compositions of Emissions From the Kuwait Oil Fires

1. 1991 Fall Meeting

R J Ferek, P V Hobbs (Atmospheric Sciences Department, AK-40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)

R E Weiss (Radiance Research, 12202 9th Ave NW, Seattle, WA 98195)

Gaseous and particulate emissions from the Kuwait oil fires were measured in fourteen research flights aboard the University of Washington's Convair research aircraft during the period 16 May through 12 June 1991. In this paper we discuss a number of surprising results on the chemistry of the smoke from the fires that limit the long-range consequences of the emissions, but which exacerbate their local and regional impact.

Flux calculations indicate that the combined oil and gas fire emissions were equivalent to the consumption of approximately 5 million barrels of oil per day. The combustion appeared to be relatively efficient, with about 96% of the fuel carbon burned emitted as CO₂. Particulate smoke emissions averaged only 2% of the fuel burned, of which only about 20% was soot. On average, about two-thirds of the mass of the smoke was accounted for by salt, sulfate and soot. The salt most likely originated from oil field brines, which were ejected from the wells along with the oil. The salt accounts for the fact that many of the plumes were white in appearance. Although sulfate may be emitted as a minor component of the brines it is also produced in the plume by rapid oxidation of SO₂ (~50% per hour during the first few hours after emission), probably through heterogeneous reactions on particles. Due to their high salt and sulfate content, a large fraction of the particles in the smoke were efficient CCN.

An Overview of the United States Interagency Airborne Study of the Smoke From the 1991 Kuwait Oil Fires

- 1. 1991 Fall Meeting
- <u>P V Hobbs</u> (Atmospheric Sciences Department, AK-40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)
- L F Radke (Research Aviation Facility, National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80307-3000; 303-497-1032)

As the Iraqi army fled Kuwait in March 1991 they damaged or destroyed 749 oil wells, 610 of which were ignited. The resulting fires produced an extraordinary large plume of black smoke that had significant local and regional effects on the Gulf States and the potential for global effects.

As part of the interagency United States effort (coordinated by the National Science Foundation) to assess the impacts of the fires on the atmosphere, the University of Washington (UW) and the National Center for Atmospheric Research (NCAR) mounted an airborne study of the smoke from the Kuwait fires utilizing the UW Convair and NCAR Electra research aircraft.

During the period 16 May through 12 June 1991, some 200 research flying hours were flown to study the smoke from the Kuwait oil fires. The primary goals of the studies were to determine the chemical and physical nature and the radiative properties of the smoke, the fluxes of various materials in the smoke, and the potential effects of the smoke on weather, climate and air quality.

A key result of this study is that the significant impacts of the smoke are most likely confined to the Gulf Region. Thus, during our five week study, the smoke was never observed above about 6 km; generally it spread out well below this height at one or more temperature inversions. Vertical transport mechanisms, such as self-lofting due to solar heating, were of limited effectiveness. Consequently, transport of the smoke to the stratosphere (which would have produced global transfer of the smoke) was negligible. Also, because the smoke particles contain a significant mass of water soluble compounds, they are efficient cloud condensation nuclei and should have short atmospheric lifetimes because of efficient cloud scavenging.

Optical Extinction Properties of Smoke From the Kuwait Oil Fires

1. 1991 Fall Meeting

- <u>R E Weiss</u> (Radiance Research, 12202 9th Ave NW, Seattle, WA 98177; 206-363-6610)
- P V Hobbs (Atmospheric Sciences Department, AK-40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)

Airborne in situ measurements have been made of the optical coefficients for extinction and the single-scattering albedo for smoke from the Kuwait oil fires. The measurements were made using a single-pass, 6.4 m long, transmission photometer for extinction and a high sensitivity, chopper-stabilized nephelometer for scattering. The single-scattering albedo and absorption coefficients were determined from the ratio and difference between the extinction and scattering coefficients, respectively. Both instruments were matched for wavelength response at 538 nm and equivalent air exchange rate. Measurement response was approximately 1 sec. Additional measurements for specific extinction (m² g⁻¹) were determined by averaging the extinction coefficients over periods for which filter samples were taken (typically about 10 seconds).

Measurements include smoke from individual well and pool fires, the composite smoke from clusters of individual fires, and the aged smoke well downwind from Kuwait. The smoke from individual fires appeared as white, black and grayish plumes, or combinations where black and white smoke was being emitted from different regions of a fires. The single-scattering albedo varied from 0.95 for the white smoke to 0.36 for the black smoke from the well and pool fires. Less variability was detected in the composite smoke. The single-scattering albedo increased to about 0.5 in the near field composite smoke and was relatively invariable in the downwind aged smoke. Specific absorption in the aged smoke was typically about 2-3 m² g⁻¹, which suggests a mass fraction for black carbon of approximately 20 to 30 percent. For the regionally expansive smoke, approximately 40 to 50 percent of the optical depth was caused by absorption. Additional data regarding soot emission factors, based on the absorption data, will be presented.

An Improved Filter-Pack Technique for Airborne Measurement of Low Concentrations of SO₂

1. 1991 Fall Meeting

P V Hobbs, R J Ferek, D A Hegg and J A Herring (Atmospheric Sciences Department, AK-40, University of Washington, Seattle, WA 98195; 206-543-6027; OMNET: P.HOBBS)

Recent improvements to the carbonate-impregnated filter technique for measuring low-level SO2 concentrations have resulted in dramatically improved performance. The improvements are: 1) a better cleaning procedure for the paper filter substrates resulting in approximately 60% reduction of their sulfate blank, 2) the use of an ion-exchange resin to remove the carbonate matrix from the sample extract resulting in a 100% increase in the signal-to-noise ratio, 3) the use of high-purity glycerol in the filter impregnate resulting in approximately 10% further reduction of blanks, and 4) improved chromatographic and standardization procedures for more accurate quantification of sample peaks. Combined, these improvements allow measurements to be made of SO₂ concentrations in marine background air with a 2σ uncertainty of \pm 6 pptv and, based on this, a 3 σ detection limit of 9 pptv for air volumes of 4 m³ (which can be collected in 15 mins aboard our research aircraft). Measurements in polluted air show better than 95% collection efficiency, even at concentrations as high as 100 ppbv. Vertical profiles of SO₂ measured during three PSI research flights off the Washington Coast (one in clean marine air) showed concentrations ranging from 15-86 pptv in the mixed layer and from 40-93 pptv in the free troposphere.

Bahrain Debriefing of DOE Monitoring Team, August 20, 1891

Members of the DOE Team (Contracted from Batelle Pacific Northwest Laboratories (PNL) and Brookhaven National Laboratory)

Scientific Team

Peter Daum Brookhaven
Ken Busness Batelle
Stan Tomich Batelle
Jake Hales Batelle

Flight Team Bob Hannigan Mike Warren Karl Bergstrom

The original purpose of the monitoring flights funded by the US Department of Energy (DOE) was to sample the plume at distances from the mid to the far range. Initial plans to sample the plume over Saudi Arabia almost as far to the southeast as Oman were limited by airspace restrictions in the Empty Quarter. Several trips in the area indicated, however, that the plume over the Empty Quartar was so diffuse that it was difficult to locate and below the sensitivity of the instrument.

The flights were successful. The first flight was on July 31. A total of 13 flights was completed over 12 days. Two-thirds of the flights directly intersected the plume, the remainder conducted background measurements. The general area monitored was between latitude 22 and 28 degrees north and longitude 46 and 51 degrees east. The flights took gaseous and particulate samples and measured the plume's optical properties, dispersion and height. The DOE team was appreciative of the good support received from the Bahrain Environmental Protection Agency and Bahrain's Meteorological Service. The DOE aircraft team also received good support from MEPA and Arameo in Saudi Arabia.

General Plume Characteristics

The true character of the plume can only be addressed after the samples taken are analyzed in the laboratory, especially the data needed to understand the plume's dispersal in the vertical and horizontal, and to project human health effects. Once completed, the analysis will consolidate the data into a form that can be used in assessments.

- 1. The plume's optical density is particularly high close to the source, according to preliminary observations, with high densities sometimes occurring again as far as 200 kilometers downwind. Occasionally the plume retained integrity for great distances. The plume's optical density was greater than any cloud and ran the teams integrating nephelometer meter off the scale.
- 2. High optical density seems to be accompanied by self-lofting. This could easily be observed at various distances along the plume's length where the darker, more optically dense segments rose higher than the lighter parts of the plume. Since the carbon particles are good absorbers of solar radiation, the result is heating at the top of the plume and vertical movement of the plume's upper surface. At lower heights the plume is dark, cool and stable. Instruments measured increased turbulence within the plume with height. Where turbulence in the plume occured at 11,500 feet, for example, the top lofted to 15,000 feet.
- 3. The top of the plume ranged from 10,000 to 18,000 feet, indicating that the plume is confined to the lower troposphere. The lowest samples in the plume were usually taken at 2,000 to 3,000 feet. While occasionally the plume was sighted below this level, it was difficult to make accurate judgements about its lower boundaries. Typically, however, below 2,000 feet the atmosphere was hazy. The haze could represent surface dust but in industrial areas in Saudi Arabia it may be from the industrial facilities.
- 4. Where dust was observed lifting from the surface it seemed to be incorporated into the plume, reaching the top of the plume through convection. Once the dust was incorporated into the plume, the plume's color changed. Captured particulate samples also changed color, shifting from gray to brown. Testing will identify the dust fraction. When the plume has a high dust content, it has a different signature on satellite imagery, giving the impression that a hole through the plume is providing a view of the desert

floor. In fact it is not the desert floor but the top of the plume with a heavy dust load. DOE will try to correlate the

change in the plume's dust content with the signature on the satellite imagery. The dust content of the plume was probably less than that recorded by NCAR/UW; perhaps reflecting the lower seasonal winds speeds.

Plume Chemistry

- 1. One of the primary concerns addressed by the DOE flights involved the fate of sulfur dioxide as the plume aged. The usual sulfur dioxide transformation to sulfate is by oxidation, in which the sulfur dioxide oxidized by the OH radical to form sulfuric acid and then sulfate. A second possible path of conversion was hypothesized in which trace metals could catalyze oxidation but preliminary evidence indicates this did not occur. The primary effect of distance on sulfur dioxide concentration is dilution as the plume diffuses. Maximum concentrations near the source were a few tenths of ppm and at greater distances the concentrations reached 5 ppb.
- 2. The plume is unusual compared to urban plumes in Europe and the U.S. It is low in nitrogen oxides when compared to areas in which high temperature combustion is common. The nitrogen oxide concentrations are in the low parts per billion, nowhere near what would be produced by power plants or automobiles. This indicates low-temperature combustion. Since nitrogen oxide concentration levels are low, the NOX is not available to help catalyze reactions within the plume and consequently the plume retains its original properties longer. The materials are not being transformed rapidly but are just diluting.
- 3. There is no evidence of ozone generation in the plume so far. This is unlike the ozone bulge commonly observed in the U.S. in which ozone levels are low near the source and increase as hydrocarbons oxidize nitrogen oxide to nitrogen dioxide, which then stimulates the formation of ozone. NCAR did detect a dip in the ozone level near the fires, possibly because it may have approached the source more closely.

Analysis planned in U.S. laboratories

Pollutant concentrations vary as a function of plume height and distance from the source. Sampled plume constitute included 03, SO2, NO, CO, and CO2.

- 1. Canister samples for gaseous organic constitutents. This will indicate how gaseous hydrocarbons evolve with distance.
- 2. Composite three stage filter that sampled aerosols, nitric acid and sulfur dioxide. The aerosols analysis will include major inorganic species. The first stage of analysis will focus on major inorganic constituents and possibly trace metals.
- 3. Separate analysis will be done for organic aerosols with a focus on major organic species including PAH's.
- 4. Aerosols number concentration and size distribution were also measured. Sampling was performed in two ranges. One instrument measures sizes from 0.1 to 3 microns, another from 3 to 47 microns.
- 5. Cloud condensation nuclei counts (ccn). Early indications are that con counts are about 3000 con per cubic centimeter, similar to the NCAR measurements. The particles are hydrophilic and should be retained in the atmosphere no longer than two to three weeks. At first DOE analysts thought that the particles would be pure elemental carbon and hydrophobic but the particles may haveabsorbed enough sulfur dioxide on their surface to make them polar, thus making them attractive to water. Ozone may also oxidize the surface of the particles, making them hydrophilic. The net result is that the supersaturation level needed for cloud formation may be similar to that for typical con rather than the elevated levels anticipated when it was assumed the particles were hydrophobic. It is possible that when the plume reaches the Intertropical Convergence Zone strong convection will result in a high degree of saturation and most of the particles my form cloud droplets. However, because there are so many con, the number of water droplets in the clouds may be smaller than the aerosol number concentration. In other words, even though the ITCZ air may be humid, there man not be enough water vapor avbailable for all of the particles present to serve as con. The clouds may also have an enhanced albedo, something which could show up on satellite imagery.

General Discussion

 Data availability and funding. The data will be available to anyone who wants it. Analysis will begin in September and . most should be complete in mid October and November. Some of the integrated samples may take longer. DOE will deposit its data with NCAR and also make its data available independently. Funding for analyzing the samples has not been arranged but the analysis will proceed anyway.

- 2. Many Gulf scientists flew on the DOE aircraft, including Bahrainians in the Civil Aviation Affairs and Meterological Service and Saudis from Aramco and MEPA. Aramco in Dhahran provided forecasts. A Saudi scientist has been invited by the DOE team to join them in the US and join in analyzing the data.
- 3. Locating the plume. Modelling efforts that forecast the location of the plume are not entirely successful. A slight shifting of local weak high and low pressure cells can alter the location of the plume greatly at distances of several hundred kilometers from the source. Weather satellites are the biggest help. Meteosat imagery arrives in Manama in the mid-morning and the DOE aircraft took off immediately after receiving the imagery. The preferred takeoff time was 6AM to take advantage of the relatively cooler, denser air but the delay to wait for the imagery paid off in efficiency in locating the plume.
- 4. Plume stratification. The DOE team speculated that the stratification in the plume could reflect different plume patterns. Some levels could contain relict smoke that represents old plume locations.





UNITED STATES ENVIRONMENTAL PROTECTION AGENCY ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORY RESEARCH TRIANGLE PARK NORTH CAROLINA 27711

September 10, 1991

MEMORANDUM

SUBJECT: Overview of the EPA/NASA In Plume

and Ground Level Measurements Made in Kuwait July 28 to August 8, 1991

FROM: Robert K. Stevens RKE

Chief, Source Apportionment Research Branch (MD-47)

Joseph P. Pinto Juliano Research Scientist

TO: Gary J. Foley

Director, Atmospheric Research and Exposure Assessment Laboratory (MD-75)

Below is a summary of the major findings and preliminary conclusions based on the chemical and physical analysis of size fractioned plume and ground level samples collected recently in Kuwait. Jack Durham of the Gulf Task Force office requested we prepare this summary today to send to Peter Hill of NOAA who is assisting John Robinson of NOAA, to prepare a summary of research results obtained by the Interagency groups participating in this project. Appendix A is an inventory of samples collected in this study. We have not completed all the analyses. Thus far we have mass, XRF elemental composition, particle morphological measurements by SEM/XRF procedures and ion chromatographic data for SO₂, HNO₃ collected with annular denuders. We are still waiting for analysis of canisters for VOC's, elemental and condensable carbon and PAH analysis of samples collected with PUF and Tenex traps. We are also waiting for the results of NASA measurements (CO₂, CO,CH₄ TMHC).

Results

1. The White oil fire plumes are enriched in fine particle (<2.0 μ m) of crystalline salts of chlorides of sodium and calcium. Most of these particles are actually less than 0.5 μ m in aerodynamic diameter. These plumes also contain several hundred μ g/m³ sulfur dioxide (SO₂) and sulfate. These plumes contain very little black carbon which suggest that these fires are fueled primarily by natural gas. These fine crystalline chloride salts are hydrophillic and can act as cloud condensation nuclei (see attached SEM/EDX spectra of one of the typical submicron particles from the white plumes).

- 2. The black oil fire plumes from the burning oil wells are enriched in submicron-carbon chain agglomerates, calcium carbonates, silicates, sulfates and sulfur dioxide. There are large >20 µm particles of oil droplets in these plumes but they appear to deposit rapidly. This probably accounts for black oil that covers the surface within the fields.
- 3. The chemical properties of <u>super plumes</u> (a mixture of the white and black plume downwind) are as expected, is a mixture of primarily the fine particles from the black and white plume fires. Since there are more black plume fires than white plumes the composition of the super plume more closely resembles the composition of the black plumes. Thus the fine particles of the super plume are dominated by the carbon chain agglomerates.
- 4. The ground level composition of fine particle aerosols collected in Kuwait City is a mixture of the super plume species (e.g., carbon chain agglomerates, chlorides) and automotive emissions (e.g., greater than 1 μ g/m³ of Pb and Br) and sulfate which may be associated with the oil fires and or the sulfur emission from the two electric power generating stations. During periods of air stagnation visibility decreased markedly to less than 1 km with a corresponding increase in fine and coarse particle mass. The fine particle become extremely black due primarily to the carbon chain agglomerates we have associated with the oil fires.
- 5. Several in plume and ground level samples were collected using Texex and PUF traps to isolate condensable and semi-volatile organics. Preliminary gc/ms analysis of PUF extracts indicated presence of 2, 4, 5, and 6 ringed polynuclear aromatic hydrocarbons. Analyses are in progress to identify and determine the amount of PAH's present in the plume and ground level samples.
- 6. Analysis to determine the amount of condensable organic and elemental carbon present in the plume and ground level samples are in progress.
- 7. One indoor sample was collected during a relatively clear day in Kuwait. Some evidence of automotive fine particle emissions were present in these samples along with oil fire emission species. Sulfur dioxide indoors was comparable to outdoor levels.

These results should be considered preliminary at this time. The KEPD are continuing to collect ground level samples within Kuwait City with the equipment the US EPA left with the Kuwait scientists.

We are seeking resources to obtain neutron activation analysis of the fine particle samples to determine the presence of trace elements that were not detected by XRF methods (e.g. As, Se, Cd, lanthanides, Na, F).

cc: Peter Hill, NOAA (FAX 8-202-377-0714)
Dale Pahl (MD-56)
James Vickery (MD-75)
Jack Durham (8-260-0154)

APPENDIX A Inventory of Samples Collected by EPA Between July 28 and August 8, 1991

Pol	lutants	<u>Sites</u>	<u>Methods</u>	Number of Samples
1.	SO ₂ , HNO ₃ , HNO ₂	G,W,A,I	Denuder IC Analysis	22
2.	PAH's/Semi- volatile organics	G,V,A,I	Quartz filters, Tenex/PUF traps GC/MS/FID	9
3.	Non-Methane Hydro- carbons, halocarbons	G,W,A	Canister Samples GC/MS/FID/ECD	28
4.	Trace elements in fine (<2.5 µm) and coarse (>2.5 µm) particles	G,A,V,I	Teflon Filters, XRF, INAA	22
5.	Aerosol Size Distribution	G,A,W	Nuclepore Filters SEM/EDX	: 10
6.	Elemental and Volatil- izable carbon (Ce, Cv)	G,A,V	Quartz Filters Combustion/FID	13

^{*}Site description = G = Ground level

PAH = polynuclear aromatic hydrocarbons, XRF = x-ray fluorescence analysis, INAA = instrumental neutron activation analysis, SEM/EDX = scanning electron microscopy/energy dispersive x-ray analysis.

A = Airborne (Helicopter)
W = Near Burning Wells

I = Indoor

Summary of Analysis of VAPS Samples Collected During Helicoper Flights Collecting Oil Fire and Super Plume Samples Over Kuwait

Date ¹		μg/m³															
·	Fine Hass	802	so,	s	Pb	Br	Ca	Al	Si	Cl	K	Cr	Ni	Zn	re	Sr	Sn
Black Plume 7/31	10,900	206	177	59	-	-	84	-	82	182	19	4.9		-	24	_	-
Black Plume 8/02	755	133	9.3	3	- :	-	•	-	-	-	-	-	-	-	-	-	-
Black Plume 8/03	955	169	114	38	-	-	6	-	-	15	-	-	-	-	-	-	8
Black Plume 8/05	493	12	25	8.4	-	0.6	34	-	48		5.4	4140			13		4.5
Super Plume 8/06	167	49	18	5.9			8.7		7	10	1.6				3.5		0.2
White Plume 8/07	4,356	319	630	210	-	21	415			3220	62				5.4	18	8
Super Plume 8/8	21.6	26	10	3.2			1.2			9	0.3				-		-

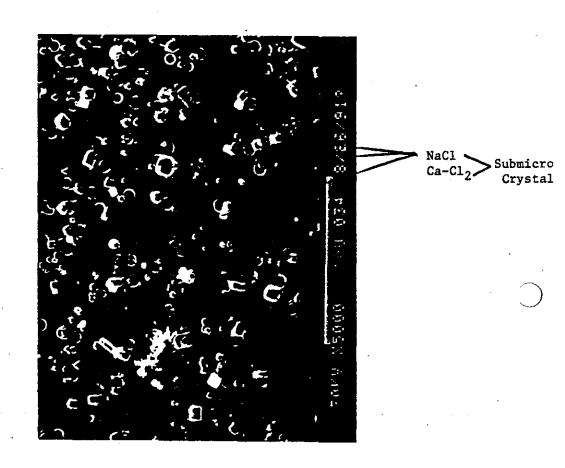
¹Sampling times were between 0.5 to 30 minutes depending on the day the samples were collected. Typically less than 0.5 m^3 of air was collected with the versatile air pollution sampler (VAPS) used by EPA to collect the SO_2 and aerosol samples.

Summary of Ground Level Air Quality Measurements Made in Kuwait

	μg/m³ ⁴																
Date	Fine Mass	50 ₂	so,	s	Pb	Br	Ca	Al	Si	Cl	K	Cr	Nī	Fe	Zn	Sn	Sr
7/281	62	11	6.9	2.3	0.12	0.04	4.34	1.74	5.12	0.14	0.70	.01	.01	1.67	.02	.04	.02
8/03 ¹	26	5.4	4.0	1.3	0.17	0.05	1.27	0.72	2.01	0.10	0.28	.003	-	0.69	.01	-	_
8/07 ¹	100	11	5.8	1.95	1.80	0.60	3.34	0.8	3.6	3.7	0.7	-	0.2	1.3	0.18	_	0.01
Indoor Sample ² 7/31	7.4	7.6	1.8	0.6	0.05	0.02	1.06	0.3	1.0	0.5	0.2	.002	-	0.4	0.02	-	0.01
Near Plume ³ 8/6	NA	19	6	1.9	-	0.10	1.9	-	1.3	0.8	0.3	-	-	0.97	1.0	_	-

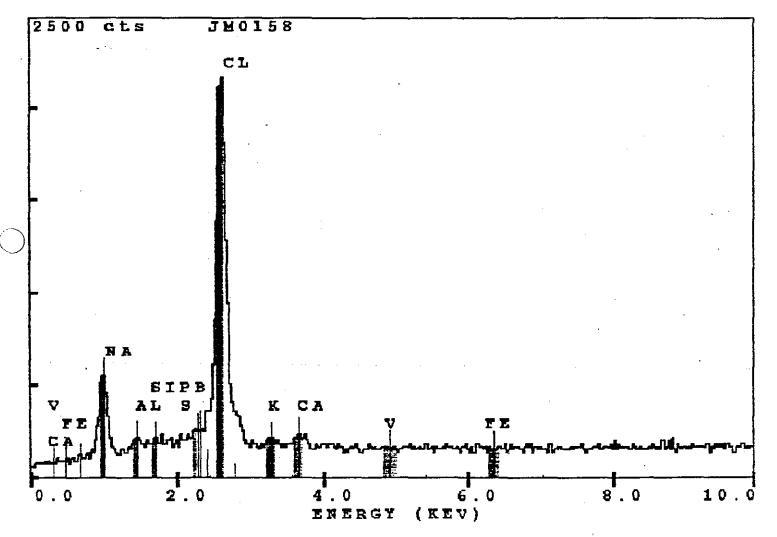
^{1 =} Date samples collected on roof of Kuwait Environmental Protection Div. (KEPD)

 $^{^2}$ = Date samples collected in family room of the Director of KEPD. 3 = Date samples collected near burning white plume in Wafra oil fields. 4 = $\mu g/m^3$ of selected species from samples collected with annular denuder systems.



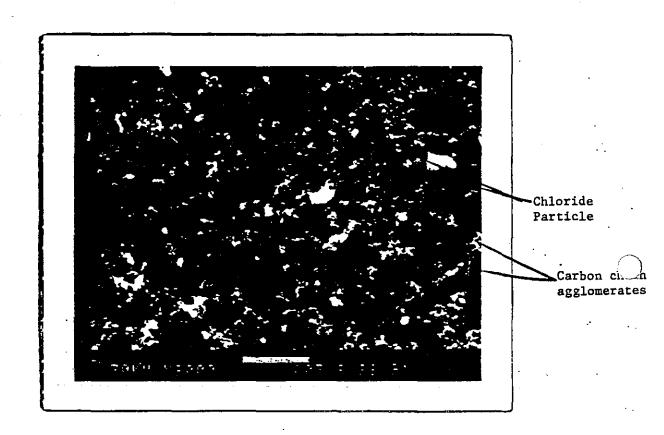
WHITE PLUME

SEM PHOTOMICROGRAPH



SEM SPECTRA OF SODIUM CHLORIDE

PARTICLE FROM WHITE PLUME



Super Plume Sample Showing a mixture of the chain agglomerates and chloride particles



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORYRESEARCH TRIANGLE PARK NORTH CAROLINA 27711

September 10, 1991

MEMORANDUM

SUBJECT: Summary of Kuwait Oil

Fire Monitoring Project

FROM:

Robert K. Stevens

Chief, Source Apportionment Research Branch (MD-47)

Joseph P. Pinto

Research Physicist (MD-84)

T0:

Dr. Gary J. Foley

Director, Atmospheric Research and

Exposure Assessment Laboratory (MD-75)

RKI

Below are three tables containing a summary of EPA's air quality measurements made at ground level sites in Kuwait (Table 1) and measurements made from a helicopter platform (Table 2) used to characterize Kuwait oil fire plumes. Table 3 contains a summary of canister sampling for volatile organic species (VOC's).

Since a major purpose of the helicopter sampling program was to characterize the chemistry of white and black plumes, separately, care was taken to choose plumes with minimum contamination by mixing from other plumes nearby. Individual plumes for sampling were chosen in the northwest corner of the northern oil fields. These plumes were judged to be least affected by mixing with others. In addition, we also obtained measurements in the "superplume", or the plume formed by mixing of all sources.

For the helicopter flights, samples were collected with a new type of dichotomous sampler. This device simultaneously collects inorganic gases [sulfur dioxide (SO_2) and nitric acid (HNO_3)] on denuders, and separates the fine (<2.5 µm) and coarse particles (>2.5 µm) and collects them on three separate filter media. One half of the fine particles are collected on a quartz filter and the other half on a Teflon filter. The coarse particles are collected on a Nuclepore filter. The mass and elemental composition of the particles collected on the coarse filters are determined by gravimetric and XRF methods respectively. Since 10% of the fine particles are also present on the coarse fraction, we are able to determine the particle size and morphological properties of the plume aerosols

by SEM/EDX methods. The semivolatile organic species are collected on a Tenex trap located downstream of the quartz filter. The $\rm SO_2$ and $\rm HNO_3$ are measured by IC analysis of the extract of a denuder that precedes the Teflon filter. The mass and elemental composition of the fine particles are determined by gravimetric and XRF methods.

Ground level samples were collected: (1) from the roof of the air monitoring laboratory of the Kuwait Environmental Protection Department (KEPD); (2) at the residence of the director, Dr. Mahmood Y. Abdulraheem; (3) the perimeter of the Burgan oil fields; and (4) within 25 meters of the fire generating the white plume in the Al-Wafra oil field.

The ground level sampling focused on collecting duplicate fine particle samples, on a Teflon filter to measure mass and elemental composition and the second one a quartz filter followed by a PUF trap to collect the semi-volatiles. Annular denuders preceded the filter packs to collect SO₂ and HNO₃.

Volatile organic compounds were collected in Summa polished canisters during several helicopter flights and at several ground level loctions. Table 3 contains the dates and location of the canister sample collection. We will analyze some of the canister samples at EPA but most will be sent to Dr. Rei Rassmussen, Oregon Graduate Center since he provided the VOC sampling system for this project. We will need to find \$12,000 to fund the analysis of these samples.

We have completed the XRF measurements of all the airborne and ground level samples collected in July and August. The XRF elemental composition data are attached. We need to send these samples to U of MD where we can have Dr. John Ondov determine the trace concentrations of V, Cr, lanthanides, As and Se by INAA. We estimate this can be completed in 4 weeks at a cost of \$14,000.

We need to measure the aliphatic and PAH content in the plume and ground level samples to compare with data obtained by KEPD and other groups monitoring the Kuwait oil fire emissions. We estimate \$15,000 will be required to obtain these measurements reliably. We left (on loan) about \$10,000 in air quality sampling equipment with KEPD. They need some additional equipment to continue their air quality monitoring program in preparation for the fall WHO human PAH exposure study. I estimate the cost of this supplemental equipment and additional QA measurements to be \$35,000. This includes upgrading their microblance, fine particle micro-environmental samplers equipped with PUF traps, pumps and flow measuring equipment and QA analysis of micro-environmental samples.

Table 1
Ground Level Samples

Date	Location		Samples Co	llected	
		Denuders SO ₂ , HNO ₃	Quartz/PUFs Ce,Cv,Organics Semi-Vol.Cond.	Teflon Mass, Elemental XRF,INAA	Nuclepore Mass, Elemental SEM/L
7/28-7/29	Roof of KEPD	x	X(1) (2)	X ⁽³⁾	х
7/31-8/01		X	x	x ⁽⁴⁾	· •
8/03-8/04		x	x	x	
8/07-8/08		x	x	x	
7/28-7/29	Indoor	x	x	x	
8/05	Al-Wafra Field	x	x .	x	
8/07	Al-Burgan Field	X	x	х	

- (1) Cv,Ce to be done
- (2) gc/ms/FID, to be done
- (3) INAA to be done
- (4) pH of extract obtained

Table 2
Helicopter Plume Samples
July 31 to August 8, 1991
All sampling was performed between 8-10 AM

Date	Location		Samples Collected								
		Denuder	Fine Pa	rticles	Coarse Particles						
		(SO ₂ , HNO ₃)	Quartz- TENNEX (Organics eg PAH, Aliphatics ² Cv,Ce	Teflon Mass, elemental composition (s,v,ni,Pb) INAA ³	Nuclepore Mass, SEM/EDEX Morpholog- ical						
7/21/91	North Fields Multiple Plumes	х	x	x	X.						
8/02/91	Al Burgan Black Plumes	x	x	x	x						
8/03/91	North Field Black Plume Sampling	x	х	х	X						
8/05/91	Near Field Super Plume	х	x	x	х						
8/06/91	Al Burgan Super Plume	х	x	x	x						
8/07/91	North Fields White Plume Sampling	x	x	х	х						
8/08/91	Near Source Super Plume	x		х							

¹Ce,Cv to be measured

A total 22 separate airborne samples were collected on 7 helicopter flights. Additional samples could have been collected, however NASA measurements took priority over EPA monitoring requests.

²GC/MS/FID of the organics to be analyzed

³INAA to be measured

Table 3 Canister Sampling

<u>Helicopter</u>

<u>Date</u>	Type of	<u>Canister</u> <u>Number</u>	Samples
8-03-91	North Field Black Plume	9	
8-04-91	Near Field Super Plume	2	
8-05-91	Near Field Super Plume	8	
8-07-91	North Field Super Plume	4	
	<u>Gr</u>	ound Levels	
8-03-91	KEPD	3	
8-05-91	Burgan Field Near oil lake	1	
8-05-91	Al-Wafra Near Field	1	
8-07-91	Al-Wafra White Plume Expt	2	(duplicates)

Kuwait Oil Fires: Helicopter Operations

History:

- March 1991 United Nations Action Plan developed to coordinate the international response to the health and environmental concerns resulting from the oil fires in Kuwait.
- April 24 United States Policy Coordinating committee on Oceans, International Environment, and Science (chaired by the Department of State) recommends the near-field sampling experiments suggested by NASA/EPA, utilizing the NASA helicopter borne sampling techniques, be implemented as part of the U.S. interagency response to the Kuwait oil fires as soon as possible.
- April 27-30, the Secretary-General of the World Meteorological Organization (WMO) convened a conference in Geneva to coordinate international responses to the atmospheric part of the UN Action Plan.
- May 17 U.S. Policy Coordinating Committee agrees to fully support the UN response and to integrate U.S. efforts into the United Nations program (WMO/WHO).

Kuwait Oil Fires: Helicopter Operations

History:

- June 11 Saudi Arabian Government (MEPA)
 informs U.S. Embassy that a Saudi Civil Defense
 helicopter and crew will be committed to the
 NASA/EPA near-field sampling experiments.
- Saudi scientific participation in the project is to be coordinated through Dr. Al-Thuwainy, Director of MEPA in Riyadh.
- Project becomes joint U.S./Saudi effort.
- July 3 Kuwaiti Government agrees to scientific participation in experiments and to grant overflight clearances and laboratory facilities at EPD in Kuwait City.
- Kuwaiti scientific participation by EPD and KISR anticipated.
- Project becomes joint U.S./Saudi Arabian/Kuwaiti effort.

Kuwait Oil Fires: Helicopter Operations

1. Purpose: Characterization of source emissions.

Identification and Quantification of combustion emissions at the source of burning Kuwaiti oil wells is necessary for assessing potential regional health issues, atmospheric and environmental impacts, and verification of combustion/dispersion model predictions.

11. Approach: Coordination of selected helicopter and ground based measurements.

A helicopter based smoke plume sampling system has been developed and used by the NASA-Langley Research Center to study global biomass burning emissions from several global habitats. Research scientists from NASA and the U.S. EPA have collaborated to develop a basic smoke sampling package (instrumentation, measurement objectives, etc.) that combine ground and airborne helicopter measurements in the near-field to quantitatively characterize of many of the important oil fire emissions.

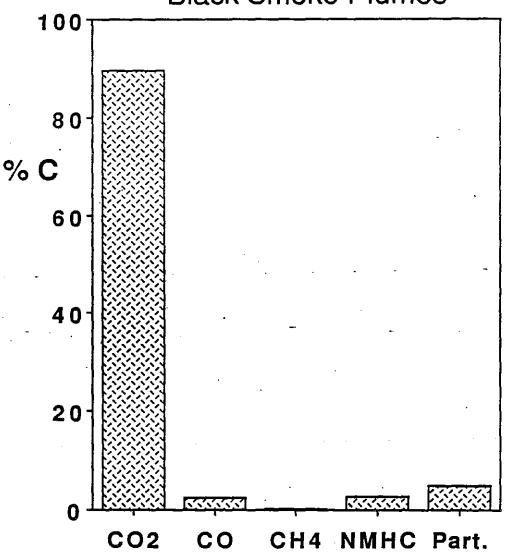
Kuwait Oil Fires: Helicopter Operations-

111. Measurements:

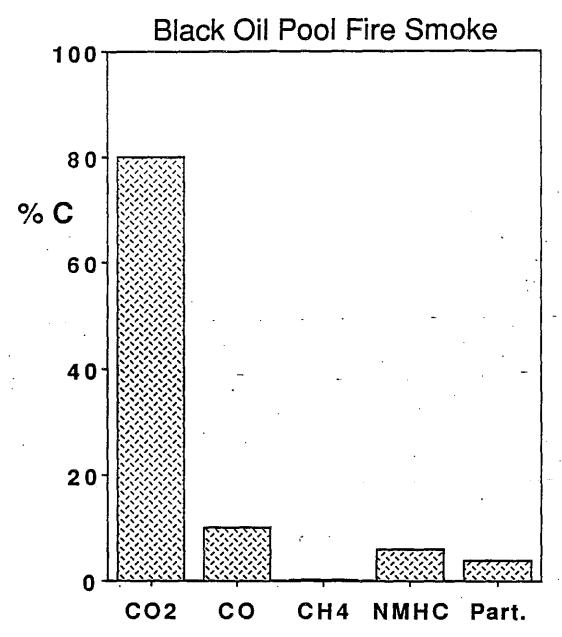
A.) NASA/EPA:

- Carbon dioxide, carbon monoxide, methane
- Total hydrocarbons, light hydrocarbons
- Nitrous oxide
- Sulfur dioxide
- Polynuclear Aromatic Hydrocarbons
- Acid aerosols (sulfate, nitrate, etc.)
- Trace metals
- Elemental carbon / organic carbon
- Total aerosol burden
- Aerosol size distribution
- Particle morphology

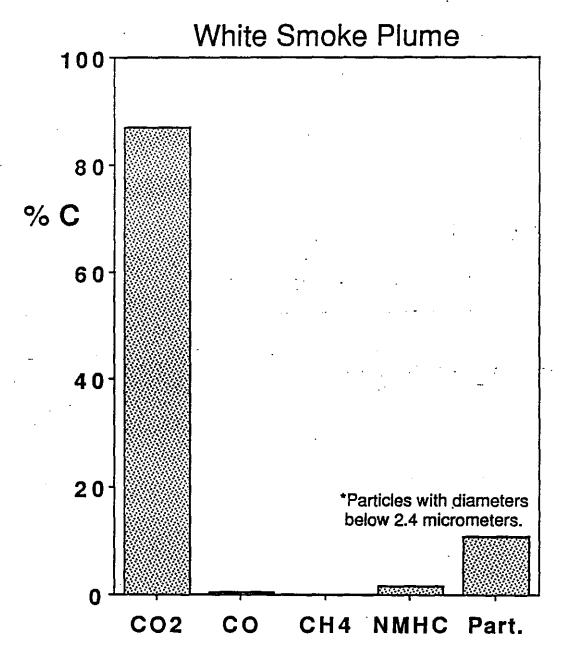
Kuwait Oil Fires NASA Helicopter Measurements Black Smoke Plumes



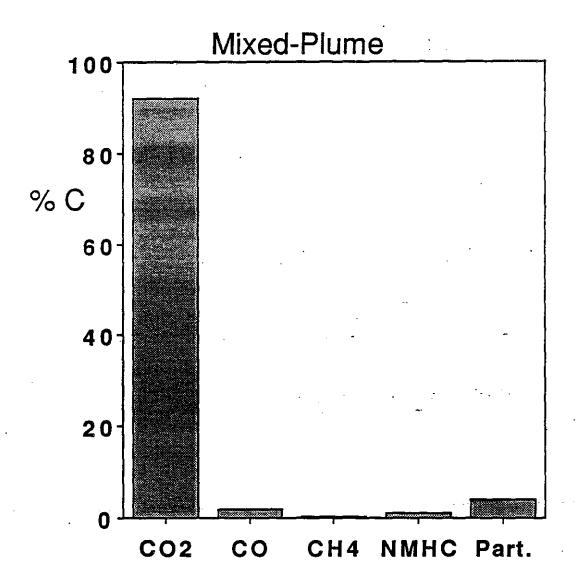
Carbon partitioning in black smoke.



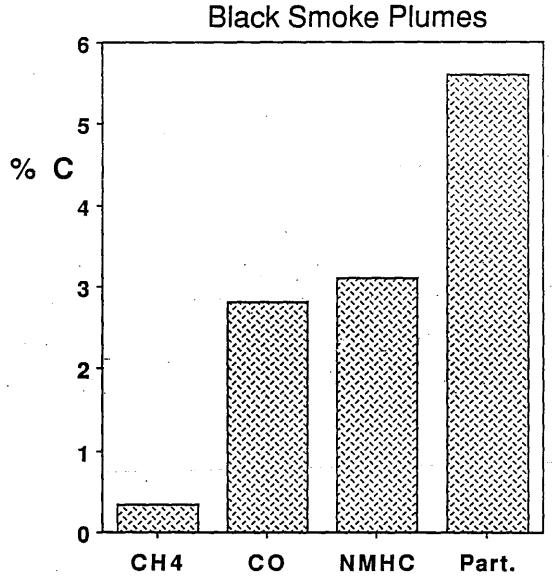
Carbon partitioning in black pool-fire smoke.



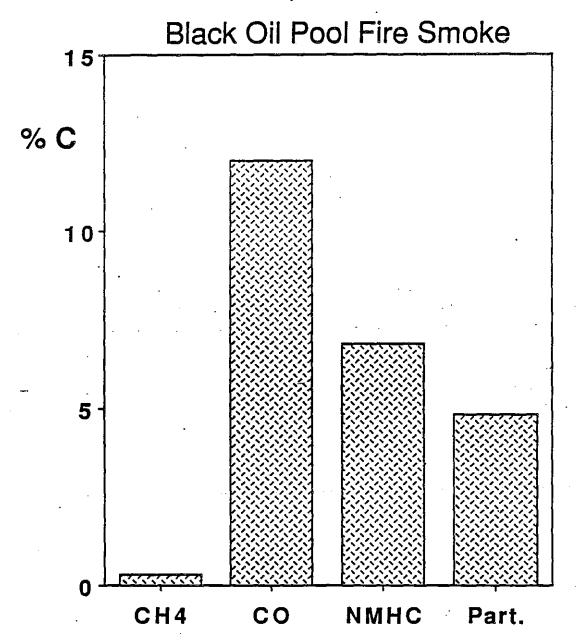
Carbon partitioning in white smoke.



Carbon partitioning in mixed-plume smoke.

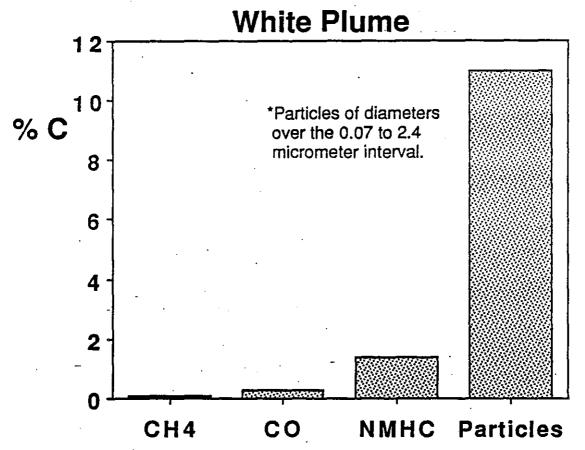


Percentage of carbon normalized to combustion produced carbon in carbon dioxide.



Percentage of carbon normalized to combustion produced carbon in carbon dioxide.

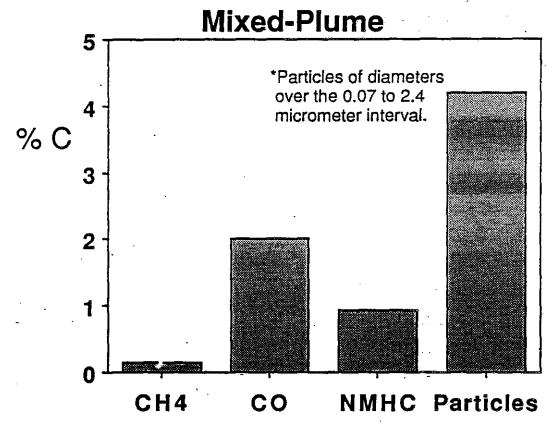
KUWAIT OIL FIRES NASA Helicopter Measurements



Percentages of carbon normalized to combustion produced carbon in carbon dioxide (mass/mass).

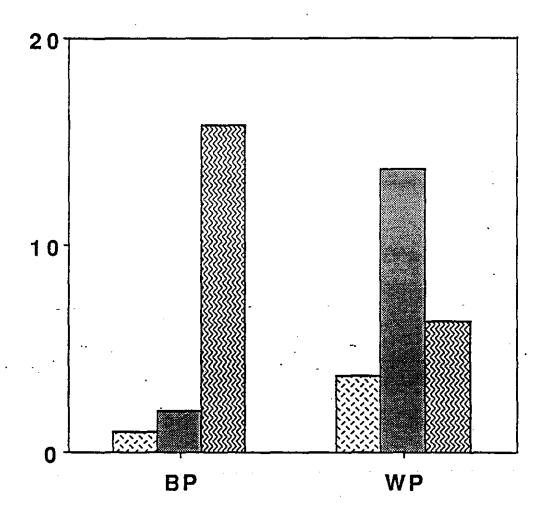
Measurements obtained in a large white verticle smoke plume in the northern oil fields of Kuwait on August 7, 1991.

Note the very high proportion of particulate carbon produced relative to carbon monoxide. Since particles of diameters greater than 2.4 micrometers have not been analyzed yet, this percentage would increase.



Percentages of carbon normalized to combustion produced carbon in carbon dioxide (mass/mass).

Measurements obtained in the mixed-plume of the southern oil fields of Kuwait on August 6, 1991.



Total particles(mg), CI- (%T), SO4 (%T)

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835

KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Gas Concentrations.

Mission 1, July 31, 1991. Northern Oil Fields. Winds 300°, 10 Kts. Takeoff 7:10 AM.

	·			Concentrations in ppmv							
Sample #	¥ Туре	Time	Altitude	CO2	CO	CH ₄	TNMHC	N ₂ 0			
1 2 3	background " "	7:25 LT 7:30 7:34	1000 ft 1000 ft 200 ft	366 368 365	1.28 0.21 0.24	1.82 1.79 1.79	0.76 0.61 0.85	0.319 0.318 0.319			
4 5 6 7 8 9	Bk oil pool-1	7:44 7:49 7:52 7:55 7:58 8:00	350 ft 350 ft 350 ft 350 ft 350 ft 350 ft	399 409 429 398 412 422,	14.1 12.2 18.1 11.5 12.1 11.6	1.85 1.84 1.88 1.82 1.81 1.84	5.91 8.96 9.52 4.49 5.87 4.04	0.322 0.325 0.350 0.324 0.331 0.323			
10 11 12	Bk oil pool-2 "	8:03 9:37 9:27	300 ft 300 ft 300 ft	419 399 422	10.3 9.4 6.7	1.83 1.83 1.85	4.48 3.94 3.54	0.323 0.319 0.320			
13	background	8:10	800 ft	405	5.80	1.81	0.89	0.320			

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835

KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Gas Concentrations.

Mission 2, August 1, 1991. Northern Oil Fields. Winds 3200, 16 Kts. Takeoff 8:40 AM.

				Concentrations in ppmv						
Sample	# Туре	Time	Altitude	co ₂	ĊO	СН4	TNMHC	N ₂ 0		
1	Vert. Bk Pl-2.	9:45 LT	250 ft	375	1.60	1.79	0.57	0.320		
2	11	10:05	250 ft	403	0.90	1.80	0.95	0.322		
3		9:55	250 ft	397	1.11	1.80	0.87	0.317		
4	•	10:03	250 ft	424	1.20	1.81	1.21	0.323		
5		10:00	250 ft	446	1.22	1.82	1.95	0.323		
6		9:51	250 ft	391'	0.83	1.80	1.42	0.322		
7	44	9:47	250 ft	427	3.11	1.81	1.48	0.321		
8	Vert. Bk Pl-1	9:34	300 ft	397	1.85	1.84	2.12	0.322		
9	16	9:37	300 ft	410	2.82	1.88	2,55	0.321		
10	16	9:27	300 ft	395	3,35	1.87	2.93	0.319		
11	Bk oil pool-3.	9:24	300 ft	418	4.33	1.83	4.62	0.320		
12	background	9:17	900 ft	364	0.90	. 1.77	0.83	0.320		
13	ji	9:09	900 ft	357	0.72	1.76	0.94	0.323		
14	14	9:07	900 ft	356	0.87 .	1.82	1.23	0.321		
15	ű	10:14	300 ft	355	0.63	1.76	0.82	0.320		
16	N	10:16	400 ft	. 354	0.70	1.79	0.73	0.322		

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835

<u>KUWAIT OIL FIRES</u> - NASA/EPA Near-Field Helicopter Source Characterizations. <u>Gas Concentrations</u>.

<u>Mission 3, August 2, 1991.</u> Southern Oil Fields. Winds 300°, 12 Kts. Takeoff 10:50 AM.

					Conce	entrations	in ρρπν	
Sample	# Туре	Time	Altitude	CO ₂	co :	СН4	TNMHC	N ₂ 0
1	Bk-0il-Pool-4.	11:25 LT	250 ft	394	2.27	5.61	15.40	0.328
2	0	11:28	250 ft	401	2.29	1.98	1.85	0.324
3	H	11:31	250 ft	393	3.27	2.57	3.37	0.325
4		11:35	250 ft	390	2.16	1.80	1.78	0.318
5		11:38	250 ft	393	1.51	1.81	1.15	0.323
6	background	11:41	250 ft	366	0.83	1.78	0.62	0.320
7	H	11:44	250 ft	359	0.85	1.78	0.76	0.321

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835 KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Gas Concentrations. Mission 4, August 3, 1991. Northern Oil Fields. Winds 280°, 10 Kts. Takeoff 8:30 AM.

					in ppmv	1 bbwa			
Sampl	е # Туре	Time	Altitu	de	CO2'	CO	СН4	TNMHC	N ₂ 0
1 2	background	8:52 LT 8:53	600 f		369 373	0.59 0.78	1.80 1.81	0.79 0.67	0.321 0.316
. 3	oil lake,no fire	9:17	100 f	: t	412	4.44	1.81	1.69	0.321
4 5	Vert. Bk Plume 3.	9:25 9:29	200 f 200 f	_	441 450	0.90 1.33	1.81 1.82	2.30 2.62	0.324 0.321
6 7 8	Bk-Oil-Pool-5.	9:42 9:45 9:47	250 fi 250 fi 250 fi	t	408 410 412	1.06 1.54 1.25	1.83 1.83 1.82	1.67 2.17 2.18	0.325 0.323 0.323
9 10 11	Vert. Bk Plume 4.	9:53 9:55 9:58	300 fi 300 fi 300 fi	t	511 546 569	0.97 1.14 1.22	1.81 1.82 1.81	2.73 2.44 2.38	0.325 0.321 0.324
12 13	background	10:02 10:05	900 fi 900 fi	t	366 369	0.33 0.35	1.78 1.78	0.62 0.76	0.324 0.324

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835 KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Gas Concentrations. Mission 5, August 4, 1991. Northern Oil Fields. Winds 330°, 17 Kts. Takeoff 8:25 AM.

					Concentrations in ppmv							
Sampl	e# Type	Time	Alti	tude	co ₂	CO	СН4	TNMHC	N ₂ 0			
1 2	background	8:45 LT 8:47	700 600		369 359	0.32 0.29	1.78 1.79	0.53 0.43	0.320 0.320			
3 4	oil pool no fire	8:58 9:02		ft ft	387 409	0.58 0.72	1.78 1.78	1.73 1.08	0.320 0.323			
5 6 7 8	Vert. Bk Plume 5.	9:08 9:10 9:13 9:18	250 250 250 250	ft ft	405 414 405 393	0.64 0.70 0.63 0.58	1.79 1.81 1.82 1.83	0.75 1.44 1.81 1.82	0.318 0.318 0.319 0.320			
13 14 15 16	Bk-Oil-Pool-6.	9:38 9:40 9:43 9:45	300 300 300 300	ft ft	397 424 395 409	0.66 0.89 0.82 0.85	1.81 1.82 1.80 1.81	2.20 2.62 1.87 1.51	0.325 0.323 0.319 0.321			
17	White Plume	9:54	300	ft	401	0.72	1.78	1.50	0.322			
18 19	background	10:02 10:05	400 500		366 450	0.23 0.29	1.78 1.78	0.76 0.76	0.319 0.317			

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835 KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Gas Concentrations. Mission 6, August 6, 1991. Southern Mixed Plume. Winds 3300, 5 Kts. Takeoff 8:02 AM.

Sample #	Туре				Concentrations in ppmv				
		Time	Alti	tude	CO ₂	ĊO	CH4	TNMHC	N ₂ 0
1 2	background	8:08 LT	300		373	0.32	1.77	0.63	0.323
		8:10	300	T;L	36 9	0.44	1.78	0.34	0.319
3	Mixed Plume	8:13	800	ft	402	0.50	1.83	0.81	0.319
4		8:16	700	ft	400	0.66	1.85	0.87	0.319
5 6	41	8:17	600		397	0.70	1.85	0.87	0.318
6	# ,	8:20	600	ft	393	0.56	1.80	0.74	0.321
7	Mixed Plume	8:26	1000	fŧ	401	0.59	1.83	0.76	0.319
8	ŧi	8:28	1000		402	0.47	1.82	0.83	0.321
9	n .	8:30	1000		402	0.66	1.80	0.89	0.319
10	#	8:32	1000	ft	399	0.96	1.86	1.02	0.321
11	Mixed Plume	8:45	1000	ft	371	0.54	1.78	0.77	0.333
12	46	8:46	1000	ft	. 400 1	1.41	1.83	0.88	0.324
13	н	8:48	1000		394	1.12	1.82	0.70	0.319
14	10	8:51	1000	ft	396	1.01	1.80	0.61	0.324
15	Mixed Plume	9:04	1000	ft	391	0.86	1.79	0.58	0.323
16	#	9:07	1000		389	0.88	1.80	0.57	0.321
17	. 11	9:09	1000	ft	389 '	0.93	1.79	0.66	0.323
18	u ,	9:11	1000	ft	388	1.02	1.80	0.59	0.319
19	White Plume	9:20	400	ft	439	0.53	2.13	1.15	0.326
20	background	9:29	300	ft	371	0.49	1.78	0.49	0.321

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835 KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Gas Concentrations. Mission 7, August 7, 1991. Northern Fields Whiteplume. Winds 3200, 9 Kts. Takeoff 8:00 AM.

Sample #	Туре	Time		Concentrations in ppmv				
			Altitude	co ₂	CO.	CH ₄	TNMHC	N ₂ 0
1	background	8:30 LT	800 ft	363	0.22	1.75	0.45	0.318
2	11	8:31	800 ft	362	0.17	1.75	0.33	0.323
` 3	White Plume	8:40	1000 ft	396	0.34	1.79	0.89	0.318
4	11	8:42	1000 ft	417	0.54	1.81	1.17	0.320
5	íl	8:44	1000 ft	442	0.56	1.82	1.26	0.318
5 6	и	8:46	1000 ft	381	0.26	1.79	0.93	0.320
7	White Plume	8:53	1000 ft	401	0.27	1.81	1.13	0.318
8	11	8:55	1000 ft	377	0.25	1.78	0.95	0.318
9	ii	8:57	1000 ft	413	0.31	1.80	0.89	0.321
10	. "	8:59	1000 ft	397	0.26	1.79	0.92	0.321
11	White Plume	9:14	1000 ft	417	0.42	1.81	0.91	0.324
12	и	9:21	1000 ft	395	0.36	1.82	1.05	0.317
13	11	9:23	1000 ft	524	0.58	1.88	1.69	0.321
14	iė	9:25	1000 ft	406	0.42	1.82	1.13	0.321
15	background	9:34	1000 ft	369	0.20	1.78	0.62	0.319
16	А	9:43	1000 ft	363	0.30	1.75	0.73	0.322

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835 KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Particle Concentration.

Ion Chromatographic Analysis:					ug/m ³						
Filter #	Bottle Mi	ssion	Туре	Tot wt	c1-	NO ₃ -	50 ₄	Na	NH ₄	Κ	
1	282	1	0-P-F	1.28 mg	3	22	105	17	6	3	
` 2	31	2	BP	2,44	90	70	400	·75	32	10	
3	25	2	ВР	(-)	176	20	128	130	4	-	
33	9	7	WP	5.7	885	6	90	265	5	3	
34	8	7	WP	4.3	838	5	65	233	3	2	
32	20	6	SP	(-)	25	4	30	11	2	_	
19	30	6	SP	1.48	13	3	17	10	2	-	
4	12	2	BP	3.88	·54	3	117	61	7	-	
5	29	2	ВР	1.60	47	-	139	54	16	· -	
3	19 (2nd ext)	2	ВР	(-)	140	11	128	134	6		
14	14	5	WP	2.5	738	-	105	393	17	32	
6	33	2	Bk	(-)	.8	-	2.2	1.9	-		
7	254	2	Вk	(-)	-	_	-	2.6	-	-	
15	. 27	4	0-P-F	0.9	1	7	140	28	19	-	

()

Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Sciences Division, (804) 864-5835 KUWAIT OIL FIRES - NASA/EPA Near-Field Helicopter Source Characterizations. Particle Concentration.

Ion Chromatographic Analysis:				ug/m ³						
Filter#	Bottle	Mission .	Туре	Tot wt	ˈc1-	NO ₃ -	so ₄	Na	NH ₄	К
12	133	6	SP/Bkg	(-)	2.1	2.0	9.4	5	· 2	••
10	7		ВР		23			16	19	2
8	15	3	0-P-F		23	3.0	88	49	13	1
16	. 36			1	•		30.8			
9	iı						17.5			
13	24	6	SP	(-)	16	1.9	14	15	2	-
11	· 268							2	1	*
17	23	•	:					7	3	-

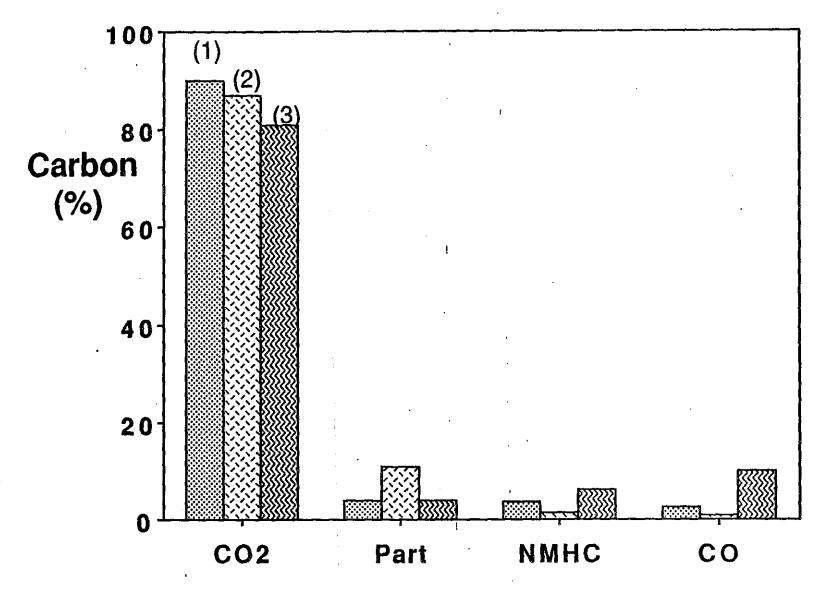


Figure 1. Carbon partitioning in (1) black plume, (2) white plume, and (3) oil pool fires. * Percentage of carbon in white plume reflects many non-carbon aerosol particles.

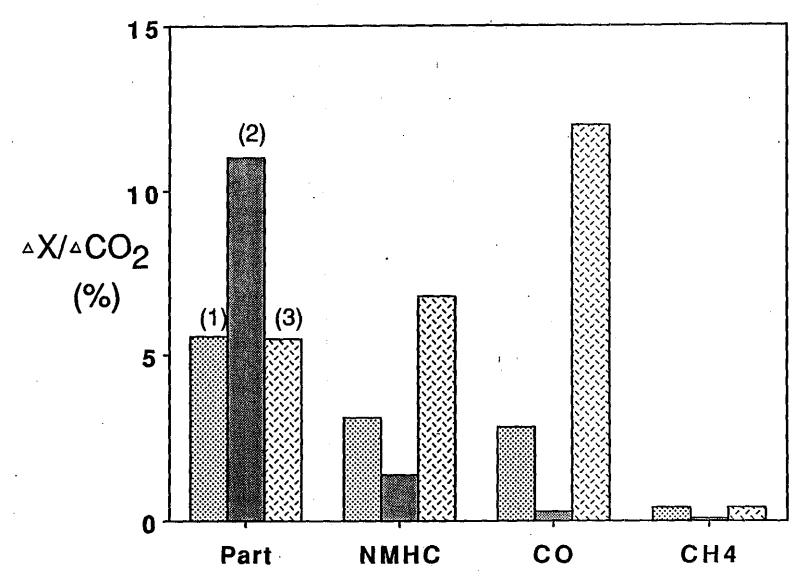


Figure 2. Normalized emission ratios for (1) black plumes, (2) white plumes, and (3) oil pool fires.

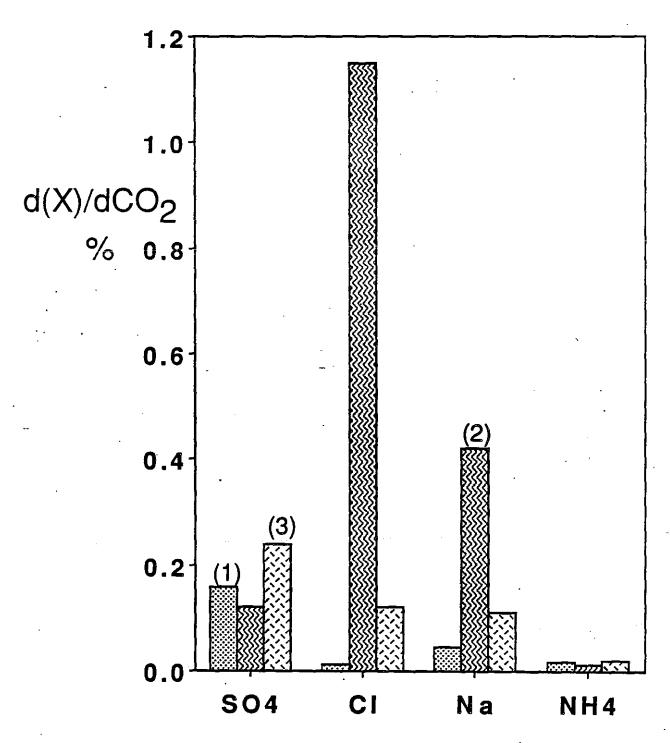


Figure 3. Emission ratios for water extracted aerosol ions. Key: (1) = oil pool fires, (2) = white smoke, (3) black plumes.

NASA/EPA Helicopter Operations: Kuwaiti Oil Fires

Wesley R. Cofer III, Atmospheric Sciences Division NASA-Langley Research Center Hampton, VA 23665.

Missions

Seven smoke sampling missions were conducted between July 31 and August 8, 1991, in the Sabriyah (northern oil field) and the Burgan oil field. A Royal Saudi Air Force UH1N (HUEY) helicopter and crew were used to acquire samples from selected oil fires representing different types of fires and smokes. The fires/smokes were generically categorized in this study as black smoke plumes, oil pool fire plumes, white smoke plumes, and mixed plumes (superplumes). A more complete description follows.

- <u>Black Smoke Plumes (BP)</u> Plumes resulting from essentially individual well fires with little pooling at their base and a sufficiently large amount of elemental carbon emissions to produce a visibly dark black smoke color.
- Oil Pool Fires (0-P-F) Fires that were substantially large ponds of burning oil typically surrounding one or more actively burning well heads. These fires usually produced dark black colored smoke emissions.
- White Plumes (WP) a significant number (est. about 10-15%) of the oil fires produced white smoke plumes. These white plumes were sometimes isolated, but many times they existed directly beside black smoke producing fires. Their coloration indicated a much different chemical, composition.

Mixed or Superplume - the large plume resulting from the mixture of many individual smoke plumes from an oil field.

Smoke analyses focused on the above generic categories of fires/smokes and used gaseous measurements of carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄), nonmethane hydrocarbons (NMHC), nitrous oxide (N₂O), sulfur dioxide (SO₂), as well as carbon and sulfur aerosols. Aerosol measurements have been used to highlight particulate smoke characteristics for each category. Other analyses (e.g., % soot carbon generated, polynuclear aromatic hydrocarbons) are being conducted and results will be offered as soon as possible.

Figures

The partitioning of carbon compounds in the Kuwaiti smoke plumes are shown in figure 1. Total particle mass attributed to carbon appears in figure 1. Total carbon mass fractions shown in figure 1. are probably reasonable for all plumes studied but the white plumes, which contained large amounts of inorganic salts, and will be discussed later. As expected, most carbon emitted from the oil fire combustion can be accounted for as CO₂.

The same results, normalized to CO_2 ($\Delta X/\Delta CO_2$, where ΔX = compound of interest less its background concentration and ΔCO_2 its plume concentration less background) are shown in figure 2. Normalization with CO_2 not only provides the percentages of non- CO_2 carbon compounds produced by the combustion, but also normalizes differences between individual samplings (sampling variability due to different times, locations in the plume, etc.). In figure 2, the relationship in concentrations of particles (Part), hydrocarbons (NMHC), carbon monoxide (CO_2), and methane (CH_4) emissions among the

generic categories (BP, O-P-F, etc.) are more clearly seen.

Figure 3 shows emission ratios for the water extracted inorganic ions sulfate (SO_4^{-}) , chloride (CI^-) , sodium (Na^+) , and ammonium (NH_4^{+}) from smoke samples collected on filters over oil pool fires, white smoke plumes, and from black smoke plumes. It is readily apparent that chloride and sodium concentrations in the white plumes are substantially higher than in the oil pool fire and black plume smokes. Elevated levels of calcium and carbonates were also determined. Total sulfur concentrations (gaseous SO_2 + sulfate in the aerosol) for the smoke plumes averaged about 0.5%, which is lower than would be anticipated from the estimates of sulfur content in the Kuwaiti crude.

Figure 4 summarizes emission ratios determined for the mixed plume (superplume). Note the low concentrations for NMHC, CO, and CH₄. Particle (aerosol) concentrations, however, can be seen to be relatively high.

Results (Synopsis)

The precentage of carbon released as CO_2 is seen (figure 1) to be lowest in the oil pool fires. These fires also produce the highest levels of CO_2 , NMHC, and CH_4 (see figure 2). They are thus the "dirtiest" and most polluting fires. Efficient combustion of hydrocarbon fuels produces mostly CO_2 and H_2O as products. Production of particles and other gases represent incomplete combustion, and are produced at the expense of CO_2 and H_2O_3 .

The very low levels of CO measured in the white plumes, particularly in light of the very high levels of aerosol particles measured, is notable. This result, however, may be explained by an examination of figure 3.

The exceptionally high emission ratios determined for sodium and chloride (figure 3) indicate overwhelmingly large amounts of inorganic salts for an oil combustion plume. This coupled with the distinctly white color of the plumes suggest that a large amount of liquid water may be associated with the white plume fires. Plume appearance coupled our with data would suggest that a steam/brine mixture may be emitted along with the combustion emissions. If so, this could account for the large amounts of aerosols that coexist with relatively low levels of combustion products (CO, NMHC, etc.) in the white smoke plumes.

Conclusions

While the Kuwaiti oil fire smoke plumes manifest pronounced impacts on solar radiation in the Gulf region (sky color, ground temperatures, visibility, etc.), concentrations of indicators of combustion generated pollution suggest that the overall impact of the smoke from these fires may be less than anticipated. Sulfur emissions (both particulate and gaseous) appear to be an example of pollutants that are in lower than predicted concentrations. Carbon monoxide generated by the Kuwaiti fires (except for the oil pool fires) is another example of a pollutant at lower than expected smoke plume concentrations.

Recommendation

Emphasis should be placed on determining the composition of the smoke aerosol. Since much of the smoke aerosol is in a respirable size, chemical compounds adsorbed or coated on particle surfaces could pose health hazards if such particles were trapped in/on the lungs.

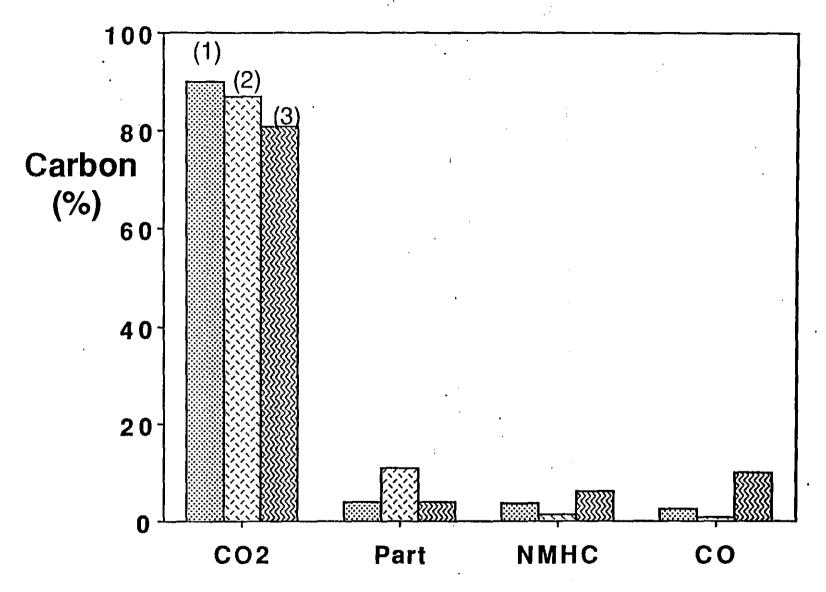


Figure 1. Carbon partitioning in (1) black plume, (2) white plume, and (3) oil pool fires. * Percentage of carbon in white plume reflects many non-carbon aerosol particles.

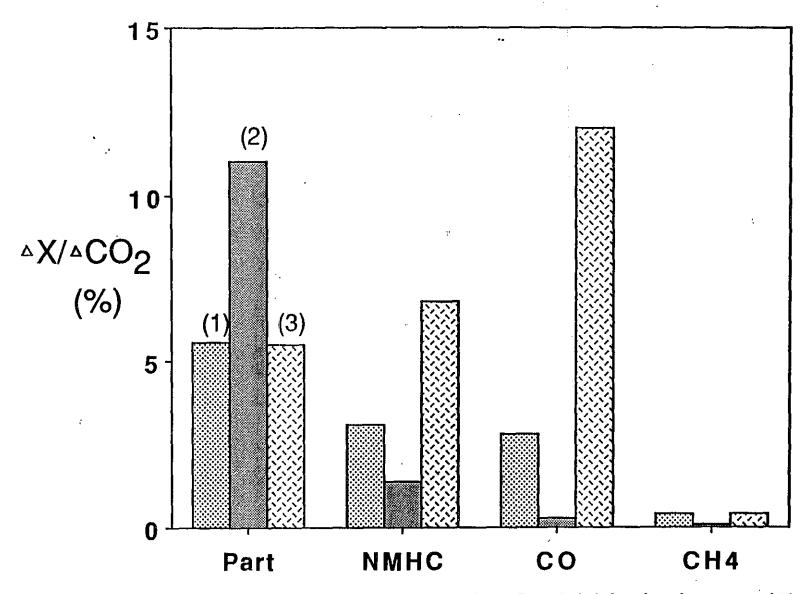


Figure 2. Normalized emission ratios for (1) black plumes, (2) white plumes, and (3) oil pool fires.

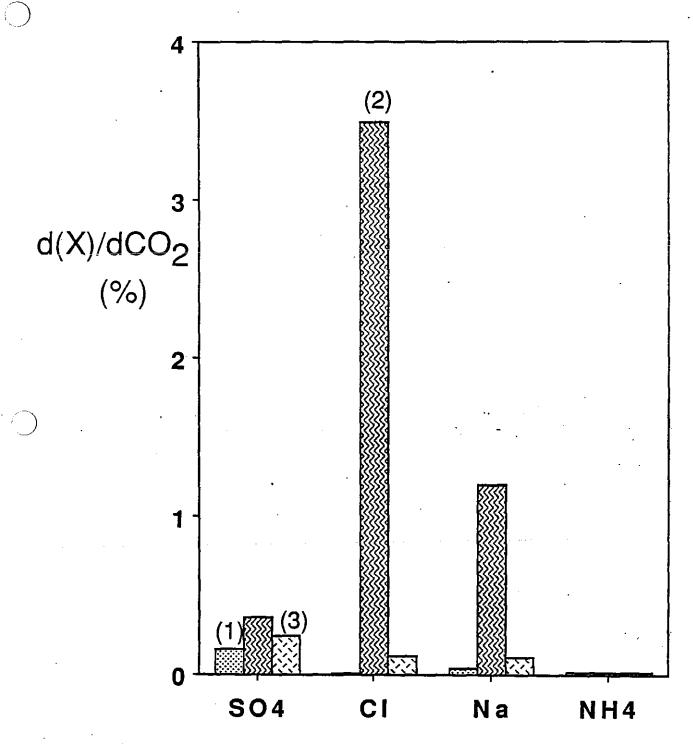


Figure 3. Emission ratios for water extracted aerosol ions. Key: (1) = oil pool fires, (2) = white smoke, (3) black plumes.

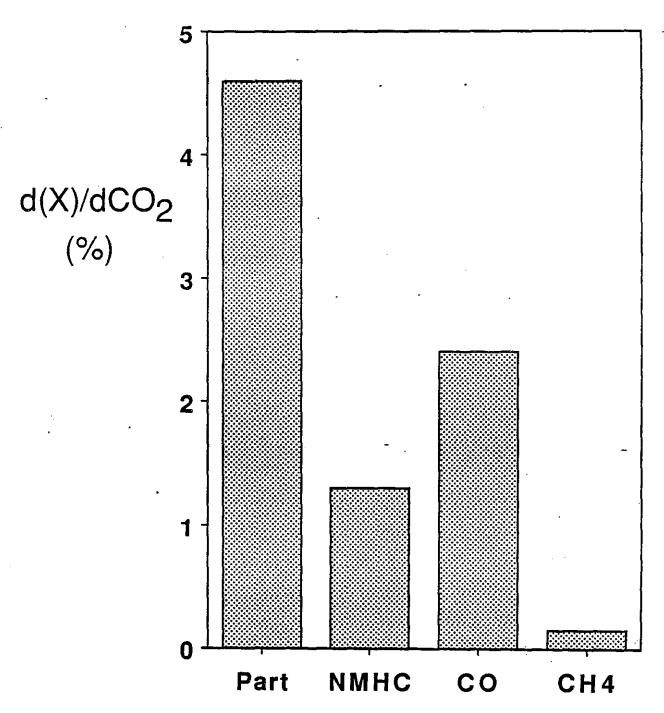


Figure 4. Normalized emission ratios for mixed plume (superplume).



10, rue Crillon 75004 PARIS Téléphone: 44.59.47.64 - Télécopie: 44.59.47.00 Paris, 27 May 1991

FINAL REPORT

MEASUREMENT CAMPAIGN OF THE REGIONAL MOBILE LABORATORY FOR MEASUREMENT OF AIR QUALITY IN KUWAIT

27 MARCH TO 4 APRIL 1991

PHILIPPE LAMELOISE Director of AIRPARIF

GERARD THIBAUT

Engineer

Laboratoire Central de la Préfecture de Police

Comments on health consequencies
Doctors R. MASSE et J. LAFUMA
Atomic Energy Commissariat
Members of French Superior Hygien Council

Laboratory of Hygien of Paris City
Analyses (LHVP)
A. PERSON

Analyses of French Institut of Petroleum (I F P)

M. PASQUEREAU

RESULTS OF ATMOSPHERIC POLLUTION

IN KUWAIT

--- GLOSSARY ---

Units:

- pollutants in µg/m3 of air at 20° C and normal atmospheric pressure

- weather conditions wind speed

N

site number on map

MOY

average over the period of measurement

MAX

maximum over 5 minutes for SO2, 03, CO, NO and NO2

maximum over 1 hour for BS

SO₂

sulfur dioxide

CO

carbon monoxide

03

:

:

:

ozone

NO

nitric oxide

NO₂

nitrogen dioxide

BS

measurement of particles suspended in the air by the black smoke method in $\mu g/m3$

HC

sample of gaseous hydrocarbons on activated charcoal support, analyzed in the

laboratory by CPG + SM (length : one campaign)

VOC:

volatile organic compounds

PAH :

sample of polycyclic aromatic hydrocarbons filter + tenax and measurement in the

laboratory by HPLC

PPA60:

sample of particles on cellulose nitrate filter and PAH analyses

LHVP :

Laboratory of Hygien of Paris City

IFP

French Institut of Petroleum

ATMOSPHERIC POLLUTION IN KUWAIT

PART ONE

I - INTRODUCTION:

In cooperation with the French and Kuwaiti environment and health ministries, a study of atmospheric pollution was undertaken from 26 march to 6 april 1991.

I-1 - Goals of the study

- 1°) Aid the Kuwaiti authorities of the ministry of public health which supervises the EPC in reactivations the air quality monitoring network in Kuwait City. This network, composed of three fixed stations set up in Kuwait City (see map 1) had been suspended during the Iraqui occupation and had not been able to be reactivated due to a lack of necessary equipment and electrical power.
- 2°) Inform the authorities of the ministries of the environment and health of the two countries of the levels of atmospheric pollution related to the burning oil wells.

We have therefore worked during the entire campaign in collaboration with the specialists of the EPC in consideration their proposal for measuring sites. We must imphasize the logic and technical aid given at all times by the detachment of the "Daguet division" in Kuwait City.

I-2 - Means

In order to reach the goals mentioned above, the departments and organizations responsible for monitoring air quality in the Paris region (AIRPARIF), Central Laboratory of the Prefecture of Police (LCPP) and Laboratory of Hygien of Paris City (LHVP) transported on site their mobile laboratory supplied with a portable generator and specifically equiped to measure atmospheric pollution in urban settings, as well as a team of two engineers.

The vehicle was transported by the special Air Force Plane TRANSAL C 160.

This equipment is composed of:

- a UV absorption ozone (O3), with its sensitivity test,
- a UV fluorescent sulfur dioxide (SO2) analyzer, with its internal reference by calibrated permeation tube.
- an infrared absorption carbon monoxide analyzer linked to an external reference,
- a chemiluminescent nitrogen oxide (NO + NO2) analyzer linked to an external reference (gaz bottle with a known quantity of NO),

- a sequential particle sampler on cellulose acetate filter, porosity 0,8 micron, for subsequent analysis in the laboratory of the compositions of particles there sampled (PPA60) (length of sampling = 1 hour), measurement of metals (nickel and vanadium were made by LHVP and IFP on these samplings (annex VI),
- a sequential particle sampler OPALE 500 for subsequent determination of the black smokes index by reflectometry (measurment of weight index).

This equipment was completed by systems for air sampling on specific solid supports with a view to the determination of others polluants:

- a sample on "tenax cartridge" with a view to the determination of "polycyclic aromatic hydrocarbons" (PAH),
- analyses of PAH and metals will also be made on PPA60 samples an on deposits from the black smokes sample,
- samples on activated charcoal tubes with a view to the determination of volatile organic compounds (HC)

PAH and HC samples were analysed by the "Laboratoire d'Hygiène" of the City of Paris and the conclusions appear in annexe VI. The following hydrocarbons were measured by LHVP on the actif charcoal samplings. Heptane, Octane, Nonane, Decane, Undecane, Tridecane, Benzene, Toluene, Ethy-benzene, Méta + Para Xylène, Ortho Xylène, 1, 2, 4 Triméthyl Benzène. Measurements of PAH (particulates phases) have been made by LHVP and IFP on samplings of black smokes (sampling on cellulose nitrate paper) analysed by HPLC fluorescence detector. PAH measured: fluoranthène, Benzo (a) Antracène, Antracène, Benzo (c) Pyrène, Benzo (b) Fluoranthène, Benzo (k) FLuoranthène, Benzo (a) Pyrène, Dibenzo (a, k) anthracène, Benzo (ghi) Perylène, Indeno (1,2,3; c, d) Pyrène, Pyrène for the VOC and PAH the levels in Paris City are added for comparison annex 6.

- the black smoke indexes were measured by the "Laboratoire d'Hygiène" of Paris City,
- manual detection of some pollutants by specific detector tubes (Draeger tubes).

The laboratory van is further equipped with meteorological sensors which can be mounted on a telescopic pole at a hight of 9 meters and which allows acquisitions of the parameters of temperature, wind speed and wind direction. For the campaigns after the 3th of April the wind direction results were cancelled, the sensor appeared out of order.

The various pollutant gaz analysers and meteorological sensors are connected to a computer system which integrates supplied analog signals and allows mathematical processing of the recorded instantaneous values.

The computer system was programmed in such a way as to acquire for all parameters:

- -> average values over 5 or 15 minutes,
- -> instantaneous maximum values read by the instrument during each 5 minutes period (average signal over 3 seconds),

From these parameters the hourly averages and the averages for the length of each study were deduced.

PART 2

II - GENERAL NATURE OF THE KUWAITI ENVIRONMENT:

II-1 - Kuwait

Before the Iraqi occupation and the events which followed, Kuwait had a population of about 2 millions inhabitants in an area of 16 000 km2, principally concentrated int the capital "Kuwait City" and its suburbs.

The main resource of the country is the extraction of crude oil by about 900 wells distributed among various oil fields:

- Al Rawdatayn, in the north
- Al Ahmadi et Al Magwa, in the southeast,
- Al Wafra, in the extreme south,
- Al Burghan, in the center,
- Al Mutriba, in the northwest (see map)

Production was about 2 million barrels (1)/day before the Iraqi invasion.

(1) reminder: 1 barrel = about 159 liters

Following the invasion, about 550 of the 900 wells were destroyed and set in fire, about 150 in the northern oil fields and 350 in the southern fields (see photos). According to information obtained from the Kuwait authorities, consumption of burning wells is on the order of 6 millions barrels/day.

II-2 - Air Pollution

These fires are at the origin of massive emissions of smokes which darken the sky to the point of creating a black "night" even in the middle of the day. The population is thus facing very spectacular and therefore badly accepted pollution. We have thus sought to quantific this pollution in order to better inform the authorities and the public on the basis of objective scientific data.

PART 3

III - ORGANIZATION OF THE STUDY

III-1 - Principle of organization of the measurement campaigns

Considering the practical problems encountered in the field, that is:

- permanent lack of electrical power necessitating the use of a portable generator limited by a range of about 18 hours.

- security of equipment and personnel during night time operations,
- It was not possible to use the laboratory van over long periods without survey. Consequently, two types of measurement campaigns were initiated:
- 1°) Diurnal (daytime) campaigns, either in town or near the oil fields (in the "plumes" of the fires). These campaigns could only be carried out over a limited time which varied, according to the site, from 3 to 8 hours;
 - 2°) Nocturnal (nighttime) campaigns organized according to security conditions:
- a) in closed and guarded Kuwaiti EPC buildings,, during the night of 27-28 mars 1991,

b) on the French military "parking lot" of the New English School (SURRA quarter in the southeast of Kuwait City); former school building occupied by detachment of the Daguet division. On this parking lot, the laboratory van and its portable generator were able to be permanent guarded by the french military from the detachment. On this site, campaigns were conducted every night from the evening of 28 march to the morning of 5 april with the exception of the night of 29-30 march.

III-2 - Measuring stations chosen:

As a function of the problems of installation and security elabored above, 14 campaigns varying in length from 3 to 16 hours were conducted.

During these campaigns, 8 measuring sites were studied:

- station 1 : EOC headquarters, western quarter of Kuwait City in the industrial zone, near the "fourth ring" (4th "ring road");
- station 2: New English School, "camp of the Daguet detachment", SURRA quarter, southeast of Kuwait City, near the "fifth ring";
- station 3: Mansouriya hospital, downtown Kuwait City, near the "second ring";
- station 4: oil fields, north of Al Rawdatayn, about 150 km north of Kuwait City, near the Iraqi border;
- station 5: in the village of Al Ahmadi, about 30 km south of Kuwait City near the Al Burgaam, Al Ahmadi and Al Magwa oil fields;
- station 6: in the Al Ahmadi hospital a few hundred meters south of the Al Ahmadi oil fields;
- station 7: on the "seventh ring", at the "international Airport" interchange, about 2 3 km northeast of the Al Magwa oil fields;
- station 8 : on the "Al Maqwa Road", within the oil fields, crossing the Al Magwa fields (to the west) and the Al Ahmadi fields (to the east).

All of these measuring stations (with the exception of station 4, located outside the map), are listed on the maps. Stations 4 is shown on the overall map of Kuwait.

III-3 - Classification of the Measuring Stations

In view of the definitions of the measuring sites described above, it clearly appears that, throughout the 10 full days of study, two classes of measuring stations could be defined.

- * <u>Class A</u>: measuring stations for "background pollution located int the city or suburbs, near habitations but far from the direct impact of the plumes emitted by burning wells. These stations are characterised, presumably by levels which are lower but to which the kuwaiti population is directly exposed over long periods of time. These stations are therefore of interest to overall health, according to the same classification defined above stations 1, 2, 3, 5 and 6 will be considered class A (background pollution). Unusual meteorological conditions may, however, cause these sites to be exposed to a high level of pollution.
- * <u>Class B</u>: measuring stations for "proximity pollution" located in the middle of the oil fields in the immediate vincinity of the plumes, in the desert far from any habitations. The levels measured at these stations, presumably the highest, represent the "maximum risk" but to which only a small sample of the population is exposed (for example the personnel of the oil companies working in the fields or participating in the fire fighting operations).

Stations numbered 4, 7 et 8, according to the above numeration, will be considered characteristic of class B (proximity pollution).

PART FOUR

IV - "BACKGROUND POLLUTION" IN KUWAIT: RESULTS

This section will show results obtained from the measuring stations for background pollution (Class A: defined above). The measuring results graphs of hourly evolution, maps and bar graphs of frequencies us concentrations are available in the six annexes found at the end of this report.

IV-1 - Measuring station n° 1 (E.P.C.) : Campaign n° 1

The study was conducted from 27 march 1991 at 5:00 p.m. (local time (1)) to 28march 1991 at 9:15 a.m., that is over a period of 16 hours 15 minutes. Computer integration of the gas pollutant levels was carried out every quarter hour.

In the course of this study, an analyzer and transducer breakdown prevented obtaining of reliable results with regard to SO2 "black smoke" and meteorological parameters.

During this first campaign, we haven't made any sampling of PAH and VOC.

With regard to the pollutants measured, the atmospheric pollution seemed very low:

carbon monoxide (CO)

general average (over 16 h 15 mn) : 1587 μ g/m-3 ; maximum over 15 mn : 4234 μ g/m-3

ozone (03)

general average : 23 μ g/m-3 ; maximum over 15 mn : 79 μ g/m-3

nitrogen oxide (NO)

general average : 77 μ g/m-3 ; maximum over 15 mn : 227 μ g/m-3

nitrogen dioxide (NO2)

general average: $54 \mu g/m-3$; maximum over 15 mn: $94 \mu g/m-3$

All of the levels measured over 15 minutes are represented on the graphs marked 27/3/91 in the annex.

IV-2 - Measuring station n° 2 : "New English School" (Daguet Detachment) : campaigns n° 2, 5, 7, 9, 10, 12 et 14

The measurements taken at this station are all nocturnal: 7 nights were thus studied (campaign 2, 5, 7, 9, 10, 12 and 14). These 7 campaigns, of a total duration of about 86 hours yielded the results summarised in the synthetic table of results in the annex 5; it gives the average concentrations observed over the duration of each campaign and the maximal concentrations of gas pollutants over 15 minutes for campaign n° 2 and over 5 minutes fo the other campaigns, and the maximal hourly levels of black smokes.

The graphs of pollutants and meteorological parameters, in annexes 1 and 2, which correspond to the English School measuring site, show the results obtained in the course of the 7 campaigns conducted at measuring station n°2 (New English School).

In general, relatively low concentrations of the pollutants 03, CO, NO and N02 were observed.

Rather low concentrations (30-100 m-3) of SO2 were measured in 6 out of 7 campaigns.

During the night of 3-4 April (campaign n° 12), an average concentration of SO2 of $\underline{472}$ $\underline{\mu g/m3}$ was observed over a period of more than 12 hours, with a peak lasting 5 minutes of over $\underline{2900}$ $\underline{\mu g/m3}$. This same night, an average concentration of black smokes of 231 $\underline{\mu g/m3}$ was observed, with an hourly maximum of 792 $\underline{\mu g/m3}$. This pollution peak appears at 1 h 40 with a strongth of wind speed and a growth of the temperature (+ 4° C) for a short time (25 minutes). This seems to indicate that the plume from the south oil field was falling down to the ground for a few minutes.

(1) local time = French standard time + 2 hours
 = French deylight seving time + 1 hour

Throughout this report the times given are in local time.

It must be underlined that this night was marked by rather high winds (3,4 m/s on average; with peaks at 12.4 m/s over 5 minutes) from the south south east sector oriented at 194° on the average; this blowing the plume from the Al Maqwa and Al Ahmadi oil fields, closest to Kuwait City, across the city. During the other campaigns, the winds observed were in the majority from the north and northwest sectors, thus coming from the Gulf (see corresponding graphs in annex 11) showing the meteorological particularities of the night of 2-4 April 1991 - campaign n° 12 English School.

For the hydrocarbons (VOC), it is the campaign number 9 which shows the highest levels for all these parameters in the english school (night from 1 to 2 April 1991).

These levels are lower than in Paris for the light hydrocarbons and almost two times for the heavy ones and the aromatics. Strong enought levels were also measured during the 31/3 to 1/4 but only for paraffinics.

With regards to PAH, exept during the night from 3 to 4 of April where the levels are hight, the highest levels were registred in English School during the night from 28 to 29 March 1991 (campaign n° 2): Fluoranthene (24 ng/m3) Benzo (ghi) perylene, indeno pyrene.

These levels are similars or are lowers that the parisian ones.

The HPLC analyses made by IFP of the black smokes sampled from 1 to 2 o'clock. The 4th of April are the highest mesured by this laboratory on Kuwait results for all the PAH exept Benzo (a) pyrene. This is surprising because this sampling is not the worst for the black smokes results. At the contrary the VOC levels measured this night are relatively low (campaign n° 10). No measurement of metals was made in English School.

IV-3 - Measuring Station n° 3 : Mansouriya downtown Kuwait City : campaign n° 3

The study at this sitting was conducted 29 March 1991 from 11:35 am to 5:05 pm, that is, for a period of 5 hours 30 minutes.

This study was conducted with the goal of aiding the E.P.C. in restarting the fixed measuring station for atmospheric pollution of the Kuwait City network, shut down for 7 months. The measurements taken served as a reference and thus helped to calibrate the analysers in this station.

The results obtained with regard to gas pollutants are summarized in the graphs of day 29/3 (annex).

The levels measured were low.

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Note, however, the high levels of O3 : 81 μ g/m3 over 5 h 30 min ; with a maximum over 5 minutes of 100 μ g/m3.

Levels of CO were extremely low, less 700 $\mu g/m3$ in peaks over 5 minutes.

The results from the mobile laboratory correlated well with those from the fixed station in Mansouriya.

Levels of black smokes were an average of 99 μ g/m3 over 5 hours for a maximal hourly value of 144 μ g/m3. Due to theses low levels we did'nt made any measurement of PAH.

The VOC levels are the lowest for all the campaigns. They are largely lower that the Paris levels.

The nickel and vanadium concentration are also very low.

The meteorological conditions were marked with low speed winds average less than 2m/s from the northern sector (from the Gulf); high temperatures reaching 30° C around 2:00 pm, related to strong sunlight, which explains the high ozone levels (weather conditions on graph for 29/3 in annexe II).

IV-4 - Measuring station n° 5 - Al Ahmadi village : campaign n° 6

The study was conducted on 31/3/91 from 11:00 am to 5:05 pm, that is, for a period of 6 h 5 min.

In spite of the relative proximity of the burning wells (about 1.5-2 km), average levels, over 6 hours were low; 23 μ g/m3 for ozone and 330 μ g/m3 for CO (graph in annex). High average levels (over 6 hours) of SO2 and black smokes were recorded: 252 μ g/m3 of SO2 and 159 μ g/m3 of black smokes. Very high maximum levels of these two pollutants were recorded: 687 μ g/m3 of SO2 over 5 minutes, 745 μ g/m3 of black smoke as an hourly maximum.

The VOC levels measured are the highest for the campaigns made outside the oil fields. They are double compared with the parisians levels for the paraffinics hydrocarbons and are equal to these levels for the aromatics. But a strong value of ortho xylene (35 μ g/m3) is shown.

These results show the action of the burning fields on the village.

Two analyses of PAH were made, one by LHVP on the 11 to 13 o'clock sampling, when the van was under the plume, the other by IFP on the 14 to 15 sampling, when the pollution was coming back to the field because of in draft.

The first sampling shows levels double more then the second for all PAH exepted indeno pyrene. The only value for indeno pyrene (40 ng/m3) is largely highest than the Paris levels.

No measurement of metals was made on this sampling site.

From the meteorological standpoint, very low winds were observed (0,6 m/s on average).

The direction of these winds, in great majority form the south to southwest sector, that is, in the direction of the wells, showed the importance of the in-drafs toward the wells created by the fires. From this standpoint, during this campaign a black plume was noticed passing at a high altitude in a north to south direction as well as winds in the opposite direction, that is, south to north, at ground level (see graphs of weather conditions on 31/3/91).

IV-5 - Measuring station n° 6 - Al Ahmadi Hospital : campaign n° 8

The hospital, located northwest of the village, is very close to the wells (about 500 m to the south).

Note the significance of this site from the health standpoint, considering the type of population exposed (the sick especially lung patients).

This campaign was conducted on 1/4/91 from 12:25 pm to 5:40 pm, that is, over a period of 5 h 15 minutes.

The levels measured were relatively low for 03 and NO2, and very low for CO and NO. Rather high levels of SO2 and black smoke were observed principally at the beginning of the campaign (until about 4:30 pm) (see graphs for 01/04 in annex).

This sampling site was rarely under the plume of the oil fields, so the VOC and PAH levels are low.

Three measurements of nickel and vanadium were made between 15 and 18 o'clock. The concentration in vanadium are about 70 ng/m3 and so, low. The nickel, levels are anormaly high for one of the sampling. Maybe a problem of metrology because the sampled quantities are small for the measured concentrations.

From the meteorological standpoint, high winds (2,4 m/s on average) from the south and southwest sectors, thus toward the wells, were observed principally at the end of the campaign (graph for 01/04/91 in annex II).

IV-6 - Conclusions Concerning Measurements of Background Pollution

The study carried out at the background pollution sites most often showed low or extremely low levels of CO and NO.

Under unfavorable meteorological conditions, with the plume emanating from the wells touching the ground, very high levels of the pollutants SO2 and black smokes were observed. These conditions occurred rarely: only on the night of 3-4 April. The meteorological results permitted, to show the complexity of the movements of air masses; it was thus shown that at ground level the indraft created by the combustion at the wells could be considerable in the direction "town-wells". It is in all likelihood this phenomenon that is the main parameter explaining the low levels most often observed.

High levels of PAH and VOC appears during the night from 3 to 4 of April 1991 in English School. A peak only limited to paraffinics hydrocarbons is also shown during the 31/3 to 1/4 night in the same site.

The campaign in Ahmadi village, where the sampling site was under the south oil fields plumes shows also high levels for the paraffinics hydrocarbons.

PART FIVE

V - "PROXIMITY POLLUTION" IN KUWAIT: RESULTS

V-1 - Principle of the Campaign

Considering the results of background pollution observed (see part IV), it seemed of major importance to look for measuring sites in close proximity to the burning wells, directly in the plume emitted by the fires.

The mobility of the equiment and electrical autonomy (tractor-drawn electrical generator) out allowed for 3 campaigns responding to this desire to look for the maximum risk to be carried out.

V-2 - Measuring Station n° 4 - Al Rawdatayn northen oil fields (near the Iraqi border) : campaign n° 4

The laboratory van was set up in the middle of the northern oil fields some 200 meters from the nearest burning wells at a location where, quite obviousy, the impact of the surrounding plumes was maximal. The campaign was conducted on 30/3/91 from 2:05 pm to 5:15 pm, that is, over a period of 3 h 10 min.

Very low or practically nonexistent levels of CO, NO and NO2 were observed.

High levels were observed of ozone (about 100 μ g/m3 on average over 3 hours), SO2 (270 μ g/m3 on average) and black smoke (265 μ g/m3 on average). Manual detection evaluated CO2 levels at 600 ppm.

The small length of this campaign didn't allowed measurement of VOC and metals. The HAP measured by IFP are low.

From the meteorological standpoint, extremely violent winds were measured (8.4 m/s on average) with gusts of up to over 15 m/s or nearly 55 km/h), a phenomenon which confirms the important role of in-drafts at ground level created by the fires) (see graphs for 30/3/91 in annexe I)...

V-3 - Measuring Station n° 7 - "Seventh Ring" : campaign n° 11

On the "Seven Ring" highway about 30 km south of downtown Kuwait City, at the level of the International Airport Interchange, this measuring station is located halfway between the Al Maqwa fields (to the west) and the Al Ahmadi fields (to the east) and is subjected to maximal fallout from the various plumes.

This campaign was conducted on 3/4/91 from 10:15 am to 6:05 pm, that is, for a period of 7 h 50 min.

Very low or practically nonexistent levels of CO, NO and NO2 were observed.

High levels of ozone (86 μ g/m3 on average) and very significant levels of SO2 (495 μ g/m3 on average with a maximum of 1223 over 5 minutes) and black smoke (595 μ g/m3 on average over 7 hours with an hourly maximum of 1365) were recorded (see graphs for 3/4/91 in annex I).

Manual detection estimated the level of CO2 at 500-600 ppm.

VOC measured during the 11th campaign shows globaly the highest levels measured. Theses levels are particularely high for heavy paraffinics hydrocarbons (10 times the Paris levels). They are low for the aromatics.

PAH analyses made by IFP on the 17 to 18 h sampling show very low levels this the level of black smokes is very high.

PAH analyses made by LHVP on the 10 to 12 h samplings shows high levels for fluoranthene (37 ng/m3) and indeno pyrene (17 ng/m3) but other PAH have low levels.

On this site a sampling of 7 hours using a cardridge (tenax and glass fiber filter) was made to measure PAH in both gaseous and particulate phase. Analyses of these sampling showed quiet no PAH in gaseous phase exepted fluoranthene (17 ng/m3). Levels detected as the particulate phase were low for all PAH.

Measurement of metals on 11 h to 12 h and 17 h to 18 h show 200 ng/m3 of vanadium.

From the meteorological standpoint, extremely high winds from the eastern sector (toward the Al Ahmadi fields) were recorded (11 m/s on average with peaks over 5 minutes of about 20 m/s or about 75 km/h) (see graphs for 3/4/91 on annexe II).

V-4 - Measuring Station n° 8 - Al Maqwa southern oil fields : campaign n° 13

This site was chosen in the middle of the oil fields some 250 meters from the nearest well.

The campaign was conducted on 4/4/91 from 11:05 am to 5:00 pm, that is, over a period of about 6 hours.

Very low levels of CO and NO rather low levels of NO2; rather high levels of ozon (71 μ g/m3 on average over 6 hours) and very high levels of SO2 (215 μ g/m3 on average, with a maximum over 5 minutes of 1833 μ g/m3) were recorded.

Exceptionally high levels of black smoke were noted (818 μ g/m3 on average with an hourly maximum of 2030) (see graphs for 4/4/91 in annex I).

Levels for VOC measured during this campaign are low exepted for heavy paraffinic hydrocarbons (decane, undecane, tridecane).

PAH analyses on 11 to 14 h sampling which is the worst sampling for back smokes give the highest levels for fluroanthene (110 ng/m3), Benzo (c) Pyrène (26 ng/m3), Benzo (a) Pyrène (30 ng/m3), Benzo (ghi) Perylène (26 ng/m3), Indeno Pyrène (41 mg/m3)). These levels, in average, are double from the parisian ones.

The metals concentrations (nickel and vanadium) are low.

High winds in the direction of the wells were recorded (5.8 m/s on average).

V-5 - Conclusion Concerning Measurements of Proximity Pollution

The measurements of proximity pollution allowed the following conclusions to be drawn:

- absence of CO and NO pollutants;
- very low levels of NO2;

. . .

- rather high levels of ozone;
- very high levels of SO2 and black smoke.

With regard to VOC relatively high levels of heavy paraffinics hydrocarbons were shown. Levels of light hydrocarbons and aromatics are low exepted orthoxylene. The light hydrocarbons seems to be destroyed by combustion. The only heavy product are staying in the air.

The contamination of particules by PAH seams to be relatively low. It is largely changing for the differents sites and for the differents PAH. The gaseous phase didn't contain theses pollutant exepted fluoranthene.

The borne concentration of metals is also low.

At the proximity sites studied, very high winds were always found, confirming the in-draft near the wells.

PART SIX

VI - ASSESSMENT AND CONCLUSIONS

In conclusion, the study conducted from 24 March to 5 April 1991 in Kuwait showed that the atmospheric pollution was most often low at ground level at sites where the population is exposed. High levels were recorded at the sites in the vicinity of the wells or whenever their emissions influenced distant sites, but only relative to the pollutants ozone (occasionally, but may be of advective origin), SO2 and black smoke.

However the meteorological conditions, often very unstable and favorable to dispersion, which prevailed during the ten days of campaigns, must be underlined.

A meteorological situation with stable air masses and low wind speeds placing Kuwait City down wind of an oil field would certainly lead to higher levels.

Among the most striking conclusions, the following should be underlined:

- the near absence of CO;
- the very low levels of NO;
- the high levels of ozone, which may be considered "normal" taking into account the latitude and amount of sunshine which is related, and the high atmospheric instability (advection?);
- the very high levels of SO2 and black smokes, either near the wells or in town with unfavorable weather conditions, this phenomenon rarely appears during the campaign.

Exepted in the 3 to 4 April, night in Kuwait City and in the oil fields, the VOC and PAH levels are lower than in Paris.

The graphs in annex ill summarise these conclusions. These bar graphs of frequency VS concentration, established on the overall 5 minutes data for NO, NO2, CO, 03, SO2 and hourly data for NO, NO2, CO, O3, SO2 and black smokes and for all of the measurement campaigns over 10 days, take into consideration the overall exposure of the mobile laboratory and thus the cumulative exposure of a person following the vehicle during the 10 days of measurement.

The meteorological conditions proved to be very complex and marked by significant indrafts in the direction of the fires, a phenomenon rather favorable to the dispersion of atmospheric pollution at ground level. The table in annex 5 gives a synoptic summary of all of the measurements taken and of the results obtained throughout the 14 campaigns.

Finally, in annex V, for purposes of comparison, can be found the standards of air quality defined this the EEC directives as well as the average annual levels of SO2, black smoke and NOx (NO + NO2) in Paris, as well as the overall results of the various measurement campaigns, and maps of the region.

Doctors MASSE and LAFUMA from French Atomic Energy Commissariat accepted to comment the possible health consequancies of these pollutions levels.

Here is their opinion:

Airborne toxicants in Kuwait atmosphere have been measured repetedly between Marc 27 and April 4. Results showed a complicated situation with multiple pollutants involved, among which SO2 and black smokes were the two major constituants. The greatest concern comes from long term exposure to their combined effects on human airways.

On the ground basis of experimental data and epidemiological data, obtained up to now in northern countries from Europe and America, it may be feared that peak values of both pollutants be associated with increased morbidity and mortality due to bronchopulmonary diseases; however, wether these observations apply or not to hot and dry climatic conditions is not known, and it may well be that no effect be observed.

Moreover, most measures made in Kuwait City were very comparable to those observed in Western cities and did not reach limit values set by WHO Guidelines for chronic exposure; unexpectedly vanadium levels, which have been considered as good indices of fuel burning, remained fortunately low, and therefore there is no adverse synergism to predict from potential cytotoxicity on lung macrophages.

Although the risk of specific diseases appears to remain relatively low, it is recommended to survey groups at risk, and notely children and asthmatic patients, owing to the expected long duration of the situation.

As regards other pollutants like ozone, NOx and CO, their levels in Kuwait atmosphere appaeared lower than those observed in western big cities. Their contribution appeared therefore very limited.

Some possible carcinogens, such as polycyclic aromatic hydrocarbons and nickel, were detected at low concentration in black smokes. This drew the attention to the risk of cancer induction. However the levels of these toxicants are also actually lower than those observed in many urban atmospheres. Finally, it turns out that the only constituant which needs further informations is carbon black itself, which makes up the greatest moiety of the airborne particulate material. It is a ill dafined compound, strongly adsorbing putative carcinogens, whose nature may differ in fonction of burning conditions. It is recommended that the material be collected locally and sent to French laboratories for biogical assays, including estimate of carcinogenic potency. Preliminary results could be obtained within a few months.

KUWAIT STUDY

27 march to 4 april 1991

ANNEXE I

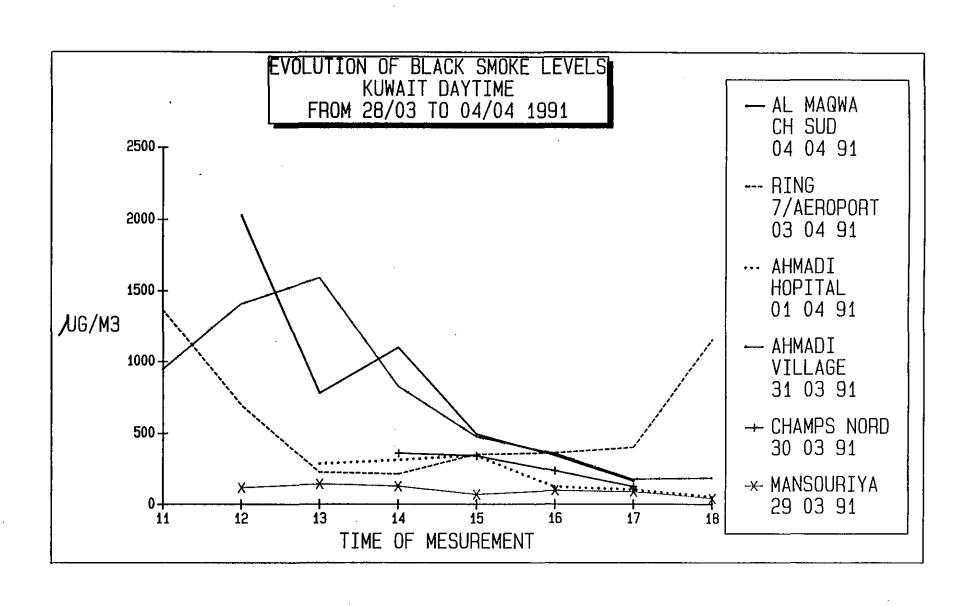
Temporal evolution of measurements of atmospheric pollutants

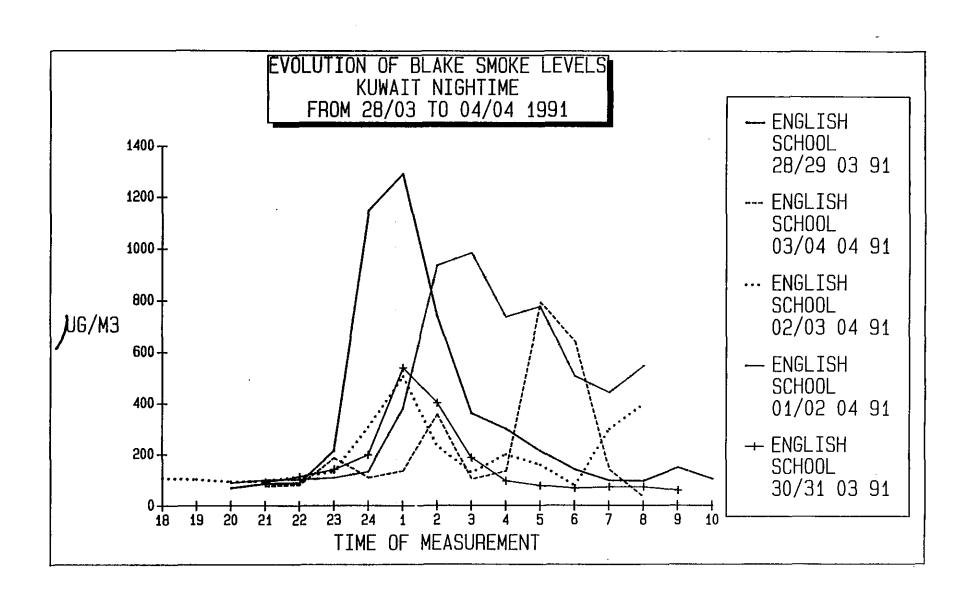
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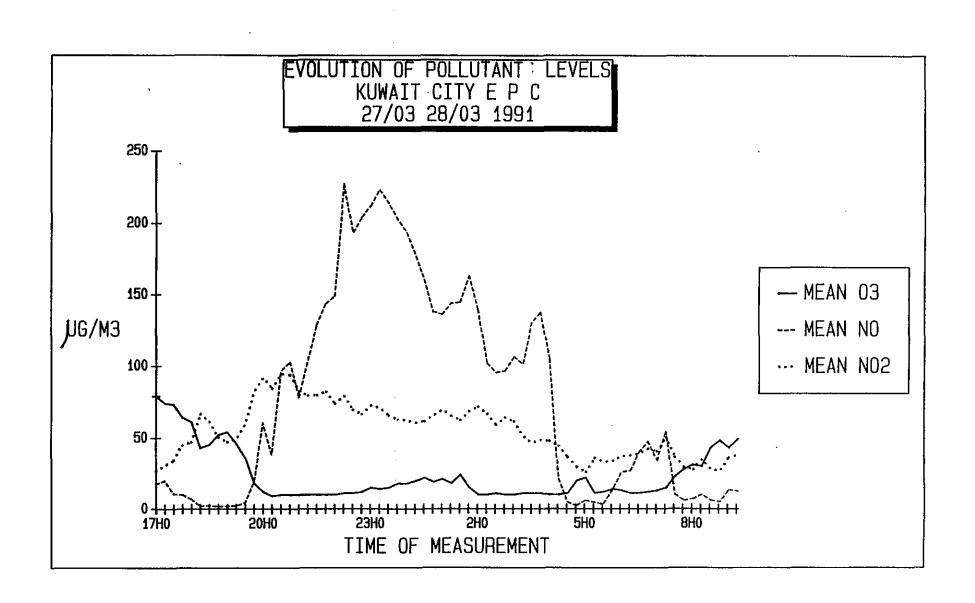
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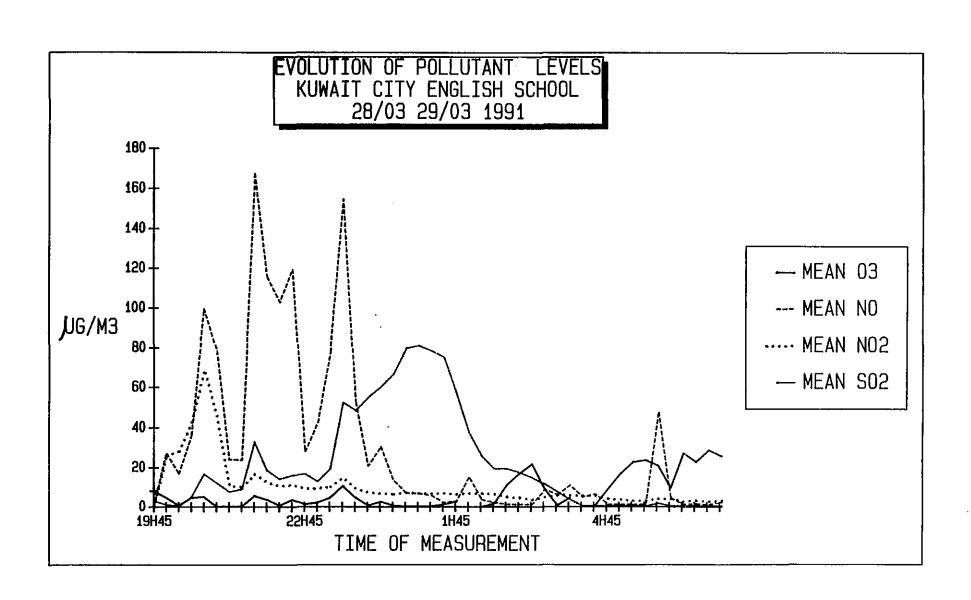
BS "black smoke"

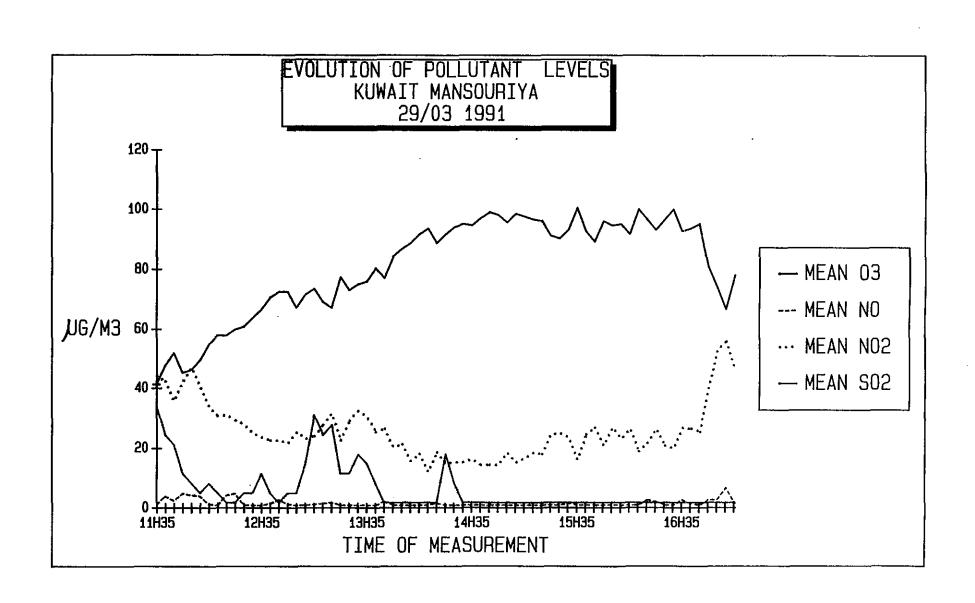
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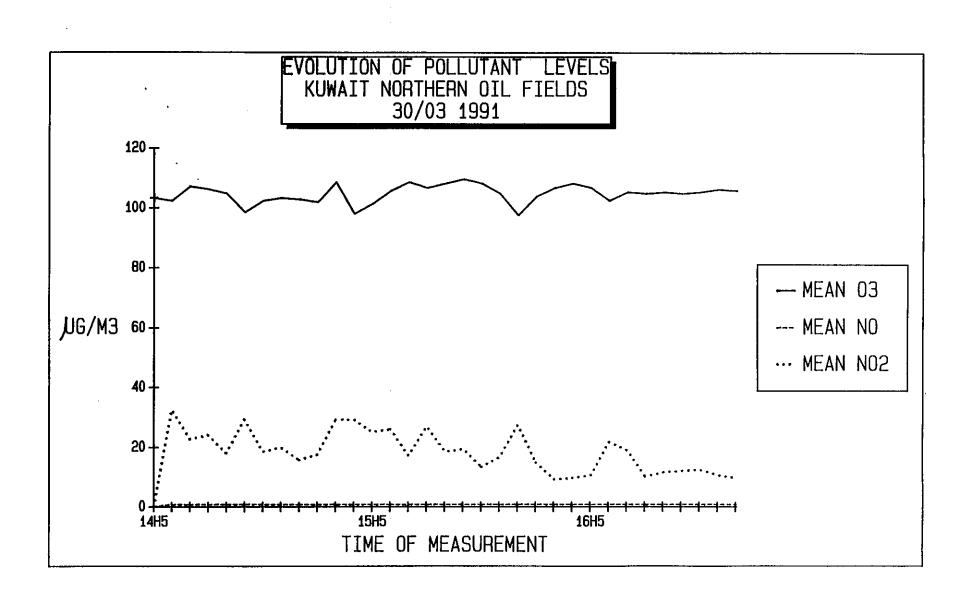


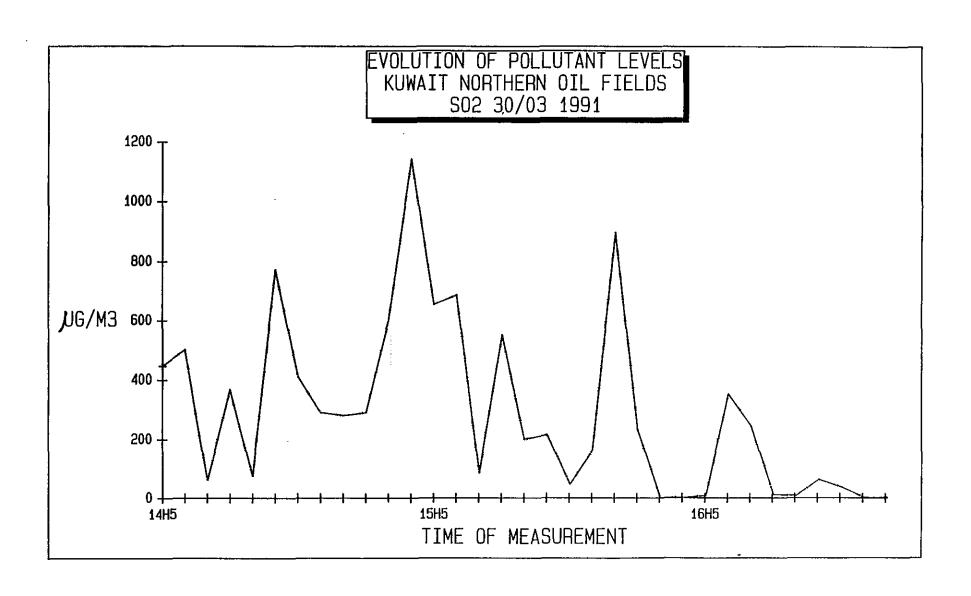


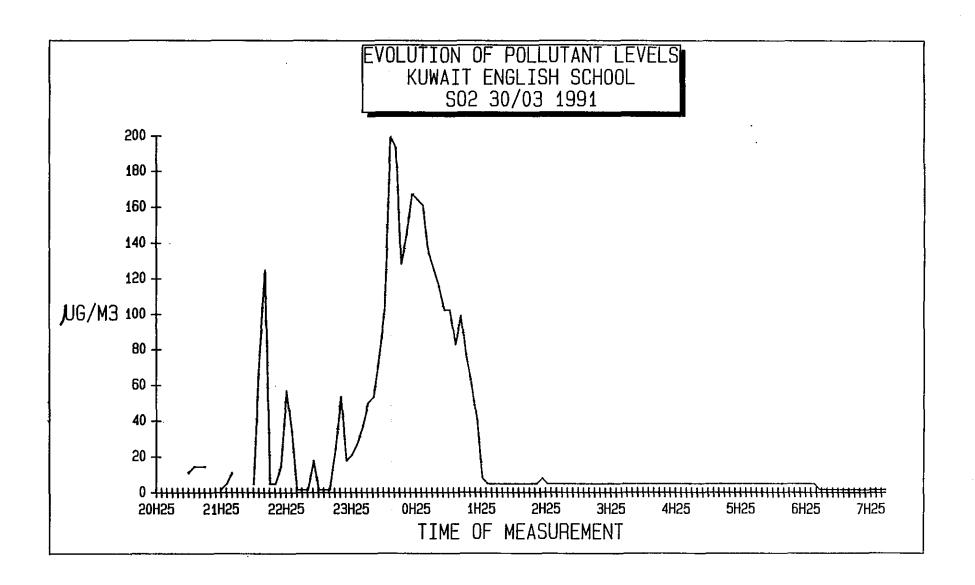


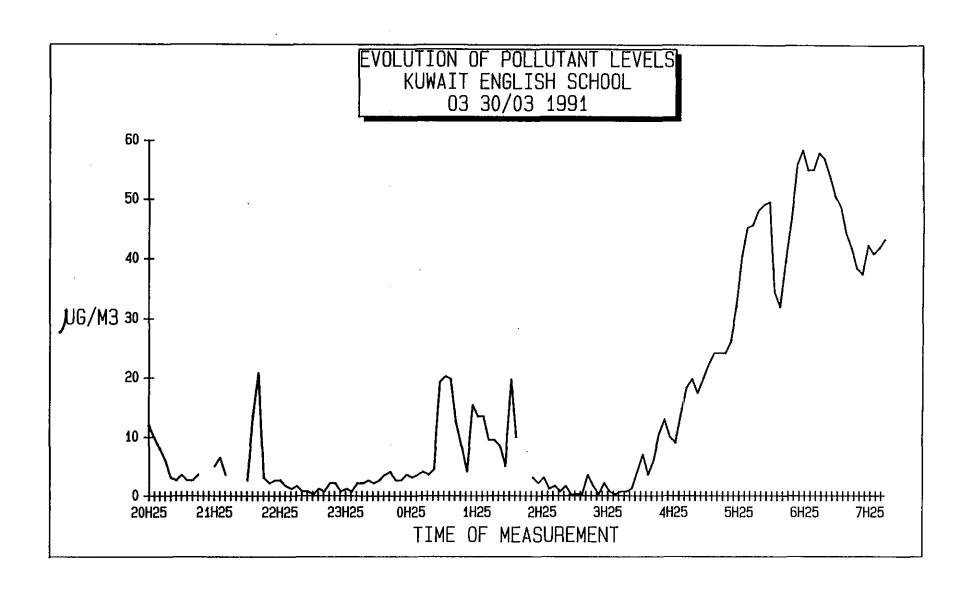


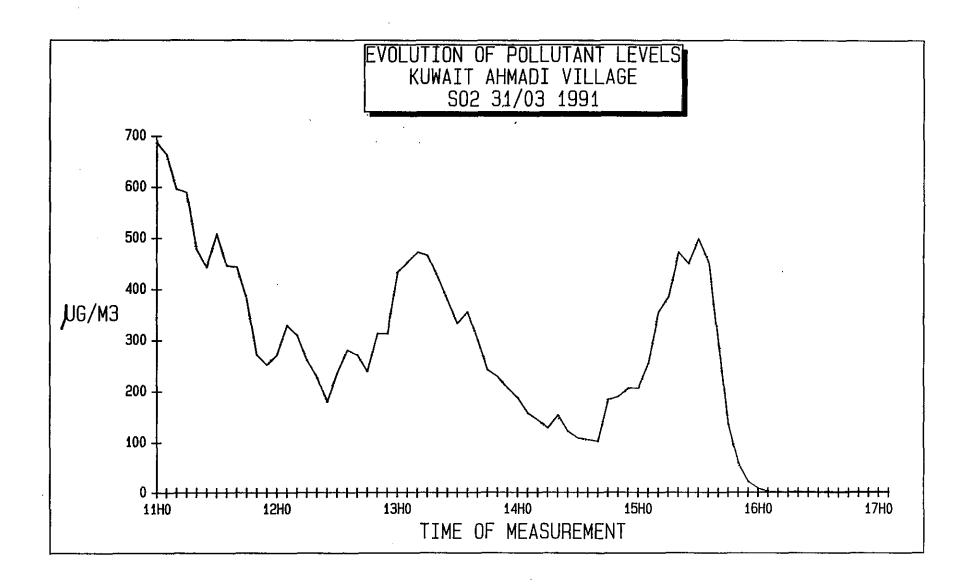


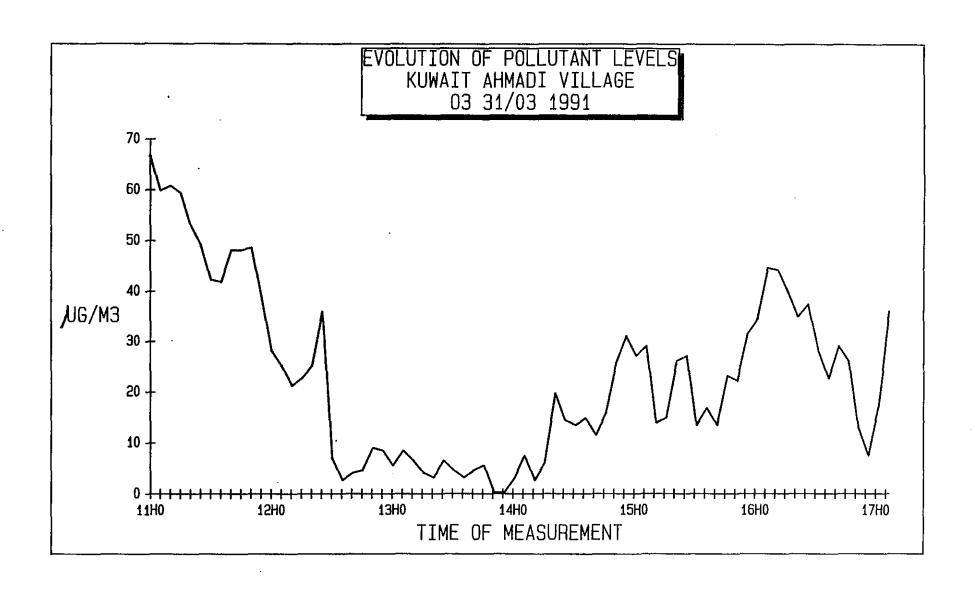










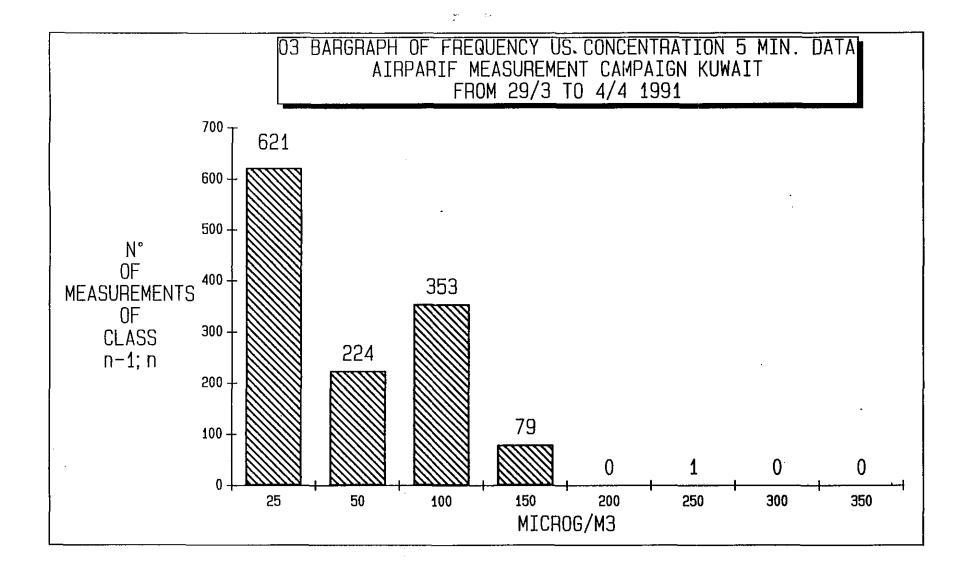


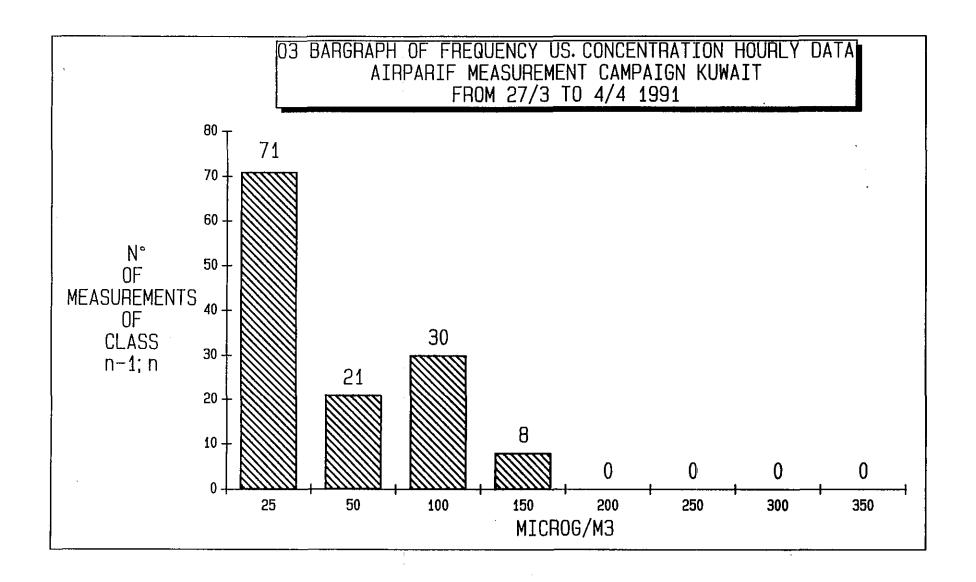
KUWAIT STUDY

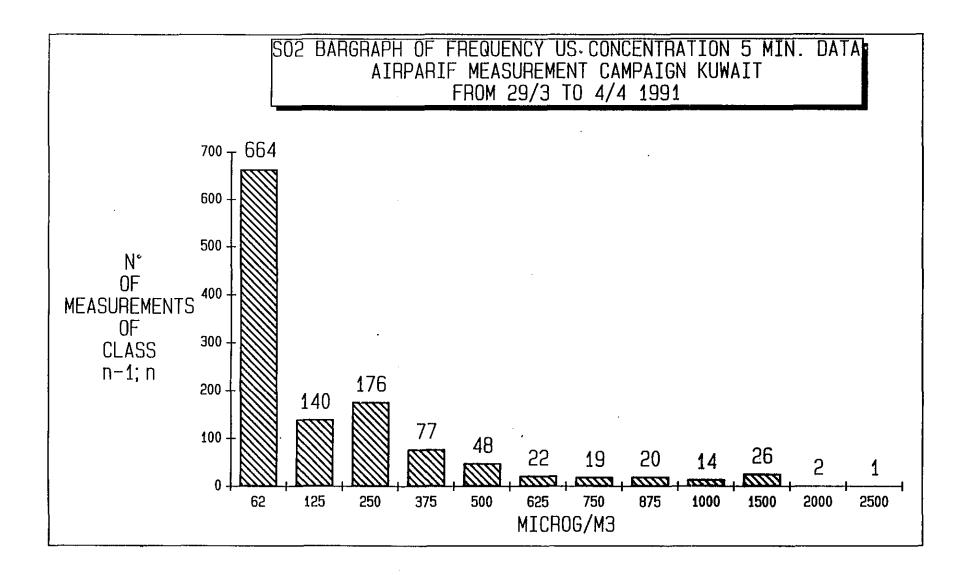
27 march to 4 april 1991

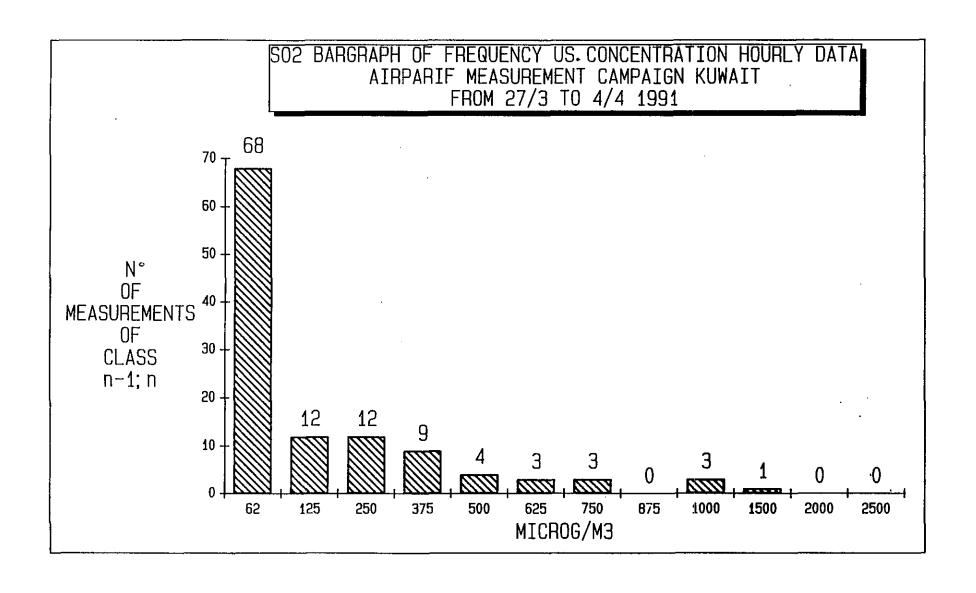
ANNEXE III

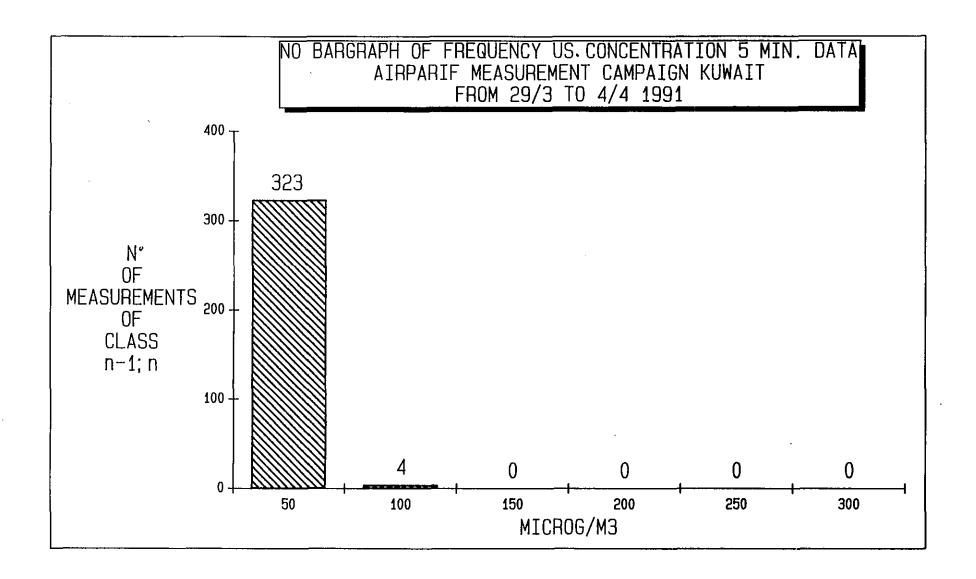
Bar graphs of frequency VS concentration of the various pollutants
established for the totality of the results of the various series of measurements
(5 minutes or 1 hour)



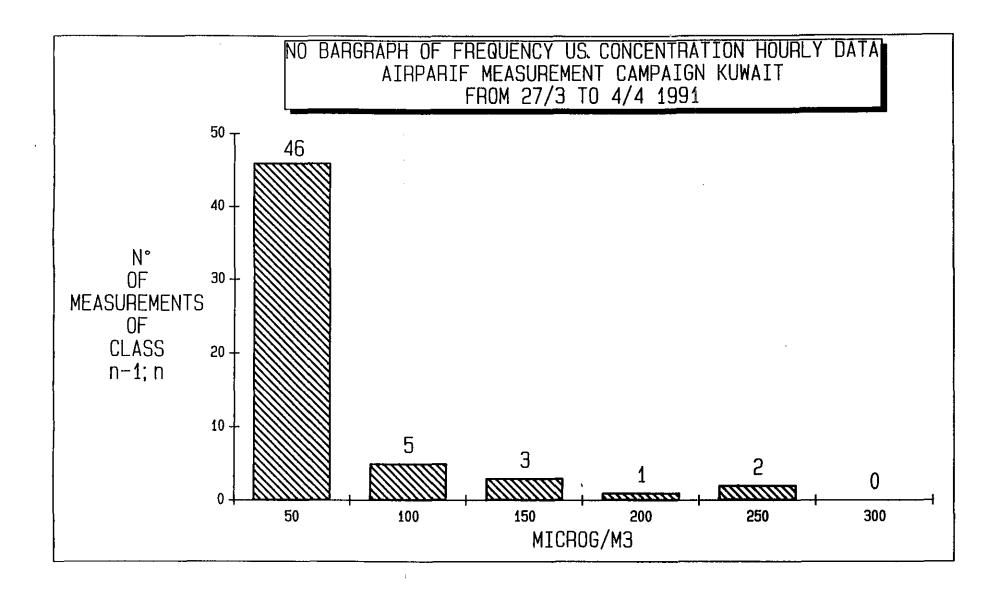


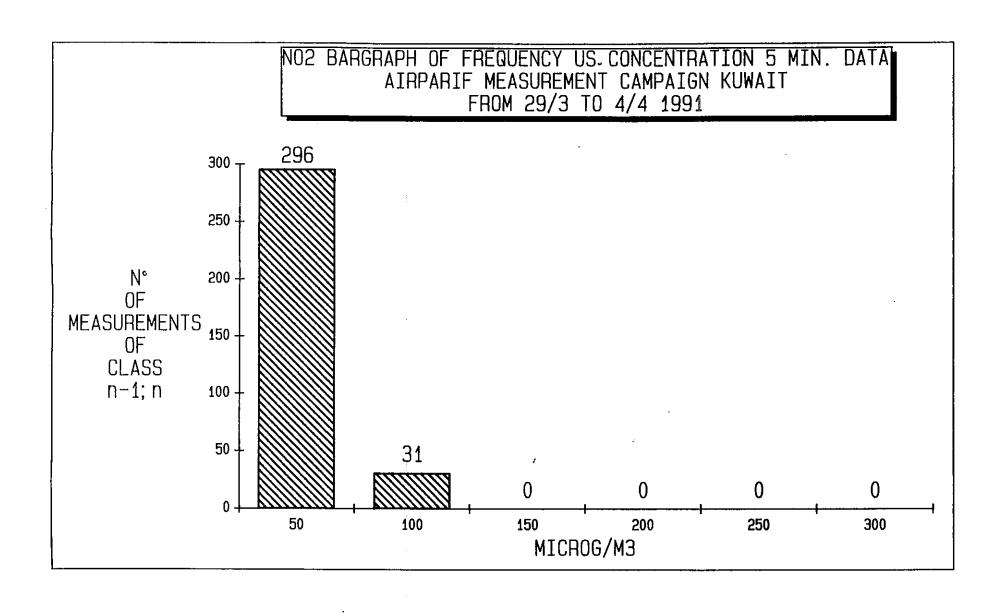


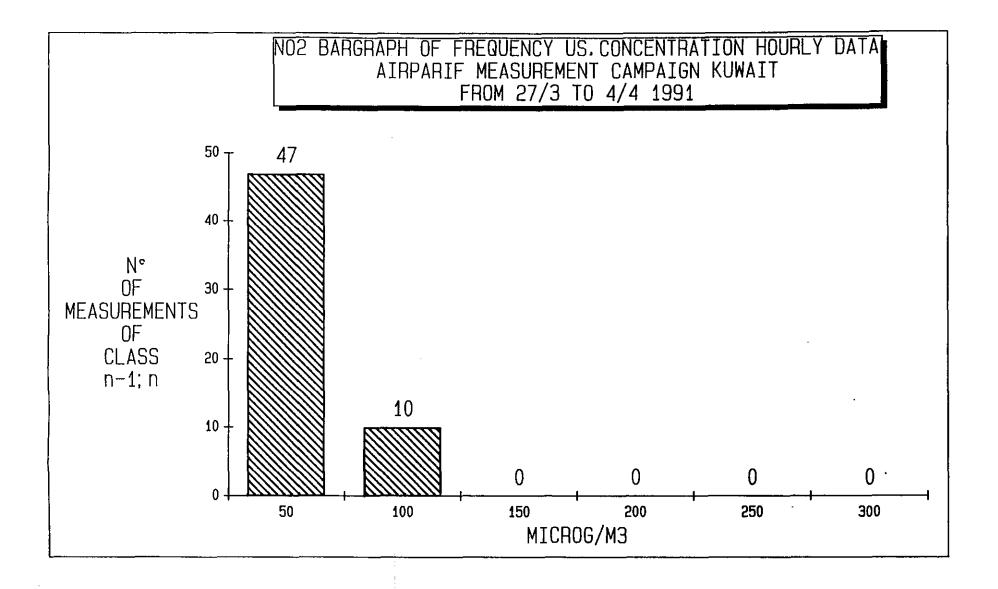


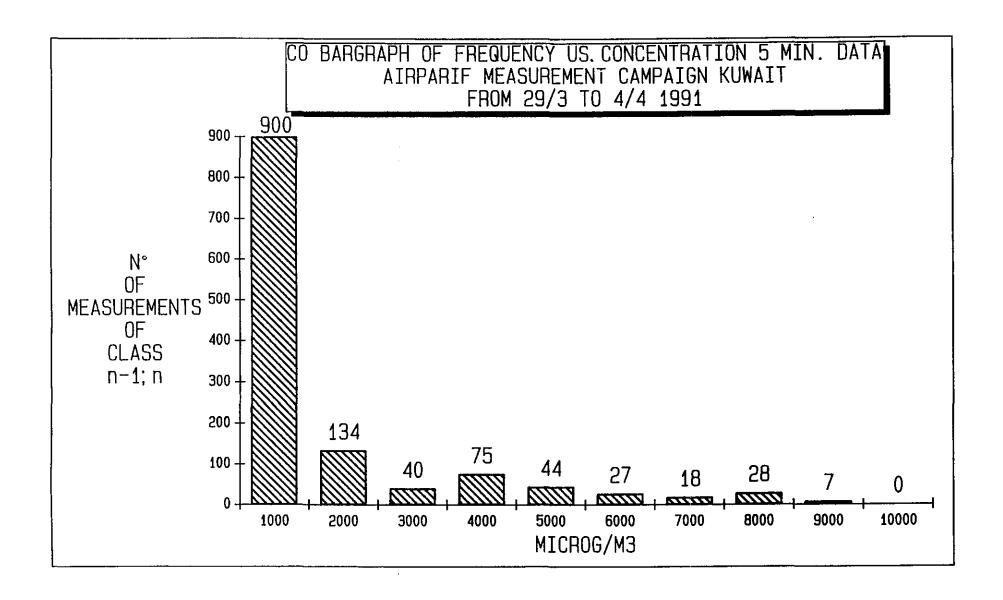


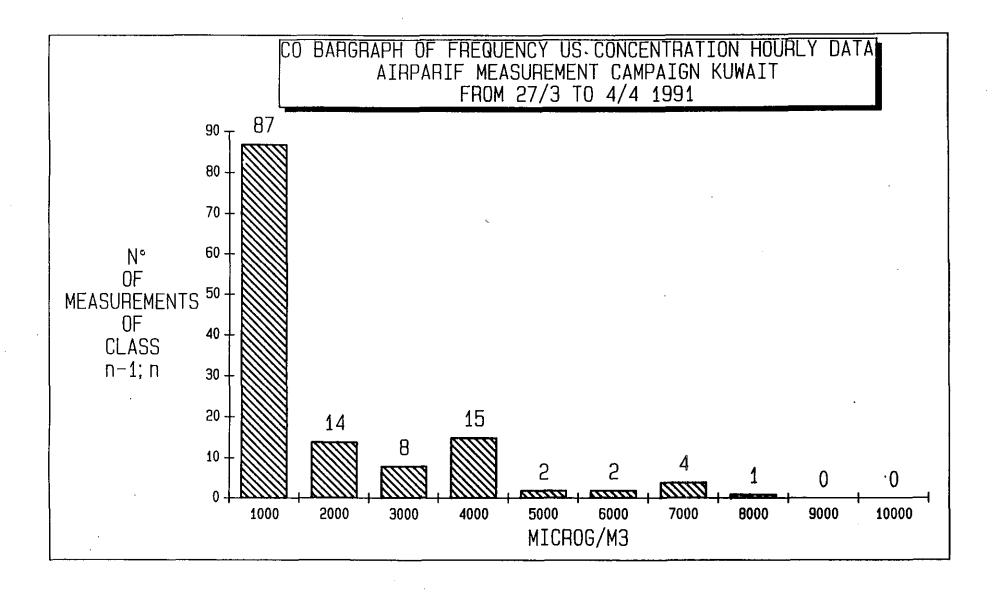
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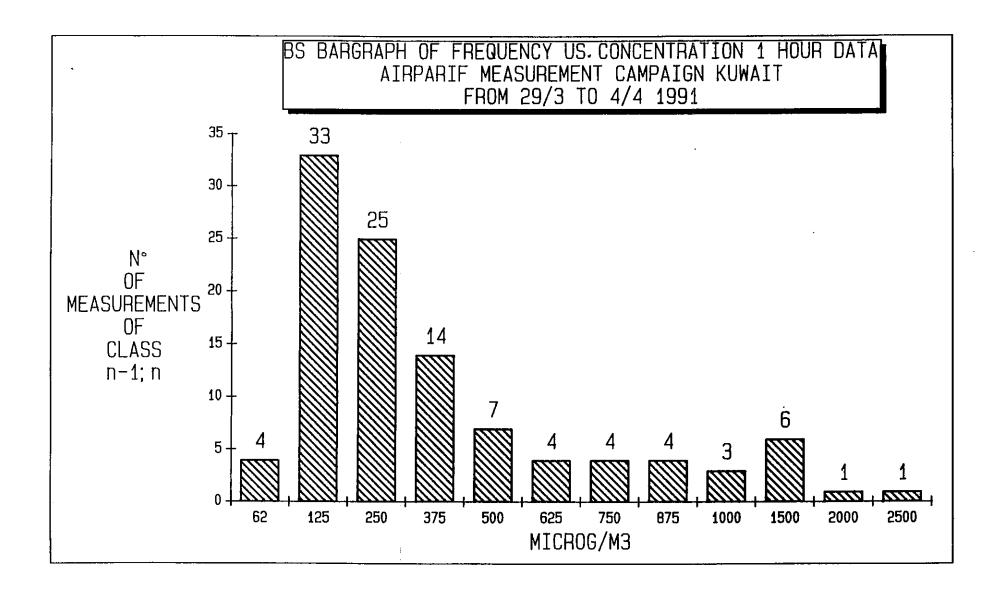












KUWAIT STUDY

27 march to 4 april 1991

ANNEXE IV

Results of measurements of "pollutants and meteorological parameters" of the various measurement campaigns established hourly

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT CITY "ENVIRONNEMENT PROTECTION COUNCIL" 27 MARCH 1991 NIGHT

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	TIME *	ug/m3	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H oC
****** 27/03/91	*********** * 18:00:00	•	*****	******* 1014	****** 12	39	*****	*****	
27/03/91	19:00:00 *	49		836	2	56			
27/03/91	20:00:00 *	28		765	22	71			
27/03/91	21:00:00 *	10		1228	79	89			
27/03/91	22:00:00 *	10		2153	131	78			
27/03/91				3185	209	72			
28/03/91	00:00:00	16		4181	208	65			شن
28/03/91	01:00:00 *			3487	153	64			
28/03/91	02:00:00 *	17		3096	148	67			
28/03/91	03:00:00 *	10		1939	100	63			
28/03/91	04:00:00 *	11		2082	118	48			
28/03/91	05:00:00 *	16		552	9	34			
28/03/91	06:00:00 *	13		196	12	35			
28/03/91	07:00:00	12		498	37	40			
28/03/91	08:00:00	24		302	19	36			
28/03/91	09:00:00	41		338	9	31			
28/03/91	10:00:00 *	· · 36		847	45	46			
	*	; ;							
*****	*********** MEAN *	********* 23	******	******** 1571	********* 77	******** 55	******	******	*****
	* * MUMIXAN	68		4181	209	89			

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT CITY ENGLISH SCHOOL 28 MARCH 1991 NIGHT

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE		* 03 H * ug/m3 *	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H oC
*****	******	********** *	*****	******	*****	*****	*****	******	*****
28/03/91		* 3 *	8	2615	58	46	1	185	308
28/03/91	22:00:00	* 2 *	17	2366	82	12	1	216	404
28/03/91	23:00:00	* 2 *	15	3149	73	10	1	240	407
29/03/91	00:00:00	 * 5 *	44	3327	76	10	1	242	404
29/03/91	01:00:00	* 1	72	1655	14	7	1	266	411
29/03/91	02:00:00	* 1	62	1050	6	7	2	270	426
29/03/91	03:00:00	* 7	20	694	2	6	1	243	421
29/03/91	04:00:00	* 9	9	729	7	5	1	172	402
29/03/91	05:00:00	* 7	0	872	3	5	1	175	391
29/03/91	06:00:00	* 19	1	907	14	3	1	173	403
29/03/91	07:00:00	^ * 26	0	890	1	3	1	169	407
29/03/91	08:00:00	* 7	22	1635	30	10	1	212	391
******	****	~ * ******	****				***		
	HEAN	* 7 *	23	1657	31	10	1	214	398
:	MUMIXAM	* 26	72	3327	82	46	2	270	426

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT" KUWAIT CITY "MANSOURIYA" 29 MARCH 1991 DAY POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

'DATE	TIME	* 03 * ug/r		CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	т н * •С *
*******	*****	*****	*****	*****	*****	*****	*****	*****	*****
, [29/03/91 [13:00:00	* * *	55 6	142	2	26	2	184	25
^{'29/03/91}	14:00:00	 *	77 13	237	1	26	2	203	28 *
29/03/91	15:00:00	* (95 4	120	1	15	2	178	29 *
29/03/91	16:00:00	* (94 2	36	1	22	2	205	29 2
29/03/91	17:00:00	* (90 2	77	2	30	2	205	28 2
29/03/91	18:00:00	* {	36 14	279	3	42	2	289	28 3
* ******	*****	* ******	******	*****	****	*****	*****	*****	*****
t t	MEAN	* {	35 7	149	2	27	2	211	28
*	MUNIXAM	* (95 14	279	3	42	2	289	29

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT" KUWAIT NORTHERN OIL FIELDS 30 MARCH 1991 DAY POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE:		* 03 H * ug/m3 *	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H * oC *
30/03/91		* * 103	437	24	1	21	******		* * *
30/03/91	16:00:00	* 106 *	311	83	1	19			*
:30/03/91 :	17:00:00	* 105 *	81	210	1	13			* *
********* -	*****	*****	******	******	******	*****	*******	*****	******
		* * 105 *	276	106	1	18			* *
t r	MUMIXAM	* 106 *	437	210	1	21			*

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT" KUWAIT CITY ENGLISH SCHOOL 30 MARCH 1991 NIGHT POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

******	**************************************	******* * 03 H	******	*****	******	******	*****	******** DV H	******* * H T
DATE	7	* ug/m3	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	degré	T H * oC * *
*******	*******	********** *	*****	******	*****	******	*****	*****	******
30/03/91	22:00:00	11	18	1951			2	182	24 *
30/03/91	23:00:00	3	22	1441			0	259	23 *
31/03/91	00:00:00	2	55	2586			0	133	23 *
31/03/91	(01:00:00	8	135	3766			0	139	22 *
[31/03/91	02:00:00	11	27	4567			0	155	21 *
31/03/91	03:00:00	5	5	3072			0	157	21 *
31/03/91	04:00:00	2	5	1228			1	108	21
31/03/91	05:00:00	`15	5	326			1	184	21 *
31/03/91	06:00:00	* 38	5	184			1	256	21 *
31/03/91	07:00:00	52	3	178			3	205	21 *
:	; ;	• •							*
*****	******	*******	*****	****	*****	*****	*****	*****	****
r	MEAN	* 15 *	28	1930			1	178	22 *
********	MAXIMUM 3	* 52	135	4567	****	*****	3	259	24 *

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT" KUWAIT "AHMADI VILLAGE SOUTH" 31 MARCH 1991 DAY POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	1 2112	* 03 H * ug/m3	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H OC
******	********	********* *	******	*****	*****	******	*****	******	*****
1/03/91	12:00:00	48	445	148			1	255	24
1/03/91	13:00:00	14	283	261			1	181	22
1/03/91	14:00:00	4	337	670			0	132	20
1/03/91	15:00:00	16	151	47			1	23	21
1/03/91	16:00:00	22	282	403			0	17	22
1/03/91	17:00:00	29	2	516			0	36	21
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
	MEAN	* 22 *	250	341			1	107	22
	MAXIMUM :	* 48	445	670			1	255	24

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT CITY ENGLISH SCHOOL 31 MARCH 1991 NIGHT

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	12112	* 03 H * ug/m3 *	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H * oC *
:******		********* *	******	******	*****	******	******	220	*******
31/03/91	23:00:00	* 2 *	7	925			0	330	22 *
01/04/91	00:00:00	* 4 *	19	1207			0	92	23 *
°01/04/91	01:00:00	 * 7	40	3140			0	235	22 *
01/04/91	02:00:00	* 16	349	3457			0	324	22 *
^{'01/04/91}	03:00:00	* 17	256	671			0	341	23 *
°01/04/91	04:00:00	* 9 *	74	807			0	322	21 *
101/04/91	05:00:00	* 15 *	45	353			0	65	21-+
'01/04/91	06:00:00	* 36 *	8	249			1	43	22 *
*01/04/91	07:00:00	* 34 *	24	244			2	211	22 *
*01/04/91	08:00:00	* 26 *	61	397			2	319	22 *
* ******	******	* *******	****	*****	*****	*****	****	*****	* ******
• •	MEAN	* 17 *	88	1145			1	228	22 *
k	MAXIMUM	* 36	349	3457			2	341	23 *

AIRPARIF : ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT "AHMADI HOSPITAL" 01 APRIL 1991 DAY

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	TIME	* * (03 H ug/m3	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H oC
*****	******	***** *	******	*****	******	*****	*****	*****	*****	****
01/04/91	14:00:00	*	25	91	332	7	39	29	103	676
01/04/91	15:00:00	* *	43	124	439	0	27	48	139	783
01/04/91	16:00:00	* *	53	9	581	1	29	60	16	1151
01/04/91	17:00:00	* *	55	2	522	0	30	60	5	1044
01/04/91	18:00:00	* * *	35	2	552	0	45	39	7	
*****	*****	****	*****	****	*****	****	****	******	*****	*****
	MEAN	*	42	46	485	2	34	47	54	914
	MUMIXAM	*	55	124	581	7	45	60	139	1151

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN " KUWAIT "
KUWAIT CITY " ENGLISH SCHOOL " 01 APRIL 1991 NIGHT
POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	TIME	* *	03 H ug/m3	SO2 h ug/m3	CO h ug/m3	NO h ug/m3	NO2 h ug/m3	VV H m/s	DV h d e gré	T h ?
*****	******	***	******	******	*****	*****	*****	******	*****	*******
01/04/91	20:00:00		2	60	984			0	34	21
01/04/91	21:00:00	*	3	81	3351			0	36	21 '
01/04/91	22:00:00	*	3	58	3434			0	271	20 '
01/04/91	23:00:00	*	6	30	3422			0	325	20 3
02/04/91	00:00:00	*	6	24	3891			0	332	20 '
2/04/91	01:00:00	*	4	105	5450			0	339	20 '
2/04/91	02:00:00	*	5	217	6702	•		0	326	19/
2/04/91	03:00:00	*	23	201	7253			0	7	18
2/04/91	04:00:00	*	4	119	6269			0	22	18
2/04/91	05:00:00	*	5	94	6215			0	32	18
2/04/91	06:00:00	*	_ 1	43	6132			0	38	17
02/04/91	07:00:00	*	0	9	4163			0	207	18
*****	****	* ***	*****	*****	*****	****	*****	*****	*****	*****
	MEAN	*	5	87	4772			0	164	19
	MUMIXAM	*	23	217	7253			0	339	21

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT CITY ENGLISH SCHOOL 2 APRIL 1991 NIGHT

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	TIME *	ug mo	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H oC
02/04/91	18:00:00	14	6	53	*****	******	1	327	21
102/04/91	19:00:00	7	5	694			1	323	21
02/04/91	20:00:00 *	1	5	445			1	333	21
02/04/91	21:00:00	1	6	919			0	346	21
02/04/91	22:00:00	2	47	1827			0	96	21
02/04/91	23:00:00	3	61	3090			0	34	19
93/04/91	00:00:00	2	124	2959			0	42	20
03/04/91	01:00:00	1	43	1827			0	274	19
03/04/91	02:00:00	2	5	1245			0	336	18
03/04/91	03:00:00	2	5	362			0	342	19
03/04/91	04:00:00	. 5	. 5	415			0	183	18
03/04/91	05:00:00	17	5	243			1	22	18
03/04/91	06:00:00	3	10	302			1	23	19
03/04/91	07:00:00	4	223	1115			. 1	34	20
103/04/91	08:00:00	20	126	2294			2	130	20
******** *	**************************************	******** * 6	45	1186	*****	*****	******* 1	190	******* 20
*	NUMIXAM	* * 20	223	3090			2	346	21

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT "RING 7 TH /AEROPORT" 03 APRIL 1991 DAY

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	TIME	* 03 H * ug/m3	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H oC
*****	******	*****	******	*****	******	*****	*****	*****	*****
03/04/91	11:00:00	* * 33 *		83	8	52	5	251	23
03/04/91	12:00:00	* 55 *	174	36	16	47	8	108	22
03/04/91	13:00:00	* 89 *	198	0	0	24	10	45	22
3/04/91	14:00:00	* 104 *	534	0	1	28	12	281	22
3/04/91	15:00:00	* 112 *	613	0	0	23	13	287	22
3/04/91	16:00:00	* 123 *	345	0	1	18	13	304	22
3/04/91	17:00:00	* 115 *	948	6	2	27	12	326	22
3/04/91	18:00:00	* 109 * *	945	112	24	45	13	305	23
******	******** MEAN	******** * 93 *	537	30	********* 7	33	********	******** 238	****** 22
	MAXIMUM	* 123	948	112	24	52	13	326	23

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT CITY ENGLISH SCHOOL 3 APRIL 1991 NIGHT

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

****	******	*****	******	*****	*****	*****	*****	*****	*****
DATE	TIME	* 03 H	S02 H	COH	NO H	NO2 H	VV H	DV H	T H *
		* ug/m3 *	ug/m3	ug/m3	ug/m3	ug/m3	m/s	degré	oC *
*****	******	*****	*****	*****	*****	*****	*****	*****	*****
		*							*
03/04/91	21:00:00	* 54 *	244	36			4	49	21 *
03/04/91	22:00:00	* 54	453	36			4	179	21 *
03/04/91	23:00:00	* * 61	895	36			4	255	* 23 *
03/04/32	. 23:00:00	* 01	030	30			4	200	23 *
04/04/91	. 00:00:00	* 59 *	638	36			4	301	24 *
04/04/91	01:00:00	* 66	412	273			4	322	24 *
04/04/91	02:00:00	* * 49	649	427			4	128	* 25 *
04/04/3	. 02:00:00	* 43	049	42/			4	120	2 5 *
04/04/91	03:00:00	* 50 *	5	599			4	175	24 *
04/04/91	04:00:00	* 41	304	474			2	181	24 *
04/04/91	05:00:00	* * 35	1369	652			2	182	23 *
		*	1303	032			~	102	*
04/04/93	06:00:00	* 37 *	524	504			2	251	23 *
04/04/91	07:00:00	* 30	29	433			2	200	23 *
04/04/91	08:00:00	* 24	5	480			2	253	22 *
		*							*
*****	******	*********	*****	*****	*****	*****	*****	*****	******
	MEAN	* 47	461	332			3	206	23 *
	MAXIMUM	* 66	1369	652			4	322	25 *

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT "AL MAQWA ROAD SOUTHERN OIL FIELDS" 04 APRIL 1991 DAY

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

DATE	TIME	*	03 H	S02 H	CO H	NO H	NO2 H	VV H	DV H	ΤH
:		*	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	m/s	degré	oC
		*				-		والمراجعة والمراجعة والمراجعة والمراجعة		
		*		*****	*****	****	********	*******	*****	
04/04/91	12:00:00	*	68	0	95	0	25	9	182	21
		*								
04/04/91	13:00:00	*	64	73	18	0	27	7	239	21
	44.00.00	*			_					
04/04/91	14:00:00	*	61	737	0	1	35	4	133	25
04/04/91	15:00:00	*	86	286	0	8	19	6	207	32
· · · · · · · · · · · · · · · · · · ·		*	-	200	J	J	13	Ū	207	
04/04/91	16:00:00	*	72	185	0	0	25	5	239	32
•		*								
04/04/91	17:00:00	*	73	12	9	9	18	4	289	31
		*								
	****	*								
	MEAN	*	71	716	20	3	25	6	215	27
r	DEAN	*	/1	216	20	3	29	0	213	21
•	MUMIXAM	*	86	737	95	9	35	9	289	32

AIRPARIF: ATMOSPHERIC POLLUTION MEASUREMENT CAMPAIGN "KUWAIT"

KUWAIT CITY ENGLISH SCHOOL 4 APRIL 1991 NIGHT

POLLUTION AND METEOROLOGICAL DATA; HOURLY MEANS

******	*****	***	*****	*****	*****	*****	*****	*****	*****	*****
'DATE	TIME	*	03 H ug/m3	SO2 H ug/m3	CO H ug/m3	NO H ug/m3	NO2 H ug/m3	VV H m/s	DV H degré	T H * oC *
·******	*****	* ***	******	*****	*****	****	*****	*****	*****	*****
r		*								*
['] 04/04/91	21:00:00	*	2	226	2360			0	128	23 *
04/04/91	22:00:00	*	4	223	5860			0	180	23 *
04/04/91	23:00:00	* *	5	114	3048			1	155	23 *
05/04/91	00:00:00	* *	41	13	635			2	178	24 *
105/04/91	01:00:00	*	49	5	409			3	204	24 *
05/04/91	02:00:00	*	63	5	202			3	106	23 *
05/04/91	03:00:00	* *	57	6	237			2	200	23 *
05/04/91	04:00:00	*	62	5	219			1	128	22 *
05/04/91	05:00:00	*	63	5	267			2	152	21 *
105/04/91	06:00:00	*	70	5	166			3	181	22 *
*05/04/91	07:00:00	*	70	.5	202		•	3	196	22 *
*05/04/91	08:00:00	*	68	5	374			4	. 131	22 *
k		*	***	****						*
**************************************	MEAN	****	****** 46	******** 51	1165	********	******	*******	162	23 *
*	MUNIXAM	*	70	226	5860			4	204	24 *

SUSPENDED PARTICULATES (BLACK SMOKE) MEASUREMENT IN KUWAIT FROM 28 03 TO 04 04 1991

AIRPARIF MEASUREMENT CAMPAIGN results in ug/M3

CAM	*	CAM 2	CAM 3	CAM	C.	AM 5	CAM 6	CA	8 M	CAM 9		CAM 10	C.A	AM 11	CAM	12	CAM	13
EU	*ENG	SCHOOL	MANSOURIYA	FIELD NOR	ENG SC	HOOL			HOSPEN	G SCHOOL	ENG	SCHOOL	RING 7	7/AER	ENG SCHO	OL A	L MAQI	ĪΑ
TE		28/29 3	29 3	30 :	•	31 3	31 3	4.4		01/02 04		02/3 04		3 04	03/4			04
*****	****	*****	*****	*****	*****	****	*****	*****	*****	*****	****	*****	*****	*****	*****	****	****	****
URE	*					**												
11	ͺ ★				•		946							1365				
12	*		119				1406							697				030
13	*		144				1591		288					224				778
14	*		129	360)		827		316					212			13	100
15	*		70	340)		475		347					351			- 4	494
16	*		98	23:	5		356		125					361			2	344
17	*		89	124	ŀ		175		106					400			-	165
18	*		42				185		55			109		1151				
19	*											104						
20	*	69								89		95						
21	*	86				92				101		98				75		
22	*	90				114				103		116				81		
23	*	214				142				109		134			1	L85		
24	*	1147				199				133		310			1	.08		
1	*	1291				539				379		507			1	135		
2	*	740				402				936		235			3	356		
	*	361				187				984		130			1	L 02		
4	*	301		•		96				736		202			1	135		
5	*	214				:78				777		161			-	792		
6	*	141				68				506		80			(38		
7	*	98				73				442		301			1	.39		
8	*	96				73				547		401				32		
	*	149				60												
10		104																
*****			*****	*****	*****	****	*****	******	*****	*****	****	*****	*****	****	*****	****	****	***
ENNE	*	340	99	265	;	163	745		206	449		199		595	2	232	8	819
	*						•											
KIMUM	*	1291	144	360	1	539	1591		347	984		507		1365		92	20	030

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KUWAIT STUDY

27 March to 4 April 1991

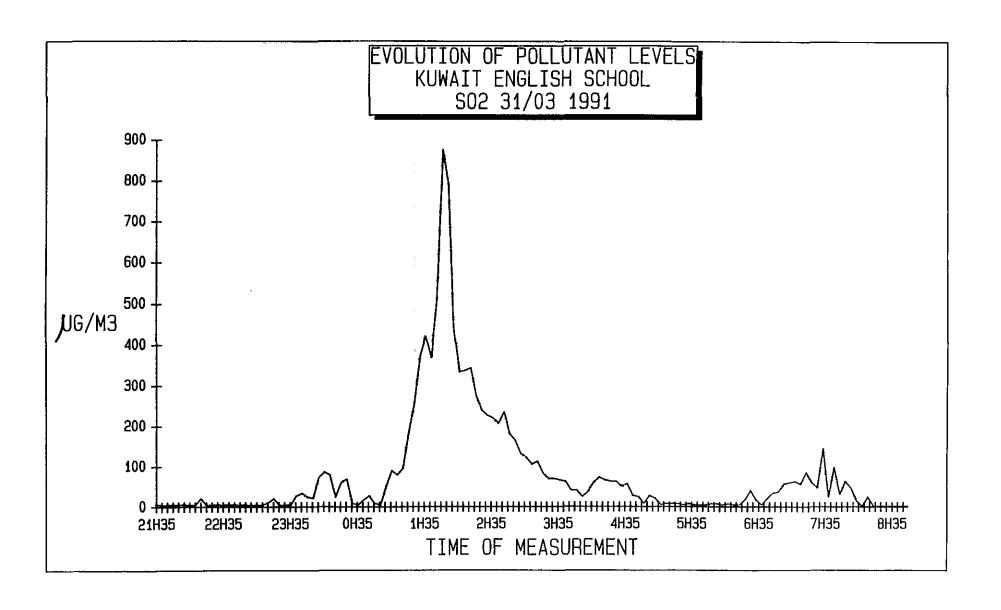
ANNEX V

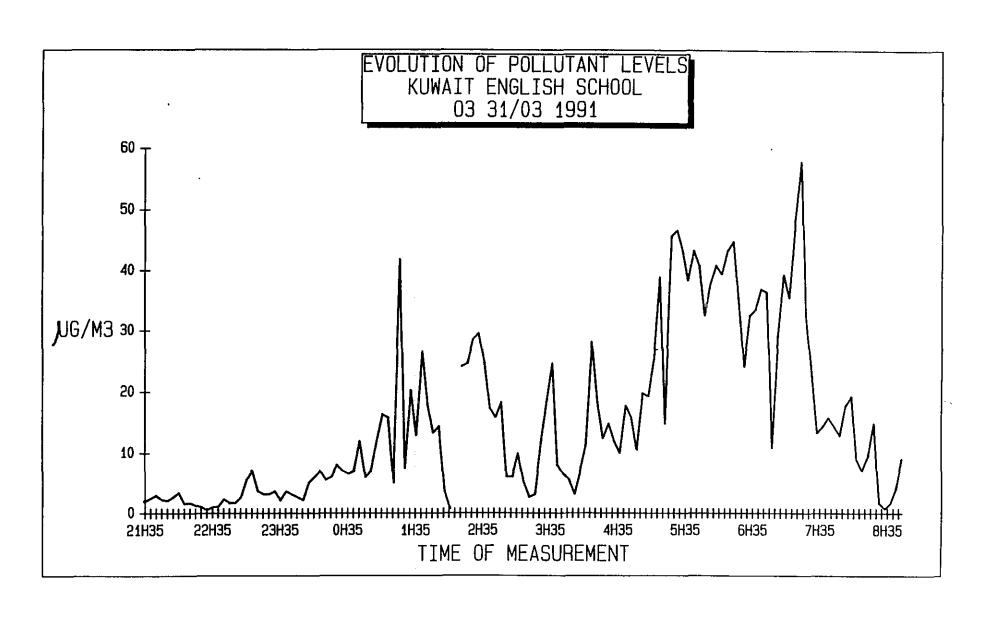
Overall Results

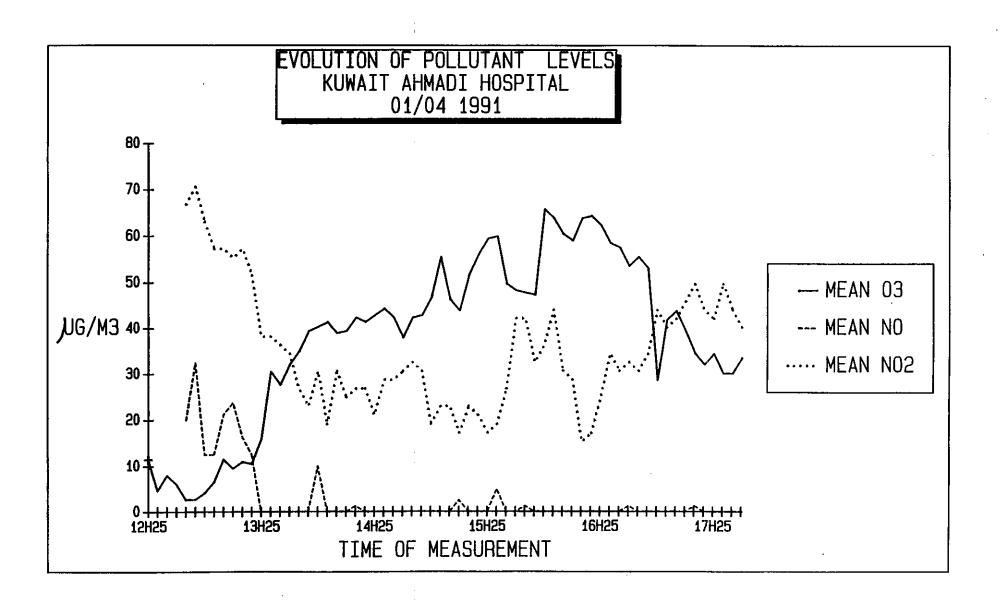
Maps of Kuwait

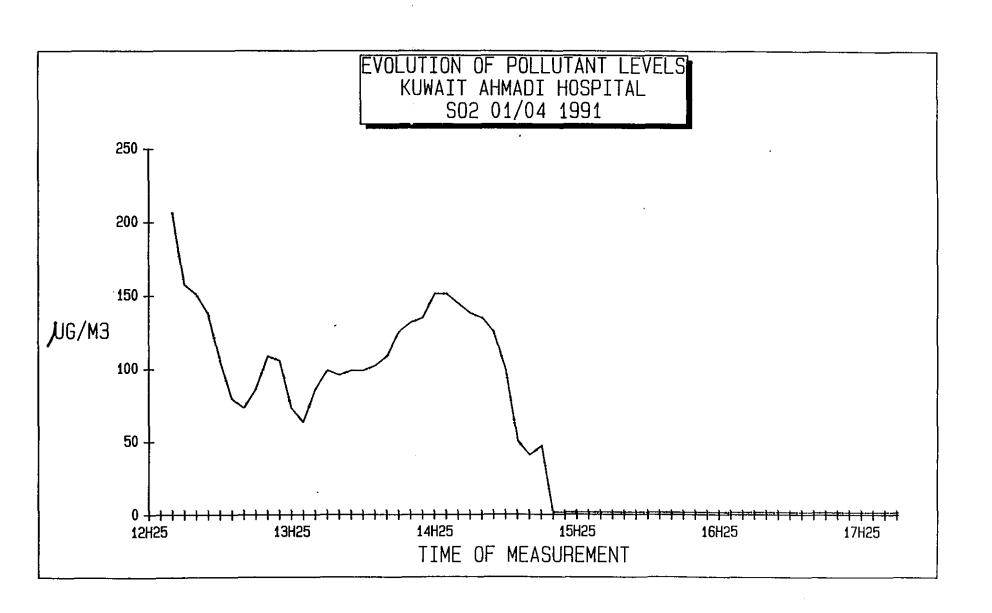
- EEC-WHO reference values
- addresses of local contacts

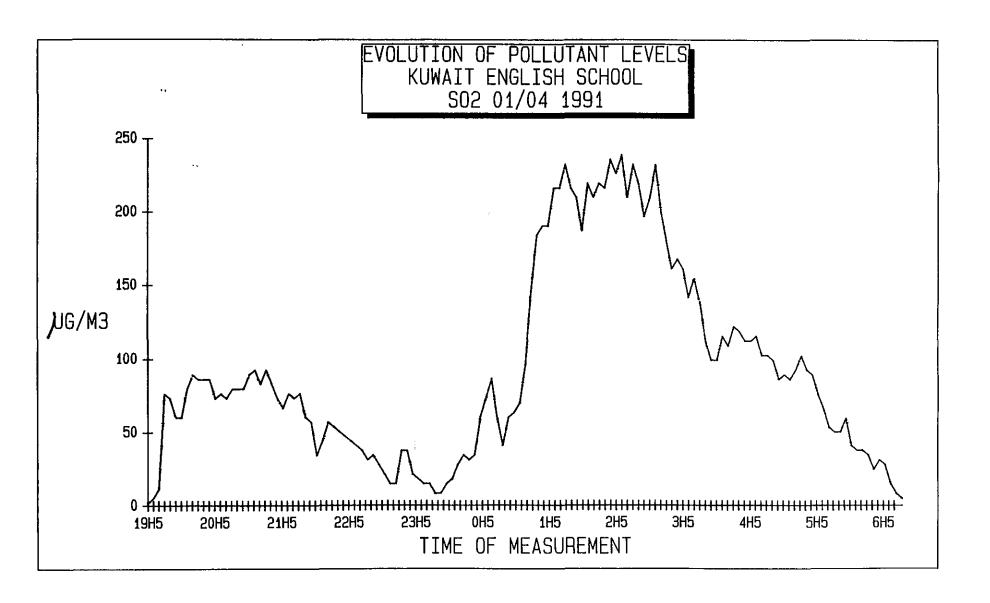
(WHO = World Health Organization)

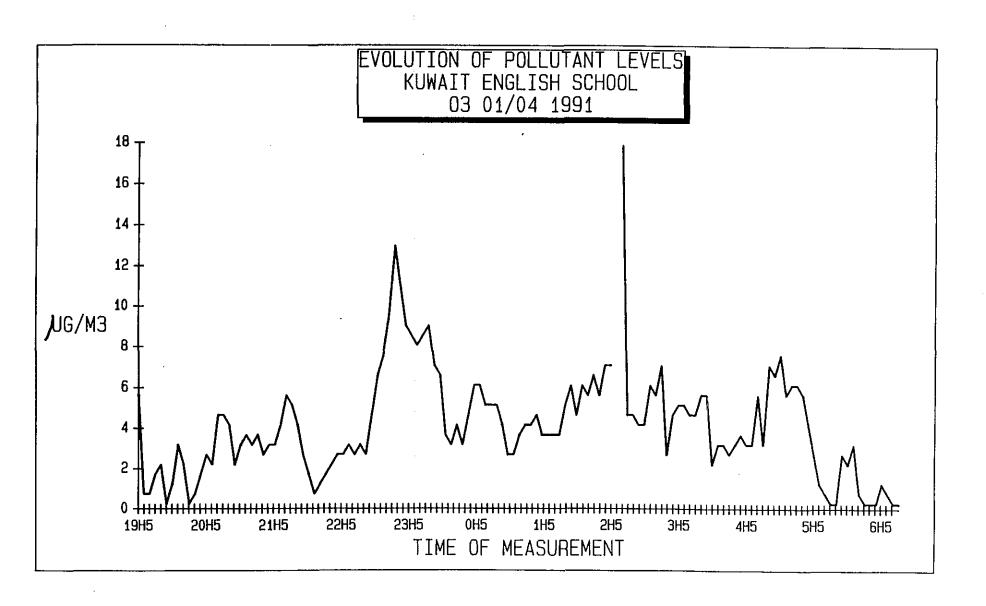


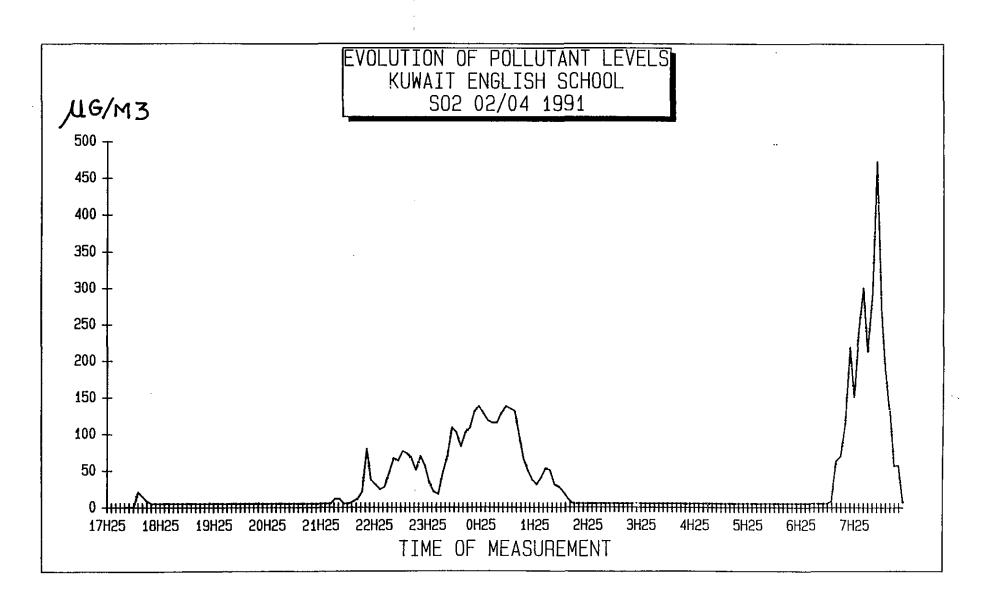


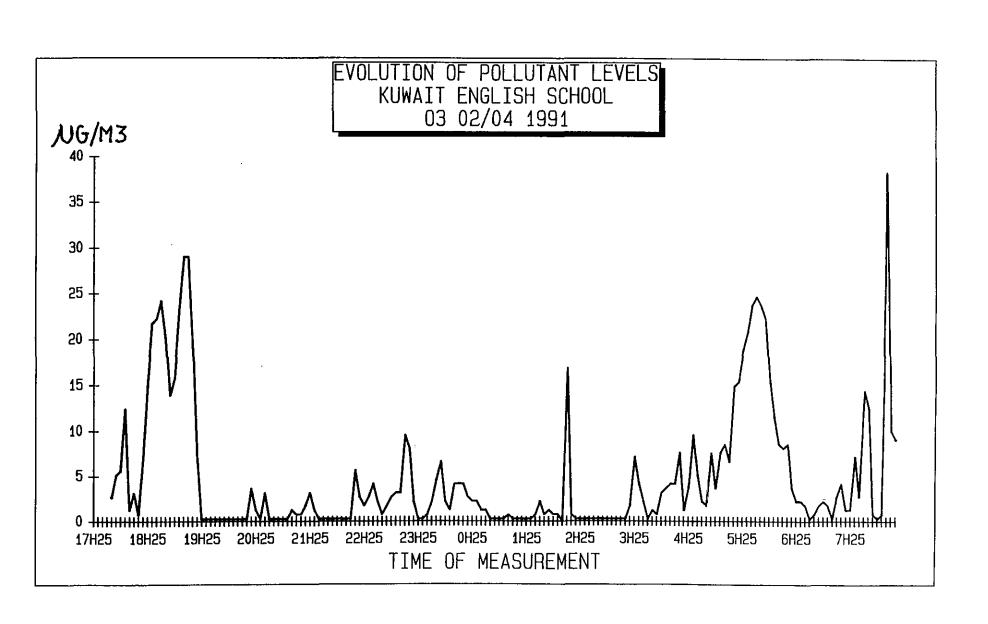


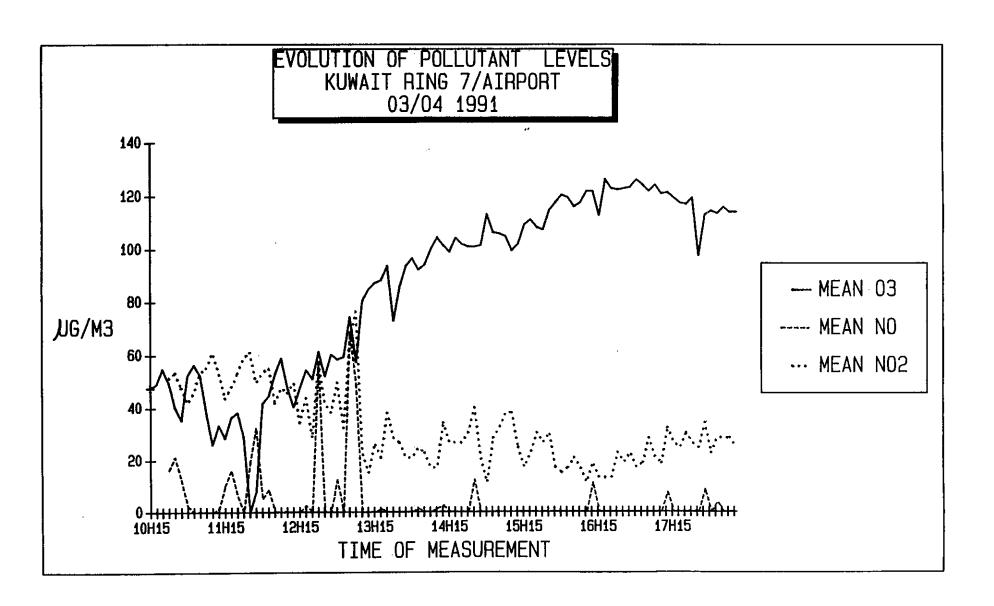


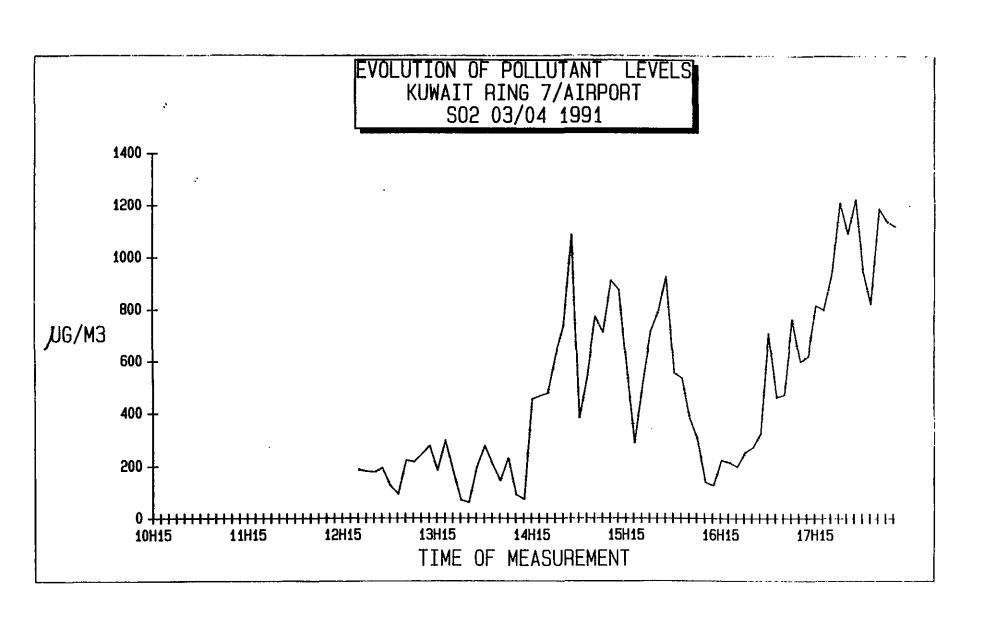




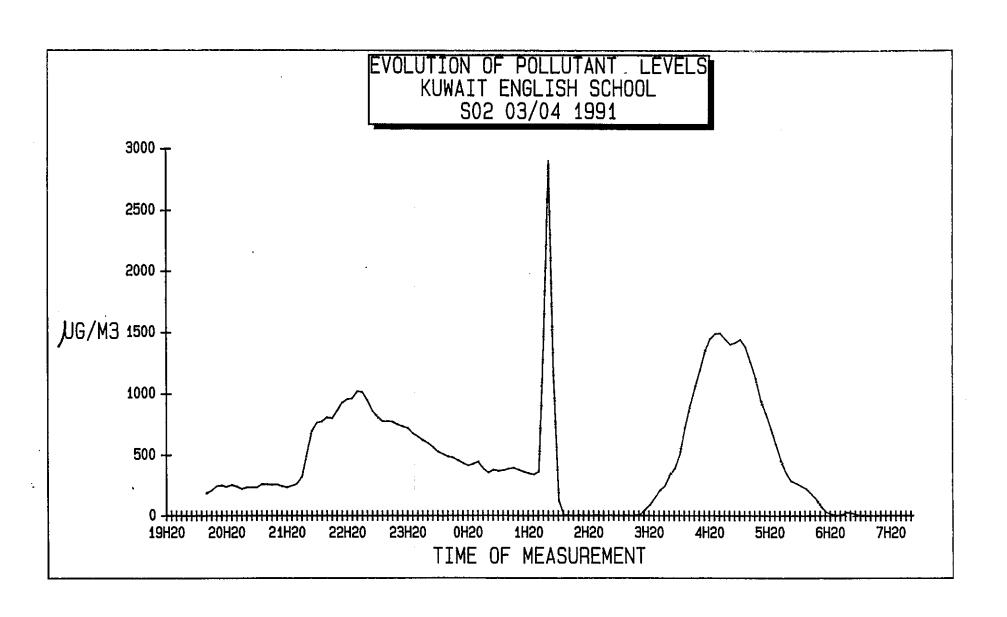


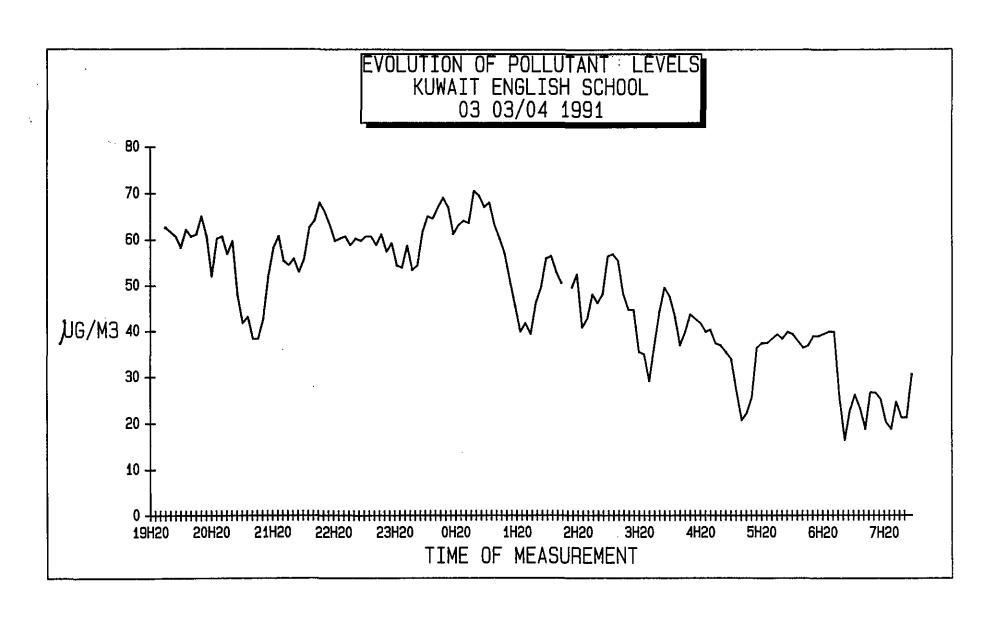


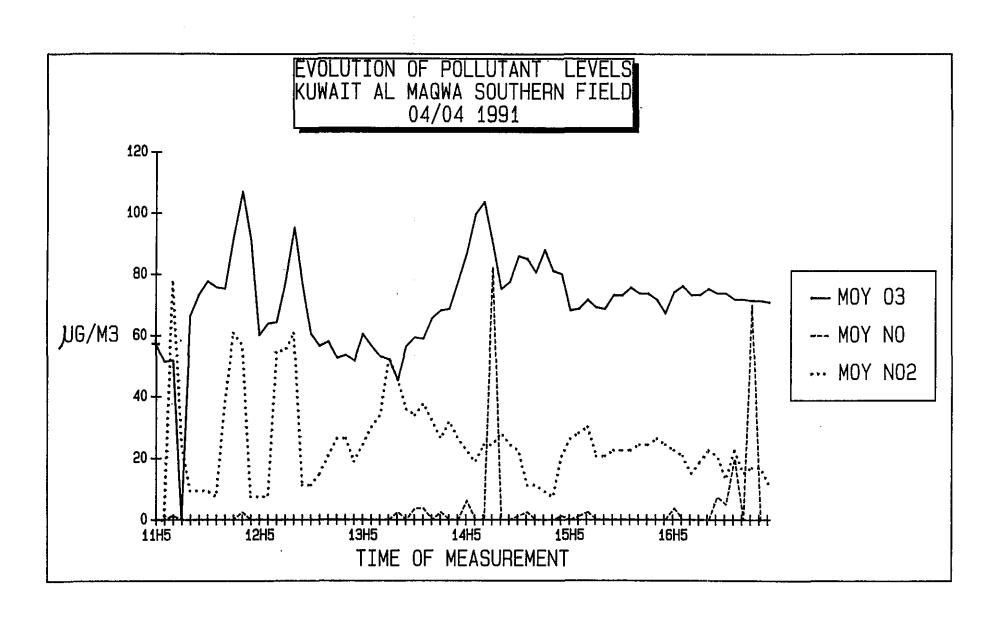


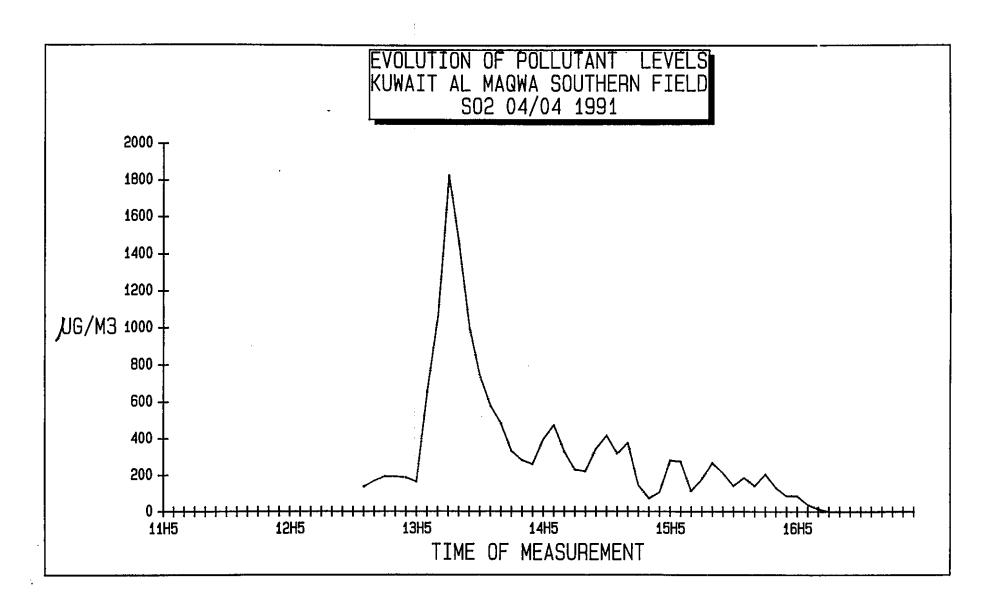


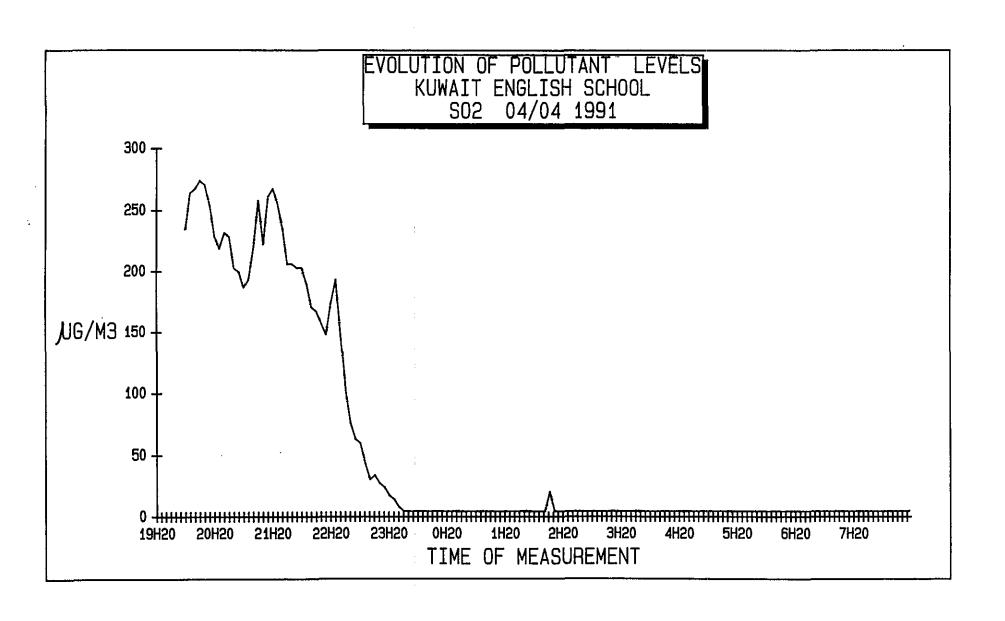
)

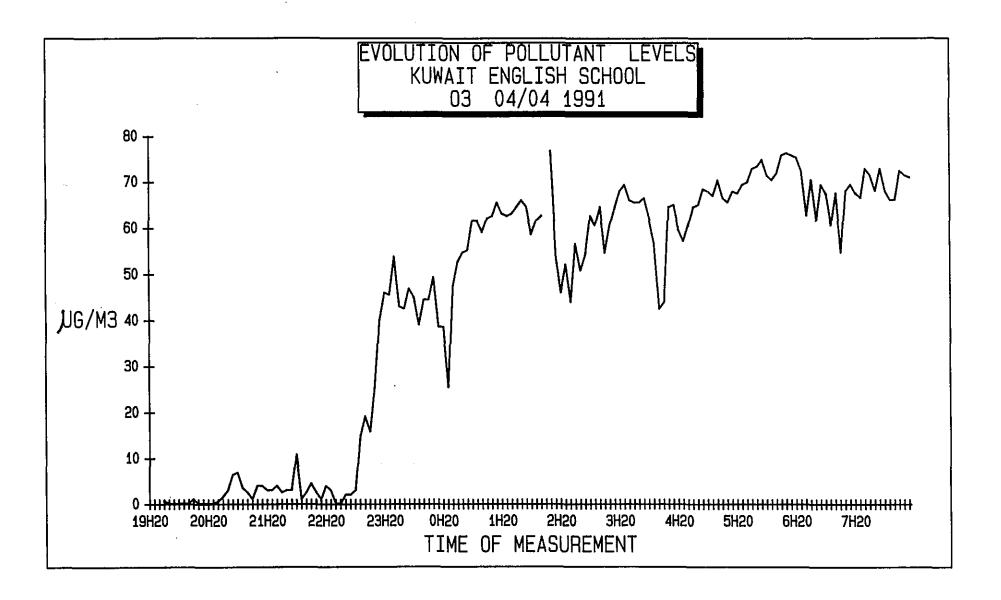












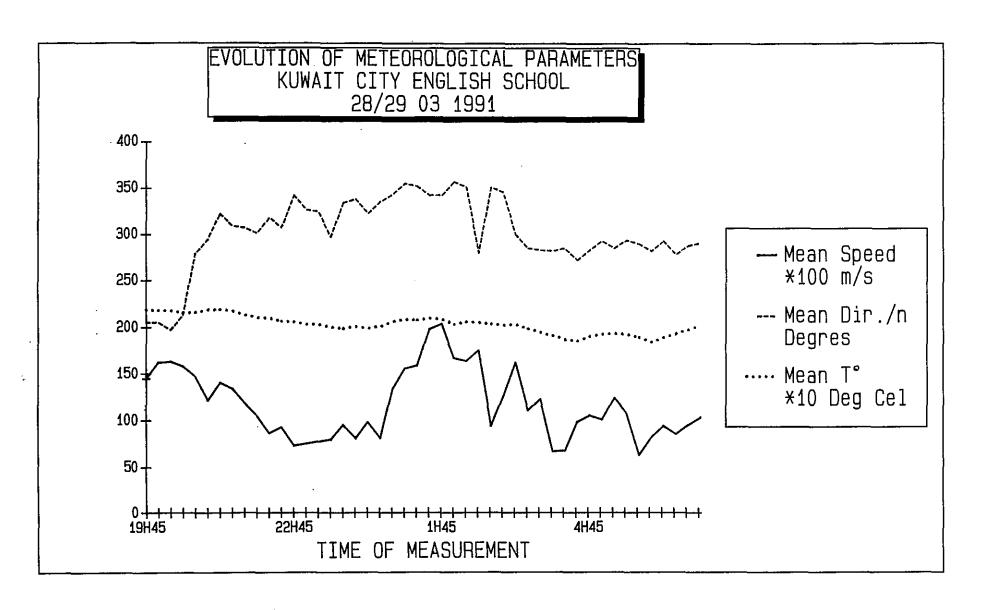
KUWAIT STUDY

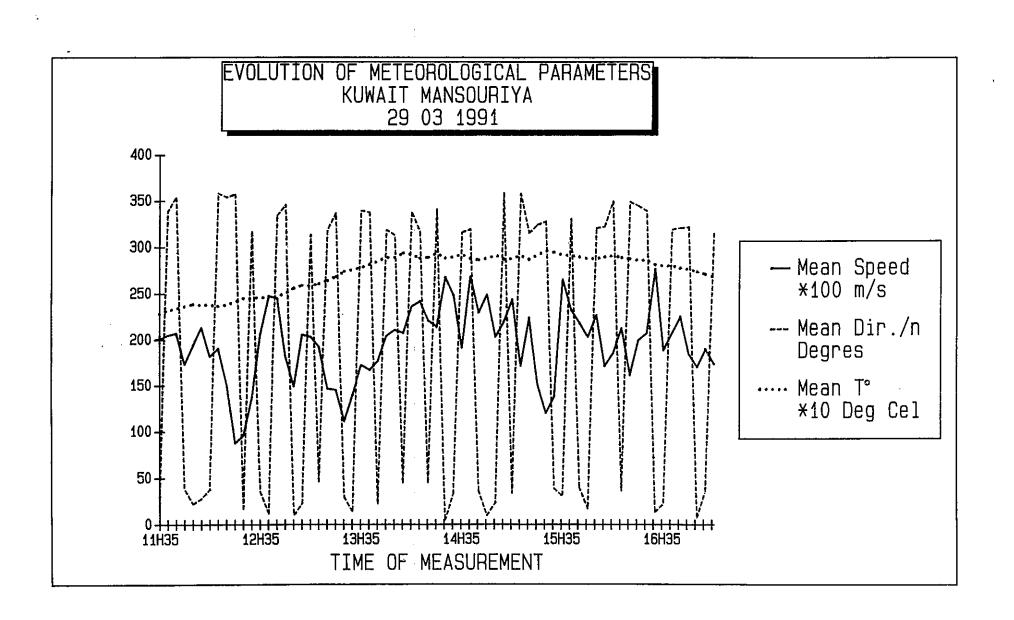
27 march to 4 april 1991

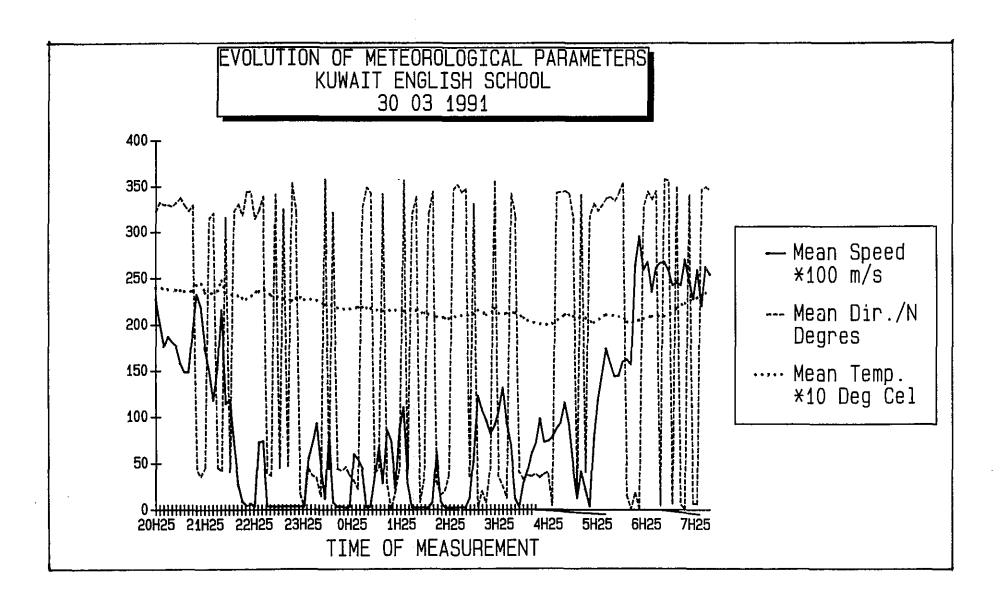
ANNEXE II

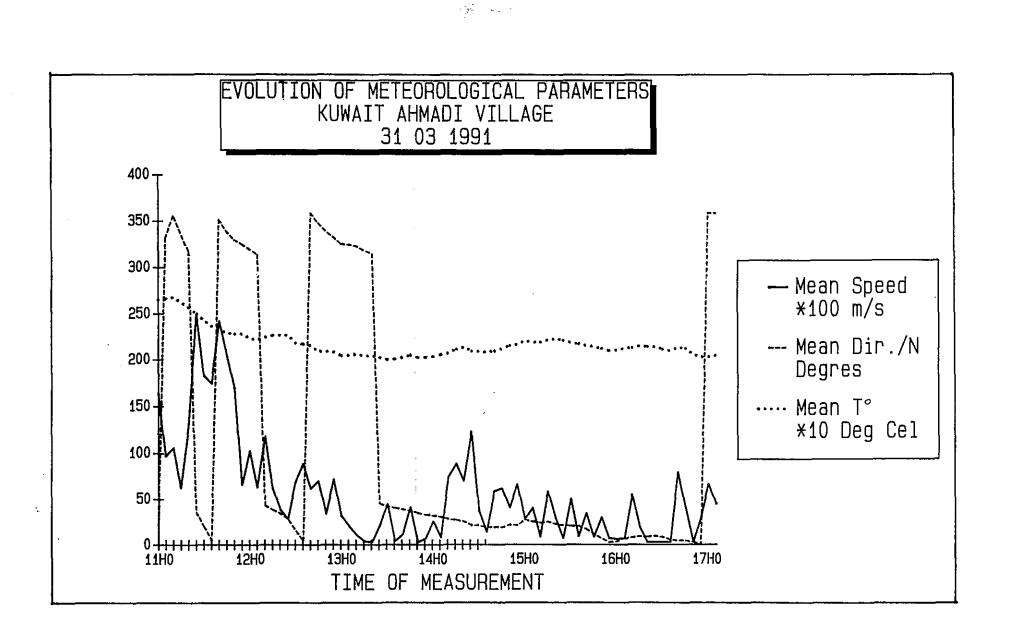
Temporal evolution of measurements of meteorological parameters

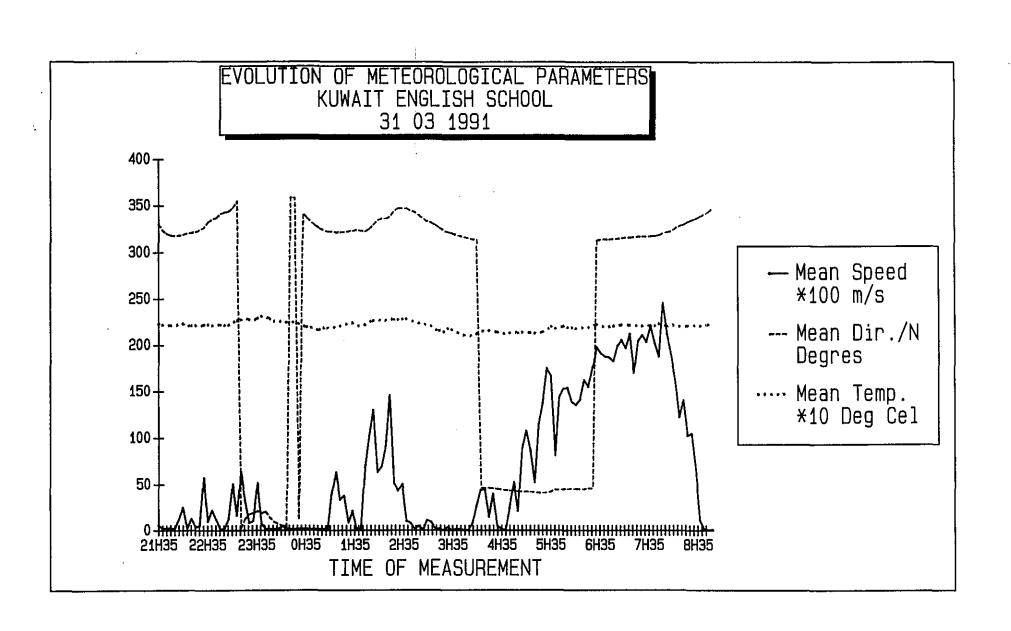
Basic data integrated over 5 minutes

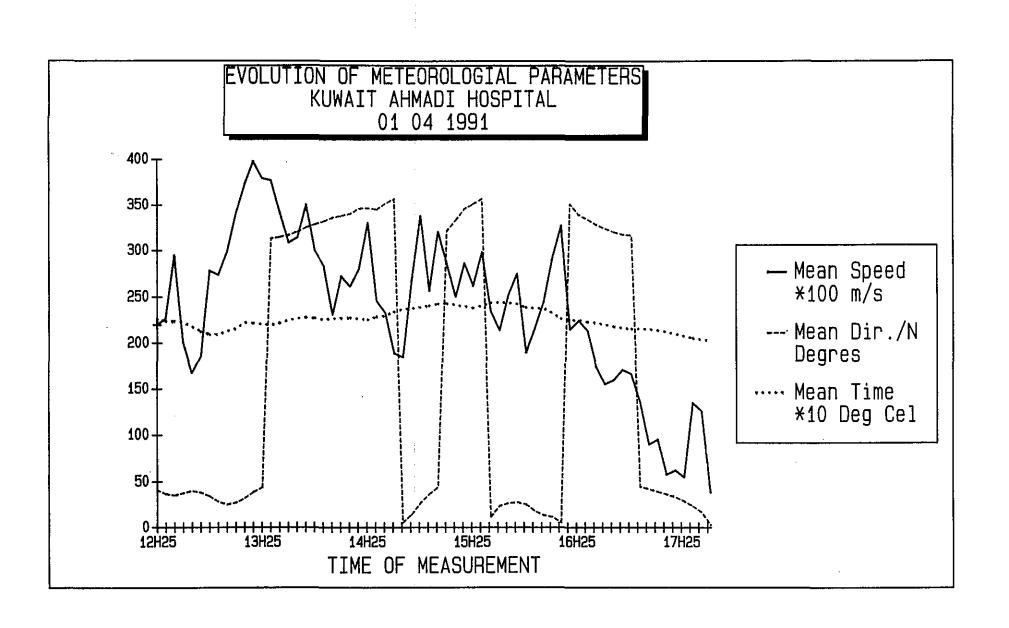


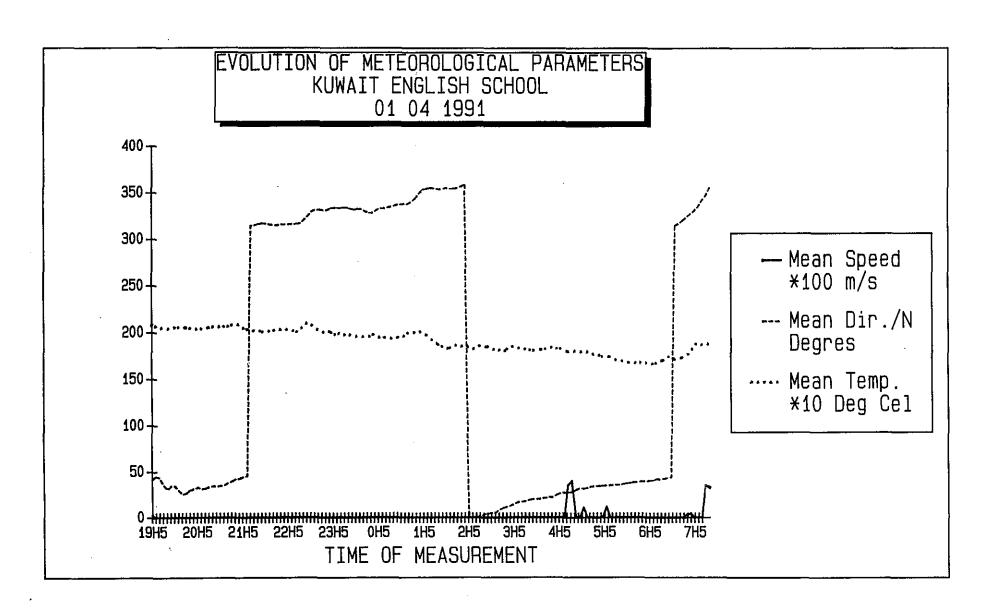


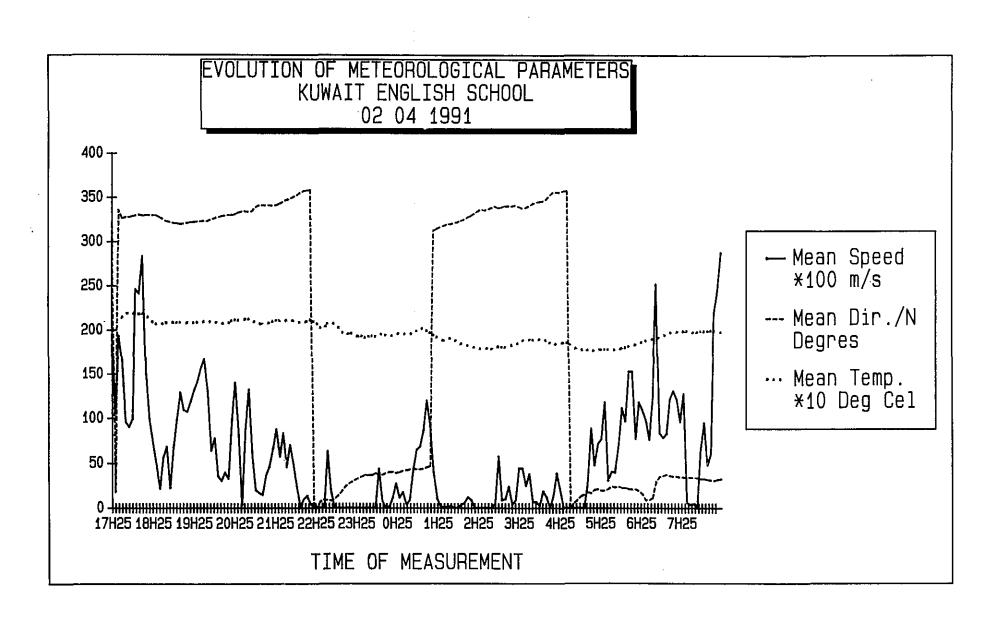


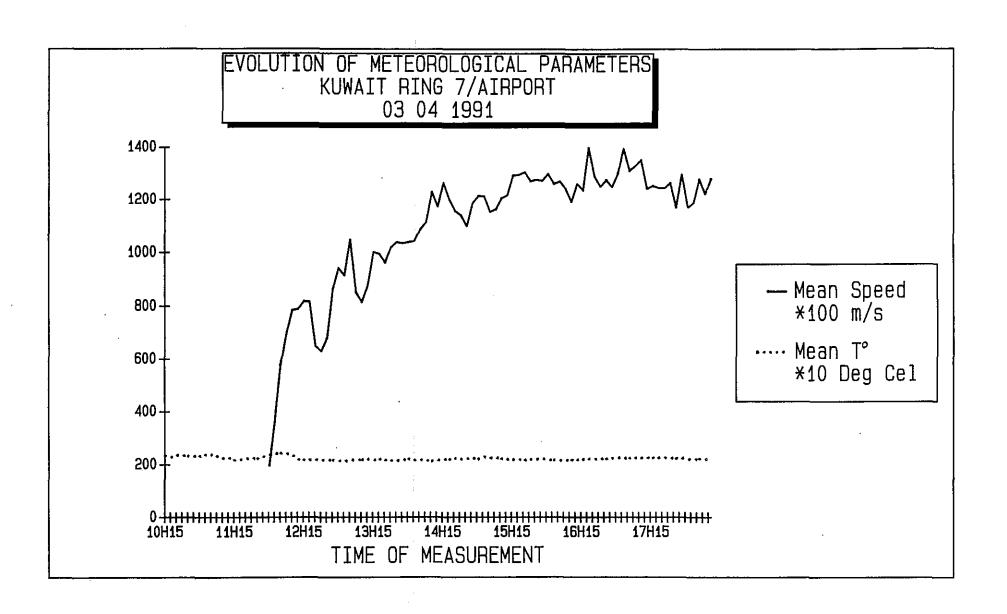


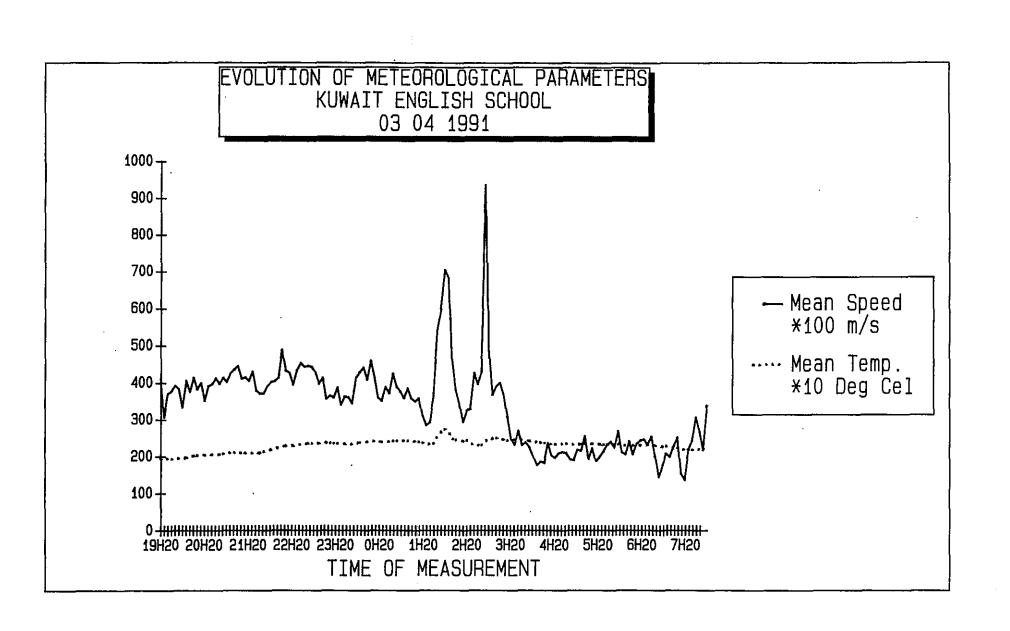


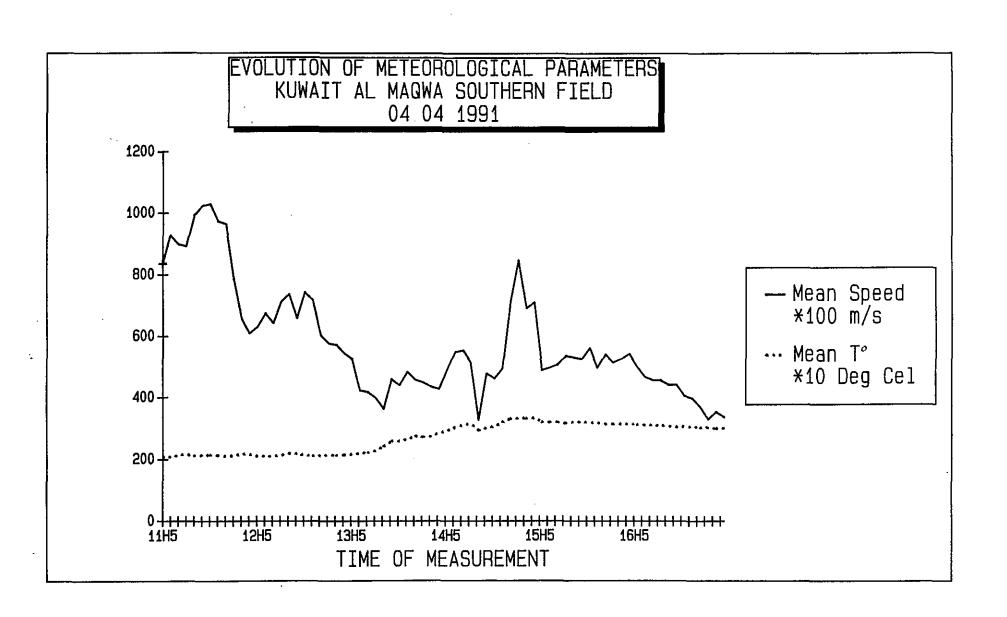


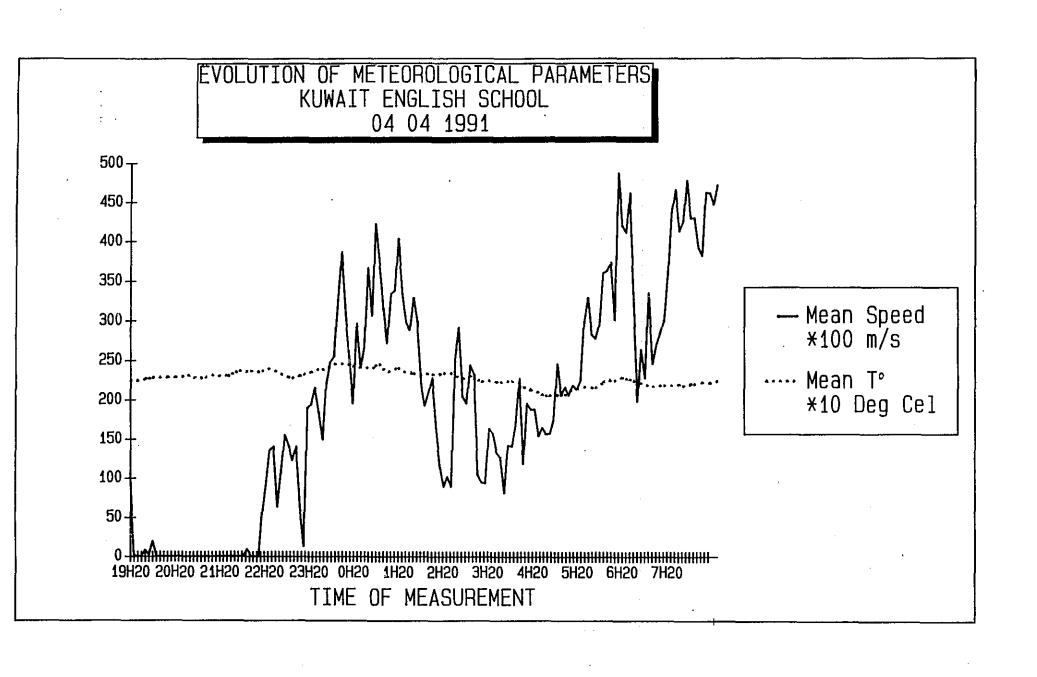












RESULTS OF THE MEASUREMENTS OF AT

N of Campaign	PLACE	STARTING TIME	ENDING TIME	LENGHT	AVERAGE	AVERAGE	AVERAGE	AVERAGE	AVERAGE
and map indicator()		AND DATE	AND DATE		О3	SO2	co	NO	NO2
1	KOWEIT CITY EPC (1/4Hourly)	27/3/91 17HOO	28/3/91 9H156	16H15	23	х	1587	77	54
(2)	KOWEIT CITY English school	28/3/91 19H45	29/3/91 7HOO	11H15	7	22	1635	30 `	10
(3)	(1/4hourly) KOWEIT CITY Mansouriya (5 Minutes)	29/3/91 11H35	30/3/91 17H05	5H30	81	6	126	1	25
(4)	KOWEIT northern oil field	30/3/91 14H05	30/3/91 17H15	3H10	96	269	127	1	16
(2) 5	KOWEIT CITY English School	30/3/91 20H25	31/3/91 7H35	11H10	16	27	1758	х ·	х
(5) 6	KOWEIT SUD Ahmadi Village	31/3/91 11H00	31/3/91 17H05	6H05	23	252	330	х	··. x
(2) 7	KOWEIT CITY English School	31/3′91 21∺35	1/4/91 8H45	11H10	15	79	1125	х	х
(6) 8	KOWEIT SUD Ahmadi Hospital	1/4/91 12H25	1/4/91 17H40	5H15	38	56	500	3	35
(2) 9	KOWEIT CITY English School	1/4/91 19H05	2/4/91 7H15	12H10	4	92	4813	х	х
(2)	KOWEIT CITY English School	2/4/91 17H25	3/4/91 8H15	14H50	4	30	1299	х	X
(7)	KOWEIT south Ring 7 Aeroport	3/4/91 10H15	3/4/91 18H05	7H50	86	495	16	4	33
(2)	KOWEIT CITY English School	3/4/91 19H20	4/4/91 7H40	12H20	49	472	318	х	х
(8)	KOWEIT AL MAQWA southern oil	4/4/91 11H05	4/4/91 17H00	5H55	71	215	20	3	25
(2)	field KOWEIT CITY English	4/4/91 19H20	5/4/91 8H15	12H55	44	55	1163	x	х
14	School								
	MEAN O	F ALL CAM	PAIGNS		40	159	1058	17	28
	MAXIMUM	ON ALL CA	MPAIGNS	 -	96	495	4813	77	54

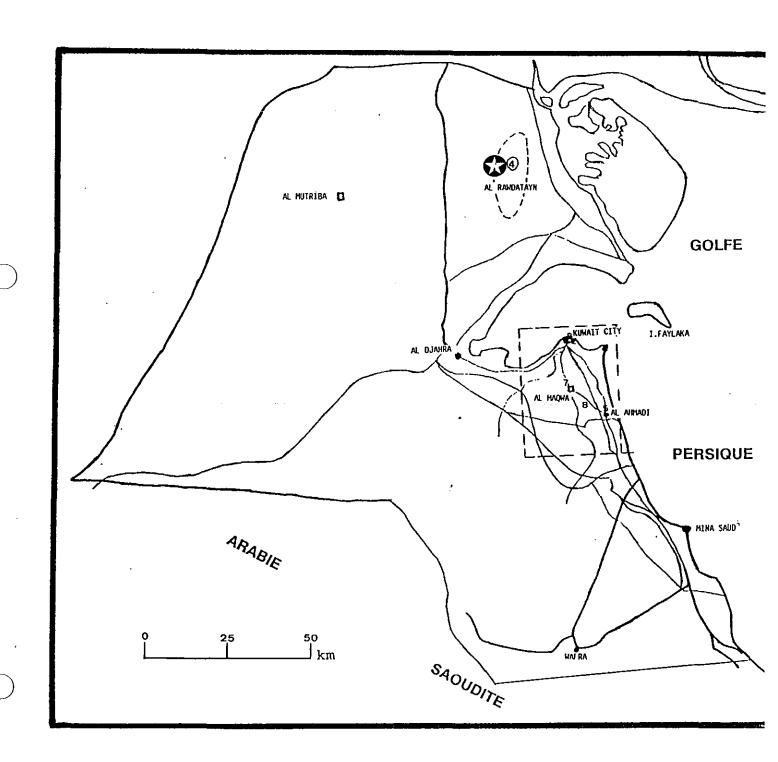
MOSPHERIC POLLUTION IN KUWAIT

AVERAGE BS	MAXIMUM 5 Minutes O3	MAXIMUM 5 Minutes SO2	MAXIMUM 5 Minutes CO	MAXIMUM 5 Minutes NO	MAXIMUM 5 Minutes NO2	MAXIMUM 1 Hour FN	AVERAGE WIND SPEED	OBSERVATIONS
· X	79	X	4234	227	94	х	х	Day without pollution, no BS, no HC
340	28	80	5027	167	69	1291	1,2	BS no HC
99	100	34	676	6	55	144	2	Day without pollution HC and FN + PPA 60
265	110	1141	463	1	32	360	8,4	in burning northern oil field, high win.do. 85.VOC no weather data .Draeger CO2= 500 PPN Other =D
163	58	199	7152	Х	х	539	1	HC and BS
745	66	687	1885	х	х	1591	0,56	underwind of southern field in the morning, noX0 NO2 BS and HC.Draeger CO2=760 PPM other D
Х	58	199	7081	Х	х	X	0,6	HC, BS H.S
206	66	206	1388	33	71	347	2,4	No direct influence, except at the begining. well at 500m.BS,HC,PPA60
449	18	239	8576	×	х	984	0,1	BS,HC
198	29	138	7651	х	Х	507	0,6	morning cloud at altitude BS,HC
595	126	1223	320	69	76	1365	11	in the plume, but very hing winds. BS,HC,HAP;PPA60
231	74	2911	747	х	х	792	3,4	black cloud on ground. BS,HC
818	107	1833	534	83	78	2030	5,8	in the heart of the southern oil field, in the plume, BS,HC,PPA60
Х	77	274	8576	х	х	х	2	no BS HC
373	71	705	3879	84	68	904	3	
818	126	2911	8576	227	78	2030	11	

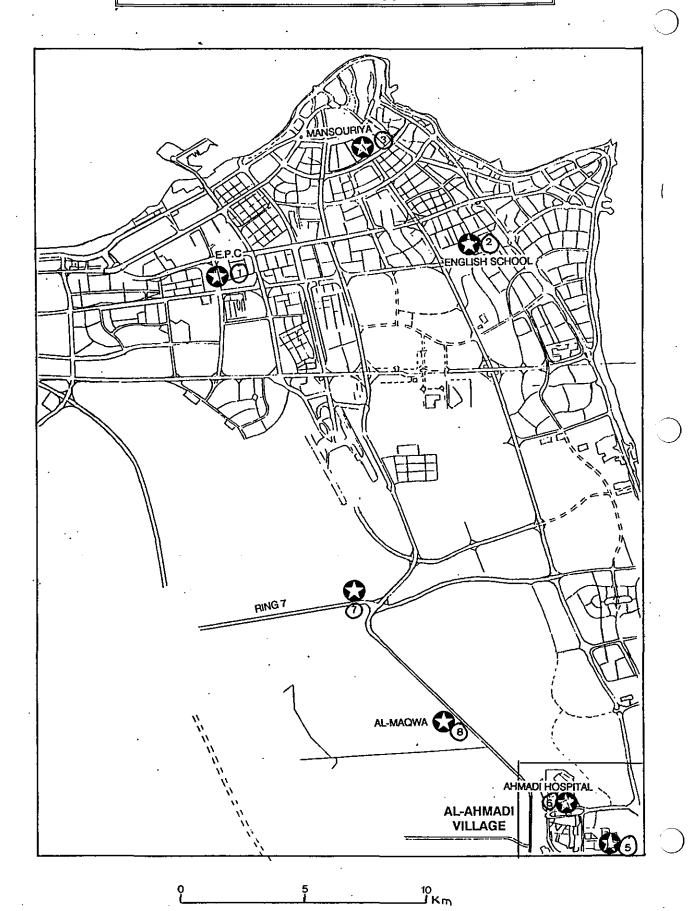
neter; wind speed in meters per second.

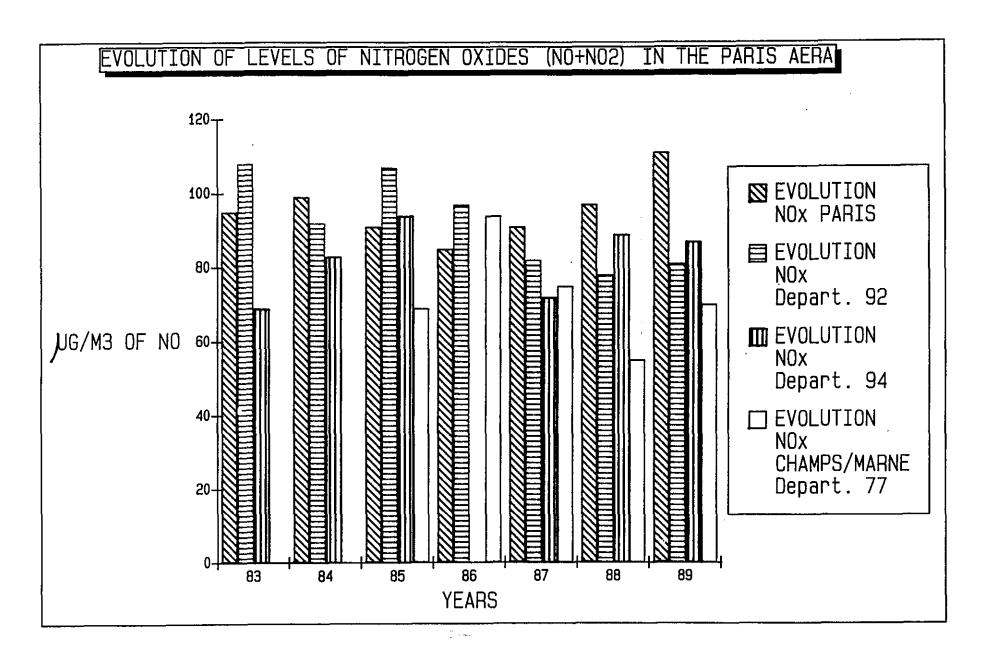
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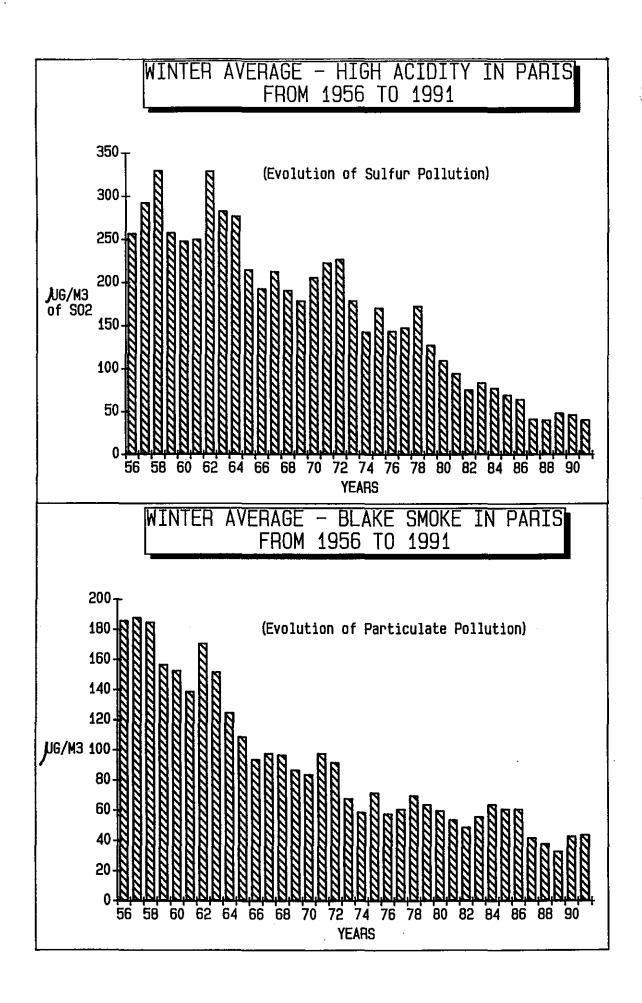
K U W A I T COUNTRY MAP



KUWAIT CITY AND ENVIRONS DETAILED MAP







POLYCYCLIC AROMATIC HYDROCARBON (PAH) LEVELS OBSERVED IN CENTRAL PARIS ; SOURCE : " LABORATOIRE D'HYGIENE " OF CITY OF PARIS

Distribution of levels observed in Paris (LHVP site) Winter period : from 11/02 to 20/03/1988

	PO,05	MED	PO,95	MOY	s	MAX	MIN
HAP ng/m3							
pyrène	8,3	13,5	26,0	15,8	7,0	38,0	7,9
f luoranthène	10,7	17,5	33,0	20,4	8,7	49,2	10,0
benzo (e) pyrène	3,4	5,5	8,8	5,9	2,5	14,9	2,6
benzo(b)fluoranthène	4,2	8,3	13,2	8,9	4,0	23,6	4.2
benzo(k)fluoranthène	1,9	4,0	6,5	4,2	2,0	11,2	1,8
benzo(a)pyrène	1,4	3,6	8.0	4,6	3,4	17,6	0,8
benzo(ghi)përylëne	2,9	6,1	8,8	6.4	2,9	17,2	2.8
indéno(1,2,3,c,d)pyrène	1,5	3,0	4.7	3,3	1,6	9,2	1,5

Distribution of levels observed in Paris (LHVP site) Autumn period : from 21/09 to 02/10/1987

	P0,05	MED	P0,95	МОҮ	s	MAX	MIN
HAP ng/m3							
pyrène	4,6	7.4	14	8,2	3,1	17	4,5
fluoranthène	3,5	5,9	9,2	6,2	2,5	15	3,4
benzo (e) pyrène	0,35	1,2	2	1,1	0,6	2,8	0,3
benzo(b)fluoranthène	0,66	1,4	3,8	1,7	1	4,2	0.4
benzo(k)fluoranthène	0,25	0,54	1.5	0,67	0.4	1,8	0,1
benzo(a)pyrène	0,22	0,50	1,6	0,70	0,5	1,7	0,2
benzo(ghi)pěrylène	0,78	1,1	3,2	1,8	2	12	0,8
indéno(1,2,3,c,d)pyrèn	e 0,43	0.86	2.1	1,1	0.6	2,9	0.4

P 0.05 : valeur percentile 5, MED : valeur médiane, P0.95 : valeur percentile 95, MOY : valeur moyenne, S : écart type, MAX : valeur maximale, MIN : valeur minimale

LIMITS DEFINED BY THE DIRECTIVES RELATIVE TO AIR QUALITY FOR COUNTRIES OF THE EUROPEAN ECONOMIC COMMUNITY

These values are considered to the limits defining acceptable air quality and must be not exceeded.

Pollutants	Concentration in air (ug/m3)	Length of exposure	Observations
SULFURE DIOXIDE (SO2) associated with suspended particules (PS)	S02 350 PS < 150 ou S02 250 PS > 150	6 days per year 6 days per year	These levels are now very rarely exceeded in the Ile de France region, but may still be reached in industrial sectors.
	S02 180 PS < 60 ou S02 130 PS > 60	half of the days of the 6 month winter period half of the days of the 6 month winter period	
	S02 120 PS < 40 ou S02 80 PS > 40	half of the days of the year half of the days of the year	
NITROGEN DIOXIDE (NO2)	200	175 hours in the year	This level is exceeded in certains parts of the Paris area.
LEAD (Pb)	2	year	This level is not reached at any of the measuring sites of Paris.

VALEURS GUIDES DE L'ORGANISATION MONDIALE DE LA SANTE EN MATIERE DE QUALITE DE L'AIR

W.H.O AIR QUALITY GUIDELINES

Below these exposure levels, no effect on health has been demonstrated.

Substance	NIVEAU D EXPOSITION EXPOSURE LEVEL	DUREE D EXPOSITION EXPOSURE TIME
Cadmium	1- 5 ng/m³ 10-20 ng/m³	1 year (rural areas) 1 year (urban areas)
Carbon disulfide	100 µg≠m³	24 hours
Carbon monoxide	100 mg/m ^{3.} 60 mg/m ³ 30 mg/m ³ 10 mg/m ³	15 minutes 30 minutes 1 hour 8 hours
1.2-Dichloroethane	0.7 mg/m³	24 hours
Dichloromethane (Methylene chloride)	3 mg/m³	24 hours
Formaldehyde	$100~\mu \mathrm{g/m^3}$	30 minutes
Hydrogen sulfide	150 μg/m³	24 hours
Lead	$0.5 1.0 \mu \text{g/m}^3$	1 year
Manganese	$1~\mu \mathrm{g/m^3}$	t year ^c
Mercury	1 μg/m³ ^d (indoor air)	1 year
Nitrogen dioxide	400 μg/m³ 150 μg/m³	1 hour 24 hours
Ozone	150-200 μg/m³ 100-120 μg/m³	1 hour - 8 hours
Styrene	800 µg/m³	24 hours
Sulfur dioxide	500 μg/m³ 350 μg/m³	10 minutes 1 hour
Sulfuric acid	e	_
Tetrachloroethylene	5 mg/m³	24 hours
	8 mg/m³	24 hours
Trichloroethylene	1 mg/m³	24 hours
Vanadium	$1/\mu g/m^3$	24 hours

List of persons encountered in the course of the Air Quality measurement campaign carried out by AIRPARIF in Kuwait from 27 March to 4 April 1991.

- IBRAHIM M HADI : Secretary of the Environment Protection Council

Director of the Environment Protection Departenement Ministry of Public Health P O BOX 24395 SAFAT KUWAIT

> TEL: 2456835 / 2456836 FAX: 2421993

- DR MOSTAFA EL-DESOUKY : Technical Advisor

Ministry of Public Health P O BOX 35035 AL-SHAAB KUWAIT

TEL: 2456832 / RES: 5717303 FAX: 2421993

- NABEEL M AL-KULAIFI : Geological Technician

Environment Protection Departenement; Air Pollution Part; Organic Chemistery

Ministry of Public Health P O BOX 35035 AL-SHAAB KUWAIT

TEL: 2456832 FAX: 2421993

-DR DANIEL TARANTOLA: World Health Organisation

W.H.O Headquarters Avenue APPIA 1211- GENEVA 27-CH

TEL: 7912706 / 7912111 FAX: 7910746

KUWAIT STUDY

27 March to 4 April 1991

ANNEX VI

Results of analyses of light hydrocarbon,

polycyclic hydrocarbon and metals samples carried out by the

"Laboratoire d'Hygiène" of the City of Paris and French Institut of Petroleum

PRELIMINARY RESULTS OF MEASUREMENTS OF GASEOUS HYDROCARBONS (HC) AND POLYCYCLIC AROMATIC HYDROCARBONS CARRIED OUT BY THE "LABORATOIRE D'HYGIENE" OF THE CITY OF PARIS ON SAMPLES TAKEN IN KUWAIT DURING THE AIRPARIF MEASUREMENT CAMPAIGN

1 - METHODOLOGY

Gaseous hydrocarbons (HC)

Te samples are taken by absorption on activated charcoal of plant origin (SKC,m = 150 mg). The volumes of air sampled generally vary from 300 to 800 liters of air according to sampling. The HC's are desorbed by carbon disulfide (2 ml) later subjected to chromatographic analyses. The compounds are separated with the aid of a high resolution capillary column (L = 50 m, d = 0.32 mm phase methyl silicone) and detected by flame ionization (quantitative aspect) or by mass detection (qualitative aspect). The compounds were identified by mass sweeping in the field 33 to 450 ums in electronic impact mode.

1/ Polycyclic aromatic hydrocarbons

The level of polycyclic aromatic hydrocarbons (PAH) of the particulate phase was estimated from particles sampled on a cellulose filter (Whatman n° 1) on the basis of the black smoke index. 1 to 3 m3 of air was sampled for the samples analyzed. The PAH are extracted and analyzed following the recommendations of the standard AFNOR N° X 43-025. After ultrasonication of the filters by dichloromethane, the analyses are made by high performance liquid chromatography (HPLC) with detection by fluorescent emissions.

2/ Métals

The atmospheric particles sampled on cellulose nitrate filters (Satorius-SM 11305 d = 47 mm) are subjected to mineralisation by nitric acid, in a teflon spray.

The metallic elements are measured bu atomic absorption spectrophotometry with electrothermal atomization (no results available at present).

RESULTS OF THE MEASUREMENTS OF A'S

VOLATILE ORGANIC COMPA

N of Campaign	PLACE	STARTING TIME	ENDING TIME	LENGTH OF	AVERAGE	AVERAGE	AVERAGE	AVERAGE	AVERAGE
and map indicator ()		AND DATE	AND DATE	TIME	HEPTANE	OCTANE	NONANE	DECANE	UNDECANE
(3)	KOWEIT CITY Mansouriya	29/3/91 11H35	30/3/91 17H05	5H30	4	2,3	1,7	2,8	2,6
3	(5 Minutes)							<u>_</u>	
(2) 5	KOWEIT CITY English School	30/3/91 20H25	31/3/91 7H35	11H10	9,6	. 7,7	7	9,6	7,6
(5)	KOWEIT SUD Ahmadi Village	31/3/91 11H00	31/3/91 17H05	6H05	57,8	43,9	38	31,2	19,4
6									<u> </u>
· (2) 7	KOWEIT CITY English School	31/3/91 21H35	1/4/91 8H45	11H10	27,6	26,4	22,8	26,2	17,7
(6)	KOWEIT SUD Ahmadi Hopital	1/4/91 12H25	1/4/91 17H40	5H15	9,5	6,7	5,1	6,7	4,9
8	·				ļ				ļ <u>.</u>
(2) 9	KOWEIT CITY English School	1/4/91 19H05	2/4/91 7H15	12H10	27,6	23,3	21,4	29,3	20,6
(2) 10	KOWEIT CITY English School	2/4/91 17H25	3/4/91 8H15	14H50	7,5	5,3	7,1	13,3	10,7
(7)	KOWEIT SUD Ring 7 Airport	3/4/91 10H15	3/4/91 18H05	7H50	40,4	51,6	55	58,6	44,4
	KOWEIT CITY	3/4/91	4/4/91	 	<u> </u>			 	
(2) 12	English School	19H20	7H40	12H20	2,8	3,8	5,2	10,7	7,6
(8)	KOWEIT SUD AL MAQWA southern field	4/4/91 11H05	4/4/91 17H00	5H55	15	17,7	22,5	35,7	41,5
13	1	<u> </u>	<u> </u>		<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
(2)	KOWEIT CITY English School	4/4/91 19H20	5/4/91 8H15	12H55	3,1	1,9	2,3	5,9	4
14			<u> </u>	<u> </u>	<u> </u>	L	<u></u>	<u> </u>	
MOYENNE DE L'ENSEMBLE DES CAMPAGNES				18,6	17,3	17,1	20,9	16,4	
MAXIN	IUM SUR L'E	NSEMBLE	DES CAM	PAGNES	57,8	51,6	38	58,6	44,4

ATMOSPHERIC POLLUTION IN KUWAIT

POUNDS (in µg/m³)

	AVERAGE DODECANE	AVERAGE TRIDECANE	AVERAGE BENZENE	AVERAGE TOLUENE	AVERAGE ETHYLBENZENE	AVERAGE m+p XYLENE	AVERAGE 0 XYLENE	AVERAGE 1,2,4 TRIMETHYLBENZENE
-								
	1,5	1,2	7,6	9,6	3,4	10,8	3,7	3,1
1	5,2	3,7	5,3	18,1	6,9	23,6	8,2	10,1
	14,5	11	9,2	21,2	9,2	14,7	35,8	13,3
-	12,3	9	4,1	15.3	6,5	32,2	12,9	13,7
	4,3	3,8	6,2	11,8	4,3	9	5,5	6,4
_	14,1	9,4	11,9	46,7	16,2	64	21,2	27,2
_	9,5	8,2	3,2	21,5	5	19	7,3	8,5
	21,8	13,1	4	13,6	7,8	10	20,2	22,6
	6,3	5,4	1,9	2,9	1,4	2,1	0,9	3,4
_	3,5	24,7	5,5	6,4	3,3	5,5	3,8	12,8
	3,8	3,2	3,6	14,6	3,5	12,3	3,8	4,9
-	8.8	8,4	5,7	16.5	6,1	18,5	11,2	11,4
•	21,8	24,7	11,9	46.7	16,2	64	35,8	27,2

RESULTS OF THE MEASUREMENTS OF

AROMATIC POLYCYCLIC HYL

Samplings (cellulose support) analyse

High performance liqu

detection by f.

N of Campaign	PLACE	SARTING TIME	ENDING TIME	LENGHT OF	AVERAGE ug/m3	VOLUME	AVERAGE	AVERAGE	
and map indicato: ()		AND DATE	AND DATE	DATE	SUSPENDED PARTICULES	. m3	FLUOPANTHENE	ANTHRACENE	LA
(4)	KOWEIT Northern Field	30/3/91 14H00	30/3/91 15H00	1H00	360	1,091	7,9	4,3	
4									
(5) 6	KOWEIT SUD Ahmadi Village	31/3/91 14H00	31/3/91 15H00	1H00	827	0,938	9,0		
(6)	KOWEIT SUD Ahmadi	1/4/91 13H00	1/4/91 14H00	1H00	288	1,084	8,3		
8	Hopital								
_ (2) 9	KOWEIT CITY English School	1/4/91 23H00	1/4/91 24H00	1H00	109	1,084	7,6		
(2)	KOWEIT CITY English School	2/4/91 2H00	1/4/91 3H00	1H00	936	1,084	12,1		
9 (2)	KOWEIT CITY English	3/4/91 1H00	3/4/91 2H00	1H00	503	1.474	17.4	<u> </u>	+
_10	School				507	1,171	17,4		}
(2)	KOWEIT CITY English School	3/4/91 4H00	3/4/91 5H00	1H00	202	1,171	9,1	7,2	
10	<u> </u>			 			<u> </u>		
(7) 11	KOWEIT SUD Ring 7 Airport	3/4/91 17H00	3/4/91 18H00	1H00	1151	1,028	8,4		
(2)	KOWEIT CITY English School	3/4/91 23H00	4/4/91 00H00	1H00	185	1,171	5,2	2,6	_
(2)	KOWEIT CITY English School	4/4/91 6H00	4/4/91 7H00	1H00	638	1,171	8,9	3,4	
(8)	KOWEIT SUD	4/4/91	4/4/91	 	 		1		+
13	AL MAQWA south field	15H00	16H00	1H00	494	0,946	9,9		
				<u></u>		-			T
MEAN OF ALL CAMPAIGNS					518		9,4	4,4	
	MAXIMUM	ON ALL C	AMPAIGNS	}	1151		17,4	7,2	

F ATMOSPHERIC POLLUTION IN KUKAIT

) IYDROCARBONS (in ng/m³)

lysed by French Institut of Petroleum

liquid chromalography

y fluorescence

AVERAGE BENZO (a) ANTHRACENE	AVERAGE PYRENE	AVERAGE BENZO (b) FLUORANTHENE	AVERAGE BENZO (k) FLUORANTHENE	AVERAGE BENZO (a) PYRENE	AVERAGE DIBENZO (a.h) ANTHRACENE	AVERAGE BENZO (ghi) PERYLENE	AVERAGE INDENO PYRENE
1.0	8,5 1,3		0,01	1,6	1,3	1,3	3,1
2,5		6,1	2,0	3,8	6,2	23,1	40.0
2,6	9,6	3,7	1,4	2,7	3,0	8,0	11,2
1,6	7,1	4,3	1,4	3,9	4,1	9,7	11 4
4,2	10,2	7,5	2,9	0,0	9,2	10,7	13.3
5,4	12,7	9,6	4,5	5,7	15,4	23,5	
	9,3	3,2	1,3	2,3	3,8	2,9	11,9
1,6	6,3	3,95	1,7	4,0	4,3	2,1	4.6
1,6	6,3	1,4	0,7	0,9	1,4	4,2	8,5
0,7	4,9	2,7	1,8	1,7	4,2	5,3	6,4
3,7	8,6	4,8	2,2	3,9	6,2	1,3	9,2
2,5	8,4	4,4	1,8	3,3	5,4	8,4	12
5,4	12,7.	9,6	4,5	6,0	15,4	23,5	40,0

RESULTS OF THE MEASUREMENTS OF ATMOSPHERIC POLLUTION IN KUWAIT

AROMATIC POLYCYCLIC HYDROCARBONS (in ng/m³)

Samplings analysed by LHVP

N of Campaign and map indicator()	PLACE	STARTING TIME AND DATE	ENDING TIME AND DATE	LENGHT OF TIME	AVERAGE FLUORANTHENE	AVERAGE BENZO (a) ANTHRACENE	AVERAGE BENZO (#) PYRENE	AVERAGE BENZO (b) FLUORANTHENE	AVERAGE BENZO (k) FLUORANTHENE	AVERAGE BENZO (a) PYRENE	AVEHAGE DIBENZO (a,h) ANTHRACENE	AVERAGE BENZO (ghi) PERYLENE	AVERAGE INDENO (1,2,3,c,d) PYRENE
(2)	KOWEIT CITY English school (1/4 hourly)	28/3/91 23H00	29/3/91 1H00	2Н	24	1,4	9,3	7,4 .	3,6	4,9	0,4	8,3	15
(5) 6	KOWEIT South Ahmadi Village	31/3/91 11H00	31/3/91 13H00	2H	30	1,9	17	13	5,6	7,6	0,9	11	21
(2) 9	KOWEIT CITY English School	1/4/91 20H00	1/4/91 22H00	2Н		0,7	3,5	2,9	1,2	3,4	0,01	4,1	5,7
(7)	KOWEIT Fing 7 Airport	3/4/91 10H00	3/4/91 12H00	2н	37	1,3	6,6	11	3,8	7,6	0,18	8,4	17
(8)	KOWEIT AL MAQWA South field	4/4/91 11H00	4/4/91 14H00	3⊢	110	3,8	26	20	12	30	0,6	26	41
(7) 11*	KOWEIT SUD Ring 7 Airport	3/4/91 11H00	3/4/91 18H00	7H	19	5,6	4	3,3	1,8	5,8	0,2	3,8	5,8
(7) 11**	KOWEIT SUD Ring 7 Airport	3/4/91 11H00	3/4/91 18H00	7H	17	< 1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1
	MEAN O	F ALL CAM	PAIGNS	- ,	34,6	2,2	9,5	8,2	4,0	8,5	0,3	8,8	14,3
	MAXIMUM	ON ALL CA	MPAIGNS		110	5,6	26	20	į Z	30	0.9	26	41

[·] particulate phase sampled on plass inter

[·] gazeous phase sampled on XAD2 resine

HYDROCABONS AND VOLATILE ORGANIC COMPOUNDS

AVERAGE LEVELS OBSERVED IN PARIS OR IN HABITATIONS

SOURCE: "LABORATOIRE D'HYGIENE" OF THE CITY OF P

MEASUREMENTS TAKEN IN SEPTEMBER/OCTOBER 1987

*1	******	**:	******	*********	**
*		*	•		*
*	SUBSTANCE	*	AMBIENT AIR	INDOOR AIR	*
*		*			*
*1	*****	**:	*****	*****	**
*		*			*
*	ALKANES	*	100	100	*
×		*			*
*	HEXANE	*			*
*	HEPTANE	*	25	10	*
*	OCTANE	*	11	5	*
*	NONANE	*	21	10	*
*	DECANE	*	20	20	*
*	UNDECANE	*	10	10	*
*	DODECANE	*	5	5	*
*	TRIDECANE	*	5 3 2 1	10	*
*	TETRADECANE	*	2	2	*
*	PENTADECANE	*	1	1	×
*	HEXADECANE	*	1	1	*
*		*			*
*	CYCLOALKANES	*		25	*
*		*			*
*	CYCLOHEXANE	*		10	*
*	METHYL CYCLOHEXANE	*		10	*
*		*			*
*	AROMATICS	*	60	160	*
*		*	-	* *	*
*	BENZENE	*	9	10	*
*	TOLUENE	*	23	8 0	*
*	ETHYL BENZENE	*	3	10	*
*	M+P XYLENE	*	10	20	*
*	O XYLENE	*	1	10	*
*		*			*
*	******	**	******	******	**

RESULTS OF THE MEASUREMENT OF ATMOSPHERIC POLLUTION

IN KUWAIT

METALS (in ng/m3)

Samplings analysed by LHVP

N of	LIEU	SARTING	ENDING	LENGHT	AVERAGE	AVERAGE
Campaign		TIME .	TIME	OF		
and map		AND	AND	TIME	NICKEL	MUICIANAV
indicator ()		DATE	DATE			
(3)	KOWEIT CITY	29/3/91	30/3/91			
` '	Mansouriya	14H00	17H00	3H00	20	< 20
3	(5 Minutes)				-~	ļ
(6)	KOWEIT SUD	1/4/91	1/4/91			
(0)	Ahmadi	15H00	16H00	1H00	150	60
	Hospital	1005	''•'	55	150	50
8 (2)	140111517 0117	4.1.2			ļ	
(6)	KOWEIT SUD	1/4/91	1/4/91			
	Ahmadi	16H00	17H00	1H00	600	70
8	Hospital			•		İ
(6)	KOWEIT SUD	1/4/91	1/4/91			
(-)	Ahmadi	17H00	18H00	1H00	200	70
_	Hospital		ì	}	200	1
8						
(7)	KOWEIT SUD	3/4/91	3/4/91			
	Ring 7	11H00	12H00	1H00	400	200
11	Airport					ļ
(7)	KOWEIT SUD	3/4/91	3/4/91			
(.,	Ring 7	17H00	18H00	1H00	330	200
	Airport			""	1 220	200
11						<u> </u>
(8)	KOWEIT SUD	4/4/91	4/4/91	l	l	l
, ,	AL MAQWA	12H00	13H00	1H00	20	20
13	south field		1	1		
(8)	KOWEIT SUD	4/4/91	4/4/91	1	† · · · · · · · · · · · · · · · · · · ·	
رد,	AL MAQWA	13H00	14H00	1H00	50	< 20
4.5	south field	101.50	1	100] 30	1 ~ 20
13		L	<u> </u>	<u> </u>	<u></u>	
	MEAN O	221	32			
, <u>, , , , , , , , , , , , , , , , , , </u>	MAXIMUN (600	200			

U.S. DEPARTMENT OF COMMERCE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY Gaithersburg, MD 20899

REPORT OF TEST FR 3985

June 20, 1991

Analysis of Smoke Samples from Oil Well fires in Kuwait

George W. Mulholland, Bruce A. Benner, Robert A. Fletcher,
Eric Steel, Stephen A. Wise, Willie E. May
Daniel Madrzykowski, and David Evans

Submitted to:

U.S. Department of Commerce NOAA Office of the Chief Scientist Arabian Gulf Program Office Rm. 6226

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by

George W. Mulholland, Bruce A. Benner, Robert A. Fletcher, Eric Steel, Stephen A. Wise, Willie E. May, Daniel Madrzykowski, and David Evans

National Institute of Standards and Technology

INTRODUCTION

This report describes results from a preliminary series of measurements concerning the smoke production from the Kuwait oil well fires. Detailed chemical analysis of the smoke is being carried out for determination of the fraction of ambient aerosol arising from the Kuwait oil well fires on a local, regional, and global scale. The overall goal is to characterize the amount of smoke particulate produced and its chemical makeup, as well as the amount of various gaseous species including SO_x and PAHs from individual well fires. This information will be used together with the burning rates of a large number of oil well fires to estimate the total production of smoke and gases from all the fires in Kuwait. The source term information is essential for risk assessment in regard to health effects, environmental/climate impact, and visibility.

Smoke samples were collected in the Al Maqwa oil field in Kuwait on May 15, 1991 from two locations illustrated on the map (Fig. 1). The first set was collected about 3 meters above ground at an "ambient" location; that is, the sampling was not from a plume but was from the oil field region. These samples are indicated as ambient oil field samples. The second set of samples, denoted as plume samples, was collected in the plume of a combination jet-pool fire at a height of about 1 meter. The ground level plume consisted of whitish smoke, while black smoke was emanating from the flames (See Figure 2). It was the whitish smoke that we were sampling.

The particulate was collected on quartz filters, polytetrafluoroethylene (PTFE) filters, on stages of a cascade impactor, and on carbon coated transmission electron microscopy (TEM) grids. Volatile polycyclic aromatic hydrocarbons (PAHs) were collected downstream on XAD-2 sorbent and CO and CO₂ were collected in PTFE sampling bags. The sampling procedures are described in more detail below.

The smoke analysis included the determination of the mass of particulate on the filter, the relative amounts of organic and elemental carbon in the particulate, the PAH content of the particulate and gas, the chemical composition by laser microprobe mass spectroscopy (LMMS), and the particle size distribution by transmission electron microscopy and by cascade impactor. Gas chromatography was used to analyze the CO and CO₂ concentration in the gas samples.

SMOKE SAMPLING

Smoke samples were collected on 47 mm diameter quartz fiber filters for thermal-optical analysis of organic versus elemental carbon content. Standard precautions were taken to avoid sample contamination before sample collection by heating the filter for two hours at 700°C to remove organic contaminant and also heating the aluminum foil used to line the sample containers to 500°C for several hours. All filters and impactor substrates were weighed and sealed with Teflon tape in Petri dishes lined with aluminum foil. As a further precaution, sets of filters were placed in plastic bags partially filled with filtered air. After the samples were collected, they were resealed with teflon tape in Petri dishes and maintained at about 5°C to avoid evaporation of the organic fraction until they were analyzed. The sample flow was maintained at 67

cm³/s (4 L/min.) using a battery operated pump (Gillian¹), which contains a flow controller element to maintain constant flow with increasing pressure drop across the filter. A calibrated flowmeter was used to adjust the pump flow before collecting the smoke. A small fraction of the exhaust from the diaphragm pump, about 2 cm³/s, was directed to a 5 L PTFE gas sampling bag for subsequent CO and CO₂ analysis.

The PAH sampling train was operated at a flow rate of 50 cm³/s (3 L/min) and contained a 37 mm filter holder followed by a 8 mm OD by 110 mm long sorbent tube filled with two sections of XAD-2. Analysis of the second section allows detection of PAH vapor breaking through the first section. The entire sampling train including disposable filter holders, sorbent tubes, connectors, and PTFE filers were obtained from one vendor, SKC. The sorbent tubes were covered with aluminum foil to minimize exposure of the PAH collected on the XAD-2 to sunlight. After collecting the samples, they were sealed and kept at about 5°C.

A six stage cascade impactor (Marple Personal Cascade Impactor), which provides size segregated samples, was used at a flow of 33 cm³/s (2 L/min). The ambient sample collected by this method was too small for gravimetric analysis, but the size segregated samples were useful for single particle analysis by LMMS. Samples were also collected directly on carbon coated TEM grids (3-mm diameter, 0.13 mm thick, and 200 mesh copper). Two grids were attached to the metal sampling housing with double stick tape in the case of the plume sample and to the side of the Van just below the roof in the case of the ambient sample.

PARTICLE AND GAS ANALYSIS

Smoke Concentration and Yield

The mass concentration of smoke was determined from the total volume of air sampled and the mass of smoke collected. The plume samples were collected for about 20 minutes and about 1 mg of smoke particulate was collected. This is a convenient sample size for gravimetric analysis with a 0.01 mg sensitivity microbalance. The Kuwait ambient sample was collected for thirty minutes resulting in the collection of about 0.05 mg of particulate matter. The time averaged mass concentrations (See Table 1) for the two plume samples are $21 \pm 1 \text{ mg/m}^3$ and $15 \pm 1 \text{ mg/m}^3$ and $0.05 \pm 0.03 \text{ mg/m}^3$ for the Kuwait ambient sample.

The CO₂ concentration in the plume corresponding to the 21 mg/m³ smoke concentration is 650 ± 20 ppm by volume and the concentration in the Kuwait ambient sample was 380 ± 20 ppm as measured by gas chromatography (GC) equipped with a thermal conductivity detector operated at 200° C. The calibration of the GC was performed using NIST Standard Reference Material 2634, 789 ppm of CO₂ in nitrogen with an accuracy of \pm 8 ppm. These values are to be compared with a reference ambient level of about 350 ppm in a pristine environment [1]. The CO concentration was below the detectable limit for the instrument (60 ppm).

From the measurement of the smoke collected on the filter and the CO₂ concentration, the smoke yield of whitish smoke in terms of grams of smoke per gram of fuel can be computed using the following equation [2]:

$$e = Y_c F_c \quad , \tag{1}$$

where F_c is the mass fraction of carbon in the crude oil and Y_s is the mass of smoke particulate divided by the mass of carbon in the combustion products including smoke and CO_2 . We estimate F_c as 0.86 based on elemental analysis for Arabian light crude and obtain Y_c of 0.13 based on the smoke mass on the filter, the CO_2 concentration minus the background concentration, and the volume of gas sampled. Using Eq.(1), we obtain a smoke yield of 0.11 g smoke per gram of fuel consumed. This number is an upper bound, since the mass of carbon in the form of volatile hydrocarbons is not included.

¹ Certain materials and equipment are identified in this report in order to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology.

Organic/Elemental Fraction

The organic/elemental carbon fractions were determined by Sunset Laboratory¹ using a method-defined analysis similar to that described by Johnson et al. [3]. The organic carbon was determined by measuring the carbon content of the vapors produced by heating the sample in a helium environment, and the elemental carbon fraction was determined by heating the residue in a mixture of 2% oxygen in helium. As indicated in Table 1, the organic content of the plume sample was found to be 92 ± 3 % and for the ambient sample was 72 ± 5 %.

PAH Analysis

Three PTFE filters (2 samples and 1 blank) and three XAD-2 cartridges (2 samples and 1 blank) were analyzed for polycyclic aromatic hydrocarbons (PAHs). The samples were fortified with perdeuterated derivatives of PAHs, which served as internal standards for the subsequent extractions and analyses. The samples were extracted with ultrasonic agitation in dichloromethane and the PAHs in the extract were measured using gas chromatography with mass spectrometric detection (GC-MS). Thirteen PAHs were measured in one of the PTFE filter samples (0.99 mg particulate loading, plume sample) whereas the other filter sample (approximately 0.05 mg particulate loading in the ambient sample) did not have detectable levels of the PAHs above the filter blank. Six PAHs were measured in extracts of XAD-2 cartridges collected downstream of a Teflon filter. Detectable levels of four of the six PAHs were observed on the downstream segment of one of the XAD-2 samples (each XAD-2 cartridge has two separate segments of the sorbent), suggesting that breakthrough occurred for those compounds on that cartridge. The details of the experimental procedure are described in the appendix.

Results of the PAH determinations of the filter and XAD-2 samples are shown in Tables 2 and 3, respectively. Except for a small phenanthrene contamination of 2.3 ng observed in the Teflon filter blank, the filter and XAD-2 blanks were free of PAHs. Significant concentrations of PAHs were observed in Filter 11 (plume sample) which was loaded with 0.99 mg of particulate matter (see Table 2). Detectable levels of PAHs were not observed in Filter 12 (ambient sample), which was composed of about 0.05 mg of collected particulate matter. A larger sample size would be needed to determine the PAH distribution in the Kuwait ambient. Results from the analysis of NIST SRM 1649, used in this study for analytical quality assurance (see Table 2), were in good agreement with concentrations listed in the SRM's Certificate.

Detectable levels of PAHs were observed in both the upstream and downstream XAD-2 segments of XAD-2 sample 11 (see Table 2). The PAHs measured on the downstream segment of XAD-2 sample 11 experienced breakthrough during sampling and may not have been collected quantitatively. Three PAHs were detected on the upstream segment of XAD-2 sample 12, with none detected on the downstream segment, suggesting that the PAHs were collected conservatively on the upstream XAD-2 segment.

As indicated in Table 4, the whitish plume smoke is more than a factor of five higher in the amount of benzo[a]pyrene, which is often used as an indicator of the health impact of PAHs, per gram of sample than either Alberta sweet crude oil or the urban dust standard; on the other hand, it is about a factor 10 lower than the black sooty smoke collected during the burning of Alberta sweet crude in the laboratory. This source information is one of the elements of a health effects analysis, which would also include the concentration of particulate to which individuals are exposed.

Laser Microprobe Mass Spectroscopy

The laser microprobe (LAMMA 500) is a time of flight mass spectrometer that utilizes a Nd:Yag pulsed laser as the ablation and ionization source [4]. LMMS has been used in a previous study on carbonaceous particles in regard to source identification of atmospheric soot [5]. Particulate was analyzed from quartz fiber filters and from the particulate deposited on the 2 μ m cutoff size (sixth stage) of the impactor transferred to a quartz cover slip for the microprobe analysis. The negative ion spectra of the smoke particle is shown in Figure 3. The carbon clusters ranging in size from C_2 to C_{10} is typical of all carbonaceous

material. The peaks at 16 (O⁻), 32, and 35 (Cl⁻) may be characteristic of the smoke, but they also may arise from the fine ambient dust. LMMS analysis for possible PAHs was conducted by operating the laser at low power to gently desorb material from the smoke. The positive ion spectra (Figure 4) suggests the likely presence of PAH compounds. Peaks at m/z=252 could be the 5 ring benzo[a]pyrene, 276 and 302 could be six ring PAHs, and 326 could be a 7 ring PAH. There are peaks not shown on this plot extending out to m/z=450. Compared to the positive ion spectra for ambient samples collected in urban areas and to soot from the burning of acetylene, it appears that the Kuwait smoke results in larger PAH type structures. Such information may useful in source apportionment though additional analytical measurements may be needed on remote samples to distinguish the crude oil smoke from other combustion sources such as wood burning.

After examining the impactor sample by LMMS, the 2 μ m sample was low temperature ashed in an oxygen plasma to remove carbon. The sample, viewed under light microscopy at 320X, revealed small dust or sand like particles. The laser microprobe analysis demonstrated that the particles are composed mostly of Si and have some Ba. Sand-like materials may be a significant portion of the aerosol.

Transmission Electron Microscopy

A TEM grid exposed to ambient smoke was analyzed with a JEOL 200 CX transmission electron microscope. Two smoke agglomerates were detected and their micrographs are shown on Figure 5. The larger agglomerate has an overall length of about 10 μ m with primary particle diameters ranging from 0.05 μ m to 0.2 μ m. The smaller agglomerate has a length of about 1.5 μ m with primary particle diameters ranging from 0.15 to 0.3 μ m. Compared to soot observed in laboratory scale burns, the two smoke agglomerates collected in Kuwait seem to have larger, less well defined primary spherules.

PRELIMINARY CONCLUSIONS/RECOMMENDATIONS

Limited data was obtained from one ambient site and one plume so that the conclusions we draw must be considered suggestive rather than definitive. Perhaps the greatest benefit of the measurements is to sharpen the focus of future studies in terms of the types of samples to be collected and the chemical analysis to be performed to allow quantitative characterization of the smoke source term for use in risk assessment.

- 1. The combination jet-pool fires produce a whitish ground level smoke that is primarily made up of organic carbon and a sooty plume emanating from the flames. Based on this observation and the high organic level of the ambient sample, we hypothesize that the whitish ground level smoke is the main component of the ambient aerosol in the local region (the country of Kuwait). To test this hypothesis, we recommend that a range of chemical measurements including organic/elemental carbon fraction be made in the whitish plume, in the sooty plume, and at several monitoring locations in Kuwait.
- 2. The carbon balance method indicates an upper bound of the white smoke yield as 0.11 g smoke per gram of fuel consumed. There is a need to include measurement of organic volatiles to obtain a more accurate estimate of the yield. Smoke yield measurements of both the black and white smoke need to be combined with burning rate information, wind velocity, and concentration for estimating the smoke emission from individual fires.
- 3. The benzo[a]pyrene in the whitish plume smoke for the one sample collected is mid range between that of soot from a laboratory crude oil burn and that of crude oil itself. It is recommended that the PAH analysis be made of the Kuwait crude oil, the whitish smoke, the black smoke, and of the ambient aerosol.
- 4. The LMMS spectra show potential for providing tracer information on a particle by particle basis for Kuwait smoke. It is recommended that smoke samples be collected from several wells together with samples of the crude oil. Single particle methods including LMMS, analytical electron microcopy, and Raman scattering should be applied to determine their applicability for source identification.

- 5. Transmission electron microscopy results, while very limited, suggest that the primary size of the smoke agglomerates is larger than is observed for laboratory scale burns. It is recommended that both electron microcopy and cascade impactors be used to quantify the size distribution and structure of the smoke from various well fires. The cascade impactor should also be used for collecting particulate smaller than $2.5 \mu m$ aerodynamic diameter for chemical analysis. Particles in this size range can penetrate deep into the respiratory tract and are of concern for their health impact.
- 6. Certified Reference Materials, when available, should be used as internal quality assurance tools by all laboratories involved in the Kuwait Oil Well Fire measurement activities. A listing of NIST Standard Reference Materials appropriate for the smoke related activities is available upon request.

ACKNOWLEDGEMENTS: James Brown measured the CO_2 concentration in the bag samples and Nelson Bryner and Randall Lawson assisted in the preparation of the smoke particulate and gas sampling equipment.

REFERNCES:

- 1. Dorko, W.D., personal communication.
- 2. Mulholland, G.W., Henzel, V., and Babrauskas, V. "The Effect of Scale on Smoke Emission," Proceeding of the Second International Symposium on Fire Safety Science, Hemisphere, N.Y., 347-357, 1989.
- 3. Johnson, R.L., Shah, J.J., Cary, R.A., and Huntzicker, J.J. in <u>Atmospheric Aerosol: Source/Air Quality Relationships</u>, ACS Symposium Series #167, Washington, DC, (1981).
- 4. Hercules, D.M., Day, R.J., Balasamugan, K., Dang, T.A., and Li, C.P., Anal. Chem. 54, #2, 280A (1982).
- 5. Currie, L.A., Fletcher, R.A., Klouda, G.A., Nucl. Instrum. Methods Phys. Res., Sect. B, 29, 346 (1987).
- 6. Benner, B.A., Bryner, N.P., Wise, S.A., and Mulholland, G.W., "Polycyclic Aromatic Hydrocarbon Emissions from the Combustion of Crude Oil on Water," <u>Environmental Science and Technology</u>, 24, 1418-1427 (1990).
- 7. Koseki, H. and Mulholland, G.W., "The Effect of Diameter on the Burning of Crude Oil Pool Fires," Fire Technology, 27, 54-65 (1991).

Table Captions.

Table 1	Analysis of Smoke from Kuwait Oil Fires	
Table 2	PAH Concentration Observed in Kuwait Air Filter Samples	.•
Table 3	Masses of PAHs Observed in Kuwait XAD Samples	
Table 4	Comparison of PAH Content of Smoke, Dust, and Oil	
Table 5	Gas Chromatographic and Mass Spectrometric Conditions used for PAH Measurements of the Kuwait Samples	f

Figure Captions

- Figure 1 Map indicating ambient (1) and plume (2) sampling sites relative to the Kuwait International Airport.
- Photograph showing whitish ground level smoke and black smoke from a combination jetpool Fire. The plume sample was collected 1 meter above the ground near the right hand side of the picture.
- Figure 3 Negative Ion Mass Spectrum of Ambient Kuwait Smoke

Figure 4 Positive Ion Mass Spectrum of Ambient Kuwait Smoke

Figure 5 Transmission Electron Micrographs of Ambient Kuwait Smoke. Left picture 6,000X, middle 20,000X of same agglomerate, Right 30,000X of second agglomerate.

APPENDIX: PAH ANALYSIS

The PTFE filters were transferred to 50 mL centrifuge tubes, spiked with 10 μ L of a standard containing 7 perdeuterated PAHs and extracted ultrasonically in 25 mL dichloromethane (DCM) for 20 min. A particulate matter Standard Reference Material with known PAH concentrations (SRM 1649, Urban Dust/Organics) was processed through the same procedure as the filter samples and served as a quality assurance sample. The filters were removed from the tubes and the extracts were centrifuged at approximately 10,000 g's for 1 min. This centrifugation did not clarify the extracts so they were concentrated under N_2 to < 2 mL and passed through a 0.2 μ m pore syringe filter (Anotop 10). The filter and SRM extracts were finally concentrated to < 100 μ L in 4 mL amber vials prior to GC-MS quantification.

The upstream and downstream segments of each XAD-2 tube were processed separately to check for breakthrough of any PAHs collected in the vapor phase. The XAD-2 cartridges were scored above the upstream segment of sorbent and the different segments were spiked with the perdeuterated PAH standard described above and extracted ultrasonically for 15 min with 10 mL DCM in 15 mL centrifuge tubes. The XAD-2 extracts were transferred to other 15 mL tubes and concentrated under N_2 to $\leq 100~\mu$ L.

Two microliter volumes of each sample extract was injected onto the GC column. Details of both the GC and MS conditions are specified in Table 5. Each sample was analyzed one time, using a PAH standard solution (prepared at NIST) as a calibrant.

Table 1. Analysis of Smoke from Kuwait Oil Well Fires

PROPERTY	PLUME	AMBIENT	LAB. SCALE ^a
PARTICULATE CONCENTRATION	$\begin{array}{c} 21 \pm 1 \text{ mg/m}^3 \\ 15 \pm 1 \text{ mg/m}^3 \text{ b} \end{array}$	$0.6 \pm 0.3 \text{ mg/m}^3$	100-200 mg/m ³
CO ₂ Concentration	650 ppm	350 ppm	1000-2000 ppm
Smoke Yield	0.11 g smoke/g oil ^c	-	0.09 - 0.15 g sm./g oil
Organic Fraction	92 ± 3 % ^d	72 ± 5 %	14 - 21 %

^a Lab. Scale refers to data for Alberta sweet and Arabian light crude pool burns at the scale of 0.6 to 3 m in diameter [6,7].

The error bounds are based on the uncertainty in the gravimetric determination of smoke particulate collected.

^c This value represents an upperbound.

The error bounds reflects the precision of the analysis.

Table 2. PAH Concentrations Observed in Kuwait Oil Fire Particulate Samples

<u>PAH</u>	(ng/mg unless FILTER Blnk (ng)	PLUME b	rwise) <u>AMBIENT(ng)</u> c	<u>SRM 1649^d</u>
phenanthrene	2.3	100	< 2.3	5.0 (4.5)
anthracene	< 1	30	< 1	0.62 (0.6)
fluoranthene	< 1	76	< 1	7.1 (7.1)
pyrene	< 1	84	< 1	6.1 (7.2)
benz[a]anthracene	< 1	28	< 1	2.7 (2.6)
chrysene	< 1	34	< 1	3.3 (3.6)
benzo[b]fluoranthene	< 1	17 ·	< 1	5.8 (6.2)
benzo[k]fluoranthene	< 1	9.0	< 1	2.0 (2.0)
benzo[e]pyrene	< 1	21	< 1	3.6 (3.3)
benzo[a]pyrene	< 1	19	< 1	2.7 (2.9)
perylene	< 1	5.8	< 1	0.77 (0.8)
indeno[1,2,3-cd]pyrene	< 1	13	< 1	3.1 (3.3)
benzo[ghi]perylene	< 1	15	< 1	4.2 (4.5)

^a Uncertainties estimated from the measurement precision to be ± 10 % of the listed concentrations or masses.

b Plume sample - filter #11.

^c Ambient sample - filter #12.

Concentrations in parentheses are the assigned values for Standard Reference Material 1649 [Urban Dust/Organics], analyzed for quality control purposes.

Table 3. Masses of PAHs Observed in Kuwait XAD Samples

РАН	XAD BLANK	(ng) PL.XAD UP ^b PL XAD DOWN ^b	AM. XAD UPC	AM. XAD DOWNC
phenanthrene	< 0.5	400 55	17	< 0.5
anthracene	< 0.5	50 4.4	< 0.5	< 0.5
fluoranthene	< 0.5	32 2.3	0.69	< 0.5
pyrene	< 0.5	26 1.9	0.92	< 0.5
benz[a]anthracene	< 0.5	0.71 < 0.5	< 0.5	< 0.5
chrysene	< 0.5	0.78 < 0.5	< 0.5	< 0.5

 $^{^{}a}$ Uncertainties estimated from the measurement precision to be \pm 10 % of the listed masses.

b Plume XAD - Sample #11.

^c Ambient XAD - Sample #12.

Table 4. Comparison of PAH Content of Smoke, Dust, and Oila

Sample	Total PAH/g sample ^b	benzo [a] pyrene/g sample					
Kuwait whitish smoke	490 μg, (16 μg/m ³) ^c	19 μg, (0.3 μg/m ³)					
Lab. Scale ^d	4800-5200 μg	180 - 240 µg					
Alberta sweet crude	1400 μg	less than 3 µg					
urban dust standard	about 50 μg	2.7 μg					

^a Uncertainties estimated from the measurement precision to be \pm 10 % of the listed masses.

b The total PAH refers to PAHs collected on the filter and does include the contribution of the volatile fraction listed in Table 3.

^c The numbers in () refer to the mass concentrations of PAH in air.

d The results for the lab scale burns and the crude oil are taken from reference [6].

- Table 5. Gas Chromatographic and Mass Spectrometric Conditions used for PAH Measurements of the Kuwait Samples

Gas Chromatography

Column: 25 m x 0.2 mm (0.15 µm phase) Smectic liquid crystalline phase

Carrier: He, 6 psi head pressure

Temperature Program: 37 °C (2 min hold), 30 °C/min, 200 °C, 3 °C/min,

270 °C (hold)

Injector: Cool on-column.

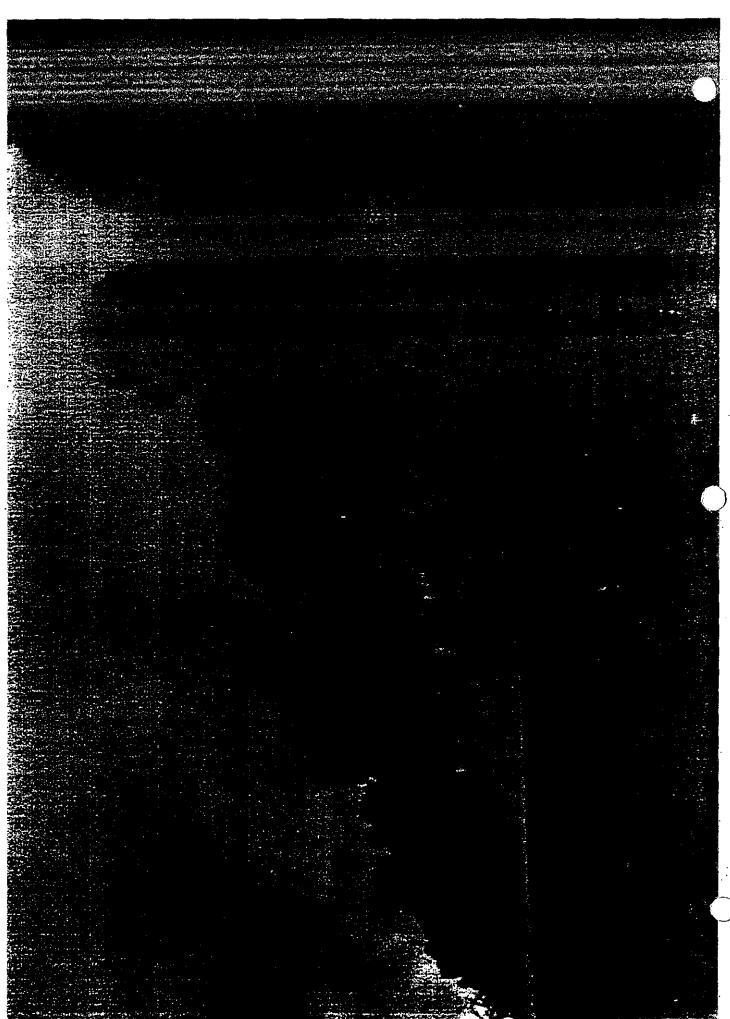
Detector Temperature: 270 °C.

Mass Spectrometry

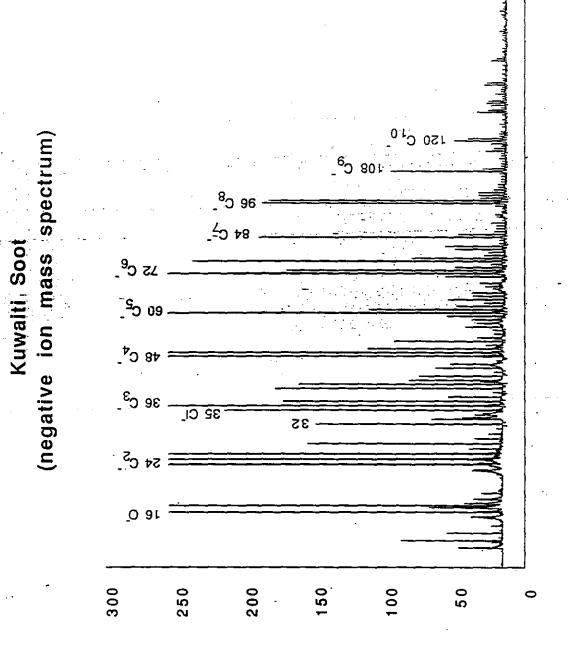
Electron Multiplier Voltage: 2500 V. Selected Ion Monitoring Program:

Time (min)	Masses Monitored (amu						
3 - 16	178, 188, 202, 212						
16 - 26	228, 240						
26 - 44	252, 264 ·						
44 - 65	276, 288						

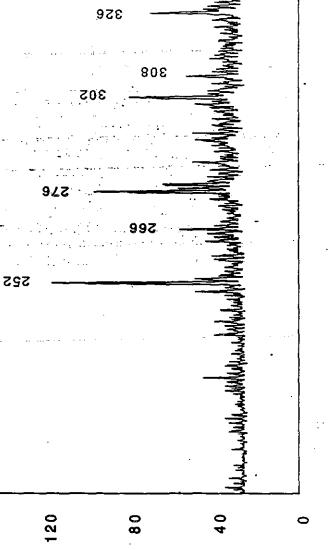
Figure 1.







Intensity



Intensity

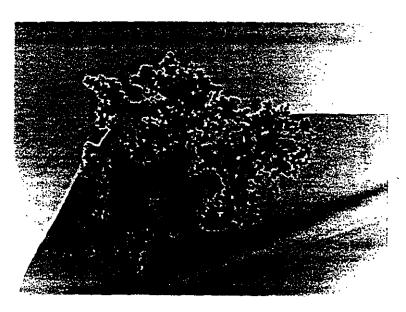
Kuwait Sample (positive ion, high mass region

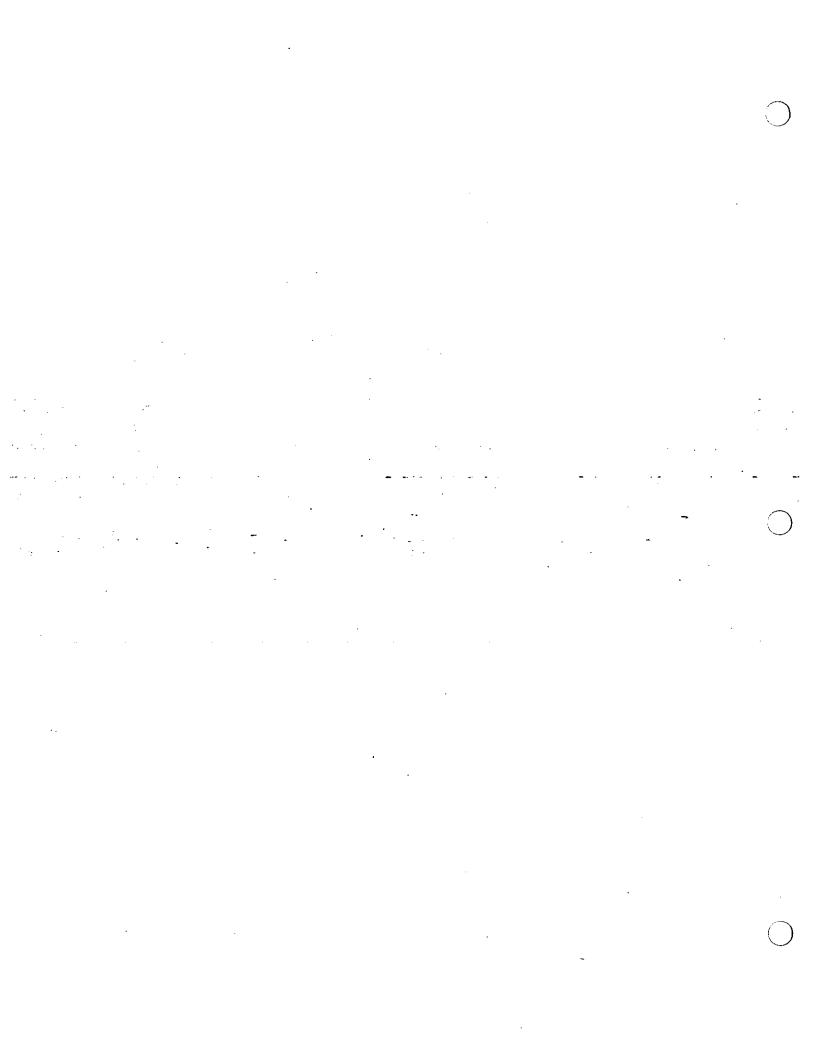
200

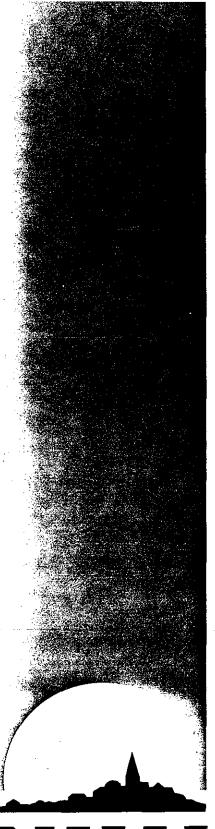
z/m

Figure 4









NILU RR : 6/91 REFERANSE: O-91042

DATO : JUNE 1991

Air Quality Monitoring in Kuwait

First NILU Mission, 5—12 June 1991

B. Sivertsen T. C. Berg



NORSK INSTITUTT FOR LUFTFORSKNING Norwegian Institute for Air Research POSTBOKS 64 - N-2001 LILLESTRØM - NORWAY

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AIR QUALITY MONITORING IN KUWAIT FIRST NILU MISSION, 5-12 JUNE 1991

1 INTRODUCTION

The Norwegian Institute for Air Research (NILU) has been asked by UNEP/WHO to plan and undertake air quality studies in Kuwait. The NILU tasks are part of the UN Inter-Agency Action Plan for the Gulf-region. The total Norwegian support amounts currently to 1 million USD, which has been transferred to UNEP in Nairobi. The Norwegian objective was to combat the destruction of the environment in Kuwait and the Gulf region through the contribution of 1 mill. USD to acquire the necessary air quality equipment.

NILU has submitted project proposals to several parts of the "Proposal for air pollution programme in connection with Kuwait oil field fires", presented by WHO on 13 May 1991. The latest versions of these proposals were:

- NILU monitoring stations for Kuwait (27 May 1991). Two permanent and one mobile station.
- NILU sampling stations for downwind support (27 May 1991).
- Use of dispersion models in an air quality surveillance and control programme for Kuwait (28 May 1991).

2 OBJECTIVES

The objectives of the first mission to Kuwait was to:

- Get acquianted with the existing air quality and meteorological monitoring systems already available.
- Present and discuss the NILU proposals with local authorities.
- Visit existing and planned sites for air quality monitoring.

 Visit to the NILU measurement site at the UNIKOM/NORMEDUNIT in Umm Quasr.

3 UNEP FUNDS AVAILABLE FOR NILU

In a meeting with Dr. David Mage in Geneva we were informed that from the 1 mill. USD transferred from Norway to UNEP in Nairobi, only 353.000 USD is available for the air quality monitoring in Kuwait to be performed by NILU. 375.000 USD was transferred to WMO, 72.000 USD went into UNEP (13% overhead), WHO has reserved 150.000 USD for the Heal-study and 50.000 USD were assigned for WHO services.

From the WMO transfer ~40.000 USD has been assigned for the "warning centre" and ~34.000 USD for the repair centre. Some of the money could be used for NILU work under the budget items mentioned. These matters have to be cleared with WMO.

4 VISIT TO UNIKOM-NORMEDUNIT IN UMM QUASR

After obtaining UN identification cards as UN representatives in Kuwait, we could visit the Norwegian NORMEDUNIT in Umm Quasr. The camp is located in the UN controlled zone within the old Iraqi territorium. Major Hoel and P.O. Vinjevold have been undertaking air quality measurements at the field hospital since 7 May 1991.

We inspected the NILU automatic air sampler (FK), the wind recorder (Woelfle) on a 2 m mast, and the PAH (PUF) sampler. All equipment have been operating perfect. Vinjevold is doing a professional job with the equipment.

The following data were obtained for analysis at NILU:

- Wind records, 7 May 7 June 1991
- One PAH filter, 21 May 1991, 0700-1300 hrs (highly polluted)

- One FK-filter for analyses of soot, and microscopical analyses for identification of particles.

The plumes from the burning oil fields to the southwest have only rarely hit the hospital area. This is due to a predominant fairly strong north westerly flow during spring and summer. Conditions might be considerably worse during the fall season.

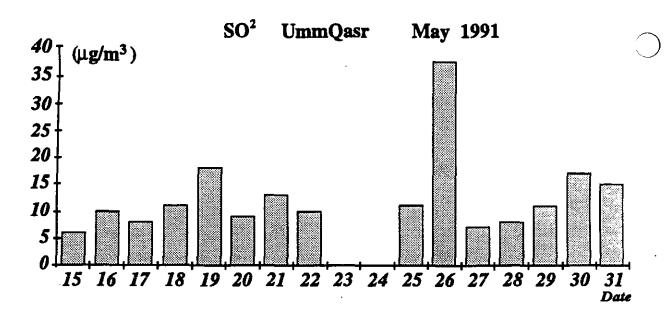
During one day on 16 to 27 May the smoke hit the Umm Quasar area. The 24 h average concentrations of SO_2 and soot were recorded to 36 μ g/m³ and 399 μ g/m³ respectively (see Figure 1).

The wind recorder is located in the middle of an open field (~100 \times 60 m^2) with high trees 30 m to the east and south and low buildings to the north.

After discussions with Major T. Munkelien and T.M. Hoel its was decided that samples (filters and bottles) should be sent by personnel travelling between Kuwait and Norway every two week. We will prepare two NILU bags for this purpose. A test using DHL from NILU via the Norwegian embassy in Kuwait proved successful. A package of 15 kg reached the embassy in 5 days from NILU, and is being picked up by UN personnel in the Embassy.

THE MONITORING STATIONS IN KUWAIT

We were informed by dr. Mostafa el Desouky about the monitoring network in Kuwait. Three stations; Mansoria, Rabia and Riqqa have been in operation for years (see map, Appendix C). Rabia has been used for repair and spare parts, which means that only two stations are operating at the moment. At these locations the following parameters are measured every 5 minute: SO_2 , H_2S (sulphate), NO, NO_2 , O_3 , CO, HC (NMHC), temperature, relative humidity, wind direction and speed. We also visited the station in Mansoria. (Fore a more detailed description of the site, see Appendix B). Data are collected on a cassette tape and printed out on a digital desk writer every 5 min. Manual calibration



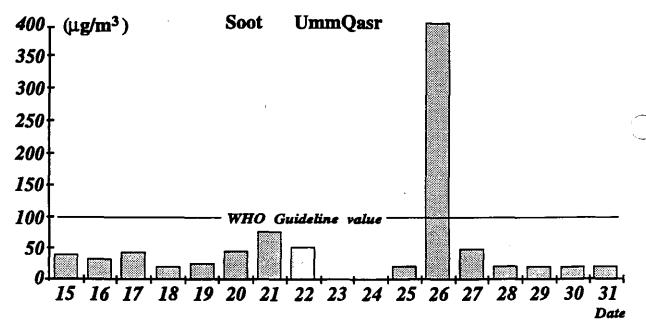


Figure 1: 24 h average concentrations of SO₂ and soot measured at the NORDMEDUNIT Hospital in Umm Quasr during 15-31 May 1991

and zero adjustment are carried out every 15 to 21 day. Automatic span cheque is performed every 25 h. Span gases have to be imported and are bought at fairly high concentrations. For SO_2 the concentration is 407 ppm, which is diluted in the instrument by a factor 1/1000.

The wind sensor is a Swiss made propeller (Gill type) with three axis. The bearing on the propeller is changed every 6 month to 1 year. The vertical propeller is not recorded at present. It might be possible to obtain a rough estimate of the one hour average $\sigma_{\rm w}$ -value.

Data on the cassettes are brought to the central computer at the Environmental Protection Department (EPD). Statistical evaluations are performed on a VAX main frame computer.

6 ENVIRONMENTAL PROTECTION DEPARTMENT (EPD)

In the EPD we had several meetings with dr. Ibrahim Hadi, dr. Mustafa el Desouky, dr. Mahmood Y. Abdulrahem, dr. Mohamed Abel and others. The EPD presents monthly and annual reports on the air quality monitoring programme. Some results are presented in Appendix C. Results from measurements performed after the war were also obtained. These are presented in Appendix D.

During the discussions we were told that several attempts have been made to estimate the emissions of gases and particles from the oil fires. None have been successful so far dr. Desouky claims. He indicated that 6 mill. barrels of oil burns every day at ~3000 °F. About 5% (some claims up to 15%) of the oil is not burned. This means that ~40.000 tonnes of soot and smoke is produced every day. With an assumption of 4.1% S in the oil, ~65.000 tonnes of SO₂ and ~40.000 tonnes of NO₂ is released into the atmosphere every day. We also received a map showing the remaining oil wells on fire as of 9 June 1991 (Appendix E).

Some of the plumes are white, which as assumed to be caused by groundwater vapourized into the plume. This vapour plumes have not been verified by aeroplane measurements performed by American scientists.

High concentrations of SO_2 dr. Desouky claimed, have not been measured downwind from the oil fires. (This is not in agreement with French measurements performed in April). Two week averages of PM_{10} have been measured at 400 to 460 μ g/m³. One day (on 9 April 1991) it was recorded 1160 μ g/m³ at a hi vol sampler in Addan hospital.

The meteorological conditions are at present beneficial for the air quality of Kuwait City. During a visit to the south of the city we could see the black clouds (~70 km from the city) darkening the sky making day into night. It is assumed that when the predominant strong winds from north east weakens during August and the winds become light and varying, the conditions get considerably worse for the larger part of the population living in Kuwait city.

Discussions with Mr: Yosi, responsible for computer operations at EPD, revealed that air quality data at present are collected every 4 day on cassette tapes. Data every 5 min are transferred to the Vax main frame computer (see Appendix F). The computer is a Vax 11/730 with VMS system version 4.4. and has no capacity for modelling purposes. NILU will have to provide a PC for data communication via modem (telephone lines) to the central.

7 THE LABORATORY IN SHUWAIKI

Dr. Mahmood Y. Abdulraheena, miss Sabah and others met with us at the laboratory in Shuwaiki. At the roof of one of the buildings we saw 2 Andersen type Hi-Vol samplers with filters and PUFs, one SO₂ bubbler for 24 h average concentrations (manually changed every morning) and a simple dustfall collector.

A semimobile lab (belonging to the University) was being built up again after the war. This isolated "container on weels" for pulling after a car was typically located for measurements during two weeks at each site.

The van had a cooled entrance room. In the air conditioned main lab. was one HC-analyzer (model 810 from Thermo-Environmental Inc.). Also the NO/NO_x (mod. 14), and a SO_2 (mod. 43 A, UV-fluorescens) was from Thermo Environmental. A met-one wind system, a CO monitor with calibration unit, and a Sum X datalogger and printer for printouts every 5 min. was included in the van. Problems with some of the instruments are not yet solved. They have, however, planned to move the van to the south of Kuwait City to catch the center plumes from the burning oil wells.

Inside the lab we were presented to the analytical procedures and equipment. It was impressive to see how much this group has managed to keep away from the plundering and damaging during the war. Among the equipment was one SP 190 Automatic Absorption Spectrometre, Autoanalyzer (UV and IR), Perkin Elmer Sigma 115 Gas Chromatographs (some of the newer GCs were taken by the enemy), and one HP GCMS 5995.

Hi-Vol filters are devided into 4 parts, one analyzed for SO_4 , NO_3 , Cl, Na, K and Ca, the second for heavy metals and the last two for organic compounds. About 30 filters are analyzed each month. PAH are analyzed at present for 11 compounds on filter. An example chromatogram show a benzo(b) fluorethene + benzen c concentration of ~96 pg/m³. The lab also uses Tenax tubes for VOC analyses. An example of a "fingerprint" of burning crude oil was presented (Apendix G). The laboratory also has used a Monostatic Sodar system from Aeroenvironment to estimate mixing heights and surface based inversion heights in Kuwait city (Appendix G B)).

8 VISIT TO THE NILU MONITORING SITES

Two sites for the NILU monitoring stations have been selected:

- Jahra, at the hospital 30 km west of EPD.
- Mina Al Zoor, at a power plant site, 80 km south south-east of EPD.

At <u>Jahra</u> the NILU station will be located at the roof of the hospital building (3 stories). Power is available a few metres from the site. Telephone lines can be obtained from the building. A truck with a lifting crane can move all the way into the building and place the NILU container on the top of the building.

At <u>Mina Al Zoor</u> the NILU container will be placed on the roof of a low building in the living quarter at the north western corner of the power plant site. Power is available. Telephone lines will be made available.

9 THE NOAA METEOROLOGICAL NETWORK

The US NOAA (National Oceanic & Atmospheric Administration) is at present locating 18 meteorological stations distributed all over Kuwait (see map Appendix H). In charge of the US team is William Pendergrass (NOAA, Oak Ridge) with whome we met. In addition to the meteorological network, US EPA has also brought in 9 PM_{10} particle samplers. The locations of these samplers are presented in Appendix H B).

The meteorological stations are equipped with R M Young Campel type wind propellers on a wind vane for measurements of horizontal wind directions and wind speeds included estimates of standard deviations. Pressure, temperature and relative humidity is also recorded. The data are transferred via radio communication to the central CPB office every hour. A data file is created with 5 min, 15 min and 1 h average data on a IBM AT

computer. Each station has also a local storage capacity of two days.

Data can be achieved from the IBM computer in ASCII-format. NOAA will create wind fields every hour in a 1 to 10 km grid. It should be no problem to establish an interface between the NOAA wind field output data, to the NILU dispersion modelling system (on HP Apollo). An example of a first temperature plot created at CPB on 9 June 1991 is shown in Appendix H C).

10 HEALTH INVESTIGATIONS

We were pleased to arrange a meeting between dr. Mustafa El Desouky and two Norwegian medical doctors; dr. Jens Holmboe, UNIKOM forces in Kuwait city and dr. Tor M. Hoel, NORMEDUNIT, Umm Quasr. Dr. Holmboe will spend one year in Kuwait, and is planning to perform a medical study (investigation) on a selection of one hundred persons highly exposed and less exposed to the plumes from the burning oil wells.

Dr. Holmboe briefly presented a first draft of a project proposal, where he indicated that a number of people would be followed every 2 month for the first half year and thereafter every 6 month. Several different types of chest studies and X-ray investigations will be undertaken.

During the discussions it was also mentioned that the Kuwait Health Department will perform a cohort investigation on ~500 persons in the Riqqa region. These are supposed to be followed up during the next 20 years. People selected from 11 clinics in Kuwait are also followed with various kind of "objective studies".

NILU pointed out the importance of establishing dose/response relationships. It was understood that also good air quality data and exposure estimates had to be available parallel to the health data.

11 WATER PROBLEMS

We briefly discussed other environmental problems in Kuwait. There is a comprehensive need for support in the field of water research. Kuwait needs "everything from simple pH-metres to research vessels". Drinking water quality problems have not been specified due to lack of instruments for bacterial counts etc. Atomic absorption instruments for analyses of water samples were destroyed during the war. Marine and sewage problems are also evident without enabling quantifying. Dr. Mahmood Y. Abdulrahmuna will visit Paris from 11 June 91 to "cry for help".

The Norwegian Institute for Water Research (NIVA) has been notified. A description of the problem, which was presented by dr. Mahmood, has been sent NIVA.

12 NORWEGIAN EMBASSY

We visited the Norwegian Embassy in Surra, Block 13, Street 13 where we met with mr. Jan Bråte, mr. Bjørn Bjerkås and mr. Bjørn Eriksen (Eksportrådet). Mr. Jan Bråte was informed about the NILU project plans, about the financial situation and about the results of discussions and site inspections in Kuwait.

13 PROTOCOL

A protocol with conclusions and agreements was established at the end of the visit to Kuwait. This protocol is presented in Appendix I.

APPENDIX A

- A) APPLICATION FOR VISUM TO KUWAIT
- B) PEOPLE WE MET



ORGANISATION MONDIALE DE LA SANTE

Téléphone Central/Exchange: 791.21.11

Direct: 791

Consulate General of the State of

Kuwait GENEVA

In reply please refer to :

Prière de rappeler la référence:



05 June 1991

The World Health Organization in Geneva presents its

compliments to the Consulate General of the State of Kuwait in Geneva

and has the honour to submit to them the enclosed

passport No G 0036655-7 issued to Mr Bjarne SIVERTSEN

being of norwegian nationality who is travelling on

official duty for the World Health Organization to Kuwait

on 5 June 1991

The World Health Organization therefore requests that this document be endorsed with

an entry visa valid 1 week within three months

The World Health Organization takes this opportunity of renewing to the Consulate General of the State of Kuwait its assurance of high esteem.

Annex : 1 laissez-passer

2 forms

2 photos

PEOPLE WE MET

Mr. Ibrahim M. Hadi, director EPD/secretary of EPC

Dr. Mostafa El Desouky, technical advisor, EPD

Dr. Mahmood Y. Abdulraheem, dep. dir., EPD

Mr. Yosi Malek, computer facility, EPD

Eng. (miss) Sabah Abd Al-Wa, responsible for monitoring stations, EPD-laboratory

Dr. Mohamed Abel, EPD laboratory

Mr. Ahmed Avorasiba, technical expert, EPD, head of workshop

Dr. Danny Foster, WMO representative

Mr. William R. Pendergrass, NOAA Oak Ridge, responsible for met. network

Mr. P.O. Vinjevoll, NORMEDUNIT, UNIKOM

Dr. Jens Holmboe, UNIKOM, health study, Kuwait city

Major Tor M. Hoel, NORMEDUNIT

Major Tor Munkelien, NORMEDUNIT, commander

Mr. Frøystein, NORMEDUNIT

Mr. Jan Bråte, Norske ambassade, Kuwait

Mr. Bjørn Bjerkås, Norske ambassade, Kuwait

Mr. Bjørn Eriksen, Eksportrådet, Ambassaden i Kuwait

ادارة حماية السئة وزارة الصحة العامة

مصطفىي النسوقيي

ص.ب: ۲۵۰۳۵ الشعب ــ الكويت تلكس : ٨٠٤٢} تلفون حکتب : ۲۲۵۹۸۳۲ فأكس : ٢٤٢١٩٩٣ منزل : ۲۰۲۷۲۰۰

Environment Protection Department Ministry of Public Health

Dr. Mostafa El-Desouky

Technical Advisor

DR. MAHMOOD Y. ABDULRAHEEM

Deputy Director

Environment Protection Dept. Ministry of Health

2451284

Tel. Off.: 2456832 Fax: 2421993 Res.: 5717303

P. O. Box 35035 Al-Shaab - Kuwait

Telex: 46408 EPCNCL KT.

P. O. Box 24395 Safat

Tlx.: 46408 EPCNCL

13104 Kuwait

Fax.: 2421993

د٠ محمود يوسف عبد الرحيم

نقب سدير ادارة حماية البيثة وزارة الصعبة

ص٠ب: ٢٤٣٩٥ منساة كــويت 13104

تلکس: EPCNCL {٦{٠٨ ناکس: ۲٤۲۱۹۹۳

ص.ب ۲۲۲۹۵

طغون: ۲۲۸۲۴ه۲۲ 371/037

النزل: ٢٨٦٢١٩٠



Tel.: 2456833

Resi. : 5386319

2456834

IBRAHIM M. HADI

Secretary

Environment Protection Council, and DIRECTOR

Environment Protection Department Ministry of Public Health

77A/037 فاكس ٢٤٢١٩٩٣

صفاة ـ كويت منزل ۲۱۹۷۶ه _ ۲۱۹۶۰۵ تلکس ۱۹۰۸ کونت

سكرتير مجلس حماية البيئة

مدير ادارة حماية السئة

وزارة الصحة المامة

Tel 2456835 2456836 Fax 2421993

Res. 5319405 - 5313374

P.O.Box 24395 Safat - KUWAIT Tix. 46408 EPCNCL

U.S. INTERAGENCY AIR MONITORING TEAM MEPA

966 - 3 - 857 5732, 5464, 6264, 5300 Ext. 411 / 412 / 417 966 - 3 - 857 6520, 6260, 0876, 1428 Ext. 32 Fax 966 - 3 - 857 5304, 6752

GULF MERIDIEN HOTEL 966 - 3 - 864 6000 - Fax 966-3-898 1651 Damy

UNITED NATIONS ENVIRONMENT PROGRAMME UN INTER-AGENCY PLAN OF ACTION IN THE ROPHE REGION

DR. PETER LITERATHY

Task Team Leader / Co-ordinator

de REGIONAL ORGANIZATION FOR THE PROTECTION OF THE MARINE ENVIRONMENT P.O. Box 26388 - 13124 SAFAT - KUWAIT Tel. Off: 5312140-3 - Tix: 44591 ROPME - Cable: ROPME Direct: 5335237

NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION ENVIRONMENTAL RESEARCH LABORATORIES ATMOSPHERIC TURBULENCE & DIFFUSION LABORATORY 458 SOUTH ILLINOIS AVE. PO BOX 2458 OAK RIDGE TN 37831-2456



WILLIAM R. PENDERGRASS PHYSICAL SCIENTIST

(615)576-6234 FAX (615)576-2222 (FTS)626-6234 FAX (FTS)826-2222

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APPENDIX B

THE HORIBA STATION IN MANSOURIA

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HORIBA STATION MANSOURIA

The station is built up in a container with an entrance room as a working place for the maintenance assistant while inspecting the station. Between the foreroom and the instrument room is a sluice to prevent dust from entering the instrument room.

Cooling off the instrument room is performed by 2 air condition units "windowtype" in the end wall.

The central intake was a 10 cm stainless steel tube through the roof ending in a small fan. All monitors took sample air from this intake. The instrumentation was as follows:

- 1. Horiba model APHA-2010 Hydrocarbon monitor. The measuring principle is a flame ionization detector (FID), a partial combustion unit and a time controlled valve which gives signal out for total hydrocarbons (THC) and non-methane hydrocarbons (NMHC). The central data logger computes the content of CH₄.
- 2. Horiba model APNA-2010 Nitrous oxides monitor. The measuring principle is a single channel chemiluminescense detector. A time controlled valve gives NO and NO_x as output. The data logger computes NO_2 as NO_x -NO.
- 3. Horiba model APOA-2010 Ozone monitor. The measuring principle is a chemiluminescense detector based on oxidizing of ethylene.
- 4. Horiba model APSA-2110 Sulphur monitor. The measuring principle is a flame photometer with a burning hydrogen flame. The monitor measures total sulphur (TS) which is defined as a sum of H_2 S and SO_2 . A scrubber which removes the H_2 S is put into the sample input with a time controlled valve to produce an output of SO_2+H_2 S=TS and SO_2 from the instrument. The H_2 S concentration is computed in the data logger.

- 5. Horiba model APMA-2010 Carbon monoxide monitor. The measuring principle is based on infrared absorption with reference to CO.
- 6. Meteorological instruments were mounted on a low mast at the roof. The instrumentation consists of:
 - a) A 3 axis propeller anemometer, Swiss type.
 - b) Temperature sensor based on termistor.
 - c) Relative humidity sensor, Vaisala Electrochemical type.
 - d) Pressure sensor
 - e) Solar radiation
 - f) Ultraviolet radiation
- 7. The particle concentration is measured with a "Digital Dust Indicator" (Aartac Inc., model P5) connected to the central intake. The principle is continuous measurement of 90 degrees scattered light.
- 8. All monitors, sensors and instruments are controlled by a data logger from the Swiss company ALCYON.

The data logger is controlling daily span and zero check on all instruments based on 25 hours intervals. Data is computed every 5 minutes and recorded on a cassette tape and on a printer. Every hour is a simple maximum, minimum and sorting on wind direction and speed statistics printed on the printer as well.

The calibration of the monitors is controlled manually every 21 days. This is performed by span gases with a dilution system of about 1:1000. Span gases for SO_2 , NO, CH_4 and CO is used.

The output to the tape and the printer is: Time, TS, H_2 S, SO_2 , THC, CH_4 , CH_4 , CO, NH_3 , NO_x , NO_2 , NO, O_3 , temperature, humidity, Ws, Wa, pressure, solar, UVR and dust. The system

has 2 spare channels for possible expansion. NH_3 is not measured on the Mansouria station, but on the other stations. The measuring principle is a converter connected to the NO/NO_x monitor.

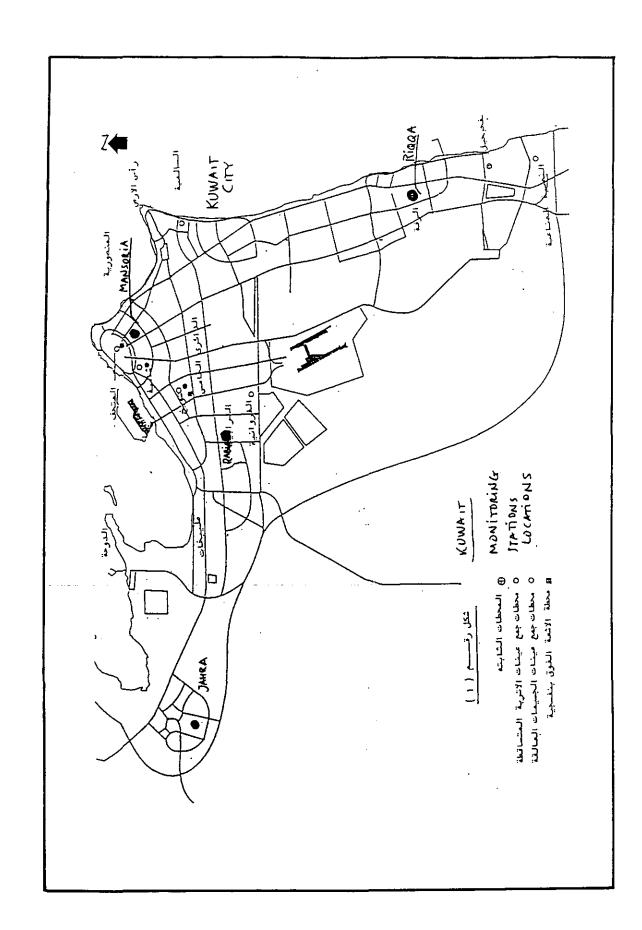
All systems are running on 110 Volt AC which requires a large 230/110 Volt transformer. The datalogger was equipped with a battery system for keeping the system clock undisturbed of mains failures.

The sample input to the monitors was protected with filters which had to be changed every week.

APPENDIX C

AIR QUALITY DATA JUNE 1990

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جـدول رقم (1)

MONTHLY MEAN CONCENTRATION OF THE GASES EXPRESSED AS PPM AND PPB RECORDED BY THE AIR POLUTION MONITORING STATIONS TOGETHER WITH THE MAXIMUM LEVEL AND THE PERCENTAGE DISTRIBUTION OF THE VALUES EXCEEDING THE THRESHOLD LEVEL DURING JUNE 1970

	!	 ! :				OCATIONS					
			MANSOR I A		! ! !	RABIA			REGA		
	GASES	MEAN!	MAX !	ZEX. LIMIT	MEAN !		XEX.		MAX !	NEX.	
:	TS IN PPB H2S IN PPB SO2 - IN PPB THC IN PPM NCH4 IN PPM NOX IN PPB NO IN PPB NO2 IN PPB CO IN PPB		85, 000 84, 000 12, 000 8, 060 6, 130 1, 520 460, 000 340, 000 178, 000 11, 910 0, 137	5. 5 0. 0	1. 431 28. 011 7. 665 20. 357 0. 803	863, 0001 142, 0001 9, 0701 4, 2501 6, 1301	16.5 1.2 1.2 87.1 87.1 2.8 3.3 0.0	2. 138; 0. 357; 1. 780; 33. 533; 10. 278; 23. 263; 0. 774;	20.000; 3.000; 7.410; 7.490; 4.600; 540;000; 445.000; 242.000; 37.060;	1. 3 0. 0 39. 2 5. 0 8. 3 0. 2	
	NH3 IN PPH		i			{	;	0.063	1.580;	10.8	

چـدول رقم (2 - ۱)

THE MEAN CONCENTRATION OF THE LEVEL OF SULFER COMPOUNDS EXPRESSED IN PPD RECORDED AT MANSORIA, RABIA & REQA DURING JUNE 1990 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

(!	יסד!				ENE SULF	HIDE !	SULPHER DIOXIDE		
: :	! MAN !	RA3	REG !	MAN !	RAB S	REG !	MAN !	RAB	REQ !
1 0-2 1	4.7651	36. 623	2. 166	3, 352	32, 372	0.706	1,335	4, 693	1. 203
: 3-5 :	5.014	39. 802	1.640	3. 580	35. 331	0. 232	1.355	4, 46B	1, 150
: 6-8 !	2.517	12. 908	1. 495	1.114	10.1771	0.101	1.347	2, 670	1.200
9-11:	1.601	2, 918;	1. 632	0.162	0. 604 (0.015	1.3781	2, 290	1. 276
12-14:	1. 572	2. 635	1. 931 :	0.002	0.3071	0.010	1.480!	2. 288	1.4721
15-17	1.617	4. 145	1. 949	0.000	2. 123	0. 003	1.511	2, 012	1.389:
18-20:	1.9801	7. 537	1. 9691	0. 214	5, 127	0. 297	1.7171	2, 441	1.329
21-23	1.759	6.0051	2.067	0. 185	3. 225	0. 537		2, 264	1.274

جـدول رقم (2 - ب)

THE MEAN CONCENTRATION OF THE LEVEL OF HYDROCARBONS EXPRESSED IN PPM RECORDED AT MANSGRIA, RABIA & REGA DURING JUNE 1990 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

1	ı			!			!		
į	! TOTAL	HYDROCAL	RBONS	NON-METHANE			•		
!	! MAN	! RAB	! REQ	! MAN .!	RAB .	REG			
1 0-2	2, 153	2.105	2. 192	0.306	0. 644	0, 32B	1,846	1, 461	1.853
3-5	2.090	1. 901	2. 117	0. 187	0. 517	0. 266	1,902	1.384	1.849
: 6-B	2. 171	1. 940	2.118	0. 334	0. 5961	0, 328	1,837	1.344	1.788
9-11	2. 180	1, 968	2. 139	0. 437	0. 5E21	0. 369	1.743	1.383	1.765
112-14	2. 090	2.059	1. 958	0. 391	0. 6211	0. 237	1, 698	1, 439	1.718
115-17	1. 959	2. 134	2. 041	0. 274	0. 4571	0. 3341	1, 679	1, 477	1.706
18-20	2. 141	2, 237	2. 351	0. 428	0. 7571	0. 584	1.709	1, 448	1.767
21-23	2. 234	2, 270	2. 308 ;	0. 480	0. 768	0. 5031	1.754	1, 502	1.804
,:	;	, ;				;		:	;

جـدول رقم (2. - جـ)

THE MEAN CONCENTRATION OF THE LEVEL OF NITROGENE COMPS.

EXPRESSED IN PPB RECORDED AT MANSORIA, RABIA & REGA DURING
JUNE 1990 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

1	·									
!	! TOTAL !	NITROCEN	E OXIDES	! NITRO	SENE MON	OXIDES	NITROGENE DIOXIDE			
1	! NAN	RAB	! REG !	MAN !	EAR	REQ :	MAN	RAD :	REQ !	
: 0-2	11.409	1 17. 670	: 23. 107	2, 925	4.710	5. 220	8.481	13.015	17.807	
1 3-5	4.844	12. 667	13. 256	0.1741	3, 055	1.724	4, 669	9. 623	11.512	
1 6-8	29. 576	: 37, 501	34.721	9. 0991	15.033	9. 586	20.479	22. 480	25. 114	
: 9-11	26.054	24. 021	27. 052	1. 350	3. 940	3. 814	24. 710	20. 052	23. 329	
112-141	20, 758	17. 674	14. 636	0. 3351	3. 254	2. 892	20. 317	14. 438	11.707	
:15-17:	23. 632	24. 085	22. 664	1.130;	5. 042	5. 195	22. 420	19. 017	17.418	
:18-20	53. 833	50.001	68.075	12. 725 !	14. 371	26.071	41.2521	35, 572	41. 9681	
21-23	56. 2661	45. 711	78. 835	17. 740	14. 049	37. 827	38, 542	31. 805	41. 320	
:	;	;	;					:	:	

جـدول رقم (2 - د)

THE MEAN CONCENTRATION OF THE LEVEL OF (CO, G3 AND NH3)
EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING
JUNE 1990 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

!	! CAR	BON MONO	XIDE	!	OZON		AINONA		
!	! NAN	! RAB	! REQ	! MAN !	RAS	! REQ	MAN	! RAB	REQ
: 0-2	0.382	0. 460	0. 433	0.008	0.011	0.010		:	0.055
1 3-5	0. 251	1 0.337	0. 275	0.0071	0.010	0.010		:	0.034
1 6-8	0. 921	Q. 91B	0. 481	0.007	0.007	0.008		:	0.045
1 9-111	1.085	0.818	0. 445	0.0101	0.012	0.015			0.045
12-14	0.772	0. 563	0. 399	0.018	0.015	0.021			0.056
115-171	0. 701	0. 738	0. 582	0. 023 :	0.014	0.018		-	0.061
118-201	1.5861	1. 516	1.8331	0.0171	0.0071	0. 0061		! !	0.091
:21-23:	1. 580 :	1. 3841	1.7231	0.0111	0.006	0. 0041	-	· ;	0. 121

جـدول رقم (3 - 1)

THE MEAN CONCENTRATION OF THE LEVEL OF SULFER COMPOUNDS EXPRESSED IN PPD RECORDED AT MANSDRIA, RABIA & REGA DURING JUNE 1790 ACCORDING TO THE WIND DIRECTION

!		TAL SULPH					SULPHER DIOXIDE		
	NAN !	RAS !					MAN !		
N :	1. 477	7. 2071	1. 937	0.018	5.030	0.360	1.376	2. 174	1. 264
ME (1.697	0.0001	1.853	0. 473	0.000	0.041	1.000	0. 000	1.415
E	1. 404	0. 0001	1.814	0. 230	0,000	0.016	1. 156	0, 000	1.413
5E	1. 0621	0. 0001	1. 8151	0. 075	0, 000	0, 007	0. 960	0.000	1.323
S	2. 9071	10. 4801	1.813:	1. 241	7. 305	0. 020	1.598	3, 167	1,2781
SW :	8.038	22. 338 !	1. 292:	6. 800	18. 849	0. 056	1.092	3, 423	1, 051
W	4. 6691	84. 149	2. 021	3. 094	75. 926	0. B07	1.463	8. 448	1.107
							1. 525		

جـدول رقم (3 - ب)

THE MEAN CONCENTRATION OF THE LEVEL OF HYDROCARBONS EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING JUNE 1990 ACCORDING TO THE WIND DIRECTION

	TOTAL	HYDROCAR	BONS	NO	N-METHA	NE.	METHANE		
							MAN !		REG
							1.697	1.388	1.745
NE	2, 277	0. 0001	1.883	0. 606	0.000	0.149	1.663	0, 000;	1, 733
E	2.839	0.0001	2. 1941	1.016	0.000	0.439	1.622	0.000:	1.754
SE :	2, 232	0.0001	2, 413;	0. 512	0.000	0. 631	1,715	0, 000 f	1.783
						0. 794	1.715	1. 9541	1.766
						0. 910	1.940	1. 4941	1. 836
							1,8491		1, 935
NM	1. 968	2 121	2. 316	0. 222	0. 633	0.361	1.744	-	

جـدول رقم (3-جب)

THE MEAN CONCENTRATION OF THE LEVEL OF NITROGENE COMPS.

EXPRESSED IN PPD RECORDED AT MANSGRIA, RABIA & REGA DURING

"JUNE 1990 ACCORDING TO THE WIND DIRECTION

			~~~~~						
				NITROGENE MONOXIDES					
! !	MAN	RAB !	REG !	. MAN	RAB	REG	MAN !	RAB !	REG !
: N :	24, 655	25, 451	30.580	3. 265	6 333;	8. 858	21, 355	19, 119;	21.717
: NE :	37.810	0.000	19. 845	6. 036	0,000;	3, 725	31, 248	0.0001	16, 0821
: E :	44. 811	0.000	32.7191	6. 663	0 000;	7. 057	38, 457	0.0001	25, 879
SE I	44. 015	0.000	25. 796	5. 952	0,000	5, 221	38.070	0.0001	20, 568
: 5 ;	91. 935	47, 902	44. 원0명 :	41. 594	13, 252	11. 524	50, 382	34, 543!	33, 309
: SW :	37. 584	35. 370	85, 402	14. 612	10, 7341	37, 109	22, 974	24. 60B1	48, 513
1 K (	24, 736	44. 966	75. 475	7. 022	20, 253	38, 638	17, 652	24. 7391	36, 994
I NW :	19, 361	23. 696	23. 331 :	1. 754	5. 178	5. 3221	16.630	18, 5471	17, 961
::			;	:	;				

جـدول رقم ( 3 - د )

THE MEAN CONCENTRATION OF THE LEVEL OF (CO, OB AND NHB) EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING JUNE 1990 ACCORDING TO THE WIND DIRECTION

!	. CARB	CARBON MONOXIDE						AMON I A	
	. NAN !	RAB S	REO .	! I1AN !	RAB	REG	. MAN	! RAB	! REG
М 1	0. 8661	0. 819	0. 611	0.017	0. 010	0.010	·		: 0.040
NE 1	1. 203	0. 000:	0. 489	0.011;	0. 0001	0.013		1	0.034
E ;	1. 333	0. 000 :	0.818	0.015	0. 0001	0.019	:	:	. 0.043
5E 1	1. 364	0. 000:	0. 4431	0.015;	0.0001	0. 026		i	0.094
s :	2. 1261	1.038;	1. 403;	0.016	0.0071	0.018		:	0.139
SW :	0. 9141	0. 638 (	2. 4291	0.0041	0.0131	0.0051	`		0.282
M :	0.756	0. 970 !	1.607	0. CO6!	0.0071	0.003!			0.122
NH 1	0. 488 ;	0. 6841	0. 439:	0.015	0.011;	0. 0071			0.043

# جـدول رقم ( 4 - 1 )

THE MEAN CONCENTRATION OF THE LEVEL OF SULFER COMPOUNDS EXPRESSED IN PPB RECORDED AT MANSGRIA, RABIA & REGA DURING JUNE 1990 ACCORDING TO THE WIND SPEED IN m/s

!	то-	TAL SULPH	IER .	HYDRO	ENE SULF	HIDE	SULPHER DIGXIDE			
! WS !	MAN	RAS !	REG	MAN	EAS	REQ	MAN !	RAD !	REQ !	
1m/s	7. 575	79. 071	1, 917	.6. 109	71.507	0. 434	1.160	7. 956	1. 257	
1-2	5. 923	28, 569	1. 873	4. 532	24. 531	0. 383	1.197	4. 017	1. 232	
2-3	2. 517	5, 912	1. 968	1. 104	3. 678	0.399	1.316	2. 302	1. 217	
3-4	1. 573	4. 890	1.719	0.034	2. 621	0. 331	1, 490	2. 094		
		4. 468	1. 940	0.000	2, 450	0. 283	1.595	2. 004	•	
5-6	1.649	4. 702	1.878	0. 000	2, 705	0.180	1.625	2. 022 ;	1.357	
6-7	1. 635	4. 135	1,753	0. 000	2. 099	0.073	1.6281		1.344	
7-8	1.548	2. 391	1.752	0. 000	0.326	0. 079	1.541			
8-9	1. 500	2, 000	1. 733	0. 000	0. 000	0. 047	1. 4291	2. 000	1.338	
9-10	1.000	2. 000	1. 789	0.000	0. 000	0. 046	1,000	2. 000	1. 366	
10+	0. 000	0.000	1.794	0.000	0. 000	0.009	0. 000	0. 000	1.411	

جـدول رقم ( 4 - س )

THE MEAN CONCENTRATION OF THE LEVEL OF HYDROCARBONS EXPRESSED IN PPH RECORDED AT MANSCRIA. RABIA & REQA DURING JUNE 1990 ACCORDING TO THE WIND SPEED IN m/s

							1			
! ! WS		HYDROCAL	28008	: NO	IAHT3M-MC	NE	! METHANE			
: WS		! RAB	REG	MAN !	RAS	! REQ	! MAN !	RAB	REQ	
11/5	2.712	1.617	2.860	0.705	0. 692	0. 966	2.007	0. 935	1.894	
1-2		1, 952	2. 706	0. 550	0. 656	0. 827	1.776	1. 294	1.878	
2-3	•	2. 049	2. 340	0. 394	0. 626	0. 541	1.714	1. 424	1.817	
3-4	2. 036	2. 072	2. 205	0. 293	0. 634	0.406	1.741	1. 438	1.799	
4-5	2.027	2. 153	1. 944	0. 238	0. 648	0. 197	1.787	1. 485	1. 746	
5-6	2. 030	2. 251	1.069	0. 220	0.703	0. 132	1,810	1. 548	1. 733	
6-7	1.779	2. 245	1.850	0. 194	0.692	0. 116	1. 804	1.553	1.730	
7-0	2.014	2.044	1.032	0.198	0. 541	0. 102	1.817	1.502	1. 729	
8-9	•	1. 856	1. 946	0. 199	0. 420	0. 119	1.883	1. 435	1. 728	
9-10	1. 755	2. 000	1. 839	0. 163	0.440	0. 121	1.800	1.560	1.717	
10+	υ. 000	0. 000	1. 900	0.000	0.0001	0. 094	0.000	0. 000	1. 705	

# جـدول رقم ( 4 - ج. )

THE MEAN CONCENTRATION OF THE LEVEL OF NITROGENE COMPS. EXPRESSED IN PPB RECORDED AT MANSORIA, RABIA & REGA DURING JUNE 1990 ACCORDING TO THE WIND SPEED IN m/s

	_	NITROCENE	OXIDES	NITRO	SENE MONO	OXIDES	NITROGENE DIOXIDE			
. WS		RAB !	REG	MAN	RAB	REQ	MAN	RAÐ	REQ	
lm/s	<b>66. 144</b>	51, 747	106. 156	28. 748	25, 493	57, 537	36, 861	26, 277	46. 780	
1-2	47. 874	41, 978	70. 998	17. 058	15. 165	31. 994	30, 765	26. 781	38. 977:	
2-3	29. 737	27, 4631	43, 953	5. 571	5. 849	13. 351	24. 111	21, 620	30. 727	
3-4	21.106	22. 322	28. 619	1. 570	4. 102	5. 695	19, 545	18. 259	22.891	
			22. 713	0. 986	3. 623	3. 798	15, 737	16, 301	18. 939:	
	14. 573		20. 524	0. 459	3, 166	2. 973	14. 182	15. 169	17.508	
6-7	13. 299	17. 876	18. 424	0. 285	3.420	2. 431	13.008	14. 584	15. 940	
7-8	10. 552	18.050	16. 357	0.096	3.444	2. 407	10, 476	14.617	13. 910	
8-9	9.667	19, 222	14. 519	0. 000	3.000	2. 624	9, 667	15. 167	12, 419	
9-10	12, 333	31.000	13. 283	o. coo	7.000	2.081	12.333	24, 000	11. 243	
10+	0.000	0, 000	13. 278	0.000	0.000	1. 926	0.000	0. 000	11.380	

جلدول رقم ( 4 - د )

THE MEAN CONCENTRATION OF THE LEVEL OF (CO. 03 AND NH3) EXPRESSED IN PPM RECORDED AT MANSORIA. RABIA & REGA DURING JUNE 1990 ACCORDING TO THE UINO SPEED IN m/s

! WS		CARDON MONOXIDE			OZON		! AMONIA		
!	•	EAR !	REQ	.MAN !	RAB	REQ	MAN	! RAB	REG
in/s	1. 564	1.092	2, 850	0.004	0. 004	0.004		;	0.118
1-2	1. 256	1.036	1.558	0.009	0, 007	0. 009			0.095
2-3	0.931	0.805	0.987	0.010	0.011	0.012			0.093
3-4	0. 758	0. 701	0. 428	0. 0131	0.013	0.011		;	0.082
4-5	0. 639	0. 648	0. 511	0.015	0.013	0.012			0,054
5-6	υ. <b>6</b> 07	0. 605	0. 451	0.017	0.012	0.012			0.033
6-7	U. <b>57</b> 8	0. 593	0. 423	0.023	0.012	0.013			0.030:
7-8	O. 568	0. 590	0. 380 :	0. 024	0.011	0.014	~		0.032:
8-9	0. 455	0. 584	0. 370	0.028	0.010	0.014			0.0301
9-10	0. 585	1, 020	0. 3491	0.029	0.005	0.015			0.026
10+	0. 750	0, 000	0. 367	0.004	0.000	0.015			0.022

#### جـدول رقم ( 5 - 1 )

Measurements of Ultraviolet Radiation (UVA) , Recorded by International Light Detector, Mutchas Meter, and Eplab UV Detector during June (1990) , expressed in W/m^2

			:	;		: ;	
	IL 442    Detector		Eplab UV-:  Detector :		i IL 442 : Detector		Eplab UV-: Detector
			290-385nm:				290-365nm
1			42.67	16	41.83	37, 30	37. 67
2	40.16	34. 30	44:33	17	44.00	38. 96	
3	40. 83	35. 23	41.00	18	43.00	37.76	45. 33
4	39.00	34. 00	32,00	19	40. 33	33, 26	44.00
5	39. 67	35. 16	38.33	20	41.67	34, 93	43, 33
6	18.33	15. 76	21.00	21	32. 67	23. 67	37. 00
7	29.33	26. 67	31, 67	22	:	t	39. 67
8		:	44.00	23	8. 67	6. 60	7. 00
9	44.00	39. 23	44. 33	24	41.67	36, 56	42. 33
10	43.33	37. 93	41.00	25	42. 67	36, 20	44.00
11	41.67	37. 37		26	41.33	35. 70	42. 33
12	44.00	38. 73	!	27	43. 00	38. 03	44. 67
13	41.33	1 36, 23		28	42. 33	37. BO	43.33
14	38. 67	33. 23	39. 67	29	:		32. 67
15			43, 67	30	·		45. 67

جـدول رقم ( 5 - ب )

# Measurements of Ultraviolet Radiation (UVB) , Recorded by Folysulfone Films and International Light Detector during June (1990) , expressed in W/m^2

1			! ! !		·
Date	Polysulfone Film 280-320nm	IL 443 Detector 280-320nm	Date	Polysulfone Film 280-320nm	IL 443 Detector 280-320nm
1			16	2. 510	2. 510
2	2. 650	2. 520	17	2. 850	2. 760
3	2. 600	2. 760	16	2. 520	2, 500
4	2. 330	2, 320	19	2. 610	2. 550
5	2. 530	2. 480	20	2. 550	2. 590
6	1. 270	1.270	21	2. 030	1.960
7 1	1. 710	1.700	22		
В			1	6. 470	0. 230
9	2. 910	2. 660	24	2. 560	2. 540
10	2. 990	2. 950	: 25	2. 910	2. 700
11	2. 900	2. 980	26	2. 740	2. 460
12	3. 120	2. 920	27	2. 950	2. 77G
13	3. 280	2. 620	28	2. 740	2. 550
14	2. 290	2. 240	29	 	
15			30		:

جـدول رقم ( 5 - جـ) Heasurements of Solar Radiation recorded by Mansoria Station during June (1990) expressed in W/m^2

											- <del>-</del>				
Hour	5	6	7-	8	9	10	11	12	13	14	15	16	17	18	19
i	 	 			!	}			!	!		! !	! !	!	1
1	] 	121	3291	5391	737 l	887	9751	1010	973	848	683	469	252 J	53 1	ļ
1 2	! 	1 147	357	5701	752	905	990	1029	987	866	6931	4851	2631	621	
3		   136	   344	5491	733	888	976	997	9591	8361	6561	4651	2511	501	
1	i	125	i l	530		845	944	990	   931	7961	6401	4571	2261	t 541	!
5	ļ	134		1	746		!	985		8501	1	4591	2341	521	
6	į	128		1		830			1	737	1	4251	236	58	
1-7	i	l '	386			916	!	!		495	1	169	i 89	30	į
i	i	152		408		937				1					1
i		I	1	1		950				1	1	1	285	   74	i
<del>9</del> 	ļ	1!	363								1			17	
1 10	ļ	1	355	3/6				1010	730			487			
1311															
1*12	 														
<b>*13</b>	] ]	 	 			1 	<i></i>	1 1	 	 				 	! !
214		i				 	970	1007	960	841	675	416	236	67	 
15	Ì 1	142	356	577	767	926	1027	1053	1000	877	715	494	264	70	
16	İ	133	320	530	715	854	941	993	962	851	625	373	234	73	i i
<b>*17</b>															j
¥18	!		!		802	892	1003	1051	987	884	713	493	278	89	
19	]	141	349	559	761	890	797	1026	957	881	710	502	283	79	
20		1 137	343	577	750	902	968	1026	1001	897	713	510	268	75	!
21		157	366	586	787	912	904	960	896	772	542	401	207	61	 
1 22	 	149	361	568	1 749	873	971	1 978	847	761	589	1 267	1 138	42	
1 23	1	1 162	1 398	601	1 760	777	1	1 446	1 519	1 525	451	1 306	181	1 43	 
1 24		1 144	1 364	577	752	1 921	11015	11013	1 978	1 776	622	1 1 377	   172	1 42	
1 25		t	351	1	1	1 916	1		1	l		l	1 259	1	1
1 26	ļ	\	1-354	<b> </b>		i	1	1		<b>I</b>	1	1	i	j	1
27	· [	1	1	1	l	909		1	1	1		1	1	1	
1		151		1	I	1	1	1	1	1	1	1	1	1	
1-28	·	164		1	1	1	1041	1	1	1	1	1	1	[	1
1 29	· i	157		1 602	1			.	-	·	\		i		
30		155	378	1 592	1 773	31 914 -j	111010	1105	21 992 -1	869	1	1	1 249	1 71	
31	1	.	.	 	 	1	↓ .j	 	.	.	.	ا ا	i 	1	 
	-	•	•	-	-	•	-						-		

# Cut-Off Electricity

جـدول رقم ( 6 - 1 ) جـدول رقم ( 6 - 1 )

#### Distribution of Settled Daily Dust JUNE (1990) (grams/square meter/day)

		Locations			
	41 111			Daily	Total
Date	Shuwaikh			Mean	No of
	Industrial	Kuwait City	Al-Jahra		Sample
	Area				
1/ 6/90	0.478	0.458		0.458	2
2/ 6/90	0.826	0.756	0.687	0.756	3
3/ 6/90	3.613	3.065	8.877	5.185	3
4/ 6/90	5.245	4.723	18.650	9.539	3
5/ 6/90	3.394	3.658	13.057	6.703	3
6/ 6/90	20'. 232	20.740	60.150	33.707	3 .
7/ 6/90	25.527	34.131		29.829	2
8/ 6/90	0.587	0.736		0.662	2
9/ 6/90	0.816	0.677	1.035	0.843	3
10/ 6/90	2.189	1.270	3.115	2.191	3
11/ 6/90	0.627	0.577	1.334	0.845	3
12/ 6/90	0.916	0.846	1.234	0.999	3
13/ 6/90	0.557	0.468	1.015	0.680	3.
14/ 6/90	4.498	2.816		3.657	2
15/ 6/90	1.065	0.806		0.936	2
16/ 6/90	1.334	1.373	1.483	1.397	3
17/ 6/90	1.509	1.015	2.185	1.570	3
18/ 6/90	0.876	0.587	1.980	1.148	3
19/ 6/90	2.787	2.249	1.821	2.286	3
20/ 6/90	2.528	1.742	6.071	3.447	3
21/ 6/90	6.747	5.792		6.270	2
22/ 6/90	10.251	12.749		11,500	2
23/ 6/90	31.349	47.829	98.499	59.226	3
24/ 6/90	2.757	2.249	5.892	3.633	3
25/ 6/90	0.796	0.617	1.921	1.111	3
26/ 6/90	0.587	0.518	0.969	0.691	3
27/ 6/90	0.806	0.717	1.188	0.762	3
28/ 6/90	. 5.304	4.429		4.867	2
29/ 6/90	6.081	7.583		6.832	2
30/ 6/90	0.916	0.766		0.841	2
31/ 6/90					-
Mean	4.840	5.531	11.558	6.779	80
\$.D.+	7.583	10.691	24.444	14.648	

# Distribution of Sulphates and Nitrates in Monthly Dust fall out samples May (1990)

جحدول رقم ( 6 - ب )

	Monthly Dust	We	eight and Pe	rcentage	
Location	fall out	Sul	phate	Nitra	ite
	(Tons/Km2)	Wt.	*	Wt.	%
1.Kuwait City	040.194	01.477	03.675	0.029	0.072
2.Shamiah	021.739	00.973	04.476	0.009	0.041
3.Sulaibikhat	032.113	05.648,	17.588	0.023	0.072
4.Mutlaa	254.971	31.283	12.269	0.115	0.045
5.Farwaniah	033.396	02.155	06.453	0.006	0.018
6.Shuaibah	005.628	01.224	21.748	0.060	1.066
7.Salmiah	126.385	15.300	12.106	0.097	9.077
8.Fahaheel	009.155	00.612	06.685	0.050	0.546
9.Shuwaikh	175.593	25.200	14.351	0.040	0.023
10.Khiran	059.262	11.250	18.983	0.097	0.164
Monthly Mean	075.844	09.512	11.833	0.053	0.212
S.D.+	_083.104	11.111	06.371	0.039	0.338
	<u> </u>		<u> </u>		

جـدول رقم ( 7 - 1 )

Concentration of Suspended Particulate Matter in daily samples
June (1990)
(micrograms/cubic meter)

Do A o		Locat	tions			
Date	Shuwaikh	Kuwait City	Shamiah	Al-Jahra	Daily Mean	Total Samples
1/ 6/90						-
2/ 6/90						-
3/ 6/90			616.9	1089.1	853.0	2
4/ 6/90	903.1	710.3			806.7	2
5/ 6/90			606.9	753.3	680.1	2
6/ 6/90		1355.2			1355.2	1
7/ 6/90			2228.3	1780.6	2004.5	2
8/ 6/90	328.0	235.2			281.6	2
9/ 6/90			229.1	456.1	342.6	2
10/ 6/90	323.9	302.2		`	313.1	2
11/ 6/90			235.4	297.6	266.5	2
12/ 6/90	382.7	226.9		}	304.8	2
13/ 6/90			214.0	318.3	266.2	2
14/ 6/90	447.4	387.6			417.5	2
15/ 6/90	l .		304.9	374.6	339.8	2
16/ 6/90		390.3			471.4	2
17/ 6/90	1		288.0	365.3	326.7	2
18/ 6/90						-
19/ 6/90			345.9	356.7	351.3	2
20/ 6/90	492.0	349.7			420.9	2
21/ 6/90			796.8	730.8	763.8	2
22/ 6/90		1266.9			1321.2	2
23/ 6/90	Ł		1443.5	1853.3	1648.4	2
24/ 6/90		767.2			827.5	2
25/ 6/90			261.4	360.5	310.9	2
26/ 6/90		310.9			359.9	2
27/ 6/90	1					-
28/ 6/90	1	<b>-</b>				-
29/ 6/90	1	455	1042.9		1042.9	1
30/ 6/90	432.9	353.8			393.4	2
Mean	594.0	554.7	662.6	728.0	636.3	48
S.D.+	327.8	391.7	600.7	560.9	478.6	

جـدول رقم ( 7 - ب )

# Size Distribution of Suspended Particulate Matter June (1990)

		Shuw	aikh (	n=2)	kuwai	t City	(n=3)	Shamiah (n=3)		
Particle Size	Size Range (micron)	Mean Conc. ug/m3	% in Size Range	Cumul Freq.	Mean Conc. ug/m3	% in Size Range	Cumul Freq.	Conc.	% in Size Range	Cumul Freq. %
Ř E S	0.1-1.1	282.7	30.3	30.3	793.9	50.6	50.6	273.6	31.82	31.8
p I R	1.1-2.0	57.8	6.2	36.5	75.6	4.8	55.4	43.0	05.00	36.8
A B L	2.0-3.3	107.0	11.4	47.9	126.7	8,1	63.5	97.4	11.33	48.2
Ê	3.3-7.0	162.1	17.4	65.3	158.8	10.1	73.6	129.3	15.04	63.2
Non Re- spirable	> 7.0	323.9	34.7	100.0	413.7	26.4	100.0	316.5	36.81	100.0
To	tal	933.5	100.0	—	1568.7	100.0		859.8	100.0	

# APPENDIX D

AIR QUALITY DATA APRIL 1991

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# جدول رقم ( 1 )

MON.LY MEAN CONCENTRATION OF THE GASES EXPRESSED AS PPM AND PPB RECORDED BY THE AIR POLUTION MONITORING STATIONS TOGETHER WITH THE MAXIMUM LEVEL AND THE PERCENTAGE DISTRIBUTION OF THE VALUES EXCEEDING THE THRESHOLD LEVEL DURING APRIL 1991

			-					
!	!	LOCA	TIONS		·:			
; ! !	MANSORIA	MANSOR IA !						
GASES	MEAN ! MAX	! ! XEX. ! LIMIT	MEAN	MAX	%EX.			
TS IN PPB H2S IN PPB SO2 IN PPB THC IN PPM NCH4 IN PPM NGX IN PPB NO IN PPB NO2 IN PPB NO2 IN PPB CO IN PPM NO3 IN PPB	1 3.124 40.000 1 0.087 11.000 1 3.016 38.000 1 6.347 18.950 1 1.742 13.140 1 4.596 18.950 1 20.264 742.000 1 8.032 341.000 1 12.226 496.000 1 0.643 7.280 0 0.003 0.015	76. 4 		6.000 22.000 8.980 6.150 3.760 1011.000 106.000 167.000 32.370	0. 1 : 0. 0 : 1 : 62. 0 : 1 : 1 : 1 : 1 : 1 : 1 : 1 : 1 : 1 :			

### جدول رقم (12)

# Daily average of measurements at: Mansoriya Apr 1991

Day	S02	CH4	NCH4	NO	NO2 :	CD	03
	ppm	ppm	ppm	рþm	ppm	ppm	ppm
1	. 0021	3. <del>9</del> 28	. 1147	. 0406	. 0258	1. <del>4</del> 79	. 0002
2	. 0021	3. 223	. 1561	. 0330	. 0325	1, 541	. 0004
3	. 0020	2. 856	. 1277	. 0120	. 0268	. 7198	. 0002
4	. 0020	3. 692	. 6543	. 0101	. 0197	. 8816	. 0034
5	. 0020	2. 637	. 2930	. 0096	. 0084	. 6355	. 0017
. 6	. 0020	3. 500	. 5097	. 0043	. 0102	. 604B	. 0014
7	. 0020	1. 918	. 4141	0. 000	. 0025	. 3225	. 0032
8	. 0020	2. 291	. 1829	. 0054	. 0155	. 5953	. 0026
9	. 0021	2. 604	1. 123	. 0088	. 0109	. 5268	. 0046
10	. 0020	2. 570	. 2177	. 0364	. 0185	_. 1. 344	. 0032
11	. 0020	3. 793	. 9782	. 0037	. 0088	. 4991	. 0034
12	. 0019	5, 119	2, 930	0. 000	. 0016	. 2669	. 0085
13	. 0018	5. 228	2. 916	0. 000	. 0005	. 3212	. 0039
14	. 0020	5. 426	2. 255	0.000	. 0035	. 3420	. 0039
15	. 0020	4. 640	1.082	. 0237	. 0172	1.030	. 0019
16	. 0179	4, 071	1. 337	. 0042	. 0156	. 6454	. 0010
17	. 0082	5. 016	2. 924	. 0001	. 0136	. 4661	. 0043
18	. 0020	3. 233	1.359	. 0034	. 0095	. 6012	. 0023
19	. 0020	3. 589	1.668	. 0154	. 0144	. 8082	. 0041
20	. 0020	3. 079	. 9405	. 0002	. 0126	. 5026	. 0035
21	. 0020	4.008	1.653	. 0002	. 0057	. 4534	. 0045
22	. 0020	5. 068	2, 284	. 0000	. 0047	. 3523	. 0012
23	. 0020	11. 26	1.755	0.000	. 0021	. 3520	. 0000
24	. 0024	6. 762	2, 145	.0018	. 0162	. 5536	. 0018
25	. 0042	3. 269	1.036	. 0013	. 0089	. 3202	. 0004
29	. 0019	4. 584	2. 892	. 0001	. 0083	. 4402	. 0053
30	. 0018	5. 049	1.077	. 0061	. 0142	. 6440	. 0034
					0100	. 6430	. 0028
TOTA	. 0030	4. 596	1, 742	. 0080	. 0122	. OTJV	. 0028

حدول رقم ( 2 ب)

# Daily average of measurements at: Reqa Apr 1991

Day	S02	CH4	NCH4	NO	N02	Co	03
•	ppm	թբա	ppm	ppm	ppm	ppm	ppm
7	. 0012					4004	00/6
é	. 0013	1. 843	1.087	•	•	. 4984	. 0045
9	. 0011	1. 833	. 9289	•	•	. 6016	. 0055
10	. 0014	1.889	. 4267 . 6418	. 0178		. 4732	. 0061
11	. 0014	2. 040	1, 303	. 0044	. 0158	. 8068	. 0097
12	. 0017	1. 834	. 0993	. 0044	. 0069	. 5283	. 0098
13	. 0017	1. 867	. 0773	•	•	. 3483	. 0114
14	. 0014	1. 864		• •	•	. 3763	.0118
15	. 0010	1. 769	. 1610	•	•	. 4117	. 0120
			1.098	•	•	. 5096	. 0094
16	. 0011	1. 877	1, 932		•	. 5058	. 0107 [.]
17	. 0015	1. 721	1.314	. 0039	. 0142	. 5207	. 0178
18	. 0013	1. 826	9252	. 0015	. 0130	. 4697	. 0173
19	. 0018	1.811	. 9210	, 0048	. 0161	. 5571	. 0175
20	. 0011	1.831	. 6204	. 0048	. 0215	. 6478	. 0154
21	. 0020	1. 792	. 1792	. 0000	. 0093	. 3217	. 0201
22	. 0018	1. 760	. 5374	. 0025	0164	. 5819	. 0199
23	. 0018	1. 762	. 2054	. 0003	. 0132	. 3686	. 0210
24	. 0020	1.824	. 6971	.0018	0174	. 5034	. 0203
25	. 0027	2.012	1.688	. 0255	. 0402	1. 493	. 0062
56	. 0021	1. 780	. 8114	. 0027	0398	. 3454	. 0093
27	. 0020	1.648	. 1872	. 0267	. 0218	. 3207	. 0188
29	. 0020	1. 676	. 0622	. 0121	. 0128	. 2911	. 0195
29	. 0020			. 2132	0173	. 1933	. 0599
30				. 2279	. 0235	. 1510	. 1250
TOTA	. 0016	1. B45	. 7811	. 0391	. 0197	. 4922	. 0172

جدول رقم ( أ ع ) THE MEAN CONCENTRATION OF THE LEVEL OF SULFER COMPOUNDS EXPRESSED IN PPB RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

			·				<u> </u>			
!	! TOT				HYDROGENE SULPHIDE					
!	! MAN !	RAB !	REQ !	MAN !	RAB !	REG !	MAN	RAB !	REQ	
0-2	3. 197	****	1. 7771	0. 194	****	0.064	2. 998	******	1. 575	
3-5	2.862	*****	1. 830	0. 033	*****	0.082	2.796	******	1.616	
8-6 1	2. 367	******	2. 172	0.017	*****	0.152	2, 329	*******   	1. 837	
: 9-11	3, 402	*****	1.805	0, 111	******	0.047	3. 255	******	1.607	
112-14	3. 602	*****	1.746	0.094	*****	0.008	3. 474	******	1, 578	
115-17	1 3. 226	****	1.711	0. 092	*****	0.008	: 3.117	####### 	1. 477	
118-20	3.079	:******	1.780	0,048	******	0.026	2. 998	******* !	1, 578	
121-23	: 3.095	. *******	1.827	0.058	******	0.033	: 3.029	: :******* !	1. 617	
				, <b></b>	:			•	•	

جدول رقم ( ج ب)

THE MEAN CONCENTRATION OF THE LEVEL OF HYDROCARBONS EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

	TOTAL HYDROCARBONS			! NI	NON-METHANE			METHANE		
!	MAN	RAB !	REG !	MAN	! RAB !	REG :	MAN	RAB !	DEA	
0-z :	6, 620	***	2. 687	1.819	****	0. 786	4, 801	*******	1 001	
3~5 i	· 6. 113	****	2. 6781	1.341	****	0.803	4. 771	!  #######	1 974	
9-B :	6. 441	****	2. 7531	1,550	******	0. 90B	4 891	******	1 944	
4-11:	6. 377	****	2, 5041	1. 950	******	0.700	4 413	! ******	1 00=	
12-14:	6. 304	****	2, 2601	2. 059	<b>  * * * * * * * 1</b>	0.496	4 205	******	1 740	
15-1/;	6. 375	****	2. 3561	1.880	******	0. 594	4 495	'! ******	1 745	
18-40:	5, 893	****	2. 863 :	1. 607	******	0.978	4 285	******	1 005	
21-23:	6. 062	****	2. 8531	1. 590	******	0. 962 9	4. 472 :		1 201	

جدول رقم (٠ ج ج)

THE MEAN CONCENTRATION OF THE LEVEL OF NITROGENE COMPS. EXPRESSED IN PPB RECORDED AT MANSORIA, RAGIA & REGA DURING APRIL 1991 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

	TOTAL (		OXIDES!	NITROG	ENE MONO		NITROGENE DIOXIDE !			
!!!	MAN	RAB!	REQ !	MAN !	RAB !	REQ	MAN	! RAB !	REG	
: 0-2	21.187	*******	79. 8091	11. 723	******	57. 159	9. 717	******	22. 371	
1 3-5	7. 704	******	59. 267	2. 542	****	46: 853	5: 144	*****	12, 125	
1 6-8	7. 547	******* !	43. 167	1. 450	*****	30. 607	6.091	******	13, 455	
9-11	14. 948	******	25. 494	3. 366	******	9. 970	11.572	******	15, 548	
112-14	11.222		20, 2551	0. 966	*****	9.476	10. 241	<del>  *****</del>	10. 770	
115-17	21, 150	******* !	35. 485	5, 282	*****	21.096	15. 720	<b>  *****</b> **	14. 360	
118-20	33, 221	: : ******* !	103. 900	12. 944	*****	67.073	20, 261	******	36. 827	
121-23	42. 565	****** 	109. 605	22, 710	******	77. 176	19. 943	******	31, 771	

#### حدول رقم ( 3 د)

THE MEAN CONCENTRATION OF THE LEVEL OF (CO, D3 AND NH3)
EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING
APRIL 1991 ACCORDING TO 3-HOUR INTERVAL OF THE DAY

i i	CAR	CARBON MONOXIDE			OZON	į				
!!!	MAN	RAB !	REG !	MAN !	RAB !	REQ !	MAN	! RAB !	REQ	
0-2	0. 633	*****	0. 437	0.002	******	0.017		******	0. 010	
3-5	0.308	****	0. 280	E00 .0	******	0, 020		-!!	0.010	
6-8	0. 327	*****	0. 337	0.003	******	0.018		-!!  ******	0. 006	
9-11	0.617	*****	0. 454	0.002	*****	0.016		-!! :******	0. 006	
112-14	0. 511	****	0. 397	0.003	*****	0.016		- [	0.009	
15-17	0. 671	******	0. 456	0.004	******	0.018		-!!  #*#####	0.015	
18-20	0. 953	*****	0. 867	0.002	******	0.017		-!!  ******	0.018	
121-23	1. 161	****	0. 803	0.002	******	0.017		-!!   *****  !	0. 023	

Am 1991

ا- جدول رقم ( 4 أ)

THE MEAN CONCENTRATION OF THE LEVEL OF SULFER COMPOUNDS EXPRESSED IN PPB RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO THE WIND DIRECTION

1			/ <b></b>					
!						SULPHER DIOXIDE		
į	! MAN ! RAB	! REG	MAN	RAB !	REG	MAN !	RAB !	
1 N	2.043 ****	1.756	0.006	*****	0. 023	2. 032	*****	1.6231
. NE	2. 989 ******	1.729	0.087	*****	0.043	2. 878	******	1.5581
: E	5. 284 ******	1 1.829	0.213	*****	0.050	5. 049	******	1.4991
: SE	6. 873 *****	1.683	0. 236	*****	0.067	6. 611	******	1.4421
: 5	3.486 *****	1 . 2. 092	0.085	******	0.092	3.389	******	1. 7761
: SW	3.047 ******	1.896	0.104	******	0.019	2. 930	******	1. 5951
: W	2. 245 *****	1 , 2, 056	0.109	******	0. 130	2. 116	******	1.677
: NW	1.997 *****	1. 991	0.001	****	0. 19B	1. 955	******	1.608;
	- , ; <b></b> -		•			•	•	

جدول , قم ( 4 ب)

THE MEAN CONCENTRATION OF THE LEVEL OF HYDROCARBONS EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO THE WIND DIRECTION

	TOTAL	TOTAL HYDROCARBONS			DN-METHAN	NE ·				
: !	MAN	! RAB !	REQ !	MAN	RAB	REG	MAN	RAB	REQ	
N I	4. 507	******	2. 275	1.066	****	0.455	3.441	******	1.820	
NE I	3, 592	******	2. 159	0. 736	*****	0.381	2.825	******	1.778	
Ε :	3. 511	[#######	2. 541	0. 608	******	0. 730	2. 890	******* !!	1.807	
SE :	6. 977	******	2. 667	2, 229	*****	0.868	4.748	******	1, 800	
S	5. 456	******	3. 030	1.498	******	1.1,88	3. 957	*****	1. 842	
SH :	5. 077	******	3.043	1.245	******	1.120	3.831	*****	1.924	
W	6. 588	******	3. 632	1.702	******	1.643	4. 877	******	1, 990	
NW I	7. 781	****	4. 338	2. 293	*****	2. 299	5. 472	******	2. 039	

جدول رقم ( 4 ح)

THE MEAN CONCENTRATION OF THE LEVEL OF NITROGENE COMPS.

EXPRESSED IN PPB RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO THE WIND DIRECTION

						(			
				NITRO	SENE MONO	IXIDES !	NITRO	OGENE DIC	
	MAN	! RAB	REG	MAN	RAB !	REQ !	MAN	RAB	REQ !
N S	14. 109	*****	66. 524	5. 574	******	46. 572	8. 711	******	20.073
NE :	20. 294	******	29. 269	6. 433	******	12, 745	13. 694	{   ******* 	16. 5291
E	27. 676	*****	37. 819	8. 646	******	25. 925	18, 759	******	11.8221
SE	25. 572	*****	28. 025	4, 660	*****	11.038	20, 908	******	16. 987
S	46, 738	*****	38. 202	21.072	******	10.528	25, 671	******	27. 4441
SW	46, 240	******	41.360	28. 155	******	11.084	18. 060	******	30. 2521
W :	20. 815	*****	90. 560	11.005	******	58. 519	9. 750	*****	-31, 6811
NW	_ 6. 395	*****	223. 084	1, 076	******	200. 661	5, 310		20, 289;
								::	

جدول رقم( ټه د)

THE MEAN CONCENTRATION OF THE LEVEL OF (CO, O3 AND NH3) EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO THE WIND DIRECTION

	CARI	CONOM NO	(IDE !	OZON			AMONIA !			
	MAN	RAB !	REQ !	MAN !	RAB !	REG !	MAN	! RAB	REG	
N	0. 592	*****	0. 387	0.004	*****	0.018		******	0.009	
NE.	0. 662	******	0. 372	0. 003	******	0.016		******	0.006	
E	0.782	*****	0. 510	0.002	*****	0. 020		******	0.006	
SE	0. 670	******	0. 587	0.002	******	0. 015		******* 	0.012	
S	1.004	******	0. 752	0.001	******	0.012		******	0.024	
SH	1.081	******	0. 672	0.001	******	0, 012		******	0.016	
W	0. 666	******	1.280	E00.0	*****	0.010		******	0. 038	
NW		******	0. 350	0.004	******	0. 033		*****	0.010	

جدول رقم ( ۶ )

THE MEAN CONCENTRATION OF THE LEVEL OF SULFER COMPOUNDS EXPRESSED IN PPB RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO THE WIND SPEED IN m/s

!			!						
WS !	TO:	TAL SULP	IER !	HYDROG	ENE SULF	HIDE	SULF	HER DIOX	IDE
!	MAN	! RAB !	REG		RAB			RAB !	
1m/s	2. 943	*****	2. 238	0. 080	*****	0. 147	2. 849	******	1.824
1-2	2. 730	******	1. 745	0. 099	*****	0.072	2. 619	******	1. 468
2-3	3. 038	******	1.715;	0.082	*****	0.047	2. 941	[	1. 470
3-4	3. 996	******	1. 792	0. 098	*****	0.035	3. 858	*****	1. 567
4-5	3.714	******	1.862	0.094	*****	0.050	3. 582	*****	1.666
5-6	2. 492	******	1.883	0. 021	*****	0.020	2, 446	*******	1.763
6-7	2.000	******	1.829	0. 000	*****	0.018	1. 977		1.753
7-8	2. 000	*****	1.873	0.000	*****	0.026	1. 962	*****	1. 828
8-9	2. 000	*******	1.857	0. 000	****	0.000	2.000	:: :*******	1. 837
9-10	2. 000	******	2.000	0.000	******	0.000	2.000	::   +*+*++*	2. 000
10+	2.000	******	2. 500	0. 000	****	0.000	2.000	******	2. 500

جدول رقم ( 5 س)

THE MEAN CONCENTRATION OF THE LEVEL OF HYDROCARBONS EXPRESSED IN PPM RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO THE WIND SPEED IN m/s

WS !-	TOTAL	HYDROCAR	BONS !	NO	ON-METHAN	E .	METHANE !			
#5 :- !					RAB					
lm/s	4. 630	******	3. 539	O. BO5	*****	1.611	3.810	*****	1. 928	
1-2	5. 113	******	3. 133	1. 136	******	1. 224	3. 971	******	1. 909	
2-3	6, 402	******	2. 668	1.614	*****	0.787	4. 787	******	1.8801	
3-4 1	7. 291	*****	2. 475	2. 156	*****	0.645	5. 111	*****	1.8311	
4-5	7. 938	******	2. 377	2.758		0. 54B	5. 064	******	1.8051	
5-6	7. 647	******	2. 094	2. 887	*****	0.344	4, 760	******	1. 749	
6-7	6.065	*****	1. 929	1.795	*****	0.216	4, 271	*****		
7-8	4. 717	*****	1.939	1.120	******	0.129	3, 594	****	1.708	
8-9	0.000	******	1.798	0.000	*****	0.087	0.000	*****	1.711	
9-10	0.000	******	1. 796	0.000	*****	0.083	0.000	******	1.715	
10+	0.000	*****	1.790	0.000	******	0.052	0.000	*****	1.735	

حدول رتم( 5 ج)

THE MEAN CONCENTRATION OF THE LEVEL OF NITROGENE COMPS.

EXPRESSED IN PPB RECORDED AT MANSORIA, RABIA & REGA DURING APRIL 1991 ACCORDING TO THE WIND SPEED IN m/s

			!	!	[!					
WS	TOTAL N	ITROGENE	OXIDES!	NITRO	SENE MONO	XIDES !	! NITROGENE DIOXIDE !			
				*	RAB				REG	
im/s	65. 460	******	162. 7771	40. 71B	******	124. 087	24. 832	*****	38.712	
	23. 812	*****	90. 177	9. 086	*****	60. 496	14. 659	******	29. 581	
	10.314	*****	61. 959	1. 365	*****	39. 829	8. 955	*****	21. 970;	
3-4	6. 230	******	51.884	0. 553	:	36, 030	7. 629	*****	16. 160 !	
4-5	7. 861	*****	35. 706	0. 417	: : * * * * * * * * :	20, 280	7, 412	*****	15. 3261	
5-6	10.078	*****	28. 451	0. 672	****** !	14. 952	9, 414	****	13.5091	
6-7	12. 833	*****	34.008	1. 253	******	20.502	11.648	*****	13, 560;	
7-8	12.038	*****	28. 747	1, 154	: : +##### !	15. 736	10,808	******	12.851	
8-9	15. 429	*****	22. 760	1.714	:	12. 120	13, 714	*****	10. 680	
9-10	23. 000	*****	18. 824	2. 000	: ****** ! ****	5. 765	21.000	******	13.000	
10+	11.000	******	10.750	1.000	: ******* ! *******	3,000	9.000	******	7. 750	
					,	<b></b>	: <b>-</b>		;	

## حدول رقم ( 5د )

THE MEAN CONCENTRATION OF THE LEVEL OF (CO, O3 AND NH3) EXPRESSED IN PPM RECORDED AT MANSORIA, RA3IA & REGA DURING APRIL 1991 ACCORDING TO THE WIND SPEED IN m/s

1				1 ~			1			
!		CONOM NO			OZON		AMONIA			
! WS !	MAN	RAB !	REG !	MAN	RAB !	REG	MAN	RAB !		
	1, 585	******	1. 442	0.002	******	0.017		******		
1-2	0. 706	******	0.748	0. 002	******	0.013		******* !	0.017	
2-3	0. 428	: ******	0. 456	0.003	******	0.016		******	0.014	
3-4	0. 405		0. 353	0, 003	******	0.019		******	0.010:	
1 4-5	0. 387	******	0. 317	0.004	******	0.018		*****	0.005:	
56	0.390	*****	0.301	0.003	******	0.019	:	: ******* : *******	0.003;	
6-7	0.403	******	0. 285	0.003	*****	0.019	·	:	0.002	
7-8	0. 404	******	0. 281	0.002	*****	0.018	;	:: :******* !!	0.002	
8-9	0.357	******	0. 279	0.001	***	0.01B	·	:	0.0021	
: 9-10	0.480	*****	0. 284	0.001	****	0.019	:	*******	0.0001	
•	0. 140	:******	0. 260	0.000		0.022	· 	* * * * * * *   	0.000	
:	!	:	!	:	!	!	!	;		

# Suspended Particulate Matter Measurements Using High Volume Sampler During MARCH & APRIL 1991

## FARWANIA HOSPITAL

ים.	ate	Total	Filter Shade	Concentration of Elements ug/m3										
D.	<b>3.</b> U.C.	ug/m3	- I I		Ca	Fa	Ni	Pb	v	Al				
16/	3/91	168.3	Gray	2.073	28.121	4:737	0.055	0.189	0.013					
20/	3/91	99.5	Black	2.350	11.750	1.427	0.039	0.197	0.024					
25/	3/91	75.1	Gray											
30/	3/91	93.5	Black	2.538	11.766	2.193	0.039	0.395	0.007					
2/	4/91	382.4	Black	2.149	26.766	2.168	0.051	0.161	0.073					
7/	4/91	140.3	Gray	2.600	6.030	3.660	0.046	0.145	0.021					
15/	4/91	278.3	Gray	2.215	27.685	9.999	0.054	0.372	0.030					
18/	4/91	174.0	Black	2.760	27.601	4.190	0.038	0.298	0.022					
23/	4/91	142.8	Gray	2.002	21.722	4.574	0.024	0.156	0.012					
26/	4/91	195.2	Black	1.352	5.981	4.359	0.026	0.144	0.024					

# Suspended Particulate Matter Measurements Using High Volume Sampler During MARCH & APRIL 1991

### MUBARAK HOSPITAL

Do	ate	Total	Filter Shade	Concentration of Elements ug/m3									
	ice	ug/m3	Shade	Na	Ca	Fa	Ni	Pb	v	Al			
18/	3/91	117.7	Black	2.204	11.023	1.384	0.036	0.317	0.020				
26/	3/91	124.9	Black	2.442	15.852	1.840	0.029	0.456	0.010				
31/	3/91	154.2	Black	2.832	6.572	3.566	0.022	0.441	0.028				
3/	4/91	263.9	Black	2.080	14.481	7.192	0.069	0.209	0.041				
8/	4/91	735.3	Sandwish	2.084	18.032	50.085	0.123	0.346	0.042				
13/	4/91	176.1	Black	2.421	14.721	3.696	0.032	0.188	0.027				
16/	4/91	212.6	Black -	1.840	23.001	6.109	0.055	0.199	0.035				
20/	4/91	132.3	Black	2.088	26.109	2.199	0.034	0.226	0.019				
24/	4/91	282.8	Black	2.364	27.415	4.329	0.045	0.329	0.045				
27/	4/91	418.3	Gray	2.616	33.961	11.872	0.093	0.244	0.043				

# Suspended Particulate Matter Measurements Using High Volume Sampler During MARCH & APRIL 1991

# ADDAN HOSPITAL

D	ate	Total Conc.	Filter Shade	Concentration of Elements ug/m3									
	200	ug/m3	Jiidd	Na ·	Ca	Fa	Ni	Pb	V	Al .			
19/	3/91	128.4	Gray	2.192	29.732	2.697	0.059	0.257	0.023				
24/	3/91	242.0	Black	2.370	17.743	5.134	0.052	0.313	0.034				
27/	3/91	182.0	Black										
1/	4/91	327.7	Black	2.912	36.400	2.004	0.056	0.279	0.040				
6/	4/91	142.8	Gray	2.387	11.936	5.026	0.039	0.143	0.015				
9/	4/91	1159.7	Sandwish	2.594	42.121	22.123	0.145	0.115	0.075				
14/	4/91	196.3	Black	2.698	31.300	2.636	0.055	0.210	0.028				
17/	4/91	353.5	Black	2.617	42.503	10.522	0.073	0.175	0.064				
22/	4/91	276.4	Black	2.873	33.324	6.800	0.073	0.288	0.035				
25/	4/91	189.5	Black	2.366	5.917	3.546	0.052	0.256	0.038				

# Microbiological Examination of Coastal Water

# APRIL / 1991

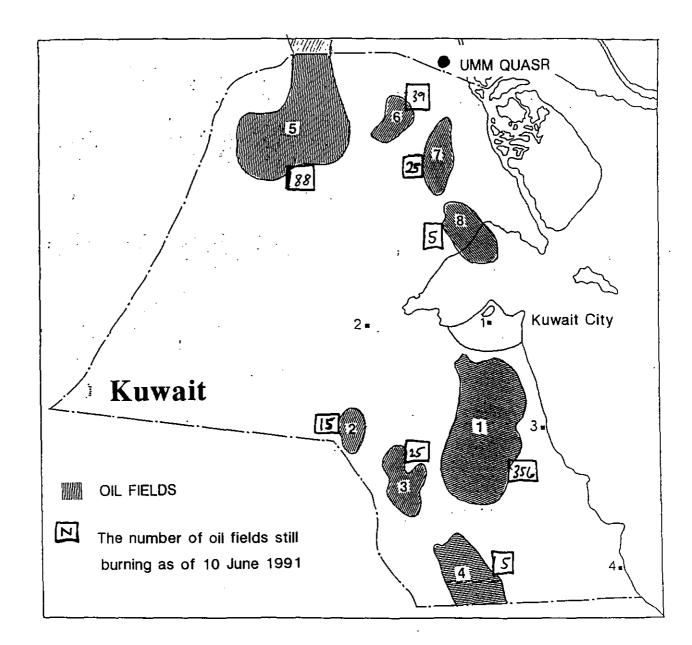
Location	Sampling Date	Air Temp	1	No.of Indicator Bacteria/100 ml				
· ·		С		Total Coliform	Faecal Coliform	Streptococcus Faecal Bacteria		
Al-Salam Beach	29/ 4/91	32	22	2360	290	660		
Benaid Al-Gar	29/ 4/91	32	22	1540	14	10		
Al-Messila	29/ 4/91	34	22	580	171	180		
Al-Beda'a	29/ 4/91	34	22	1100	140	290		

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# APPENDIX E

OIL WELLS BURNING IN KUWAIT
AS OF 10 JUNE 1991

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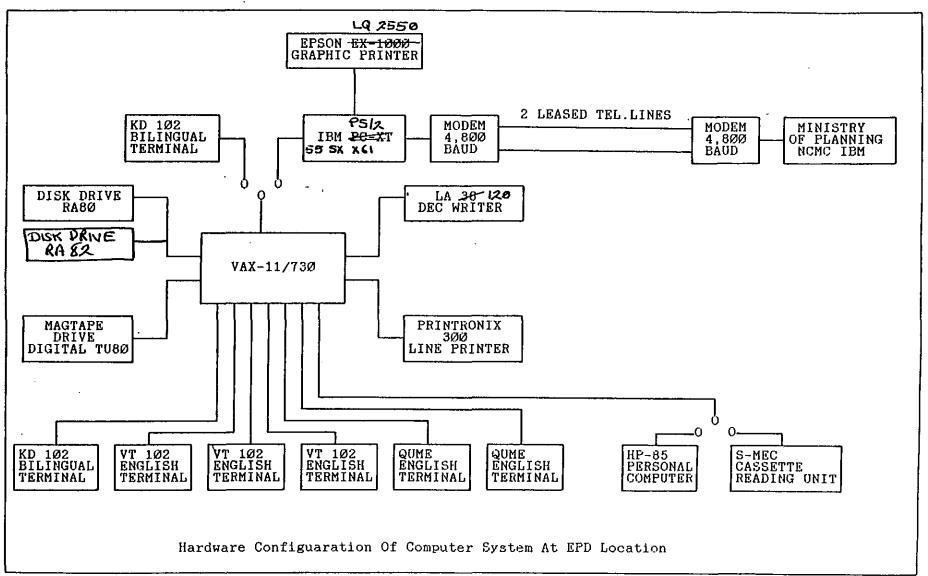


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# APPENDIX F

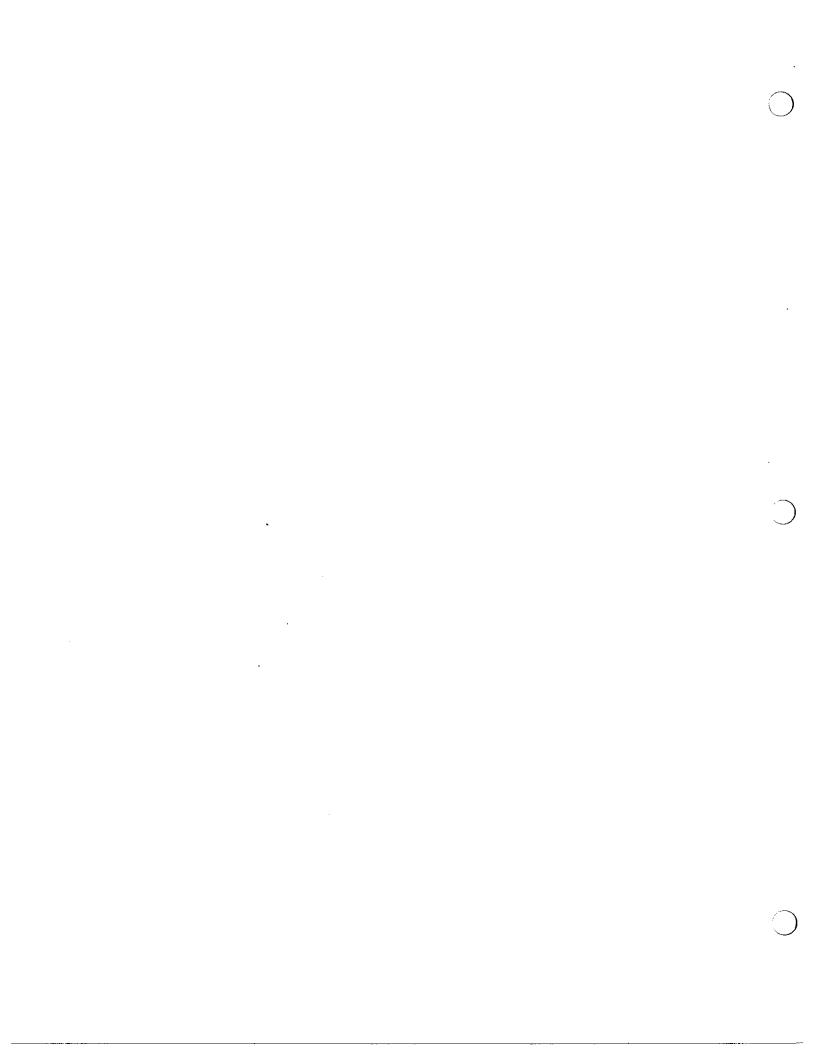
COMPUTER SYSTEM AT EPD

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# APPENDIX G

- A) "FINGERPRINT" OF CRUDE OIL ANALYSES
- B) HEIGHT OF GROUND BASED INVERSION AS MEASURED BY A MONOSTATIC SODAR



8/6/91 Euloil Exp. At. = 16 ·i Firequist of coule oil mining 11.54 29 20 न ।। ra ci chil

PHH # 16 ARENY 1.25 1.35 OPFO TYPE 36,7429 54.7190 14 19 87 Pi 56 30 1120000 124 1,81 67.58 81.41 63.18 83.97 85.51 56ค99ค 1834300 ٠, *** 1213909 w 277420 263949 26.02 26.53 27.97 29.61 7777 ....7 1691400 ٧r رة ا -625930 7,44 P 472250 ٧r 33. 9F 186770 70-

MUL FACTOR- 1 0000F100

Report: Grand band invessions
in Vinnait.

by Dr. M. R. Bennely
Eng Sabah Aka M-Walhab.

Table (11.2)

1981-64 data from 1968.

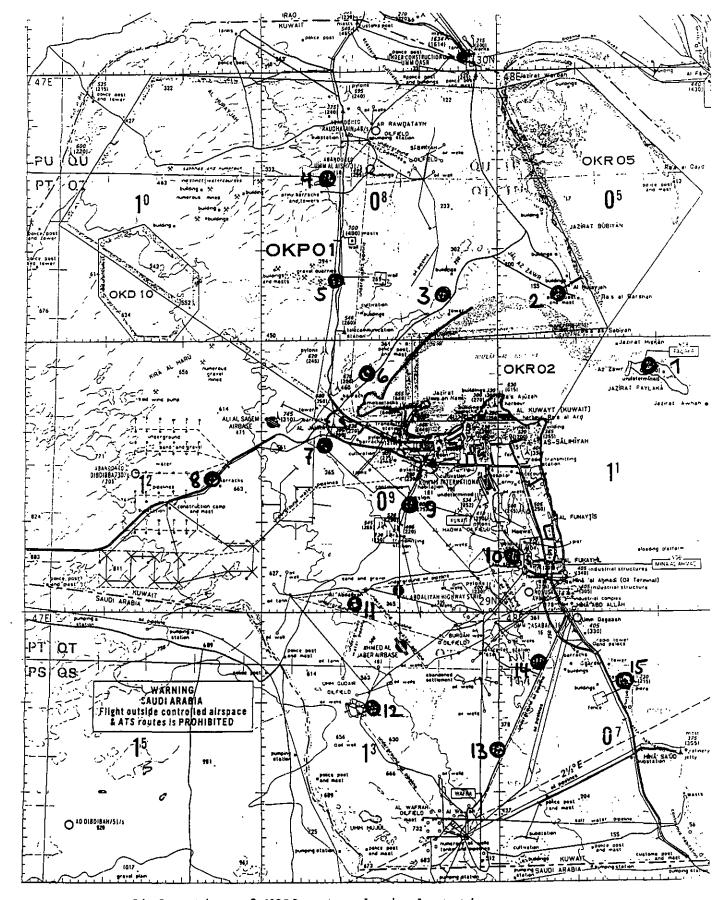
The mean and s.d. of the height of the ground based thermal inversion detected by the sonic radar in Kuwait in the period covered by the study in the various hours of the day according to the season.

11 a.v.a 5					Height	i in	Heters					
Hour of the day		Autumn			luter		Sį	pring		Sui	was r	
~~~~~	Mean			Mean							S.d.	N
0	140.0	42.2	54	147.1	40.9	34	146.7	36.1	42	201.1	35.9	37
1	142.8	41.6	58	149.9	42.7	35	141.9	35.0	42	204.3	38.9	3
2_	143.2	42.9	57	154.1	42.5	34	138.1	39.2	41	219.5	40.4	3
3	146.3	42.6	57	155.3	38.5	34	141.0	34.2	40	228.6	49.8	3
4	149.1	39.N	55	156.6	38.7	35	1/2.5	37.9	40	235.0	50.2	3
5	152.3	39.1	57	156.6	41.9	35	146.1	41.1	36	230.4	44.0	2
6	148.3	38.4	58	157.8	37.0	36	142.7	40.9	37	232.0	17.9	
7	146.3	37.3	4]	155.2	41.8	33	150.8	34.5	26	-	-	
8	170.0	30.3	6	168.6	41.4	7	158.0	30.5	10	-	-	
9	-	-	-	-	-	-	•	-	-	-	-	
10	-	-	-	-	-	-	-	-	•	-	-	
11	~_	-		-	-	-	-	-	-	-	-	
12	-	-	-	-	-	-	-	-	-	-	-	
13	-	-	-	-	-	-	-	-	-	-	-	
14		-	-	-	-	-	-	-	-	-	-	
15	190.0	-	2	166.7	30.6	3	200.0	-	1	200.0	28.3	
16	144.0	15.8	10	153.3	32.7	6	168.0	48.2	5	197.8	18.6	
17	136.5	23.9	23	142.2	21.1	9	169. l	38.3	11	186.7	27.4	1
18	133.5	25.9	34	133.8	27.1	16	157.0	36.9	20	182.5	20.7	2
19	138.0	29.3	40	140.0	31.4	1.9	153.3	34.6	30	175.2	30.0	3
20	139.0	29.2	46	145.2	35.3	23	152.2	36.2	36	174.3	34.5	:
21	139.6	30.4	55	145.0	33.8	28	152.6	30.7	35	184.0	34.6	3
22	139.3	31.8	57	144.0	37.3	30	154.7	34.1	38	185.0	25.5	:
23	140.3	34.1	59	148.8	36.6	32	153.5	38.8	40	180.5	33.9	

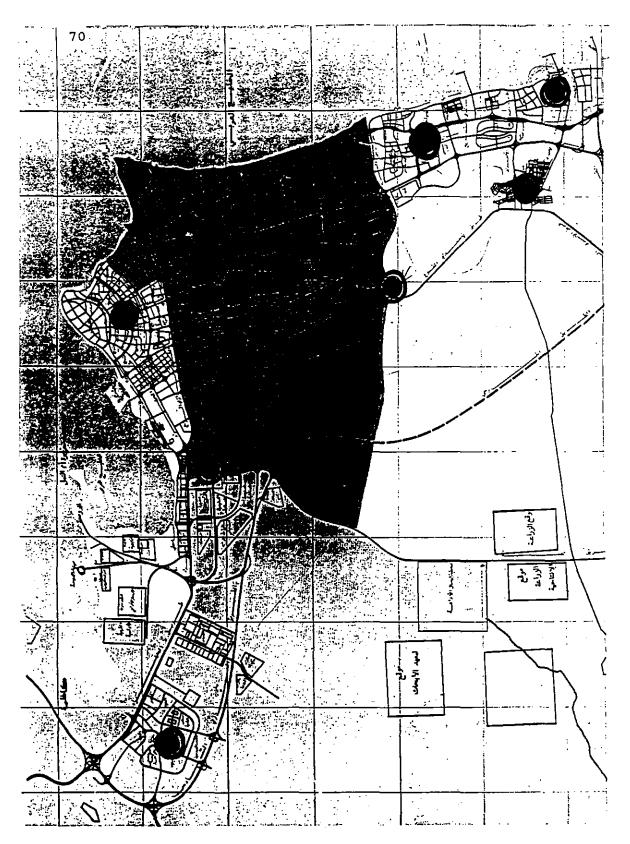
APPENDIX H

- A) LOCATION OF NOAA METEOROLOGICAL STATIONS
- B) LOCATION OF $PM_{1\ 0}$ SAMPLERS (FROM US EPA)
- C) EXAMPLE PLOT OF TEMPERATURE

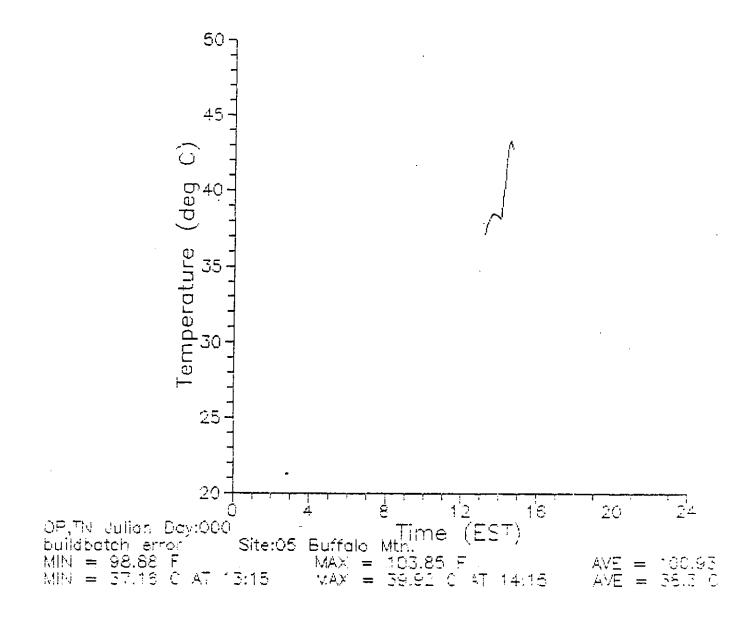
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A) Location of NOAA meterological stations



H 5) Location of ERA PMIS samplers.



Hc) Temperatur plot from NOAA station in Kuwait.

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APPENDIX I

PROTOCOL OF VISIT IN KUWAIT 7-12 JUNE 1991

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NORWEGIAN INSTITUTE FOR AIR RESEARCH (NILU) Our ref.: BS/SBH/O-91042/26 June 1991



PROTOCOL OF VISIT IN KUWAIT 7-12 JUNE 1991

The following conclusions have been drawn from discussions with representatives from the Environment Protection Department (EPD) and site visits in Kuwait 7-12 June 1991:

- 1. Two fixed air quality monitoring stations will be delivered from NILU, Norway to Kuwait. Instruments will be placed in isolated and air conditioned containers, size: 4.1 m x 2,0 m, height 2,3 m, weight included instruments approximately 2.200 kg.
- 2. Locations of the two stations will be:
 - a) Jahra, 30 km west of EPD centre in Kuwait city.
 - b) Mina Al Zoor, at the north western corner of the power plant site, 80 km SSE of the EPD centre.

At both locations the containers will be placed at the roof of low, flat buildings. Standard 3 phase power and telephone lines will be made available at both sites. Power requirements: 20 kW.

3. First priority air pollutants and parameters

The Norwegian contribution of 1 mill. USD has by UNEP been divided into administration, WMO and WHO contributions. The amount left for AQ stations from NILU is at present 350.000 USD. We therefore have divided the AQ instrument package into first and second priority. Only first priority can be delivered within the 350.000 USD.

First priority monitors are:

 ${\rm SO_2}$ (by Monitor Lab.), ${\rm PM_{10}}$ (by TEOM), ${\rm NO/NO_x}$ (by Monitor Lab), meteorology (wind speed and direction, temperatures, radiation) by Aanderaa Instruments. The stations will be automatic on telephone

line. Local calibration and maintenance will be undertaken once a week.

4. Second priority A.Q. parameters

If funds are available, the following parameters can be added to the NILU stations:

- 1. Dustfall (NILU international standard collectors)
- 2. Ozone (by Monitor Lab, UV absorption)
- 3. H₂S (by Monitor Lab)
- 4. CO (by Monitor Lab, infrared absorption)
- 5. THC (not decided, SIMRAD Optronics?)
- 6. PAH (NILU PUF sampler)
- 7. Soot/SO₂ (NILU sequential 24 h sampler)

5. Data transmission

All data from the NILU AQ station (first priority) will be transmitted via good quality public telephone lines for data transmission, up to 2400 baud (see flow chart). Three switched lines and five dedicated lines have to be prepared by Kuwait. These includes also data transmission from the EPD Horiba AQ-stations, where NILU provides 3 logger/transmission systems included 6 modems.

6. Warning centre at EPD

To obtain printouts of concentrations and meteorological variables from all 5 AQ stations (2 NILU + 3 EPD) NILU will provide a data logger and a printer. To transfer data to the VAX main frame computer, Norway will also provide a PC with floppy disc. (The format available every 5 min is indicated on page 7).

7. Modelling for warning purpose

No money is at present available for modelling. However, it will be possible to establish the NILU modelling system, provided that a HP Apollo work station with at least 8 MB RAM and preferably 300 MB disc capacity will be available. Wind field data from the NOAA meteorological network can be transferred to the HP computer as input to the

dispersion/statistical model. Further details on displays and possible applications have to be discussed later.

8. Optional information and warning centre

Based upon the NILU experience from planning and performance of tracer experiments and from information system for air quality in Oslo, NILU can provide training of local personnel for air quality information and warning in Kuwait.

9. Future possibilities

During the discussions, several aspects were indicated as possible future co-operations:

- a) NILU is responsible for intercalibration and intercomparisons of chemical analyses in EMEP (European Monitoring and Evaluation Programme). Possibilities for participatation by the EPD will be discussed by NILU experts.
- b) Remote sensing of various air pollutants is being performed and further developed in Scandinavia. Some of these instruments can be included in the present network if funds are made available:
 - DOAS (differential optical absorption spectroscopy) is at present used by NILU in Oslo.
 - New HC instruments based upon IR spectroscopy are available in Norway for high concentration ranges.
 - Development of new diode laser based absorption spectroscopy is being developed by NILU/NEO. These instruments for HC and other gases can be used in future programmes.
- c) NILUs experience with doppler sodars for measurements of wind and turbulence profiles from the surface to 1000 m can be transferred to Kuwait if requested.

10. NILU samplers

NILU will provide 5 dustfall buckets (international standard), and one stand within the first priority delivery to the EPD laboratory in Kuwait.

NILU will also estimate costs and prepare PAH samplers (NILU PUF) for installation in the two NILU stations. Three additional PUF samplers will be delivered as a kit for building into existing stations.

11. <u>Draft cost estimate</u>

The first priority monitoring equipment, installation and operation is estimated to 402.900 USD, consisting of the following items:

One NILU monitoring st Container SO ₂ TEOM NO _x Wind Data logging*	USD 12.0 " 15.4 " 25.4 " 16.0 " 9.2 " 14.1		
2 set span gas	" 9.1 USD 101.2		
Two NILU stations		USD	202.4
EPD warning centre 2 modems Ram memory logger Modem out Printer PC + disc	USD 1.8 " 12.3 " 0.9 " 3.1 " 3.7		
Horiba stations		USD	21.8
Site logger 5.5x3 and modem	USD 16.6		
Central modem	2.8	USD	19.4
Operations Transport Site inspections Preparation Start up Inspections Follow up (telephone) man power	USD 18.5 " 21.2 " 15.4 " 47.2 " 31.0	030	15.4
man pone.	235 20.0	USD USD	159.3 402.9

Not included:

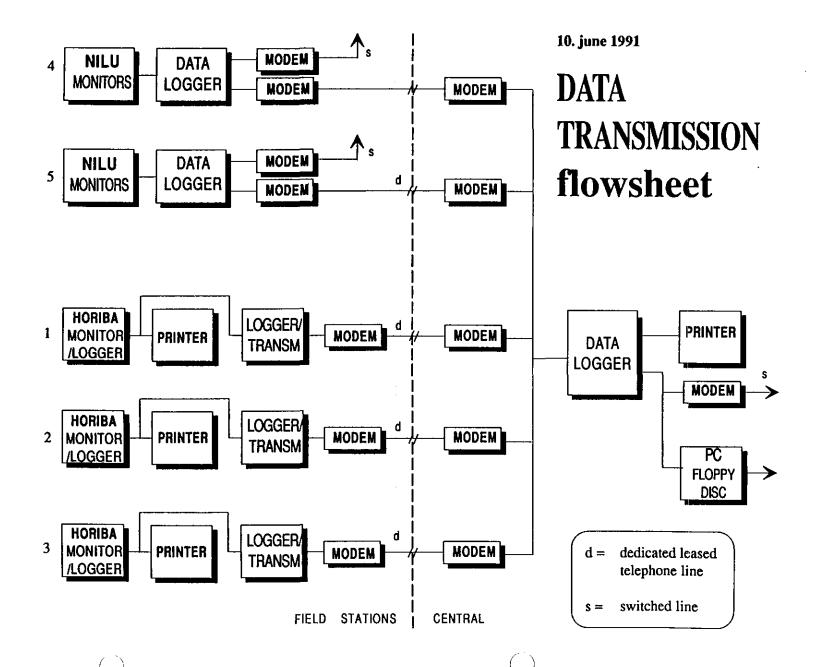
- Sparepart kit and extras
- Electric power and telephone lines
- Transport, handling, lifting in Kuwait
- Local inspections

Tickets, accommodation in Kuwait and local transportation can be made available from Kuwait. A total cost for these services was estimated to ~35.000 USD.

In reference to chapter 7, modelling for warning purpose, these tasks have been estimated to:

Modelling/interface/work station

~ 100.000 USD



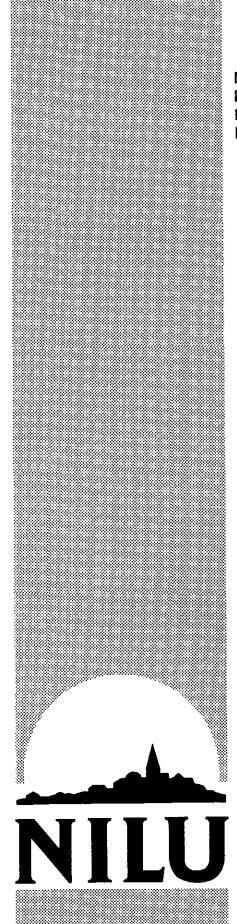
Format available on printout every five minute at EPD warning centre in Kuwait.

PRINTER FORMAT CENTRAL

\$T	DATE	INST	T\$	H2S.	S02	THC	etc	
01	910608	1005	0001	0000	0002	0600		
02	910608	1005	0000	0010	0001	0590		
03	910608	1005	0003	0005	0003	0430		ALTERNATIVE 1
04	910608	1005	-	-	0003	-		
05	910608	1005		-	0006	-		
			•					
ST	DATE	INST	TS	H2S	S02	THC	etc	

\$T	DATE	INST	TS	H2S	S02	THC	etc	
1	910608	1005	1	0	2	600		
2	910608	1005	0	10	1	590		
3	910608	1005	3	5	3	430		ALTERNATIVE 2
4	910608	1005	-	-	3.	-		
- 5	910608	1005	-		6	-		
ST	DATE	INST	TS	H2S	S02	THC	etc	

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NILU TR : 6/91 REFERENCE: O-91042

: JULY 1991 ISBN

: 82-425-0262-5

Air Quality Measurements at Nordmedunit, Umm Quasr, Iraq

B. Sivertsen

NORSK INSTITUTT FOR LUFTFORSKNING Norwegian Institute for Air Research POSTBOKS 64 — N-2001 LILLESTRØM — NORWAY

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5	THE FIRST RESULTS	3
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AIR QUALITY MEASUREMENTS AT NORDMEDUNIT, UMM QUASR, IRAQ

1 INTRODUCTION

The Norwegian Institute for Air Research (NILU) was asked by the Norwegian army field hospital (UNIKOM/NORDMEDUNIT) in Umm Quasr to provide instruments for air quality measurements. The objectives of these measurements were to daily collect air samples to quantify the air pollution impact at the hospital. The health personnel consists of 50 Norwegians. Some of these persons will be located in the area for up to 12 months. A selection of persons will be followed up through medical tests. Information about air quality is thus needed for explanatory reasons. The concern about potential health effects was also mentioned in the request to NILU.

2 INSTRUMENTATION

The following instruments are being used at the Umm Quasr site:

- One automatic 24 h sampler (NILU-FK) for SO₂ and soot measurements (filter and absorption solution).
- One NILU PUF sampler for PAH sampling on filter and on polyurethane foam (filters can also be used for analyses of heavy metals).
- One analog wind recorder (Woelfle) mounted on a 2 m mast, located in an open field.

Temperatures are also measured at 01, 07, 13 and 19 hrs every day.

3 LOCATION

The monitoring site is located near Umm Quasr in the UN controlled zone at the border between Kuwait and Iraq (see map, Figure 1). The area is located 20-50 km north and north east of some of the burning oil fields in the north of Kuwait. The distance from the larger part of the burning oil field is about 100 km.

4 WIND DIRECTIONS

The predominant winds in May and June have been from around north and north-west (roughly 80% of the time). This means that smoke from the fires only rarely has been blown directly from the fire areas towards Umm Quasr. One such period was, however, observed between 26 and 27 May 1991. In the morning of 27 May weak winds (0.5 m/s) from south and west were observed in Umm Quasr.

5 THE FIRST RESULTS

The 24 h average SO_2 concentrations in May and June 1991 varied between 5 and 36 $\mu g/m^3$. The average concentration was 11.5 ± 6.4 $\mu g/m^3$. The highest concentration, 36 $\mu g/m^3$, was measured on 26-27 May 1991.

The measured 24 h average soot concentrations were between 8 and 400 μ g/m³. The average concentration was 43.3 \pm 71.5 μ g/m³.

The WHO air quality guideline value for black smoke (reflectance method), which is 125 $\mu g/m^3$ as a 24 h average, was exceeded on two occations. On 26-27 May 1991 the measured concentration was more than 3 times the WHO guideline value. On 14-15 June 1991 the soot concentration was 156 $\mu g/m^3$.

Four PAH samples have been analyzed so far. The total PAH con-

centrations varied between 207 and 412 ng/m³. Naphtalene alone accounted for between 45 and 60%. The naphtalene concentrations in air were probably considerably higher. At high temperatures the sampling efficiencies of naphtalene and other volatile PAH-components are usually poor.

The average total PAH concentration of (296 ± 87) ng/m³ is rather low, and much lower than the concentrations measured in some of the industrialized areas in Norway or in streets with high traffic.

6 CONCLUSIONS

Strong conclusions cannot be drawn based on these rather limited data, collected during a period with favourable weather conditions with little air quality impact on the location in Umm Quasr. However, during winds from south and south west, the concentrations of black smoke (soot) at the border between Kuwait and Iraq exceeded the WHO air quality guideline value by a factor of 3. The SO_2 concentrations were surprisingly low and not higher than $36~\mu\text{g/m}^3$.

Also the total PAH concentrations were rather low. The most volatile compounds might, however, have been considerably higher than measured by the methods used.

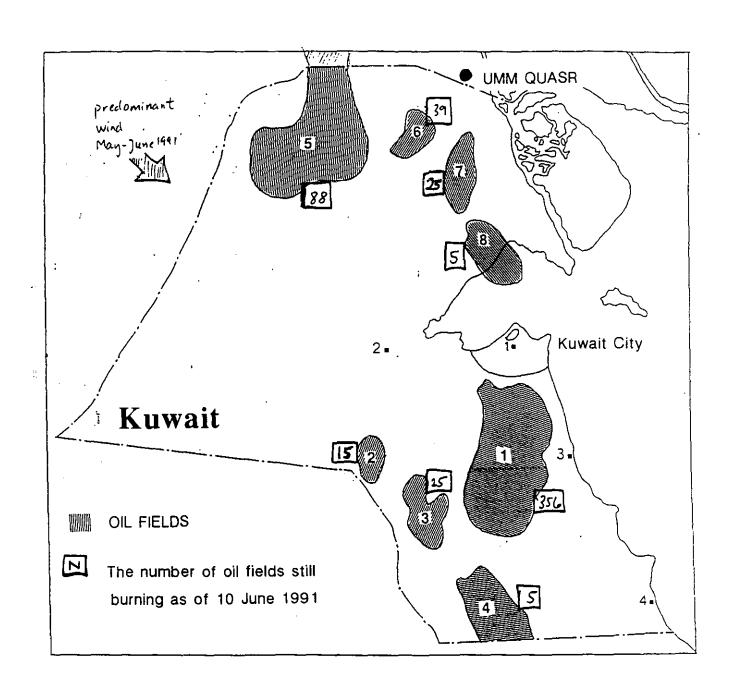
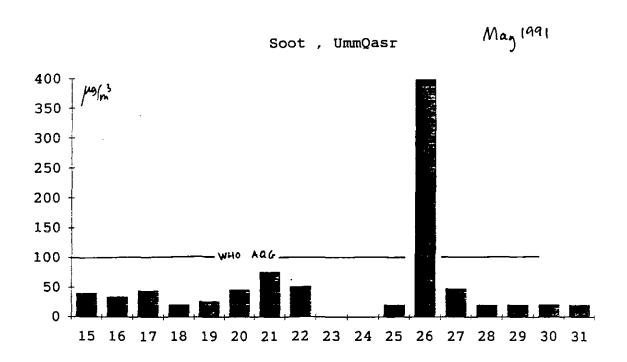


Figure 1: Burning oil fields and location of monitoring site in Umm Quasr.



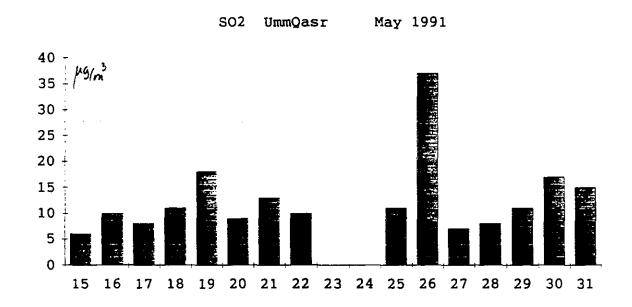


Figure 2: 24 h average concentrations of SO_2 and soot (black smoke) in Umm Quasr at the border between Kuwait and Iraq (May 1991).

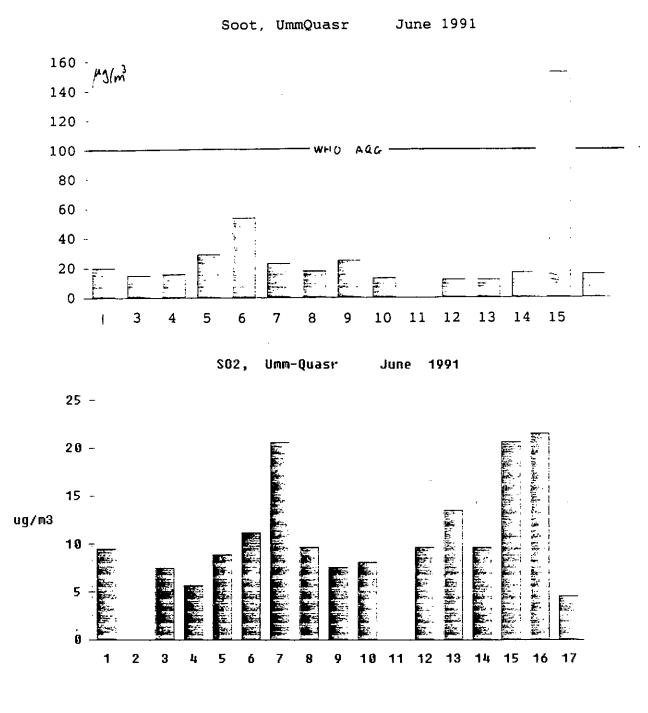


Figure 3: 24 h average concentrations of SO_2 and soot (black smoke) in Umm Quasr at the border between Kuwait and Iraq (June 1991).

Table 1: Concentration of PAH in air (ng/m^3) Umm Quasr, Kuwait

PAH	21.5.1991 Total	27.5.1991 Total	14-15.6.1991 Total	15.6.1991 Total
Naphtalene	228	94.4	184	132
2-methylnaphthalene	8.8	4.5	7.2	9.3
1-methylnaphthalene	4.6	2.1	4.2	5.6
Biphenyl	5.0	2.1	7.4	17.4
Acenaphthylene		1.4		
Acenapthene				
Dibenzofuran	5.7			
Fluorene	15.4	7.2	17.6	34.8
Dibenzothiophene	26.6	12.2	2.7	5.5
Phenanthrene	48.7	31.7	33.2	22.3
Anthracene	10.8	4.5	6.1	10.4
2-methylphenanthrene	11.4	3.4	2.5	3.0
2-metylanthracene	İ			
1-methylphenanthrene	}			
Fluoranthene	17.3	11.5	15.3	6.6
Pyrene	16.1	11.3	9.6	6.1
Benzo(a)fluorene		1		
Retene]		
Benzo(b)fluorene		1		
Benzo(g,h,i)fluoranthene		1.4	0.5	
Cyklopenta(cd)pyrene	(2.9)	(2.7)	(2.0)	(1.7)
Benz(a)anthracene	1.3	1.0	1.3	~0.4
Chrysene/Thriphenylene	4.6	2.4	1.9	1.I
Benzo(b,j,k)fluoranthenes	2.7	5.9	2.9	1.4
Benzo(e)pyrene	~0.8	1.3	1.2	0.6
Benzo(a)pyrene	-0.8	0.3	1.0	0.5
Perylene				
Inden-(1,2,3-c,d)pyrene		1.8	0.7	0.7
Dibenzo(ac/ah)anthraces		1		
Benzo(g,h,i)perylene		1.8	1.1	1.0
Anthanthrene				
Coronene		2.0	1.0	
1,2,4,5-dibenzopyrene				
Total	412	207	303	260

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RAPPORTTYPE TEKNISK RAPPORT	RAPPORTNR. TR 6/91	ISBN-82-425-0262-5						
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FORFATTER(E)		TILGJENGELIGHET *						
B. Sivertsen		OPPDRAGSGIVERS REF.						
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ABSTRACT

The first results of air quality measurements performed by NILU in Umm Quasr, at the border of Kuwait and Iraq show high concentrations of black smoke, and rather low concentrations of SO2 and PAH.

* Kategorier: Åpen - kan bestilles fra NILU Må bestilles gjennom oppdragsgiver B Kan ikke utleveres

[April - May]

DRAFT

AMBIENT AIR MONITORING DATA Dammam

MEPA - Dammam Industrial Estates April 1991 Hourly Averages for SO2 in ppm

Hour ay ⊨	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
1	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ИD	ND	ND	ND	ND	מא	ND	****
2	ND	ND	ND	ND	. אם	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
3	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
4	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
5	ND	NO	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
6	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
9	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
10	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
11	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
12	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ОN	ND	ND	ND	****						
14	ND	ND	ND	DN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
15	ND	ND		ND	ND			ND	ND	ND	ND	ND	ND	ND	*					0.020					0.0114
16							0.009						-												0.0047
																								0.057	0.0154
18							0.013																		0.0207
19							0.014																		0.0135
																								0.011	
21							0.021																		0.0150
22 23							0.019																		0.0143
							0.028																	0.011	0.0156
25	ND.	ND	ND	O,UIS	ND.	U.U43	0.046 ND	DCU.U	0.001 D	0.040 ND		CAL	0.080 CAL	ND CAL	ND CAL	.ND	ND 0.007	ND n nos	ND COO	ND 0.003	ND O OO4	ND NO O	ND COOK	ND 0.007	0.0378 0.0053
26			,				טא 0.016				ND non														0.0055
27							0.018																		0.0100 0.0125
							0.061																		0.0140
	-													- • • • •											0.0221
							0.012																		0.0221
, ,,	U.U.O	0.010	0.017	0.010	0.011	0.010	0.014	0.017	0.020	0.020	0.020	0.041	0.021	0.010	0.020	۷.023	0.019	0.017				o.ozo Honthly			0.0150

Maximum Hourly Average was 0.096 at Hour 14 on Day 18 with 1 occurences and there were no Hourly Violations

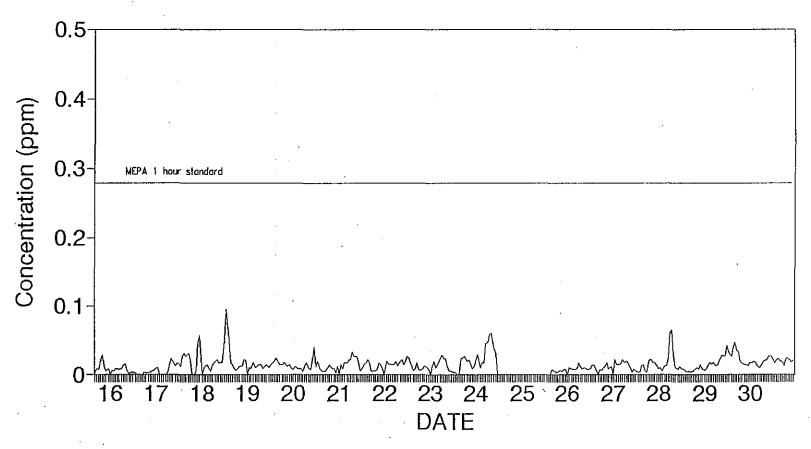
Maximum Daily Average was 0.0378 on Day 24 with 1 occurences and there were no Daily Violations

Operating Efficiency = 46.8 percent

MEPA - Dammam Industrial Estates April 1991 Frequency Distribution Hourly Averages for SO2 in ppm

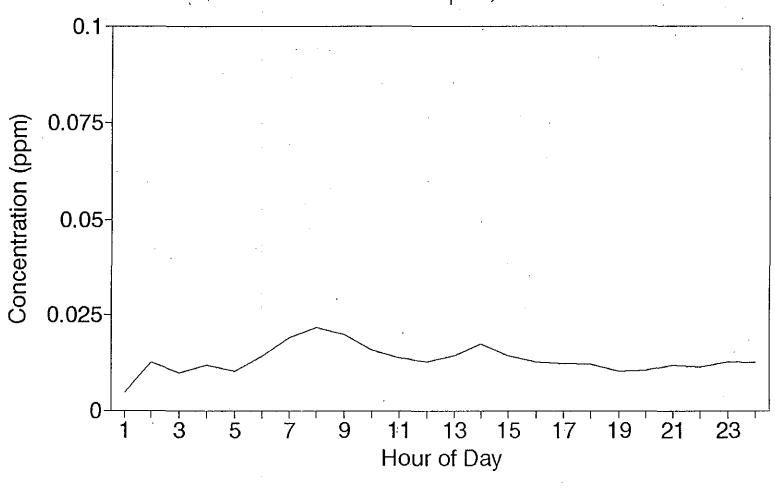
Concentration I	# of Hours	Percentage
0.000 - 0.020	263	6.67
0.021 - 0.060	09	18.2
0.061 - 0.110	. 4 9	1.8
0.111 - 0.170	0.	0.0
0.171 - 0.340	Ö	0.0
0.341+	0.	0.0

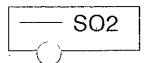
Hourly SO2 - April, 1991



— SO2

Diurnal SO2 - April, 1991





MEPA - Dammam Industrial Estates April 1991 Hourly Averages for NOx in ppm

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
ay -			·																						Average
1	ND								ND									ND						ND	****
2	ND		ND	*	ND				ND		HD				ND			ND						ND	****
3	ND		ND		ND	ND			ND	ND	ИD		ND	ND	ND		ИD	ND						ИD	****
4	ND		ND	•	ND	ND	ND	ОИ	ND	ND	•	ND			•	ND	****								
5	ND	ND	ND	ND	ИD	ND	ND	ND	NO	ND	ND	ND	ND	ND	ИD	ND	ND	ND	****						
6	ND	ND	ND	HD	ND	ND	ND	ND.	ND	HD	ИD	ND	ND	ND	****										
7	ND	NĎ	ND	HD	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	****								
8	ИD	ND	DN	ND	ФИ	ND	ND	****																	
9	ND	ND	ND	***																					
10	ND	ND	ND	****																					
11	ND	ИĐ	ND	ND	****																				
12	ND	ND	ND	****																					
13	ND	סא	ND	ŅD	ND	****																			
14	ND	DN	ND	ND	ND	ND	ND	ИD	ИD	ND	ND	ND	ИD	ND	ND	ND	ND	****							
15	ND	0.047	0.027	0.047	0.032	0.050	0.068	0.080	0.056	0.0509															
16	ND	0.049	0.035	0.061	0.058	0.046	0.080	0.100	0.032	0.024	0.014	0.018	0.012	0.013	0.014	0.017	0.019	0.024	0.088	0.086	0.053	0.052	0.052	0.091	0.0451
17	0.113	0.085	0.038	0.022	0.038	0.030	0.053	0.060	0.038	0.030	0.025	0.041	0.031	0.028	0.026	0.028	0.048	0.039	0.056	0.060	0.064	0.058	0.143	0.050	0.0502
18	ND	0.016	0.018	0.020	0.039	0.037	0.058	0.045	0.087	0.063	0.045	0.042	0.036	0.035	0.036	0.036	0.052	0.068	0.097	0.081	0.088	0.195	0.134	0.124	0.0631
19	ND	0.051	0.045	0.042	0.055	0.053	0.074	0.050	0.023	0.021	0.017	0.017	0.015	0.018	0.026	0.040	0.037	0.071	0.114	0.105	0.078	0.076	0.087	0.066	0.0513
20	0.052	0.028	0.027	0.021	0.030	0.028	0.038	0.063	0.033	0.038	0.036	0.032	0.026	0.027	0.039	0.040	0.051	0.068	0.039	0.063	0.097	0.072	0.030	0.027	0.0419
21	ND	0.019	0.019	0.017	0.014	0.024	0.038	0.085	0.061	0.047	0.037	CAL	CAL	0.069	0.038	0.044	0.059	0.058	0.064	0.060	0.068	0.097	0.083	0.057	0.0504
22	ND	0.019	0.015	0.014	0.014	0.021	0.045	0.054	0.049	0.045	0.035	0.040	0.043	0.026	0.029	0.035	0.057	0.061	0.067	0.090	0.086	0.121	0.081	0.046	0.0475
23	ND	0.017	0.017	0.010	0.013	0.017	0.038	0.053	0.047	0.035	0.024	0.025	0.029	0.030	0.027	0.048	0.046	0.100	0.102	0.111	0.117	0.066	0.048	0.043	0.0462
24	0.025	0.021	0.014	0.016	0.015	0.024	0.058	0.113	0.072	0.045	0.038	0.043	0.037	0.034	0.033	0.041	0.049	0.052	0.066	0.090	0.108	0.118	0.100	0.086	0.0541
25	ND	0.073	0.063	0.045	0.046	0.051	0.086	0.091	0.087	0.054	0.043	0.041	0.053	0.038	0.025	0.020	0.032	0.038	0.067	0.086	0.120	0.149	0.152	0.096	0.0677
26	ND	0.066	0.109	0.073	0.050	0.037	0.045	0.024	0.017	CAL	CAL	CAL	CAL	CAL	0.027	0.032	0.034	0.050	0.072	0.120	0.219	0.154	0.081	0.071	0.0712
27	ND	0.045	0.041	0.032	0.019	0.036	0.062	0.055	0.045	0.036	0.028	0.027	0.020	0.024	0.024	0.038	0.059	0.060	0.056	0.053	0.057	0.051	0.044	0.030	0.0410
28	0.019	0.019	0.020	0.020	0.020	0.030	0.058	0.079	0.041	0.030	0.032	0.029	0.026	0.029	0.028	0.028	0.040	0.046	0.059	0.060	0.071	0.074	0.100	0.079	0.0432
29	0.063	0.032	0.019	0.015	0.016	0.027	0.055	0.074	0.064	0.060	0.053	0.050	0.073	0.070	0.052	0.056	0.078	0.107	0.122	0.111	0.108	0.105	0.096	0.098	0.0668
30	0.083	0.048	0.040	0.028	0.027	0.037	0.069	0.105	0.064	0.066	0.048	0.048	0.043	0.047	0.043	0.044	0.046	0.064	0.100	0.114	0.146	0.141	0.155	0.093	0.0708
,																						uonth l	y Avera	100 -	0.0537

Maximum Hourly Average was 0.219 at Hour 21 on Day 26 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0712 on Day 26 with 1 occurences and there were no Daily Violations

Operating Efficiency = 49.9 percent

MEPA - Dammam Industrial Estates
April 1991
Frequency Distribution
Hourly Averages for NOx in ppm

Concentration	# of Hours	Percentage
0.000 - 0.050	197	56.0
0.051 - 0.110	132	37.5
0.111 - 0.210	22	6.2
0.211+	.1	n 3

MEPA - Dammam Industrial Estates April 1991 Hourly Averages for NO2 in ppm

																•									
Hour	1	2	3	4	5	6	7	8	. 9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
y F																	construction (pg.								Avera
1	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****										
2	ND	ND	ND	ND	סא	ND	ND	ND	ND	ND	ND	ND	ND	****											
3	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	סא	ND	ND	ИD	ND	ND	ИD	ND	ND	ND	ND	ND	ND	NĐ	****
4	ND	, ND	ND	ND	ND	ND	ИD	ND	ND	ND	ИD	ND	ND	ND	ND	****									
5	ND	, ND	. ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ИD	****										
6	ND	₩D	ND	ND	ND	ND	ND	ND	ND	ND	****														
7	מא	ND	· ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****												
8	ND	ND	NĐ	ND	ND	ND	ND	ND	ND	ND	ИD	****													
9	ND	ND	ND	ND	ND	ND	ND	ND	****																
10	ND	NO	ND	, ND	ND	ND	ND	ND	ND	****															
11	ND	· ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
12	ND	ND	ND	ND	ND	. ND	ND	ND	****																
13	ND	· ND	ND	ND	ND	ND	- ND	ND	ND	ND	ND	ND	ND	ND	ND	****									
14	ND	ND	ИD	ND	מא	ND	ND	ND	סא	ND	ND	ND	ND	ND	ND	ND	ND	****							
15	ND		ND	ND		ND	0.041	0.026	0.044	0.031	0.044	0.051	0.053	0.045	0.0419										
16	ND	0.040	0.033	0.039	0.038	0.037	0.038	0.041	0.024	0.019	0.011	0.016	0.011	0.012	0.012	0.015	0.017	0.023	0.042	0.041	0.043	0.045	0.046	0.045	0.0299
17																		•						0.044	0.0355
18	ND	0.016	0.018	0.019	0.032	0.031	0.040	0.033	0.038	0.037	0.032	0.034	0.033	0.032	0.034	0.033	0.044	0.049	0.054	0.058	0.055	0.054	0.050	0.049	0.0380
19					-				_				_												0.0329
20																								0.025	0.0316
21	ND	0.018	0.018	0.016	0.013	0.021	0.032	0.047	0.040	0.033	0.028	CAL	CAL	0.029	0.033	0.037	0.044	0.042	0.045	0.047	0.050	0.055	0.047	0.041	0.0350
22																									0.0299
23	-				_				_				_				-								0.0315
24									_				-	-											0.0328
25																									0.0419
26																									0.0449
27									_																0.0324
																									0.0294
																								0.045	0.0395
					_				_							0.035									0.0405
i JŲ	0.040	U.U39	0.032	0.024	0.024	0.030	0.039	0.04/	V.U4U	U.U46	0.037	V.U33	0.032	0.055	0.034	0.033	0.033	V.U44	0.032	0.039					0.0351
-																						Monthly	, Avera	age =	0.0331

Maximum Hourly Average was 0.078 at Hour 21 on Day 26 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0449 on Day 26 with 1 occurences and there were no Daily Violations

Operating Efficiency = 49.9 percent

MEPA - Dammam Industrial Estates April 1991 Frequency Distribution Hourly Averages for NO2 in ppm

Concentration	# of Hours	Percentage
0.000 · 0.050	320	6.06
0.051 - 0.110	- 32	9.1
0.111 - 0.210	0	0.0
0.211+	0	0.0

MEPA - Dammam Industrial Estates April 1991 Hourly Averages for NO in ppm

Hour ay ⊨	1	2	. 3	4	5	. 6	7	8	9	10	- 11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily ⊶ Average
' ^{''} '' '	ND	אר	סא י	ND	ND	ND	ИD	ND	ДK	ND	. ND	ND	ND	ND	ND.	ND	ND	NO	ND	ND	ND.	ND	ND	ND	****
2	ND			-	_		ND	ND	ND		. ND		ND				ND		ND			ND	ND	ND	****
3	ИD				ND		ND	ND	ND	ND	ND		ND				ND		ND			ND	ND	ND	****
4	ND				ND		ND	ND	ND	ND	ND		ND				ND		ND			סא	ND	ND	****
5	ND	ND	ND	ND	ND	ND	N D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	סא	ND	ND	ND	ND	****
6	ND	ND	ND	מא	ND	ND	ЖD	ND	ND	ND	ND	· ND	ND	ND	ND	מא	ND	ND	ND	ND	ND	ИD	ND	ND	****
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	****						
8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	.ND	ND	ND	ND	****						
10	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
11	ND	ND	ND	ND	NĎ	ND	₩D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
12	ND	ND	ND	ŊD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	****						
13	ND	ND	ND	ND	ND	ND	ND	ND	מא	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
14	ND	ND	ND	ND	ND	ND	ND	ND	מא	ND	DM	ND	ND	ND	ND	ND	ND	ND	****						
15	ND	-			ND	ND	ND	ND	ND	ND	ND	ND	ND	*	ND						0.006				0.0095
16									- •	,	••			• • • • •		•								0.047	
													_												0.0150
18																									0.0256
19																									0.0187
			-		-									-					-						0.0107 0.0156
21 22						••								•											0.0150
23											• •								- •						0.0150
											-							-							0.0218
25																									0.0262
26								0.004																	0.0268
27					-								-												0.0087
28											-														0.0138
																							•	0.054	
30	0.044	0.010	0.007	0.004	0.003	0.007	0.031	0.058	0.025	0.020	0.010	0.013	0.011	0.013	0.009	0.010	0.011	0.021	0.048	0.056	0.088	0.090	0.102	0.045	0.0307
 																					······	Monthly	y Avera	age =	0.0190

Maximum Hourly Average was 0.143 at Hour 22 on Day 18 with 2 occurences and there were no Hourly Violations

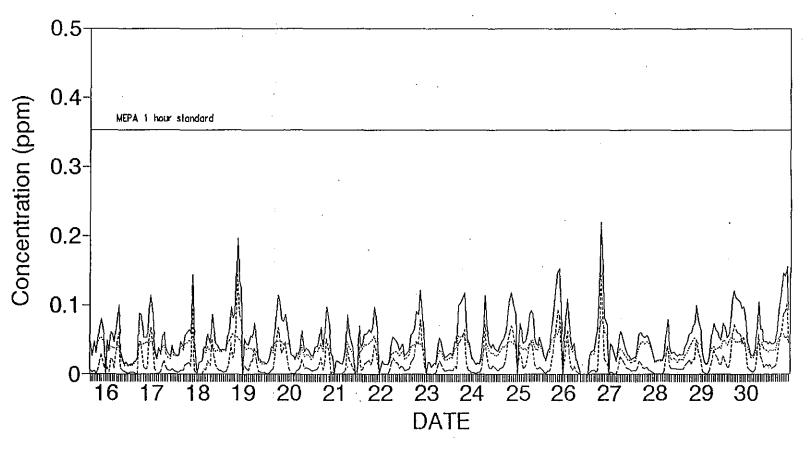
Maximum Daily Average was 0.0307 on Day 30 with 1 occurences and there were no Daily Violations

Operating Efficiency = 49.9 percent

MEPA - Dammam Industrial Estates
April 1991
Frequency Distribution
Hourly Averages for NO in ppm

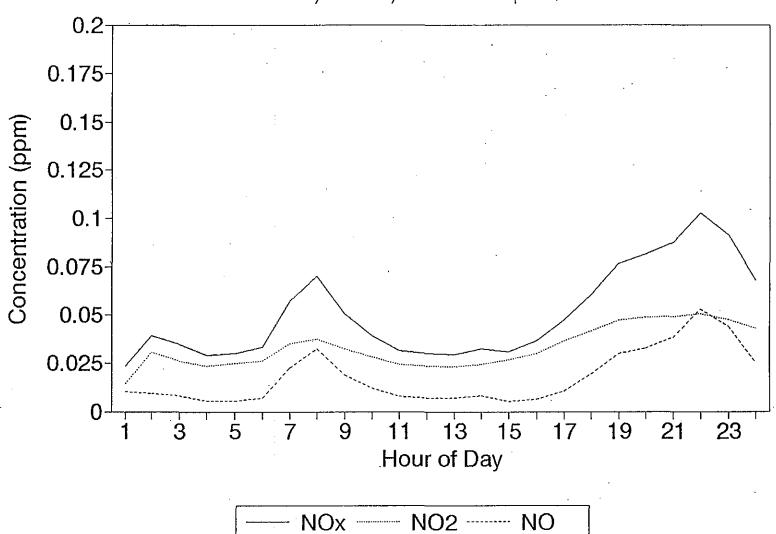
Concentration	# of Hours	Percentage
0,000 - 0,050	318	90.3
0.051 - 0.110	32	9.1
0.111 - 0.210	.2	9.0
0.211+	0	0.0

Hourly N0x/N02/N0 - April, 1991



— NOx — NO2 — NO

Diurnal NOx/NO2/NO - April, 1991



MEPA - Dammam Industrial Estates April 1991 Hourly Averages for NH3 in ppm

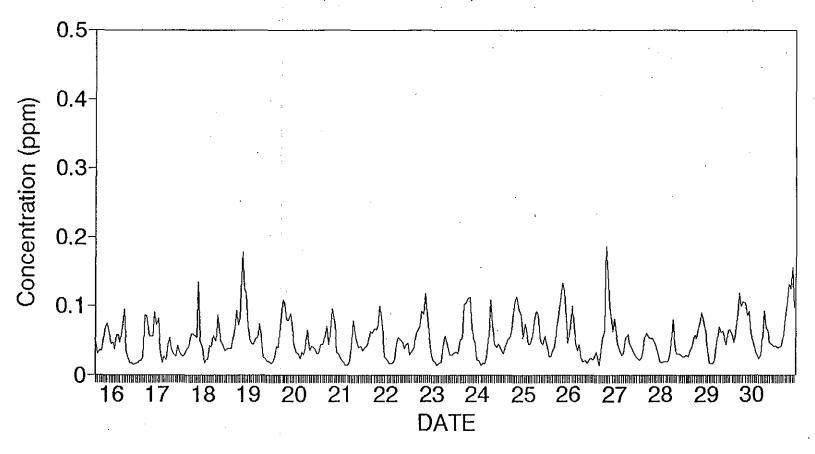
Hour Day	1	2	3	4	5	6	, 7	8	9	10	11	12	13	14	. 15	16	17	18	19	20	21	22	23	24	Daily — Average
1	ND	ND	ND	ND	ND	ND	מא	ND ND	ND	ND	****														
2	ND	ND			ND	ND			ИD		ND		_				ND		ND	ND	. ND	ND	ND	ND	****
3	ND	ND	ND	ND	ND	ND	מא	ND	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ИD	ND	ND	ND	****
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NĐ	ND	ND	ND	ND	ND	****
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	ND	ND	, ND	ND	ИD	ND	ND	ND	ИD	ND	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
9	ND	ND	ND	ND	ND	ND	ND	ND.	ND ND	ND	ND	****													
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
11	ND	ND	ND	ND	ND	ND	ND	ND.	ND ND	ND	ND	****													
12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	HD	ND	ND	ND	ND	ND	ND	****
13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND	ND		ND	ND			ND	ND	ND		ND		ND ND	ND	NO	***							
15	ND	ND	ND		ND	ND		***	ND	ND	ND		ND		ND					0.035					0.0501
				0.058	_								-								_		-		0.0458
				0.018	_																				0.0456
				0.023									_		-						-				
	- •																			• • •			• •		0.0529
																									0.0442
				0.014													-								0.0481
			-						-																0.0479
		-		0.013									_												0.0479
																					_				0.0535
																									0.0530
				0.037				i									•								
							-						_								-	-			0.0433
				0.019																					
																									0.0650
JU L	V.001		0.037	0.031	0.024	0.029	0.00.0	U 073	0.000	0.004	0.040	Ų.043	0.041	V.04Z	0.040	J.040	0.041	0.000	0.003				/ Avera		0.0518
F																					, r	wiit)	AVELE	196 -	0.0510

Maximum Hourly Average was 0.186 at Hour 21 on Day 26 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0650 on Day 30 with 1 occurences and there were no Daily Violations

Operating Efficiency = 51.1 percent

Hourly NH3 - April, 1991



- NH3

MEPA - Dammam Industrial Estates April 1991 Hourly Averages for 03 in ppm

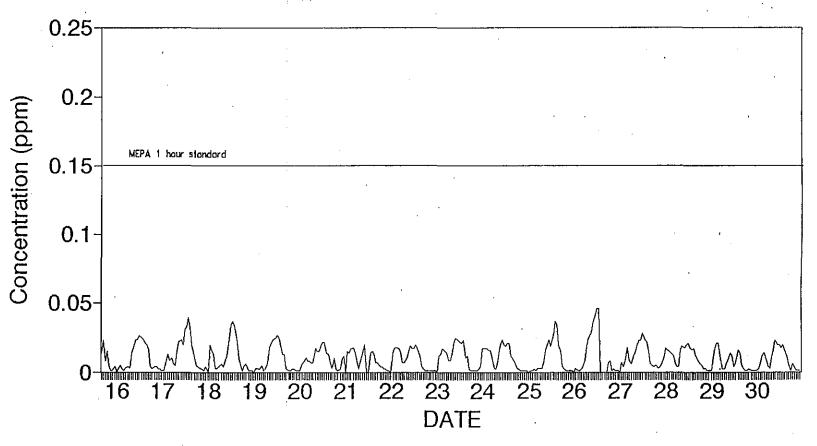
our	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	. 18	19	20	21	22	23	24	Daily
у												_							_						→ Averag
1	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	****
2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ИD	ND	ND	ND	ND	****
3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	нD	ND	ND	ND	ND	ND	ND	ND	****
5	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ND	ND	ND	****
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	NĎ	ND	ND	ND		ND	ND		ND	ND	ND	ИD	ND	ND	ND	****
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
8	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	· ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
9	ND	ND	ND	ND	HD	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND		ND	NO	ND		ND	ND	ИD	ND	****
10	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	-ND	ND	ND	ND	ND		DN	ND	ND		ND	ND	ND	ND	****
11	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ИD	ND	ND	NO	ND	ND		ND	ND	ND		ND	ND	ND	ИD	****
12	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND			ND	ND		ND	ND	ND	ND	****
13	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	• • •		ND	ND		ND	ND	ND	ND	****
14 15	ND ND	ND ND	ND	ND ND	ND ND	ND	ND	ND	ND	ND	NO	ND	ND ND	ND	ND	ND	ND 0-014	ND 0.027	ND 0.000		ND O ODE	ND 0.001	ND O OO1	D OO	
16			ND 0.005	0.002		ND O DOZ	ND O OO4	ND 0.007	ND O O16	ND 0.018	ND 0 024	U 034	•	ND 0.035	UN TEO O										0.0089
-				0.013											• • • • • •					- •					0.0132
18				0.013												-									0.0132
19				0.002																					0.0095
				0.011																					
21				0.017																					0.0095
22				0.018		7.7		-	-																0.0103
23	-			0.017										• • • • •											0.0120
				0.016																					0.0111
25				0.002																					0.0107
26				0.001																		0.002			0.0148
27				0.008		-				-															0.0120
28 (0.013								-													
				0.021																					
																	0.012								0.0094
30 (J. UU I	4.005				0.007	0.004																		

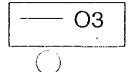
Maximum Hourly Average was 0.046 at Hour 13 on Day 26 with 2 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0148 on Day 26 with 1 occurences and there were no Daily Violations

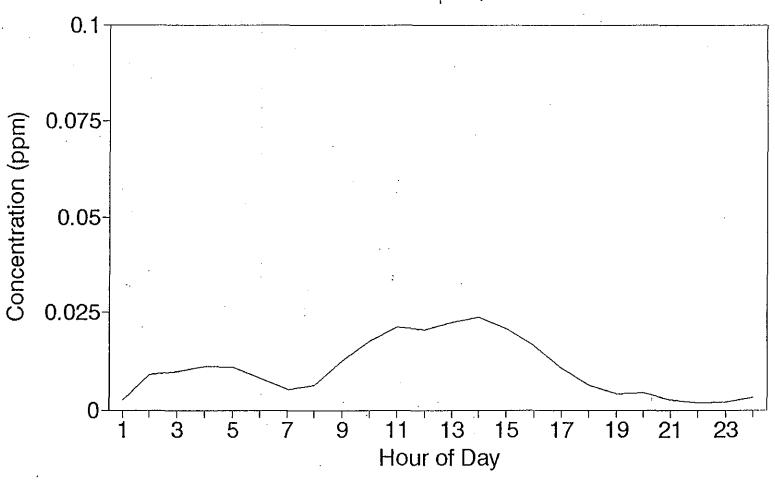
Operating Efficiency = 49.9 percent

Hourly 03 - April, 1991





Diurnal 03 - April, 1991



MEPA - Dammam Industrial Estates
April 1991
Hourly Averages for Carbon Monoxide in ppm

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day -	MD	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	מא	ND	ND	ND	ND	ND	ND.	ND	ND	Average *****
2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	' ND	ND	. ND	ND	ND	ND	****
3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	****
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	***
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NĐ	ND	ND '	ND	ND	****
7	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
8	ND	ND	ND	ND	ND	ND	ND	ND	. ND	ND	ND	ND'	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	. ND	****
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	'ND	ND	ND	ND	ND	****
11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	· ND	ND	ND	ND	ND	ND	****
12	ND	ND	ND	ND	ND	ND	ND	ИĐ	ИD	ND	ND	ND	ND	1 ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
13	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	0.6	0.6	0.9	0.6	8.0	1.0	1.0	0.4	0.74
16	ND	0.5	0.5	0.9	0.9	0.7	0.9	1.2	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.9	1.0	0.8	1.0	1.1	1.4	0.70
17	1.6	1.3	0.9	0.5	0.6	0.6	1.2	1.0	0.8	0.6	0.6	8.0	0.7	0.6	0.7	0.6	0.7	0.7	0.9	1.0	0.9	1.0	1.8	0.9	0.88
18	ND	0.4	0.5	0.5	8.0	0.8	0.8	0.7	1.0	1.0	0.9	1.0	1.0	0.9	8.0	0.8	0.9	1.1	1.4	1.2	1.4	2.6	1.8	1.5	1.03
19	NO	0.7	0.9	0.7	0.9	0.8	1.0	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.8	1.1	1.6	1.5	1.5	1.7	1.4	1.3	0.94
20	1.3	0.7	0.7	0.6	0.5	0.6	0.9	1.4	1.0	1.1	0.9	0.8	8.0	0.8	0.8	0.9	1.1	1.4	1.1	1.3	1.4	1.0	0.7	0.6	0.93
21	ND	0.4	0.4	0.4	0.3	0.5	0.7	1.5	1.1	1.0	1.1	CAL	CAL	0.7	1.0	0.9	1.1	1.3	1.2	1.1	1.6	2.2	1.3	0.7	0.98
22	ND	0.4	0.4	0.4	0.4	0.5	0.9	1.0	1.0	0.9		1.0	1.0	0.8	0.8	0.9	1.2	1.3	1.3	1.5	1.9	2.2	1.2	0.8	0,99
23	ND	0.5	0.4	0.4	0.4	0.5	0.9	1.2	1.0	8.0	0.7	0.9	CAL	CAL	CAL	1.7	1.6	2.4	2.3	2.5	1.8	1.2	1.1	1.1	1,17
24	0.9	0.9	0.8	0.8	0.8	1.0	1.6	2.5	2.0	1.7	1.4	1.5	1.5	1.4	1.5	1.8	1.9	2.0	2.2	5.6	2.5	2.6	2.4	1.9	1.67
25	ND	1.7	1.6	1.3	1.2	1.4	1.9	1.8	2.3	2.0	1.7	1.5	1.5	1.4	0.7	0.5	0.6	0.9	1.1	1.4	1.8	1.8	1.8	1.5	1.45
26	ND	1.0	1.4	1.1	0.9	0.7	0.6	0.4	0.4	0.4	0.4	0.6	0.6	0.5	0.6	0.6	CAL	CAL	1.2	2.0	3.3	2.0	1.0	1.0	0.99
27	ND	0.7	0.5	0.3	0.2	0.5	1.1	1.1	0.7	0.7	0.5	0.4	0.2	0.4	0.4	0.5	0.7	0.9	0.8	0.8	0.9	0.9	0.7	0.5	0.63
28	0.3	0.2	0.2	0.2	0.2	0.3	1.0	1.4	0.9	0.7	0.6	0.6	0.6	0.5	0.6	0.7	0.9	1.0	1.1	1.0	1.2	1.6	1.3	0.9	0.75
29	0.5	0.3	0.2	0.1	0.1	0.3	0.8	1.1	0.8	0.8	0.8	0.7	1.0	0.9	0.7	8.0	1.1	1.6	1.7	1.8	2.0	1.8	1.9	1.3	0.96
30	8.0	0.4	0.3	0.2	0.6	0.4	0.8	1.3	0.8	1.1	0.8	0.6	0.4	0.3	0.5	0.7	0.9	1.2	1.5	1.6	1.6	2.2	2.8	1.6	0.98
-																					 -∤ M	onthly	Avera	ge =	1.00

Maximum Hourly Average was 3.3 at Hour 21 on Day 26 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 1.67 on Day 24 with 1 occurences and there were no Daily Violations

Operating Efficiency = 49.9 percent

MEPA - Dammam Industrial Estates

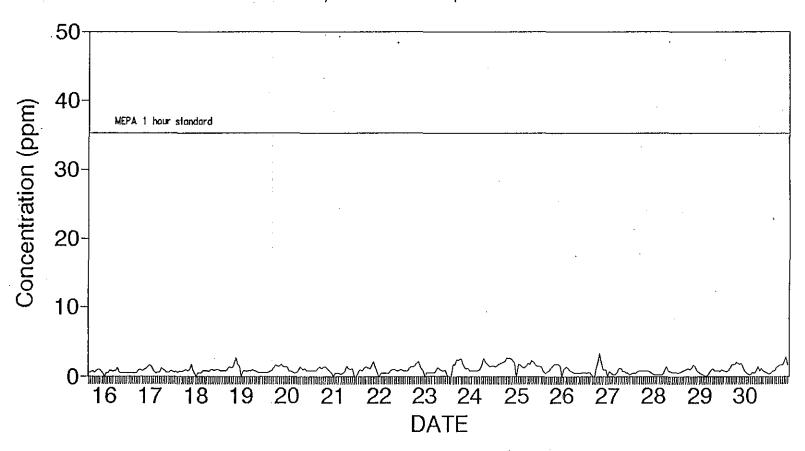
April 1991

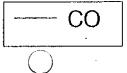
Frequency Distribution

Hourly Averages for Carbon Monoxide in ppm

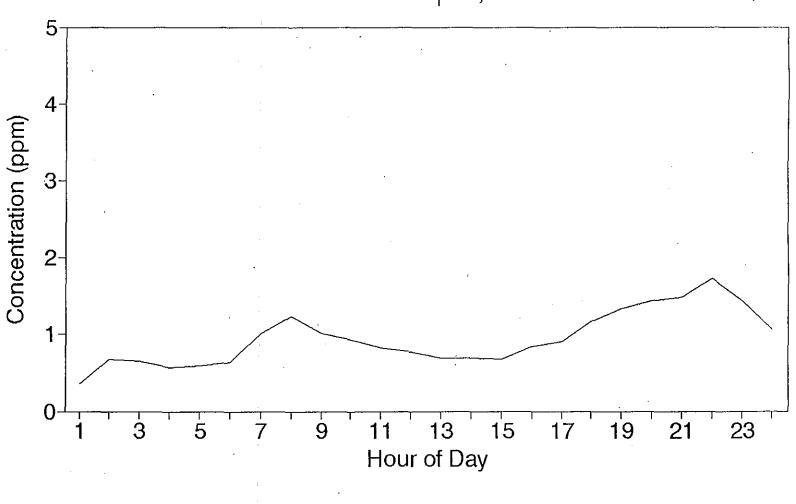
Concentration	# of Hours	Percentage
0.0 - 5.0	352	100.0
5.1 - 10.0	0 ,	0.0
10.1 - 30.0	0	0.0
30.1 - 50.0	0	0.0
50.1+	0 ·	0.0

Hourly CO - April, 1991





Diurnal CO - April, 1991



MEPA - Dammam Industrial Estates May 1991 Hourly Averages for SO2 in ppm

our		1	2	3	4	. 5	6	7	8	9	10	11	12	13	14	1,5	16	17	18	19	. 20	21	22	23	24	Daily
γŀ																										- Average
1	ı	ND	0.011	0.016	0.023	0.009	0.009	0.014	0.021	0.012	0.010	0.007	0.037	0.051	0.039	0.020	0.018	0.023	0.021	0.029	0.048	0.046	0.055	0.046	0.030	0.0259
2			••						0.027																	
3																										0.0226
4	١	ND	0.008	0.005	0.013	0.013	0.026	0.039	0.052	0.051	0.044	0.036	0.017	0.009	0.011	0.014	0.011	0.007	0.003	0.001	0.002	0.007	0.009	0.011	0.009	0.0173
5	0.0	09	0.004	0.009	0.012	0.010	0.013	0.017	0.016	0.011	0.012	0.008	0.005	0.006	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	0.0102
6	ı	ND	ND	ИD	ND	ND	ND	ND	NĐ	ND	, ND	ND	NĐ	ND	ND	ND	. ND	ND	ND	ND	ND	0.010	0.016	0.017	0.018	0.0153
7	!	NĐ	0.005	0.007	0.015	0.017	0.013	0.013	0.009	0.017	0.018	0.020	0.018	0.020	0.010	0.012	0.008	0.013	0.022	0.012	0.013	0.019	0.016	0.013	0.018	.00143
8	- 1	ND	0.021	0.018	0.014	0.008	0.007	0.013	0.012	0.012	0.010	CAL	CAL	0.007	0.006	0.004	0.009	0.008	0.012	0.017	0.021	0.026	0.030	0.034	0.063	0.0168
9	- 1	ND	0.013	0.009	0.005	0.005	0.004	0.007	0.013	0.011	0.011	0.010	0.011	0.015	0.019	0.025	0.015	0.009	0.014	0.025	0.025	0.024	0.028	0.033	0.028	0.0156
10	H	ND I	0.034	0.025	0.023	0.027	0.025	0.021	0.013	0.008	0.024	0.021	0.004	0.002	0.009	0.002	0.001	0.000	0.000	0.000	0.001	0.005	0.004	0.002	0.003	0.0110
11	0.00	07⊡	0.008	0.007	0.006	0.002	0.008	0.008	0.018	0.030	0.036	0.055	0.046	0.023	0.011	0.005	0.008	0.010	0.013	0.006	0.007	0.008	0.013	0.016	0.009	0.0150
12	0.00	09	0.004	0.010	0.005	0.005	0.006	0.008	0.011	0.014	0.019	0.010	0.008	0.006	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0088
13	ŀ	ND	ND	ND	ND	ND	ND	ND	NĐ	ND	ND	ND	ND	ND	ND	0.011	0.016	0.012	0.008	0.007	0.008	0.006	0.005	0.011	0.019	0.0103
14	ŀ	ND I	0.011	0.011	0.010	0.019	0.018	0.010	0.013	0.010	0.007	0.007	0.005	0.005	0.004	0.009	0.014	0.010	0.012	0.008	0.009	0.012	0.025	0.013	0.018	0.0113
15	0.02	20	0.022	0.016	0.014	0.016	0.017	0.015	0.011	0.011	0.012	CAL	0.010	0.009	0.009	0.010	0.010	0.007	0.011	0.010	0.011	0.010	0.012	0.037	0.021	0.0140
16	•	ND I	0.011	0.009	0.009	0.009	0.007	0.010	0.010	0.010	0.009	0.007	0.006	0.005	0.004	0.007	0.006	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.001	0.0062
17	ŀ	ND I	0.007	0.010	0.008	0.004	0.002	0.005	0.013	0.011	0.005	0.003	0.004	0.004	0.004	0.003	0.003	.0.005	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.0040
18	•	ND I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.008	0.005	0.0010
19	ŀ	ND I	0.007	0.006	0.005	0.004	0.005	0.007	0.003	0.001	0.001	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001	0.003	0.001	0.006	0.015	0.007	0.003	0.0036
20	0.00	04 (0.002	0.003	0.004	0.004	0.011	0.021	0.040	0.040	0.029	0.012	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	· ND	ND	ND	0.0155
21	ŀ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИĐ	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
22		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
23	ŀ	ND	ND	ND	ND	ND	ND	ND	ND	ND	MD	ND	ND	ND	ND	ND	ИD	ND	ND	ND	, ND	ND	ND	ND	ND	****
24	ŀ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	****
25	•	ND	ND	ND	ND	ND	ND	ND	ND :	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	,ND	****
26	ŀ	ND	ND	ND	ND	ND	ND	ND	ИD	ND	0.018	0.008	0.007	0.003	0.010	0.003	0.002	0.002	0.003	0.005	0.006	0.009	0.009	0.010	0.008	0.0069
27	N	ND (0.008	0.005	0.002	0.003	0.004	0.004	0.007	0.009	0.008	0.004	0.004	0.003	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.002	0.007	0.005	0.0047
28	0.00)4 (0.004	0.013	0.013	0.009	0.015	0.016	0.004	0.003	ND	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.002	0.005	0.007	0.004	0.0044
29	0.00	D5 (0.004	0.002	0.005	0.005	0.009	0.010	0.002	0.000	0.000	0.005	CAL	CAL	CAL	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0043
30	ŀ	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	· ND	ND	ND	ND	ND	ND	ND	ND	****
31	ŀ	4D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
-																						 ∤ :	Monthly	/ Aver	age =	0.0117

Maximum Hourly Average was 0.072 at Hour 5 on Day 3 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0259 on Day 1 with 1 occurences and there were no Daily Violations

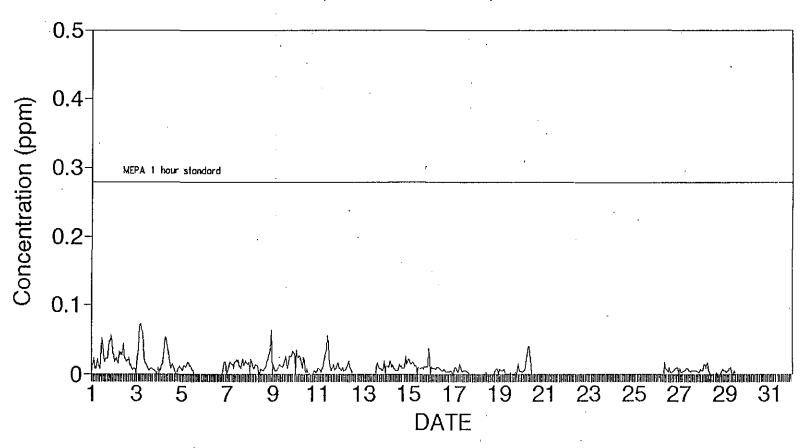
Operating Efficiency = 63.7 percent

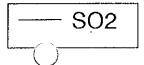
MEPA - Dammam Industrial Estates May 1991

Frequency Distribution Hourly Averages for SO2 in ppm

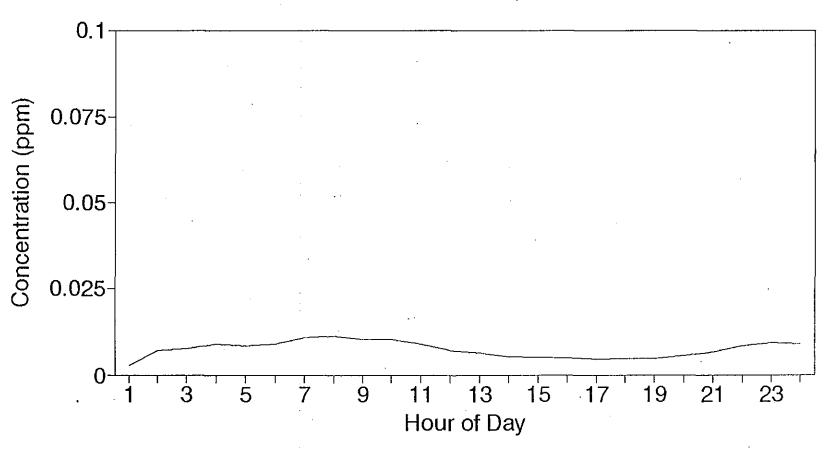
Concentration	# of Hours	Percentag
0.000 - 0.020	398	85.0
0.021 - 0.060	99	14:1
0.061 - 0.110	4	6.0
0.111 - 0.170	0	0.0
0.171 - 0.340	0	0.0
0.341+	0	0.0

Hourly SO2 - May, 1991





Diurnal SO2 - May, 1991



--- SO2

MEPA - Dammam Industrial Estates May 1991 | Hourly Averages for NOx in ppm

Hour	1	1 2	3	4	5	6	. 7	8	9	10	- 11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day										· ·												-			Average
1																								0.107	=
		0.056	-																			•			0.0577
3		0.020		- •										• • • • •											0.0261
4		0.014																							0.0446
	100	0.024												•			ND	0.0388							
6						****		****				****	ND		****	****	ND	ND				- •		0.098	
7																								- •	0.0787
. 8				• •							- •						• •			*****				**	0.1096
. 9																								0.083	
10																									0.0340
																									0.0598
		0.034													ND	0.0395									
13			ND			**-	,	ND	ND		ND		HD											0.112	
14		0.047																							0.0768
		0.118																							0.0874
16		0.142																							0.0641
17		0.017							-		_			–											0.0217
18		0.010						-			_														0.0281
19		0.021																							0.0349
		0.019											ND		ND	ND	ND	ND	, ND	ND	ND	ND	ND	ND	0.0368
21	ND		ND	ND	ND	ND	ND	ND	ND	ND			ND		ND	ИD	****								
22 23	ND ND		ND ND	ND	ND	ND	ND	סא	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
24	ND ND	טא סא	ND.	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND DX	ND ND	ND	ND ND	ND ND	ND ND	ND ND	ND.	ND ND	ND ND	ND	****
25	ND		ND.	ND	ND		ND		ND ND	עא D		ND ND	ND	טא ND	ND ND	ND ND	ND ND	ND.	ND ND	ND	ND ND	ND	UN UN	ND ND	****
26	ND		ND.	ND	ND	ND	ND	ND		*	ND CO.O.	0.058						•							0.0856
26 27	•	0.063				ND 0.047		ND O 070																	0.0635
							-		-				-		-	-	_						-		
		0.024		-			-					0.032			_		-	-	-				-		0.0314
												•													0.0308
31							_		-		_		_		_										0.0252
3 I	NU	0.016	0.011	0.009	0.00/	Ų.UU9	0.012	0.011	0.010	0.010	0.009	0.010	0.010	0.010	U.UI]	0.013	U.U18	0.025	0.039	0.03/	•				0.0199
-																					—- 1	10nthly	Avera	ige =	0.0564

Maximum Hourly Average was 0.469 at Hour 22 on Day 8 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.1173 on Day 9 with 1 occurences and there were no Daily Violations

Operating Efficiency = 71.4 percent

MEPA - Dammam Industrial Estates May 1991 Frequency Distribution Hourly Averages for NOx in ppm

Percentage	62.0	28.4	9.9	3.0
# of Hours	329	151	32	16
Concentration	0.000 - 0.050	0.051 - 0.110	0.111 - 0.210	0.211+

MEPA - Dammam Industrial Estates May 1991 Hourly Averages for NO2 in ppm

Hou Day		1	2	: 3	4	5	6	, 7	8	· 9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily — Average
- Juy		ND	0.039	0.038	0.032	0.019	0.025	0.041	0.041	0.036	0.035	0.043	0.039	0.044	0.045	0.042	0.049	0.058	0.063	0.071	0.071	0.064	0.059	0.062	0.054	0.0465
7	0.	045	0.044	0.045	0,044	0.039	0.039	0.049	0.040	0.050	0.065	0.050	0,035	0.031	0.026	0.025	0.028	0.044	0.038	0.044	0.043	0.042	0.055	0.050	0.025	0.0415
3	\$	NĐ	0.019	0.017	0.015	0.017	0.019	0.017	0.017	0.020	0.025	0.013	0.013	0.014	0.015	0.015	0.017	0.019	0.035	0.049	0.042	0.045	0.033	0.033	0.027	0.0233
	•	ND	0.012	0.016	0.016	0.020	0.021	0.033	0.041	0.039	0.033	0.038	0.036	0.025	0.024	0.028	0.030	0.029	0.034	0.040	0.044	0.050	0.055	0.051	0.048	0.0332
	0.0	040	0.018	0.018	0.014	0.012	0.018	0.033	0.039	0.029	0.038	0.031	0.024	0.018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0255
6	•	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.056	0.056	0.055	0.051	0.0545
7	•	ND	0.032	0.030	0.036	0.030	0.037	0.042	0.037	0.044	0.043	0.030	0.024	0.039	0.025	0.027	0.036	0.037	0.046	0.056	0.059	0.063	0.059	0.059	0.047	0.0408
٤	3	ND	0.037	0.030	0.029	0.021	0.027	0.043	0.042	0.035	0.029	0.020	0,020	0.022	0.028	0.030	0,036	0.049	0.056	0.058	0.057	0.051	0.043	0.053	0.052	0.0377
5)	ND	0.038	0.028	0.020	0.027	0.021	0.036	0.037	0.038	0.038	0.050	0.041	0.032	0.035	0.043	0.049	0.051	0.052	0.056	0.052	0.048	0.052	0,049	0.033	0.0403
10	1	ND	0.029	0.025	0.034	0.040	0.029	0.023	0.017	0.014	0.017	0.015	0.011	0.013	0.014	0.012	0.015	0.019	0.024	0.030	0.035	0.041	0.045	0.047	0.037	0.0255
11	0.0	030	0.016	0.011	0.015	0.013	0.035	0.037	0.039	0.037	0.035	0.047	0.045	0.036	0.029	0.031	0.037	0.047	0.052	0.054	0.058	0.060	0.058	0.052	0.045	0.0383
12	0.0	035	0.032	0.018	0.016	0.013	0.019	0.043	0.045	0.035	0.037	0.031	0,032	0.031	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0298
13	í	ND	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.025	0.030	0.032	0.036	0.047	0.053	0.048	0.051	0.052	0.050	0.0424
14		ND	0.039	0.027	0.024	0.033	0.035	0.035	0.039	0.041	0,029	0.023	0.027	0.025	0.030	0.028	0,041	0.042	0.045	0.043	0.047	0.047	0.044	0.045	0.051	0.0365
15	0.0	149	0.044	0.041	0.037	0.035	0.036	0.036	0.032	0.030	0.026	0.016	0.029	0.028	0.033	0.045	0.056	0.060	0.067	0.059	0.055	0.048	0.059	0.057	0,054	0.0430
16	•	ND	0.059	0.058	0.050	0.048	0.038	0.040	0.041	0.035	0.035	0.033	0.029	0.046	0.064	0.065	0.059	0.102	0.067	0.062	0.050	0.049	0.041	0.026	0.019	0.0485
17	•	ND	0.015	0.010	0.009	0.010	0.008	0.016	0.022	0.021	0.015	0.014	0.014	0.015	0.016	0.016	0.018	0.020	0.025	0.024	0.029	0.022	0.024	0.017	0.018	0.0173
18	}	ND	0.008	0.006	0.006	0.005	0.009	0.017	0.022	0.021	0.022	0.024	0.022	0.018	0.014	0.016	0.020	0.024	0.032	0.036	0.041	0.041	0.048	0.039	0.040	0.0231
19)	ND	0.019	0.014	0.013	0.013	0.017	0.026	0.029	0.026	0.026	0.021	0.024	0.021	0.020	0.019	0.024	0.034	0.039	0.039	0.047	0.048	0.049	0.045	0.038	0.0283
20	0.0	37	0.017	0.012	0.010	0.009	0.011	0.036	0.047	0.046	0.033	0.025	ND	ND	ND	ND	HD	ND	ND	ND	ND	ND	ND	ND	ND	0.0257
21		ND	ND	ND	ИD	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
22		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
23		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
24		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	HD	ND	ND	ND	ND	ND	HD	ND	ND	ND	ND	ND	****
25		MD	ND	HD	ND	ИD	ND	ND	****																	
26		ND	ND	ND	ND	סא	ND	ND	ND	ND	0.031	0.019	0.044	0.023	0.028	0.032	0.033	0.046	0.050	0.057	0.058	0.058	0.056	0.055	0.057	0.0431
27		ND	0.043	0.026	0.023	0.031	0.042	0.044	0.039	0.033	0.030	0.018	0.018	0.018	0.033	0.029	0.031	0.035	0.045	0.050	0.048	0.044	0.047	0.049	0.045	0.0357
28	0.0	36	0.022	0.016	0.020	0.022	0.014	0.022	0.024	0.022	ND	0.018	0.023	0.020	0.016	0.017	0.023	0.020	0.025	0.034	0.034	0.031	0.030	0.034	0.027	0.0239
29	0.0	18	0.009	0.007	0.008	0.010	0.023	0.032	0.029	0.022	0.017	0.016	0.009	0.010	0.011	0.015	0.022	0.029	0.031	0.035	0.040	0.033	0.041	0.040	0.036	0.0226
30	0.0	142	0.024	0.018	0,017	0.016	0.018	0.018	0.020	0,015	0.015	0.015	0.017	0.015	0.015	0.010	0.009	0.018	0.019	0.031	0.030	0.030	0.027	0.029	0.027	0.0206
31		ND ·	0.014	0.009	0.007	0.005	0.007	0.009	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.010	0.014	0.022	0.033	0.033	0.034	0.039	0.042	0.037	0.0162
 - -		_																				h	ionthly	/ Avera	age =	0.0325

Maximum Hourly Average was 0.102 at Hour 17 on Day 16 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0545 on Day 6 with 1 occurences and there were no Daily Violations

Operating Efficiency = 71.4 percent

MEPA - Dammam Industrial Estates
May 1991
Frequency Distribution
Hourly Averages for NOZ in ppm

Percentage	9.78	12.1	0.0	0.0
# of Hours	197	E	0	0.
Concentration	0.000 - 0.050	0.051 - 0.110	0.111 - 0.210	0.211+

MEPA - Dammam Industrial Estates May 1991 Hourly Averages for NO in ppm

Hour Day	•	1	. 2	3	4	. 5	6	7	8	9	10	. 11	12	13	14	15	16	17	18	19	20	· 21	22	23	24	Daily — Average
1		ND	0.006	0.009	0.013	0.002	0.007	0.020	0.033	0.021	0.012	0.011	0.013	0.012	0.018	0.013	0.023	0.067	0.180	0.208	0.205	0.270	0.206	0.147	0.053	0.0673
2	0.0	10	0.013	0.026	0.030	0.013	0.021	0.054	0.030	0.035	0.037	0.010	0.005	0.005	0.004	0.003	0.003	0.008	0.007	0.009	0.010	0.013	0.027	0.017	0.002	0.0163
3	.	ND	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.005	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.004	0.006	0.006	0.005	0.002	0.003	0.002	0.0029
4	•	ND	0.001	0.001	0.001	0.001	0.005	0.011	0.028	0.019	0.014	0.013	0.010	0.005	0.006	0.006	0.007	0,006	0.008	0.009	0.008	0.010	0.019	0.042	0.037	0.0116
5	0.0	10	0.006	0.006	0.007	0.005	0.007	0.017	0.034	0.028	0.022	0.015	0.010	0.006	ND	ND	ND	. אם	ND	ND	ND	ND	ND	ND	ND	- 0.0133
6	•	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.043	0.020	0.042	0.047	0.0380
7	۱ ۱	ND	0.005	0.006	0.007	0.004	0.009	0.029	0.035	0.032	0.019	0.009	0.009	0.012	0.005	0.006	0.014	0.041	0.023	0.070	0.133	0.086	0.106	0.189	0.031	0.0383
. 8		ND	0.009	0.007	0.007	0.005	0.007	0.023	0.031	0.024	0.015	0.009	0.059	0.004	0.008	0.011	0.009	0.025	0.094	0.072	0.107	0.261	0.437	0.246	0.206	0.0729
9	۱ ۱	ND	0.039	0.007	0.001	0.004	0.008	0.024	0.025	0.024	0.033	0.068	0,028	0.020	0.022	0.038	0.010	0.048	0.202	0.402	0.206	0.198	0.193	0.144	0.050	0.0780
10	۱ ا	ND	0.004	0.002	0.004	0.007	0.011	0.013	0.010	0.005	0.004	0.003	0.003	0.003	0.003	0.003	0.005	0.006	0.008	0.011	0.015	0.031	0.028	0.011	0.005	0.0085
11	0.0	01	0.001	0.001	0.001	0.001	0.010	0.015	0.041	0.032	0.026	0.030	0.017	0.010	0.007	0.008	0.012	0.024	0.031	0.057	0.042	0.037	0.055	0.055	0.011	0.0219
12	0.0	03	0.002	0.002	0.002	0.002	0.006	0.025	0.031	0.017	0.014	0.009	0.009	0.008	ND	ND	ND	ND	0.0100							
13		ND	ND	ND				ND	ND	ND	ND	ND		ND										- •		0.0304
14						-													• •		• •					0.0409
																										0.0450
16																										0.0163
17																										0.0046
18												-				· ·			-							0.0054
19								0.006				-							-							0.0069
21		ND 03	ND	0.002 ND				0.008 ND		1 CU . U	CIU,U		HD	ND DK	ND	ND	ND	ND	ND	ND	ND	ND . ND	ND	ND	ND	0.0114
22		ND	ND	ND				ND	ND ND	ND	ND	ND ND	ND ND	ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	. ND	ND ND	ND ND	ND ND	****
23		ND	ND	ND	. עם מא	ND	ND	ND	ND		ND	ND	ND	ND.	. ND	ND	ND ND	DK	ND	ND	ND	ND ND	ND ND	ND	ND .	****
24		ND	ND	NO	нD	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND ND	ND	ND	ND	ND ND	ND	ND	ND	ND	****
25		ND	ND	סא	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	****
26		ND	ND	ND	ND	ND		ND	ND										*				0.094	***		0.0431
27		ND I	0.020	0.007	0.004	0.008	0,022	0.036	0.039					-												0.0282
28								0.007															0.004			0.0077
											0.005	0,005	0.026	0.033	0,004	0.005	0.010	0.012	0.011	0.007	0.010	0.005	0.005	0.007	0.006	0.0084
30	0.00)9 (0.003	0.004	0,003	0.003	0.004	0.008	0.008	0.005	0.005	0.005	0.006	0.005	0.005	0.003	0.003	0.004	0.004	0.006	0.005	0.006	0.004	0.004	0.003	0.0048
31		ND I	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.003	0.003	0.005	0.004	0.007	0.005	0.004	0.005	0.014	0.007	0.0039
-																						I	4onthly	Avera	age =	0.0243

Maximum Hourly Average was 0.437 at Hour 22 on Day 8 with 1 occurences and there were no Hourly Violations

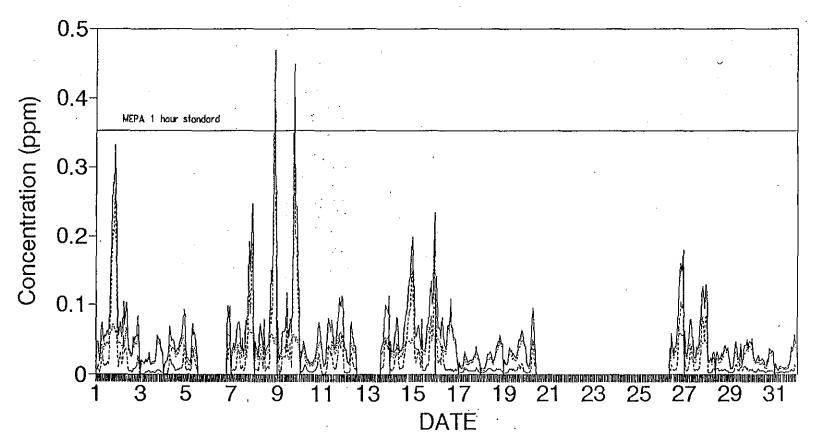
Maximum Daily Average was 0.0780 on Day 9 with 1 occurences and there were no Daily Violations

Operating Efficiency = 71.4 percent

MEPA - Dammam Industrial Estates May 1991 Frequency Distribution Hourly Averages for NO in ppm

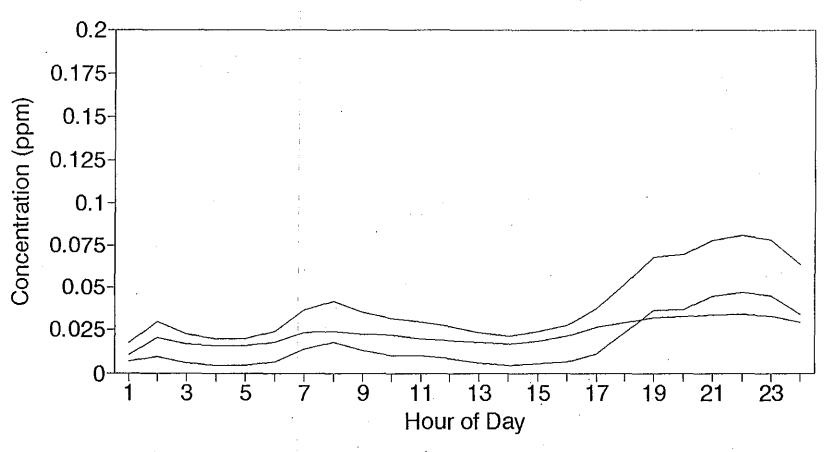
Percentage	88.9	9.9	3.6	6.0
# of Hours	725	32	. 61	5
Concentration	0.000 - 0.050	0,051 - 0,110	0.111 - 0.210	0.211+

Hourly N0x/N02/N0 - May, 1991



--- NOx --- NO2 --- NO

Diurnal N0x/N02/N0 - May, 1991



— NOx — NO2 — NO

MEPA - Dammam Industrial Estates Hay 1991 Hourly Averages for NH3 in ppm

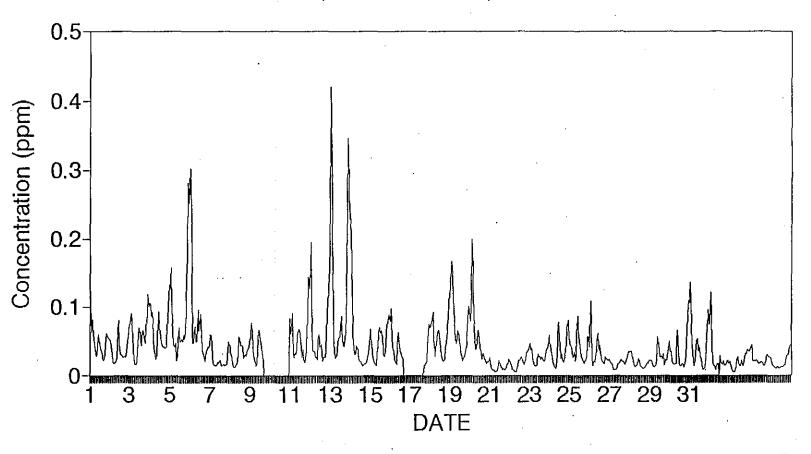
11 12 22 Daily Hour Day -Average 1 0.063 0.045 0.041 0.046 0.021 0.026 0.053 0.070 0.062 0.049 0.050 0.052 0.050 0.059 0.052 0.062 0.105 0.184 0.281 0.252 0.302 0.275 0.206 0.135 2 0.047 0.047 0.062 0.071 0.049 0.050 0.096 0.064 0.078 0.089 0.059 0.036 0.030 0.024 0.021 0.020 0.035 0.036 0.041 0.040 0.043 0.059 0.058 0.028 3 0.017 0.015 0.015 0.013 0.015 0.019 0.018 0.017 0.020 0.022 0.013 0.013 0.015 0.016 0.014 0.015 0.016 0.028 0.049 0.044 0.044 0.033 0.032 0.025 0.0220 4 0.018 0.012 0.012 0.014 0.016 0.018 0.031 0.057 0.054 0.043 0.044 0.042 0.026 0.025 0.028 0.030 0.028 0.034 0.038 0.041 0.050 0.057 0.076 0.066 0.0358 5 0.037 0.023 0.021 0.016 0.014 0.017 0.037 0.065 0.065 0.051 0.047 0.033 0.021 ND ND ND ND ND ND ND ND ND ND ND 0.082 0.061 0.066 0.090 0.0748 ND ND ND ND ND ND 7 0.032 0.026 0.028 0.033 0.031 0.038 0.059 0.064 0.067 0.061 0.040 0.026 0.037 0.023 0.019 0.025 0.036 0.044 0.083 0.144 0.134 0.126 0.194 0.101 8 0.036 0.035 0.034 0.025 0.026 0.023 0.051 0.059 0.052 0.041 0.042 0.045 0.020 0.025 0.026 0.026 0.038 0.087 0.112 0.118 0.193 0.420 0.330 0.257 0.0884 9 0.199 0.101 0.047 0.025 0.026 0.029 0.049 0.054 0.055 0.059 0.087 0.065 0.043 0.042 0.058 0.047 0.062 0.143 0.346 0.327 0.228 0.237 0.206 0.119 0.1106 10 0.058 0.040 0.030 0.032 0.042 0.040 0.037 0.031 0.022 0.020 0.019 0.015 0.014 0.016 0.016 0.017 0.020 0.025 0.032 0.039 0.057 0.067 0.054 0.048 11 0.030 0.021 0.018 0.017 0.015 0.033 0.042 0.062 0.069 0.062 0.066 0.055 0.039 0.030 0.028 0.031 0.044 0.065 0.079 0.088 0.083 0.079 0.097 0.057 12 0.040 0.035 0.023 0.019 0.016 0.017 0.045 0.062 0.050 0.036 0.033 0.027 0.024 ND ND ND. ND ND 0.0328 ИD ND ND ND ND ND ND 0.014 0.017 0.018 0.022 0.043 0.062 0.075 0.070 0.072 0.083 0.0476 14 0.091 0.052 0.034 0.028 0.042 0.044 0.056 0.065 0.065 0.066 0.050 0.029 0.025 0.020 0.022 0.023 0.041 0.048 0.064 0.074 0.088 0.120 0.113 0.154 0.167 0.0632 15 0.148 0.113 0.078 0.053 0.046 0.054 0.064 0.059 0.048 0.041 0.033 0.027 0.022 0.025 0.027 0.033 0.037 0.045 0.082 0.101 0.085 0.079 0.120 0.199 0.0675 16 0.157 0.119 0.089 0.053 0.038 0.039 0.060 0.065 0.054 0.039 0.034 0.024 0.032 0.026 0.024 0.019 0.023 0.017 0.020 0.019 0.021 0.025 0.011 0.009 17 0.009 0.008 0.006 0.006 0.006 0.007 0.011 0.022 0.019 0.017 0.012 0.011 0.009 0.010 0.008 0.009 0.012 0.016 0.016 0.023 0.020 0.018 0.015 0.015 0.012 18 0.009 0.008 0.006 0.006 0.005 0.008 0.014 0.022 0.022 0.024 0.026 0.023 0.020 0.016 0.017 0.019 0.023 0.032 0.034 0.038 0.041 0.046 0.037 0.039 0.0223 19 0.024 0.018 0.014 0.014 0.013 0.015 0.023 0.030 0.027 0.028 0.023 0.027 0.024 0.022 0.020 0.024 0.035 0.038 0.039 0.044 0.058 0.046 0.045 0.036 0.0286 20 0.027 0.019 0.014 0.011 0.010 0.013 0.029 0.077 0.067 0.042 0.024 0.030 0.028 0.022 0.019 0.026 0.037 0.043 0.068 0.080 0.070 0.045 0.043 0.039 0.0368 21 0.027 0.026 0.033 0.027 0.020 0.027 0.059 0.087 0.066 0.050 0.034 0.026 0.023 0.020 0.018 0.020 0.022 0.029 0.044 0.055 0.057 0.041 0.082 0.108 0.0417 22 0.025 0.014 0.020 0.019 0.027 0.035 0.051 0.061 0.040 0.034 0.043 0.025 0.022 0.019 0.018 0.017 0.027 0.024 0.023 0.022 0.023 0.020 0.018 0.018 0.0269 23 0.014 0.009 0.008 0.008 0.008 0.009 0.012 0.016 0.017 0.019 0.020 0.023 0.020 0.020 0.017 0.016 0.021 0.022 0.024 0.029 0.035 0.033 0.035 0.035 24 0.028 0.021 0.016 0.012 0.013 0.013 0.018 0.021 0.024 0.021 0.014 0.012 0.011 0.010 0.010 0.011 0.013 0.015 0.019 0.018 0.022 0.022 0.021 0.021 25 0.021 0.015 0.012 0.012 0.013 0.015 0.035 0.055 0.055 0.045 0.027 0.026 0.028 0.024 0.030 0.017 0.015 0.018 0.023 0.022 0.033 0.039 0.049 0.035 0.034 0.0268 26 0.021 0.018 0.016 0.016 0.018 0.018 0.018 0.033 0.065 0.051 0.017 0.014 0.014 0.016 0.017 0.012 0.014 0.021 0.029 0.066 0.090 0.110 0.106 0.117 0.136 0.0431 27 0.073 0.043 0.020 0.014 0.022 0.031 0.051 0.052 0.036 0.039 0.027 0.024 0.014 0.013 0.009 0.010 0.011 0.024 0.040 0.071 0.096 0.073 0.077 0.121 0.0413 28 0.047 0.018 0.013 0.013 0.014 0.008 0.012 0.016 0.016 MD 0.028 0.019 0.018 0.016 0.020 0.015 0.015 0.017 0.020 0.021 0.019 0.018 0.020 0.017 0.0183 29 0.010 0.007 0.005 0.005 0.007 0.012 0.023 0.027 0.017 0.013 0.013 0.015 0.021 0.015 0.013 0.020 0.027 0.032 0.031 0.037 0.036 0.035 0.038 0.039 30 0.044 0.035 0.022 0.020 0.022 0.020 0.021 0.022 0.018 0.017 0.017 0.019 0.019 0.017 0.014 0.014 0.016 0.022 0.027 0.028 0.029 0.027 0.026 0.025 0.025 31 0.020 0.015 0.013 0.012 0.011 0.010 0.012 0.012 0.011 0.010 0.010 0.010 0.011 0.012 0.012 0.012 0.013 0.015 0.020 0.028 0.029 0.029 0.029 0.034 0.042 0.043 0.0182 0.0417 Monthly Average =

Maximum Hourly Average was 0.420 at Hour 22 on Day 8 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.1106 on Day 9 with 1 occurences and there were no Daily Violations

Operating Efficiency = 92.3 percent

Hourly NH3 - May, 1991



--- NH3

MEPA - Dammam Industrial Estates May 1991 Hourly Averages for 03 in ppm

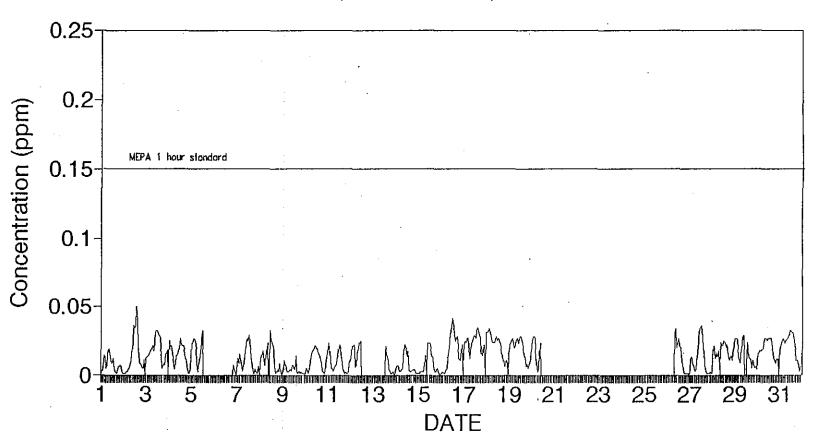
Hour		1 2	2 3	4	5	. 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day								 -																	Average
1	NO	0.002	0.003	0.006	0.014	0.013	0.005	0.007	0.015	0.019	0.017	0.013	0.010	0.008	0,012	0.007	0.002	0.001	0.002	0.006	0.006	0.007	0.006	0.002	0.0080
2	0.00	0.001	0.001	0.001	0.002	0.002	0.004	0.005	0.007	0.010	0.024	0.036	0.034	0.036	0.050	0.039	0.020	0.015	0.009	0.008	0.006	0.005	0.005	0.011	0.0138
3	N	0.012	0.013	0.014	0.016	0.017	0.019	0.021	0.021	0.017	0.031	0.032	0.032	0.031	0.029	0.028	0.026	0.014	0.005	0.008	0.007	0.015	0.015	0.018	0.0192
4	N	0.025	0.021	0.021	0.017	0.016	0.007	0.004	0.008	0.014	0.014	0.019	0.026	0.023	0.021	0.021	0.021	0.018	0.012	0.010	0.006	0.002	0.001	0.003	0.0143
5	0.00	0.023	0.023	0.026	0.025	0.019	0.008	0.002	0.007	0.011	0.017	0.026	0.032	, ND	ND	ND	ND	ND	ND	· ND	ND	ND	ND	ИD	0.0172
6	N) ND	, ND	ND	ND	ND	ND	ND	ND	ND	, ND	סא	ND	0.001	0.007	0.004	0.003	0.0038							
7	N	0.008	0.012	0.008	0.015	0.009	0.003	0.005	0.009	0.017	0.024	0.026	0.025	0.029	0.023	0.018	0.013	0.006	0.001	0.001	0.004	0.002	0.001	0.006	0.0115
8	N	0.008	0.014	0.014	0.017	0.014	0.007	0.010	0.016	0.023	CAL	CAL	0.033	0.025	0.021	0.018	0.006	0.001	0.002	0.002	0.004	0.002	0.008	0.003	0.0118
9	N	0.001	0.005	0.011	0.007	0.007	0.002	0.002	0.004	0.004	0.003	0.007	0.007	0.005	0.004	0.014	0.002	0.001	0.002	0.002	0.001	0.002	0.001	0.001	0.0041
10	HE	0.003	-0.005	0.003	0.001	0.004	0.006	0.013	0.016	0.017	0.019	0.021	0.021	0.019	0.019	0.016	0.013	0.011	0.008	0.003	0.002	0.001	0.003	0.011	0.0102
11	0.013	0.020	0.023	0.014	0.017	0.005	0.005	0.003	0.006	0.007	0.008	0.014	0.018	0.022	0.019	0.015	0.008	0.005	0.002	0.001	0.002	0.001	0.001	0.003	0.0097
12	0.009	0.012	0.021	0.021	0.022	0.018	0,006	0.007	0.015	0.019	0.024	0.024	0.025	ND	ND	ND	ND	ND	ND	ŅD	ND	ND	ND	ND	0.0172
13	NE) ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.021	0.015	0.013	0.011	0.004	0.003	0.001	0.001	0.002	0.001	0.0072
14	NE	0.002	0.006	0.007	0.003	0.003	0.003	0.004	0.005	0.013	0.022	0.021	0.019	0.013	0.017	0.004	0.003	0.002	0.003	0.004	0.004	0.002	0.001	0.001	0.0070
15	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.005	0.011	0.014	CAL	0.023	0.023	0.022	0.015	0.013	0.013	0.006	0.003	0.002	0.004	0.005	0.002	0.001	0.0075
16	NC	0.001	0.001	0.002	0.001	0.003	0.004	0.005	0.012	0.018	0.026	0.032	0.038	0.041	0.036	0.029	0.025	0.027	0.028	0.021	0.012	0.011	0.018	0.022	0.0180
17	NE	0.022	0.025	0.024	0.026	0.027	01021	0.015	0.012	0.023	0.025	0.027	0.029	0.027	0.032	0.035	0.033	0.029	0.027	0.015	0.016	0.014	0.7022	0.021	0.0238
18	NE	0.031	0.031	0.032	0.034	0.031	0.025	0.024	0.024	0.024	0.026	0.028	0.025	0.027	0.026	0.023	0.023	0.016	0.014	0.010	0.010	0.006	0.011	800.0	0.0221
19	ND	0.022	0.024	0.025	0.026	0.025	0.020	0.020	0.025	0.026	0.027	0.023	0.026	0.028	0,028	0.023	0.017	0.013	0.013	0.006	0.008	0.005	0.006	0.009	0.0193
20	0.012	0.022	0.026	0.028	0.028	0.026	0.012	0.002	0.005	0.016	0.024	ND	ND	ND	ND	ND	ND	ND	ND	ND	, ND	ND	ND	ND	0.0183
21	NO	סא פ	' ND	ND	ND	ND	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
22	NO	ND.	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
23	NE	םא ס	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	КD	ND	ND	ND	****							
24	ND) ND	ND	ИD	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	****
25	ND) ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	****
26	ND	ND.	ND	ND	ND	ND	ND	ND.	ND	0.031	0.034	0.020	0.026	0.022	0.020	0.020	0.010	0.007	0.002	0.001	0.001	0.001	0.001	0.001	0.0131
27	ND	0.004	0.012	0.013	0.008	0.004	0.003	0.005	0.011	0.016	0.028	0.034	0.035	0.036	0.028	0.019	0.018	0.007	0.003	0.001	0.001	0.001	0.002	0.001	0.0126
28	0.001	0.013	0.021	0.016	0.012	0.016	0.013	0.015	0.017	ND	0.024	0.021	0.022	0.025	0.024	0.020	0.022	0.017	0.012	0.011	0.013	0.014	0.011	0.015	0.0163
29	0.022	0.026	0.026	0.026	0.025	0.013	0.009	0.014	0.023	0.028	0.029	CAL	CAL	CAL	0.024	0.017	0.013	0.012	0.010	0.005	0.011	0.010	0.005	0.006	0.0169
30	0.004	0.015	0.016	0.017	0.018	0.018	0.019	0.019	0.026	0.026	0.026	0.025	0.026	0.026	0.027	0.027	0.020	0.016	0.012	0.010	0.009	0.012	0.011	0.012	0.0182
31	ND	0.020	0.023	0.025	0.026	0.025	0.023	0.025	0.026	0.028	0.029	0.033	0.032	0.031	0.031	0.029	0.025	0.018	0.010	0.011	0.011	0.007	0.003	0.006	0.0216
																						ionthly	/ Avera	age =	0.0143

Maximum Hourly Average was 0.050 at Hour 15 on Day 2 with 1 occurences and there were no Hourly Violations

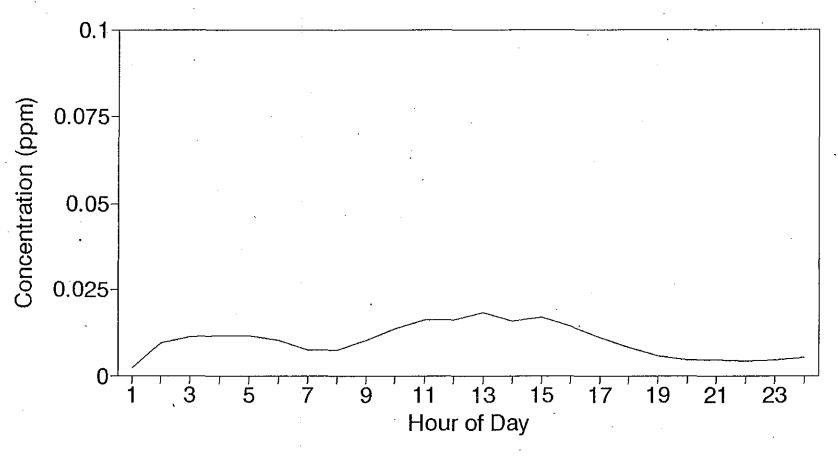
Maximum Daily Average was 0.0238 on Day 17 with 1 occurences and there were no Daily Violations

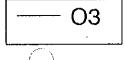
Operating Efficiency = 71.4 percent

Hourly 03 - May, 1991



Diurnal 03 - May, 1991





MEPA - Dammam Industrial Estates
May 1991
Hourly Averages for Carbon Monoxide in ppm

Hour Day ⊨	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily — Average
1	ND	0.6	0.4	0.3	0.2	0.2	0.6	0.7	0.6	0.7	1.1	1.0	1.1	0.8	0.8	1,3	2.0	3.4	3.7	3.9	4.1	3.3	2.3	1,1	1.49
2	0.4	0.4	0.4	0.4	0.2	0.3	0.6	0.6	1.1	1.5	1.0	0.7	0.4	0.3	0.3	0.4	0.8	0.9	0.9	1.0	1.1	1.4	1.2	0.6	0.70
3	ND	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.7	0.6	0.5	0.3	0.35
4	ND	0.1	0.1	0.0	0.1	0.2	0.6	1.0	0.7	0.7	0.6	0.5	0.4	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.8	1.2	0.8	0.4	0.57
5	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.2	0.4	0.5	0.4	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.22
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.3	0.8	1.2	1.1	1.10
7	ND	0.3	0.3	0.2	0.2	0.2	0.3	0.4	0.6	0.4	0.3	0.3	0.5	0.4	0.5	0.7	1.1	1.0	1.8	2.3	1.6	2.9	3.7	0.7	0.90
8	ND	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.2	0.2	CAL	CAL	1.0	1.0	1.0	1.3	1.7	2.9	3.0	3.2	4.7	7.1	4.5	4.6	1.76
9	ND	1.0	0.6	0.5	0.7	0.7	0.9	0.9	0.9	1.2	2.4	1.7	1.1	1.2	1.3	1.3	1.9	3.9	7.2	5.6	5.5	4.4	2.5	1.1	2.11
10	ND	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	8.0	0.9	0.8	0.7	8.0	0.9	1.0	1.1	1.3	1.6	1.7	1.4	1.3	0.89
11	1.0	0.7	0.6	0.6	0.6	0.8	0.9	1.4	1.0	1.1	1.4	1.4	1.2	1.0	1.1	1.4	1.6	1.7	2.2	2.0	2.1	2.3	1.4	0.7	1.26
12	0.6	0.6	0.5	0.5	0.5	0.6	1.1	1.0	0.9	1.1	1.0	1.0	1.0	ND	NO	ND	ND	ND	ND	ND	ИD	ND	ND	ND	0.80
13	ND	ND	MD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0	1.1	1.1	1.3	1.7	2.0	1.8	1.7	1.5	1.8	1.50
14	ND	8.0	0.7	0.6	0.6	0.7	1.0	1.3	1.2	0.9	0.9	0.9	0.9	1.0	1.0	1.2	1.2	1.4	1.3	1.8	1.6	1.8	2.1	1.9	1.17
15	1.7	1.1	0.8	0.6	0.5	0.6	0.7	0.8	0.7	0.7	CAL	1.0	1.1	1.1	1.3	1.4	1.5	1.4	1.7	1.9	1.7	1.6	2.4	2.5	1.25
16	ND	1.6	1.5	1.0	8.0	0.8	1.0	1.2	1.0	0.9	0.9	8.0	1.0	1.0	0.9	8.0	0.9	0.9	1.0	1.2	1.4	1.1	0.9	0.7	1.01
17	ИD	0.6	0.5	0.4	0.4	0.4	0.5	0.6	0.4	0.5	0.6	0.6	0.7	0.8	0.9	0.9	8.0	0.9	0.8	8.0	0.7	0.7	0.5	0.5	0.63
18	ND	0.3	0.3	0.3	0.4	0.4	0.6	0.8	0.8	8.0	8.0	0.7	0.7	0.6	0.6	0.7	0.7	8.0	0.9	0.9	0.9	1.1	0.9	0.6	0.68
19	ND	0.3	0.3	0.3	0.3	0.4	0.7	1.0	0.8	0.6	0.6	0.7	0.6	0.6	0.5	0.7	0.9	0.9	0.9	1.,1	1.4	1.1	0.7	0.5	0.69
20	0.5	0.2	0.1	0.1	0.1	0.3	0.7	1.5	1.2	0.9	0.8	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ИD	ND	0.58
21	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ΝD	ND	ИD	ND	ND	ND.	ND	ND	ND	ИÐ	ND	ND	МĎ	ND	****
22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	****
23	ND ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND ND	ND	ND	ND	ND	ND	ND ND	ND	****
24 25	ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND	ND:	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND DK	ND ND	ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND	ND ND	****
26	ND	ND	ND	ИD	ND	ND	ИD	ND:	ND	0.7	0.5	1.0	0.5	0.6	0.9	0.8	1.1	1.2	1.8	1.8	1.9	2.0	2.9	2.8	1.37
27	ND	0.4	0.0	0.1	0.0	0.2	0.3	0.5	0.4	0.7	0.4	0.4	0.4	0.7	0.5	0.5	0.7	0.9	1.1	1.8	1.9	1.3	2.3	2.0	0.75
28	1.1	0.2	0.1	0.1	0.1	0.3	0.6	0.8	0.8	ND	0.4	0.7	0.7	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.5	0.4	0.5	0.3	0.50
29	0.2	0.0	0.1	0.1	0.1	0.4	0.8	0.8	0.6	0.4	0.5	CAL	CAL	CAL	0.9	1.1	1.2	1.2	1,3	1.5	1.3	1.4	1.3	0.9	0.77
30	1.1	0.7	0.5	0.5	0.6	0.6	0.7	1.0	0.9	0.9	1.0	0.9	0.8	0.8	0.7	0.7	0.8	0.8	1.1	1.0	0.9	0.8	0.8	0.8	0.81
31	ND	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0,6	0.6	0,6	0.7	0.6	0.6	0.7	0.7	0.8		0.9	1.0	1.0	1.1	8.0	0.70
 																***********						onthly	Averag	1e =	0.94

Maximum Hourly Average was

7.2 at Hour 19 on Day 9 with 1 occurences and there were no Hourly Violations

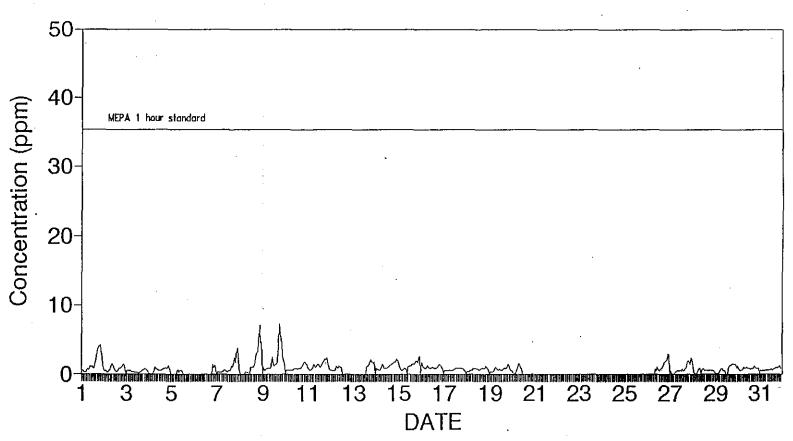
Maximum Daily Average was

2.11 on Day 9 with 1 occurences and there were no Daily Violations

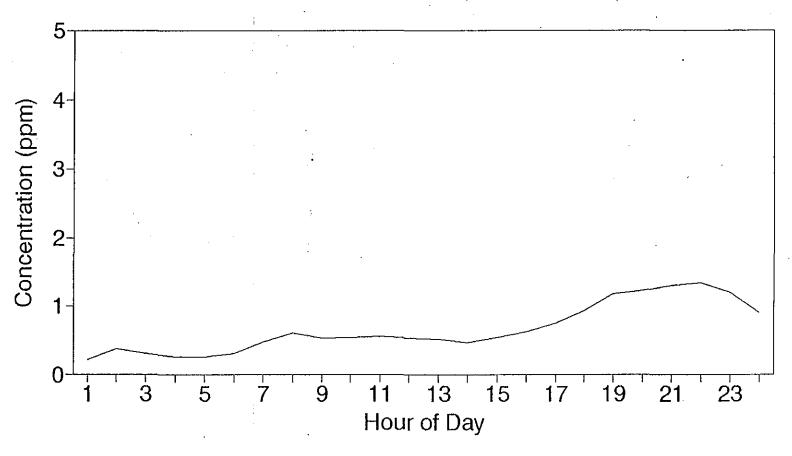
Operating Efficiency = 71.4 percent

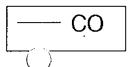
MEPA - Dammam Industrial Estates May 1991 Frequency Distribution Hourly Averages for Carbon Monoxide in ppm

Hourly CO - May, 1991



Diurnal CO - May, 1991





[April, May, June]

DRAFT

AMBIENT AIR MONITORING DATA Kuwait



MEPA - Kuwait

April 1991

Hourly Averages for Direction(degrees)

Ноиг	1	2	3	4	5	6	7	8 .	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day —	**	**	**	**	**	**	**	: **	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	Average
2	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
3	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
4	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
5	**	**	**	**	**	**	**	**	**	**	**	**	**'	**	**	**	**	**	**	**	**	**	**	**	***
6	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
7	**	××	**	××	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
8	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
9	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
10	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
11	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
12	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
13	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**.	**	**	**	**	**	***
14 15	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
16	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
17	**	**	**	**	**	**	**	148	144	. 0	129	110	119	113	133	146	156	149	153	155	154	157	164	161	141.03
18	277	331	351	19	32	54	58	59	69	58	59	56	71	83	30	20	79	259	50	173	7	5	152	200	44.28
19	188	313	294	289	297	319	248	256	0	0	333	322	6	22	18	17	19	91	110	181	277	303	330	340	328.09
20	332	336	311	331	303	310	327	321	330	341	326	349	336	6	35	55	47	7	5	5	355	325	299	297	340.81
21	286	293	315	307	301	318	291	290	304	0	317	338	338	340	339	350	12	13	14	12	359	330	304	286	327.10
22	272	268	262	258	260	269	283	272	274	308	308	313	328	34	355	336	340	338	351	4	4	354	337	332	314.01
23	314	304	305	315	308	308	322	325	335	0	2	345	337	341	338	341	349	348	334	313	314	305	304	294	325.79
24	294	282	272	271	265	270	272	275	319	7	8	22	21	38	64	85	125	138	143	152	165	168	185	226	269.60
25	250	256	241	245	254	242	235	231	227	109	109	112	112	113	104	117	137	141	115	139	143	155	169	192.	
26	201	206	221	257	270	259	261	291	302	0	312	314	316	315	324	326	332	346	335	342	336	332	331	330	305.68
27	332	331	336	344	356	351	338	334	338	334	337	334	341	348	342	340	341	343	337	333	334	330	326	316	
28	307	316	317	318	327	325	327	327	325	0	327	329	335	0	333	333	331	0	328	279	274	312	322	326	325.14
29	311	309	318	313	310	310	315	312	330	322	315	307	321	321	321	320	320	316	301	303	293	15	252	261	
30	265	269	270	263	264	265	263	276	`301	310	311	321	0	26	44	36	61	36	316	331	330	306	288	280	310.43
									•													Monthl	A WAS	age =	325

Operating Efficiency for Wind Direction = 45.7 percent Last Instrument Calibration Date - unknown [CEM] ** = missing or no data

MEPA - Kuwait
April 1991
Hourly Averages for Wind Speed(meters/sec)

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day —	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	. **	**	**	**	**	**	**	**	**	→ Averag
2	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	****
3	**	**	**	**	**	**	**	**	**	**	**	**	**	` * *	**	**	**	**	**	**	**	**	**	**	****
4	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	****
5	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	****
6	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	****
7	**	**	**	**	**	**	**	**	**	**	**	**	**	**	. **	**	**	**	**	**	**	**	**	**	****
8	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	***
9	**	**	**	**	**	**	**	**	**	**	**	· ##	**	**	**	**	**	**	**	**	**	**	**	**	****
10	##	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	****
11	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	****
12	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	* **	**	**	**	**	****
13	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	** .	**	**	**	**	**	**	**	****
14	**	**	**	**	5 *	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	****
15	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**** .
16	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	R R	**	**	**	**	**	**	****
17	**	**	**	**	**	**	**	4.6	5.0	0.0	2.7	2.3	1.7	2.6	4.7	4.1	4.7	4.0	5.4	5.4	5.5	5.7	6.1	2.8	3.96
18	1.2	2.5	4.3	6.0	4.8	5.6	4.7	3.0	3.1	4.0	4.3	3.9	2.3	1.3	1.5	1.4	1.9	1.2	8.0	1.9	2.4	2.4	1.5	1.7	2.82
19	2.2	4.0	2.0	2.9	1.6	0.5	1.3	4.6	0.0	0.0	2.8	2.4	2.4	3.9	4.4	4.4	3.2	1.1	0.7	0.9	0.4	1.5	1.6	1.8	2.11
20	2.2	2.1	2.1	2.1	3.0	2.6	1.9	1.0	2.0	2.0	1.9	2.8	2.7	3.3	3.5	3.0	1.8	0.5	2.1	2.6	2.2	0.7	1.3	1.7	2-13
21	2.0	1.9	1.2	1.7	2.1	1.6	2.3	2.8	3.3	0.0	4.5	3.9	3.7	4.0	3.8	3.5	4.7	4.5	2.9	2.7	1.0	0.8	0.9	1.8	2.57
22	2.2	2.3	2.9	3.2	3.4	3.4	2.7	3.3	4.5	3.5	4.5	6.1	4.9	4.0	3.9	5.0	4.9	4.4	3.4	4.1	4.0	3.3	2.8	2.6	3.72
23	2.4	3.4	2.9	3.4	3.4	2.6	2.7	3.3	3.6	0.0	3.9	5.0	5.7	6.0	6.3	5.2	4.3	3.7	2.9	2.2	2.5	3.7	3.8	2.9	3.57
24	2.4	2.7	2.3	2.8	3.0	3.0	3.0	3.0	1.9	3.1	3.9	4.5	3.6	3.9	4.5	3.9	4.2	4.2	3.2	3.1	3.4	3.9	3.2	3.1	3.33
25	3.2	3.8	4.9	3.7	3.4	4.0	3.8	3.4	2.1	1.0	1.3	2.1	3.4	4.1	2.7	3.5	3.6	3.8	2.2	1.5	1.4	2.2	2.3	2.8	2.93
26	2.8	2.3	1.8	2.4	3.6	3.7	3.2	4.6	4.0	0.0	4.8	5.3	5.6	6.4	5.4	6.0	5.0	4.5	3.4	2.4	2.2	3.4	3.4	3.6	3.74
27	4.1	3.5	3.9	4.4	4.8	3.6	3.3	3.6	4.8	4.9	4.7	6.3	5.3	5.1	5.7	5.9	5.6	4.8	5.0	5.3	5.4	4.8	4.2	4.2	4.72
28	6.1	4.7	4.1	3.8	4.5	4.6	5.8	6.4	6.4	0.0	6.9	6.7	7.2	0.0	7.3	5.8	5.6	0.0	4.3	2.5	3.1	3.4	2.6	2.8	4.36
29	3.5	4.5	3.5	3.7	4.2	3.7	3.5	4.4	3.9	4.4	5.3	6.1	5.3	5.3	5.6	5.2	5.6	3.5	2.6	1.3	0.8	0.1	0.2	1.4	3.65
30	2.5	2.5	2.5	2.7	2.9	3.2	3.7	3.1	3.6	3.0	2.7	2.4	0.0	3.0	2.8	2.1	0.2	0.0	0.2	1.8	1.8	1.5	1.6	2.1	2.16
																						Monthl	y Aver	age =	3.25

Maximum Hourly Average Wind Speed was 7.3 meters/sec at Hour 15 on Day 28

Maximum Daily Average Wind Speed was 4.72 meters/sec on Day 27

Operating Efficiency for Wind Speed = 45.7 percent ** = missing or no data
Last Instrument Calibration Date - unknown

[CEM]

MEPA - Kuwait April 1991

Hourly Averages for Wind Speed(meters/sec) and Direction

our	1	;	2	3	4	!	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily — Avera
/	** *	* **	**	** **	** *	* **	**	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
2	** *	* **	**	** **	** *	* **	**	** **.	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	**.**	** **	** **	** **	** **	** **	*****
3	** *	* **	** •	** **	** *	* **	**	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
4	** *	* **	**	** **	** *	* **	**	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
5	** *	* **	** :	** **	** *	* **	**	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
6	** *	* **	** 1	** **	** *	* **	**	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
7	** *1	* **	** :	* **	** *	* **	**	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
•																											*****
•																											*****

12																											*****
13																											****
14	** **	* **	** 1	** **	** **	* **	**	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	****
15	** **	* **	** 1	** **	** *1	* **	**	** **	** **	** **	女女 女女	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
16											** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	** **	*****
17	** **	* **	** 1	* **	** **	* **	**	** **	** **	5SSE	5SE	ON	3SE	2ESE	2ESE	3ESE	5SE	4SE	5SSE	4SSE	5SSE	5SSE	6\$\$E	6SSE	6SSE	3SSE	4SE
18	1W	21	INW	4N	6NN	. 5I	NNE	6NE	5ENE	3ENE	3ENE	4ENE	4ENE	4NE	2ENE	1E	2NNE		2E	1W	1NE	2\$	2N	2N	2SSE	2SSW	3NE
19	2\$	41		2WNW	3WNI		MM	0WM	1WSW	5WSW	ON	ON	3NNW	2NW	2א	4NNE	4NNE	4NNE	3NNE	1E	1ESE	18	OW	SMMA	2NNW	2NNW	2NNW
20	2NNI		INW	2NW	2NNI		MNM	3NW	2NNW	1NW	ZNNW	2NNW	2NW	3N	3NNW	3N	4NE	3NE	2NE	ON	2N	3N	2N	1NW	1WNW	2WNW	200
21	ZWNV			1NW	2NW	-	NN	2NW	2WWW	3444	3NW	ON	4NW	4NNW	4NNW	4NNW	4NNW		5NNE	4NNE	3NNE	3NNE	1N	1888	184	2WNW	3888
22	ZW	214		3W	3WSV	_		3W	3WWW	3₩	4W	4NW	4NW	6NW	5พพษ	4NE	4N	รพพพ	5หมพ	4NNW	3N	4N	4N	3N	3888	3NNW	4NW
23	2NW	3N		3NW	3NW	31	•••	3NW	3NW	3NW	4NNW	ON	4N	5NNW	6NNW	6NNW	6NNW	5NNW	4N	4NNW	3NNW	2NW	200	4NW	4NW	3WNW	4NW
24 25	2WNV		INW IOU	2W	3W	. 31		3W	3W	3W	SWM	3N	4N	4NNE	4NNE	4NE	4ENE	4E	4SE	4SE	3SE	3SSE	3\$\$E	488E	3S	3sW	3W
25 24	3WS1		ISW	5WSW	4WSV		'SM	4WSW	4SW	35W	2SW	1ESE	1ESE	2ESE	3ESE	4ESE	3ESE		4\$E	4SE	2ESE	2SE	1SE	2SSE	2\$	355W	3s
26	3551			2SW	ZWSV		•	4U	3W	שאש	4WNW	ON	5NW	5NW	6NW	6NM	5NW	6NW	5NNW	4NNW	3NNW	2NNW	ZNNW	3NNW	3NNW	4NNW	4NW
27	4		NW	4NNW	4NNV			4N	3NNV	4NNW	5NNW	5NNW	5NNW	6NNW	5NNW	SNNW	6NNW	6NNW	6NNW	5NNW	5NNW	5NNW	5NNW	5NNW	4NW	4NW	5NNW
28	6NW	5N	•••	4NW	4NW		INW.	5NW	6NNW	6NNW	6NW	ON	7NNW	7nnv	7NNW	ON	7NNW	6NNW	6NNW	ON	4NNW	2W	3W	3NW	3NW	3NW	489
29	4NW 2W	4N 2W		4NW 2W	4NW 3W	4N 31		4NW 3W	4NW 4W	4NW 3W	4NNW 4WNW	4NW 3NW	5NW 3NW	6NW 2NW	5NW On	5NW 3NNE	6NW 3NE	5NW 2NE	6NW OENE	4NW ONE	3WNW ONW	1WNW 2NNW	1WNW 2NNW	ONNE 2NW	OWSW 2WNW	1W 2W	4NW 2NW
30																											

Maximum Hourly Average Wind Speed was

7 meters/sec at Hour 15 on Day 28 and Wind Direction was from the NNW.

Maximum Daily Average Wind Speed was

5 meters/sec on Day 27 and Wind Direction was from the NNW

Operating Efficiency for Wind Speed = 45.7 percent

Operating Efficiency for Wind Direction = 45.7 percent

** = missing or no data

Last Instrument Calibration Date - unknown

[CEM]

MEPA - Kuwait April 1991 Hourly Averages for Pressure in millibars

Kour	1	2	3	4	5	6	7	8	9	10	11	_. 12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day -						<u>:</u>													ND.			ALC:	ND.	ND	Average ****
1	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	-ND	ND	ND	ND	ND	ND	ND .	ND	ND	ND	ND	ND	ND		****
2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	סא	ND	ND	ND	ND	ND	ND	ND	****
6	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
8	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NQ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
10	ND	ND	ND	ND	ND	ND	ИD	ND	ND T	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
11	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	****
12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
13	ND	ND	ND	ND	ND	ND	ND	ND	ŃD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND	ND	ND	NÜ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	DIA	ND	ND	ND	ND	DM	ND	ND	ND	ND	ND	ND	ND	****
16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	DM	ND	ND	ND	****						
17	ND	ND	ND	ND	ND	ND	ND	1003	1004	ND	1005	1001	1008	1008	1010	1009	1008	1002	1008	1009	1009	1008	1008	1008	1006.8
18	1008	1008	1008	1008	1008	1008	1007	ND	1007	1007	1008	1009	1009	1010	1010	1010	1009	1009	1009	1009	1008	1008	1008	1008	1008.4
19	1008	1008	1008	1008	1008	1008	1008	1008	ND	ND	1013	1014	1016	1017	1020	1020	1020	1017	1014	1012	1013	1011	1010	1010	1012.3
20	1010	1009	1009	1009	1009	1008	1008	1008	1008	1008	1010	1014	1018	1025	1026	1025	1022	1015	1010	1008	1007	1007	1007	1007	1012.0
21	1007	1007	1007	1008	1008	. 1008	1007	1008	1012	ND	1021	1022	1017	1017	1018	1017	1015	1011	1008	1008	1008	1009	1009	1010	1011.4
22	1008	1006	1006	1006	1006	1006	1007	1007	1017	1022	1025	1026	1029	1035	1040	1041	1036	1031	1025	1021	1017	1012	1009	•	1018.5
23	1007	1007	1007	1007	1007	1007	1007	1007	1011	ND	1010	1013	1012	1013	1013	1012	1012	1012	1011	1009	1008	1007	1007	1008	1009.3
24	1006	1005	1005	1005	1005	1005	1005	1005	1006	1008	1009	1014	1020	1026	1023	1019	1016	1013	1008	1007	1007	1006	1006	1007	1009.8
25	1009	1008	1008	1009	1009	1009	1010	1011	1011	1012	1011	1012	1013	1010	1011	1011	1009	1008	1008	1008	1008	1009	1009	1008	1009.6
26	1008	1007	1007	1007	1007	1006	1007	1006	1007	ND	1012	1012	1012	1014	1016	1016	1016	1013	1010	1007	1007	1007	1009	1007	1009.6
27	1006	1006	1005	1005	1006	1007	1007	1008	1007	1009	1016	1015	1013	1013	1011	1009	1007	1006	1006	1006	1006	1007	.1007	1006	1008.1
28	1005	1005	1005	1005	1005	1005	1005	1005	1007	ND	1013	1016	1020	ND	1025	1028	1026	ND	1020	1015	1013	1011	1010	1007	1012.0
29	1006	1005	1005	1006	1006	1006	1006	1006	1008	1011	1015	1018	1021	1024	1024	ND `	1017	1013	1009	1006	1003	1002	1001	1001	1009.5
30	1002	1005	1006	1006	1006	1006	1006	1005	1006	1009	1010	1011	ND	1015	1017	1015	1013	1011	1009	1007	1006	1004	1003	1002	1007.8
J																					M	lonth l y	Avera	ge =	1010.4
•					•																				

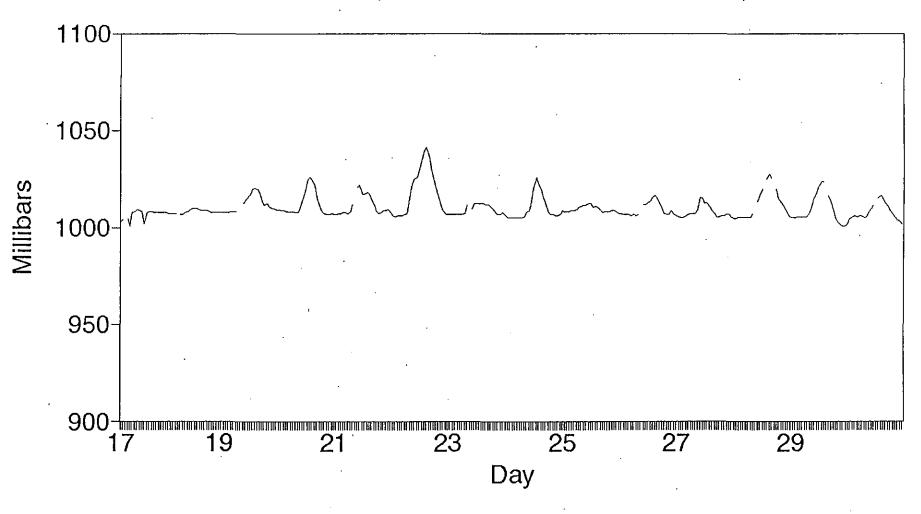
Maximum Hourly Average was 1041 at Hour 16 on Day 22 with 1 occurences

Maximum Daily Average was 1018.5 on Day 22 with 1 occurences

Operating Efficiency = 44.0 percent

KUWAIT

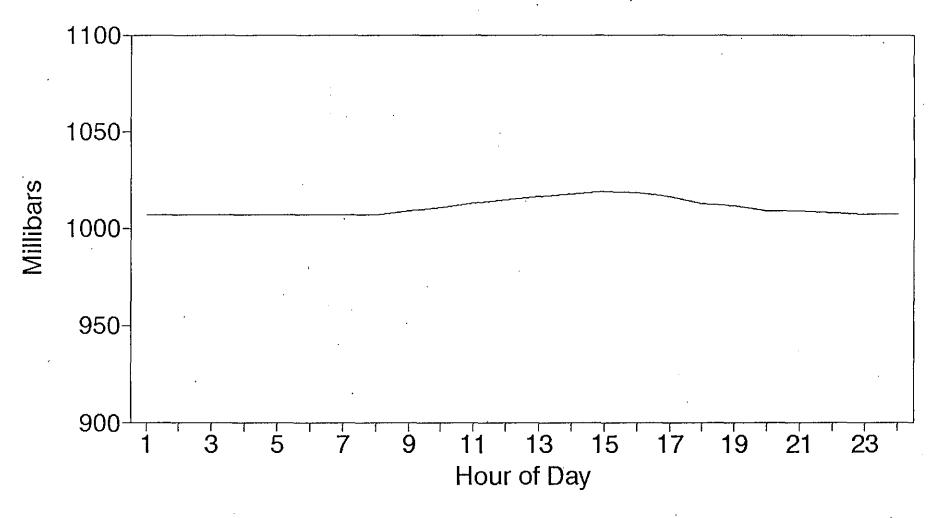
Hourly Barometric Press — April, 1991



Pressure

KUWAIT

Diurnal Pressure - April, 1991



Barometric Pressure

MEPA - Kuwait

April 1991

Hourly Averages for Solar Radiation in Watts/ M2

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day										LIP			ALD.	ND.	110	110	in	up.	.UD	ND.	ND.	ш	ND.	UD.	- Average
1	ND,	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND '	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	****
2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	· ND	ND	ND	ND	ND	****
3	ND	ND	ND	ND	ND .	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
4	ND	ND	ND	ND	ND	ND	ND	ИD	' ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	DΝ	ND	ND	ND	ND	ND	ND	ND	****
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	ND	ИD	ND	ND	ND	ND	ND	ND	סא	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
8	ND	ND ·	ND	ND	ND	ND	ND	ND	ND	ND	ND .	ND	ND	ND	ND .	ND	ND	ND	ND	ND	ND	ND	ND	ND	
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
11	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND'	ND	ND	ND	ND	ND	ND	ND	ND	****
12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ВD	****
15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
16	ND	ND	ИD	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	D	ND	ND	****
17	ND	ND	ИD	ND	ИD	ND	ND	14	32	ND	61	194	155	5	17	77	9	6	0	0	0	0	0	0	35.6
18	0	0	0	0	0	2	20	38	89	299	359	126	29	63	9	36	27	1	0	0	0	0	0	0	45.8
19	0	0	0	0	0	1	40	65	ND	ND	356	295	389	506	445	299	121	22	0	0	0	0	0	0	115.4
20	0	0	0	0	0	3	27	23	48	116	264	494	590	556	469	347	201	55	1	1	0	0	0	0	133.1
21	0	0	0	0	. 0	29	50	78	345	ND	713	543	664	619	378	300	128	35	0	0	0	0	0	0	168.8
55	0	0	0	0	0	19	67	135	452	553	641	699	663	606	528	397	233	72	2	0	0	0	0	0	211.1
23	0	0	0	0	0	11	46	98	422	ND	595	547	476	324	246	156	76	25	1	0	0	0	0	0	131.4
24	0	0	0	0	0	7	39	32	304	508	577	609	553	570	484	366	224	66	2	0	0	0	0	0	180.9
25	0	0	0	0	0	0	0	0	1	39	141	. 170	168	192	179	252	63	38	1	1	0	0	0	0	51.9
26	0	0	0	0	0	6	55	129	341	ND	539	420	482	580	479	387	154	61	3	0	0	0	0	0	158.1
27	0	0	0	0	0	9	52	87	317	348	341	302	217	306	187	111	66	31	1	0	0	0	0	0	99.0
28	0	0	0	0	0	12	64	99	391	ND	626	620	573	ND	556	352	149	ND	3	0	0	0	0	0	164.0
29	0	0	0	0	0	17	74	86	448	568	. 646	688	666	539	437	403	254	91	5	0	0	0	0	0	205.1
30	0	0	0	0	0	15	63	120	383	219	176	211	ND	275	240	116	61	39	1	0	0	0	0	0	83.4
}	 							·····													— Мо	nthly	Averag	je =	129.3

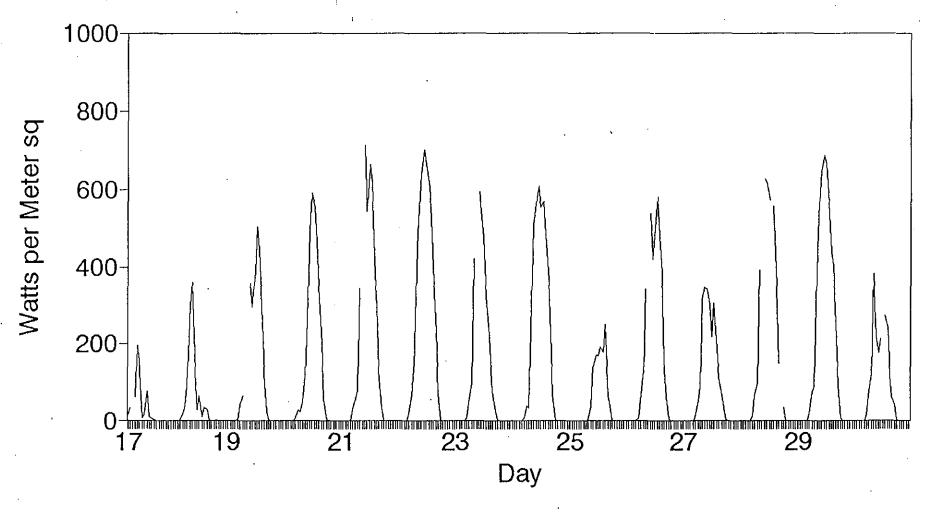
Maximum Hourly Average was 713 at Hour 11 on Day 21 with 1 occurences

Maximum Daily Average was 211.1 on Day 22 with 1 occurences

Operating Efficiency = 44.3 percent

KUWAIT

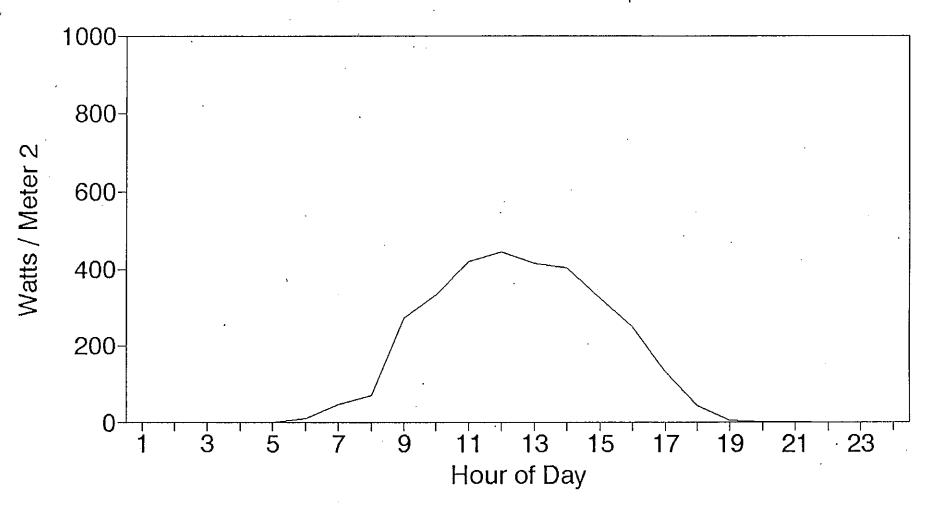
Hourly Solar Radiation - April, 1991



Solar Radiation

KUWAIT

Diurnal Radiation - April, 1991



Solar Radiation

MEPA - Kuwait

April 1991

Hourly Averages for Relative Humidity in Per Cent

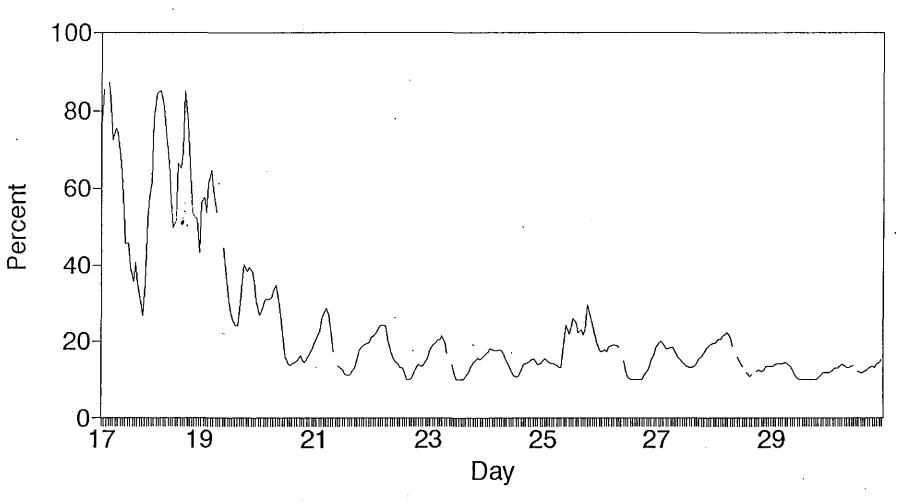
1 ND ND ND ND ND ND ND ND ND ND ND ND ND	Hour Day	1	2	3	4	5	6	7	8	. 9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily ⊢ Average
3 MO NO NO NO NO NO NO NO NO NO NO NO NO NO	1	ND	ND	ND																						
4 ND ND ND ND ND ND ND ND ND ND ND ND ND	2	NĐ	ND	ИD	ND	ND	ND	****																		
5 NO NO NO NO NO NO NO NO NO NO NO NO NO	3	ND	ND	ND	****																					
6 ND ND ND ND ND ND ND ND ND ND ND ND ND	4	ND	ND	ND	ND	· ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7 ND ND ND ND ND ND ND ND ND ND ND ND ND	5	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****							
8 ND ND ND ND ND ND ND ND ND ND ND ND ND	6	ND	ND	ND	ND	ND	ИD	ND	. ND	ND	ND	ND	ND	ND	ND	ND	****									
9 NO NO NO NO NO NO NO NO NO NO NO NO NO	7	ND	ND	ND	ND	NĐ	ND	DN	ND	ND	****															
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	8	NĐ	ND	ND	ND	****																				
11 NO ND ND ND ND ND ND ND ND ND ND ND ND ND	9	ND	ИD	ND	ND	ND	ND	ND	ND	ИD	ND	****														
12 NO NO NO NO NO NO NO NO NO NO NO NO NO	10	ND	ND	ND	****																					
13 ND ND ND ND ND ND ND ND ND ND ND ND ND	11	ND	ND	ND																						
14 ND NO NO NO NO NO NO NO NO NO NO NO NO NO	12	ND	ND	ND	ND	ND	ИD	ND	ИD	ND	ND	ND	. ND	ND	ND	ND	ИD	ND	•							
15 ND ND ND ND ND ND ND ND ND ND ND ND ND				ИD	ND		ND	ND			ND		ND						ND	=	ND					
16 ND ND ND ND ND ND ND ND ND ND ND ND ND			_													-										
17 NO NO NO NO NO NO NO NO NO NO NO NO NO				•																						•
18 26.6 34.7 52.1 57.8 61.8 77.9 84.2 84.8 85.1 80.9 75.1 66.6 57.1 49.7 51.6 66.3 65.2 69.5 85.1 77.0 66.6 53.7 52.5 52.1 63.92 19 43.3 56.2 57.5 53.6 61.2 64.6 59.4 53.7 ND ND 44.6 38.9 30.4 27.3 25.7 24.0 23.9 30.1 35.7 40.1 38.3 39.4 38.2 35.4 41.89 20 30.4 27.0 27.9 30.5 31.0 30.9 31.2 33.5 34.6 30.4 26.6 20.4 16.1 14.0 13.6 14.2 14.3 15.0 16.3 14.9 14.3 15.6 16.8 18.3 22.41 21 19.8 21.0 22.8 26.1 27.6 28.6 26.9 22.0 17.2 ND 13.5 13.2 12.4 11.3 11.0 11.1 12.2 13.0 15.1 17.7 18.7 18.8 19.3 19.5 18.21 22 21.0 21.3 22.0 23.6 24.3 24.3 24.0 20.7 17.4 15.9 14.7 14.1 13.1 12.9 11.6 10.1 10.1 10.3 11.7 12.8 13.9 13.5 13.7 15.0 16.33 23 16.0 17.7 19.2 19.4 20.4 20.5 21.5 19.7 16.7 ND 14.0 11.9 10.1 10.0 10.0 10.0 10.4 11.8 13.2 14.4 14.9 15.4 15.3 15.6 15.13 24 16.5 16.9 18.0 17.8 17.5 17.6 17.7 17.5 16.3 15.0 13.4 12.1 11.1 10.5 10.7 12.6 14.0 14.1 14.3 15.0 15.4 14.7 14.0 14.2 14.87 25 14.6 15.4 15.0 14.3 14.2 14.2 13.6 13.2 13.2 20.5 24.2 22.0 23.5 26.1 24.8 22.3 23.0 21.6 22.9 29.4 27.0 24.3 21.9 19.9 20.05 26 17.5 17.4 17.7 17.4 18.6 18.8 19.1 18.8 18.4 ND 14.8 12.1 10.6 10.0 10.1 10.1 10.1 10.0 10.1 11.1 12.1 13.0 14.6 16.4 14.30 27 18.3 19.7 20.2 19.3 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 28 19.3 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 ND 16.0 14.6 13.3 ND 11.8 10.7 11.2 ND 12.0 12.3 12.2 12.4 13.3 13.5 16.09 29 13.4 13.3 14.0 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.1 10.0 10.0			=		•							***				-				**-			•			
19 43.3 56.2 57.5 53.6 61.2 64.6 59.4 53.7 NO NO 44.6 38.9 30.4 27.3 25.7 24.0 23.9 30.1 35.7 40.1 38.3 39.4 38.2 35.4 41.89 20 30.4 27.0 27.9 30.5 31.0 30.9 31.2 33.5 34.6 30.4 26.6 20.4 16.1 14.0 13.6 14.2 14.3 15.0 16.3 14.9 14.3 15.6 16.8 18.3 22.41 19.8 21.0 22.8 26.1 27.6 28.6 26.9 22.0 17.2 ND 13.5 13.2 12.4 11.3 11.0 11.1 12.2 13.0 15.1 17.7 18.7 18.8 19.3 19.5 18.21 22 21.0 21.3 22.0 23.6 24.3 24.3 24.0 20.7 17.4 15.9 14.7 14.1 13.1 12.9 11.6 10.1 10.1 10.3 11.7 12.8 13.9 13.5 13.7 15.0 16.33 23 16.0 17.7 19.2 19.4 20.4 20.5 21.5 19.7 16.7 ND 14.0 11.9 10.1 10.0 10.0 10.0 10.0 10.4 11.8 13.2 14.4 14.9 15.4 15.3 15.6 15.13 24 16.5 16.9 18.0 17.8 17.5 17.6 17.7 17.5 16.3 15.0 13.4 12.1 11.1 10.5 10.7 12.6 14.0 14.1 14.3 15.0 15.4 14.7 14.0 14.2 14.87 25 14.6 15.4 15.0 14.3 14.2 14.2 13.6 13.2 20.5 24.2 22.0 23.5 26.1 24.8 22.3 23.0 21.6 22.9 29.4 27.0 24.3 21.9 19.9 20.05 26 17.5 17.4 17.7 17.4 18.6 18.8 19.1 18.8 18.4 ND 14.8 12.1 10.6 10.0 10.1 10.1 10.1 10.0 10.1 11.1 12.1 13.0 14.6 16.4 14.30 27 18.3 19.7 20.2 19.3 18.0 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 28 19.3 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 ND 16.0 14.6 13.3 ND 11.8 10.7 11.2 ND 12.0 12.3 12.2 12.4 13.3 13.5 16.09 29 13.4 13.3 14.0 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.0 10.0 10.0			_																							
20 30.4 27.0 27.9 30.5 31.0 30.9 31.2 33.5 34.6 30.4 26.6 20.4 16.1 14.0 13.6 14.2 14.3 15.0 16.3 14.9 14.3 15.6 16.8 18.3 22.41 19.8 21.0 22.8 26.1 27.6 28.6 26.9 22.0 17.2 ND 13.5 13.2 12.4 11.3 11.0 11.1 12.2 13.0 15.1 17.7 18.7 18.8 19.3 19.5 18.21 22 21.0 21.3 22.0 23.6 24.3 24.3 24.0 20.7 17.4 15.9 14.7 14.1 13.1 12.9 11.6 10.1 10.1 10.3 11.7 12.8 13.9 13.5 13.7 15.0 16.33 23 16.0 17.7 19.2 19.4 20.4 20.5 21.5 19.7 16.7 ND 14.0 11.9 10.1 10.0 10.0 10.0 10.0 10.4 11.8 13.2 14.4 14.9 15.4 15.3 15.6 15.13 24 16.5 16.9 18.0 17.8 17.5 17.6 17.7 17.5 16.3 15.0 13.4 12.1 11.1 10.5 10.7 12.6 14.0 14.1 14.3 15.0 15.4 14.7 14.0 14.2 14.87 25 14.6 15.4 15.0 14.3 14.2 14.2 13.6 13.2 20.5 24.2 22.0 23.5 26.1 24.8 22.3 23.0 21.6 22.9 29.4 27.0 24.3 21.9 19.9 20.05 26 17.5 17.4 17.7 17.4 18.6 18.8 19.1 18.8 18.4 ND 14.8 12.1 10.6 10.0 10.1 10.1 10.1 10.1 10.1 11.1 12.1 13.0 14.6 16.4 14.30 27 18.3 19.7 20.2 19.3 18.0 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 28 19.3 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 ND 16.0 14.6 13.3 ND 11.8 10.7 11.2 ND 12.0 12.0 12.3 12.2 12.4 13.3 13.5 16.09 29 13.4 13.3 14.0 14.2 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.0 10.0 10.0			•																							
21 19.8 21.0 22.8 26.1 27.6 28.6 26.9 22.0 17.2 ND 13.5 13.2 12.4 11.3 11.0 11.1 12.2 13.0 15.1 17.7 18.7 18.8 19.3 19.5 18.21 22 21.0 21.3 22.0 23.6 24.3 24.3 24.0 20.7 17.4 15.9 14.7 14.1 13.1 12.9 11.6 10.1 10.1 10.3 11.7 12.8 13.9 13.5 13.7 15.0 16.33 16.0 17.7 19.2 19.4 20.4 20.5 21.5 19.7 16.7 ND 14.0 11.9 10.1 10.0 10.0 10.0 10.0 10.4 11.8 13.2 14.4 14.9 15.4 15.3 15.6 15.13 16.5 16.9 18.0 17.8 17.5 17.6 17.7 17.5 16.3 15.0 13.4 12.1 11.1 10.5 10.7 12.6 14.0 14.1 14.3 15.0 15.4 14.7 14.0 14.2 14.87 15.0 14.3 14.2 14.2 14.2 13.6 13.2 20.5 24.2 22.0 23.5 26.1 24.8 22.3 23.0 21.6 22.9 29.4 27.0 24.3 21.9 19.9 20.05 17.5 17.4 17.7 17.4 18.6 18.8 19.1 18.8 18.4 ND 14.8 12.1 10.6 10.0 10.1 10.1 10.1 10.0 10.1 11.1 12.1 13.0 14.6 16.4 14.30 18.3 19.7 20.2 19.3 18.0 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 18.1 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 ND 16.0 14.6 13.3 ND 11.8 10.7 11.2 ND 12.0 12.3 12.2 12.4 13.3 13.5 16.09 19.9 19.9 19.9 19.9 19.9 19.9 19.9 1																										
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23 16.0 17.7 19.2 19.4 20.4 20.5 21.5 19.7 16.7 ND 14.0 11.9 10.1 10.0 10.0 10.0 10.0 10.4 11.8 13.2 14.4 14.9 15.4 15.3 15.6 15.13 24 16.5 16.9 18.0 17.8 17.5 17.6 17.7 17.5 16.3 15.0 13.4 12.1 11.1 10.5 10.7 12.6 14.0 14.1 14.3 15.0 15.4 14.7 14.0 14.2 14.87 25 14.6 15.4 15.0 14.3 14.2 14.2 13.6 13.2 13.2 20.5 24.2 22.0 23.5 26.1 24.8 22.3 23.0 21.6 22.9 29.4 27.0 24.3 21.9 19.9 20.05 26 17.5 17.4 17.7 17.4 18.6 18.8 19.1 18.8 18.4 ND 14.8 12.1 10.6 10.0 10.1 10.1 10.1 10.0 10.1 11.1 12.1 13.0 14.6 16.4 14.30 27 18.3 19.7 20.2 19.3 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 28 19.3 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 ND 16.0 14.6 13.3 ND 11.8 10.7 11.2 ND 12.0 12.3 12.2 12.4 13.3 13.5 16.09 29 13.4 13.3 14.0 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.1 10.0 10.0												•														
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25 14.6 15.4 15.0 14.3 14.2 14.2 13.6 13.2 13.2 20.5 24.2 22.0 23.5 26.1 24.8 22.3 23.0 21.6 22.9 29.4 27.0 24.3 21.9 19.9 20.05 26 17.5 17.4 17.7 17.4 18.6 18.8 19.1 18.8 18.4 ND 14.8 12.1 10.6 10.0 10.1 10.1 10.1 10.0 10.1 11.1 12.1 13.0 14.6 16.4 14.30 27 18.3 19.7 20.2 19.3 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 28 19.3 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 ND 16.0 14.6 13.3 ND 11.8 10.7 11.2 ND 12.0 12.3 12.2 12.4 13.3 13.5 16.09 29 13.4 13.3 14.0 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.1 10.0 10.0	24																									
26 17.5 17.4 17.7 17.4 18.6 18.8 19.1 18.8 18.4 NO 14.8 12.1 10.6 10.0 10.1 10.1 10.0 10.1 11.1 12.1 13.0 14.6 16.4 14.30 27 18.3 19.7 20.2 19.3 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 28 19.3 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 NO 16.0 14.6 13.3 NO 11.8 10.7 11.2 ND 12.0 12.3 12.2 12.4 13.3 13.5 16.09 29 13.4 13.3 14.0 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.1 10.0 10.0	25	- +																								
27 18.3 19.7 20.2 19.3 18.0 18.0 18.4 18.2 17.4 15.9 15.1 14.4 14.0 13.5 13.2 13.1 13.5 14.2 15.1 15.9 16.8 18.0 18.7 19.2 16.59 28 19.3 19.6 20.5 20.5 21.1 21.7 22.3 20.9 18.7 ND 16.0 14.6 13.3 ND 11.8 10.7 11.2 ND 12.0 12.3 12.2 12.4 13.3 13.5 16.09 29 13.4 13.3 14.0 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.0 10.0 10.0	26																									•
29 13.4 13.3 14.0 14.2 14.2 14.2 14.3 14.1 13.5 12.5 11.3 10.2 10.1 10.1 10.1 10.1 10.1 10.0 10.0	27													,											19.2	16.59
30 11.9 11.9 12.3 12.8 12.9 13.4 13.8 13.6 13.0 13.2 13.5 13.6 ND 12.0 11.9 11.9 12.0 12.7 13.2 13.3 13.0 13.9 14.3 15.1 13.01	28	19.3	19.6	20.5	20.5	21.1	21.7	22.3	20.9	18.7	ND	16.0	14.6	13.3	ND	11.8	10.7	11.2	ND	12.0	12,3	12.2	12.4	13.3	13.5	16.09
30 11.9 11.9 12.3 12.8 12.9 13.4 13.8 13.6 13.0 13.2 13.5 13.6 ND 12.0 11.9 11.9 12.0 12.7 13.2 13.3 13.0 13.9 14.3 15.1 13.01	29	•																								11.86
	30	11.9	11.9	12.3	12.8	12.9	13.4	13.8	13.6	13.0	13.2	13.5	13.6	ND	12.0	11.9	11.9	12.0	12.7	13.2	13.3	13.0	13.9	14.3	15.1	13.01
	} —															·						{ м	onthly	Avera	ge =	23.79

Maximum Hourly Average was 87.1 at Hour 11 on Day 17 with 1 occurences

Maximum Daily Average was 63.92 on Day 18 with 1 occurences

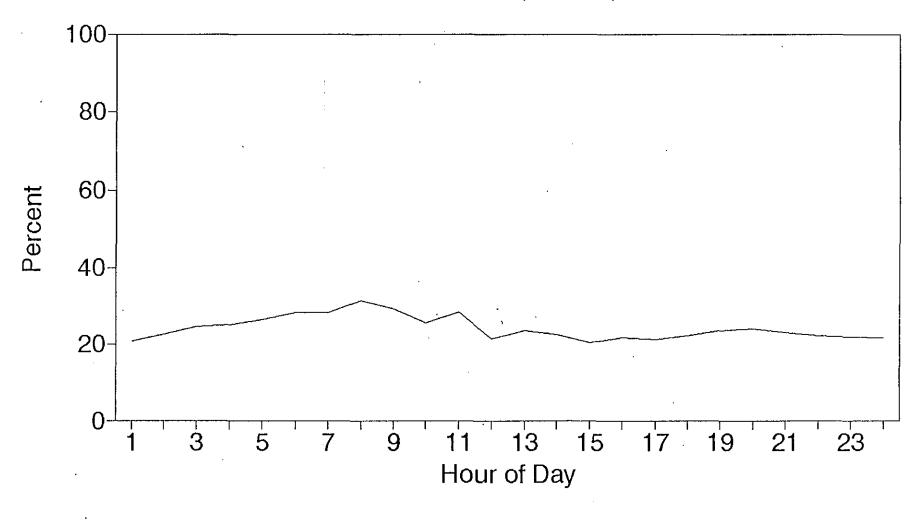
Operating Efficiency = 44.3 percent

Hourly Humidity - April, 1991



— Humidity

Diurnal Humidity - April, 1991



--- Humidity

MEPA - Kuwait

April 1991

Hourly Averages for Temperature in Degrees C

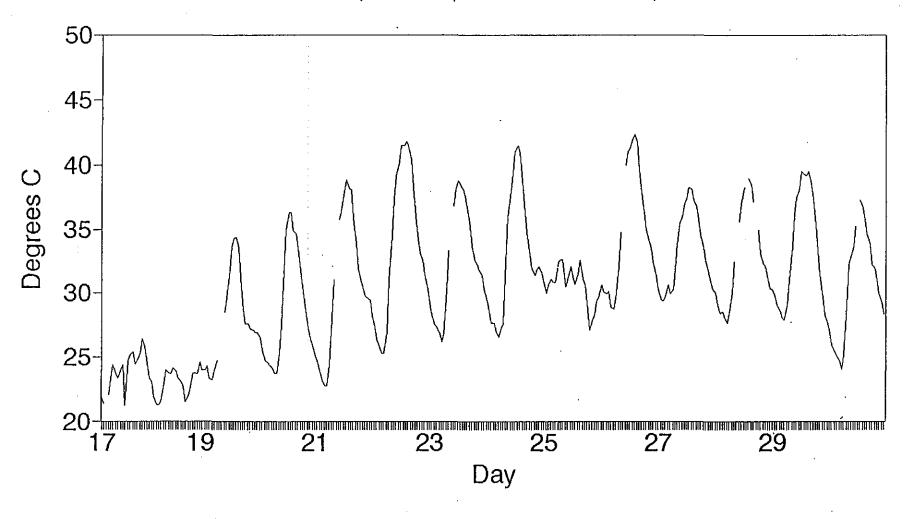
Hour	1	2	3	4	5	6	7	8	9	. 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day					······································																				→ Average
1	DM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
2	ND	ND	ND	MD	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ŅD	ND	ND	ND	ND	ND	ND	DM	ND	ND	ND	ND	ND	ND	****
4	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	****
5	ND	ИD	ND	ND	ND	ND	ND	ND	ND	NĐ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	****
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	סא	ND	ND	ND	ND	ND	ИD	ND	ND	****
. 7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND,	ND	ND*	ND	****
8	ИD	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ИĐ	ND	ND	ИD	ИD	ND	****
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	****
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	DM	ND	ND	ND	***
11	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	****
12	ND	ND	ND	ND	ИĎ-	ND	NĐ	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
13	ND	ND	ND	ND	Вþ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ИD	ИD	ND	ND	ND	****
15	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
17	ND	ND	ND	ND	ND	ND	ND	21.8	21.4	ND	22.1	23.4	24.4	23.7	23.4	24.1	24.4	21.2	24.8	25.2	25.4	24.5	24.7	25.3	23.74
18	26.4	25.8	24.5	23.4	23.1	21.9	21.3	21.3		22.9	24.0	23.8								22.0			23.8	23.7	23.27
19	24.6		24.0	24.3			23.9	24.7	ND 27:0		28.5				34.3					27.6			27.1		27.89
20	26.9 25.1		25.6					23.8												30.1		27.3		25.7	28.74
21 22							24.4	28.0 31.0												31.0				29.5	30.57
23	29.2							30.3												32.5				30.3	33.77 32.51
24	29.4							27.6																	33.02
25	30.8							32.7														28.4			30.63
26	30.6							32.1												35.0					34.93
27	30.3		29.4					31.9														31.6		30.3	33.40
28	29.9		28.4					30.0			35.6				39.0			ND O.CC		33.1		32.1	31.1	30.4	32.47
29		29.8						31.0									-				31.5			27.6	33.30
		-						29.0												32.0					30.53
	20.7	20.0	27.4	۱ ، د ء	4.1	۲۳۰۱	42.4	27.0	34.3	33.0		33.3		31.3	30.7	٥, رو	34.1	73.7	32.3	32.0					30.78
						-							. —									onthly	Avera	9e =	30.10

Maximum Hourly Average was 42.3 at Hour 15 on Day 26 with 1 occurences

Maximum Daily Average was 34.93 on Day 26 with 1 occurences

Operating Efficiency = 44.3 percent

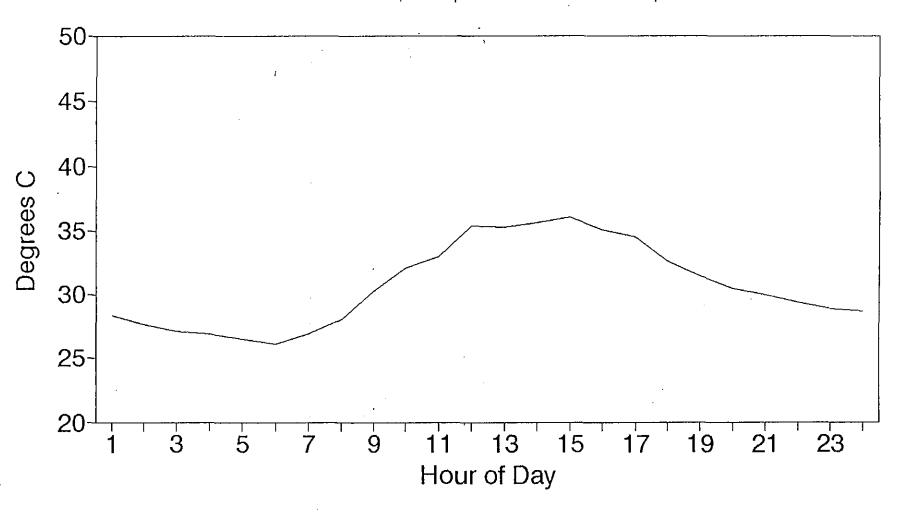
Hourly Temperature - April, 1991



— Temp

KUWAIT

Diurnal Temperature - April, 1991



Temperature

MEPA - Kuwait

April 1991

Hourly Averages for Total Particulate in MG/M3

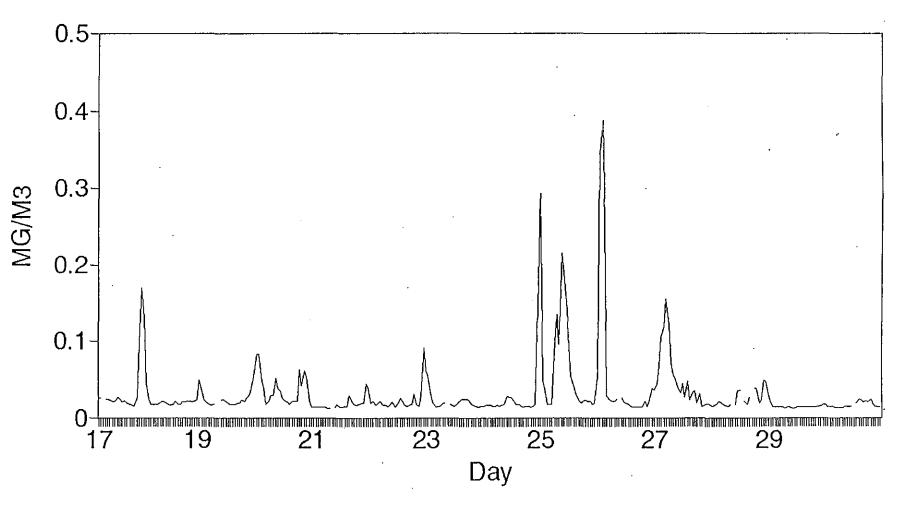
Hour	1	2	: 3	4	5	6	, 7	8	9	10	11	. 12	13	14	. 15	16	17	18	19	20	21	22	23	24	Daily
Day -	ND	ND	ND.	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Average *****							
2	ND		_						ND	ND		-							ND			_	ND	ND	****
3	ND		ND	ND	ND	ND		ND	ND	ND	ND	****													
4	ND D	ND	NO	ND	ND	ND	ND	ND	ND	ND	ND	****													
5	ND	ND,	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
6	ND D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
7	ND D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
8	ND D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
9	ND D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
10	ND	ИD	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
11	ND D	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ИD	****													
12	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	DIA	ND	ND	NĐ	ND	ND	ND	ND	****						
13	ND D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
14	ND	ND.	ND	ND	ND	ND	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
15	ND D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
16	ND	ND		ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	· ND	ND	ND	****
17	ND	ND		ND	ND	ND		0.025		-							0.024					. –			0.0217
								0.018																	0.0345
			0.032						ND							-	0.018					-			0.0236
								0.029						-	_				-			-			0.0379
								0.012								•	0.029								0.0168
								0.016										-							0.0226
								0.019	-			_	-				0.024								0.0219
								0.015																	0.0240
								0.135																	0.0701
			_		-			0.021									0.013								0.0617
•				•				0.071																	0.0505
				-				0.014				0.035					0.026					0.024			0.0244
				-				0.012														_			0.0144
30 1	0.018	0.014	0.013	0.013	V.U12	0.012	0.012	0.012	0.013	U.U13	U,U13	0.013	ND	U.U19	U.U24	0.023	0.020	U.U21	0.020	U.U24					0.0160
-																	•		···		ر ہــــــ	Monthly	Aver:	age =	0.0318

Maximum Hourly Average was 0.388 at Hour 3 on Day 26 with 1 occurences

Maximum Daily Average was 0.0701 on Day 25 with 1 occurences

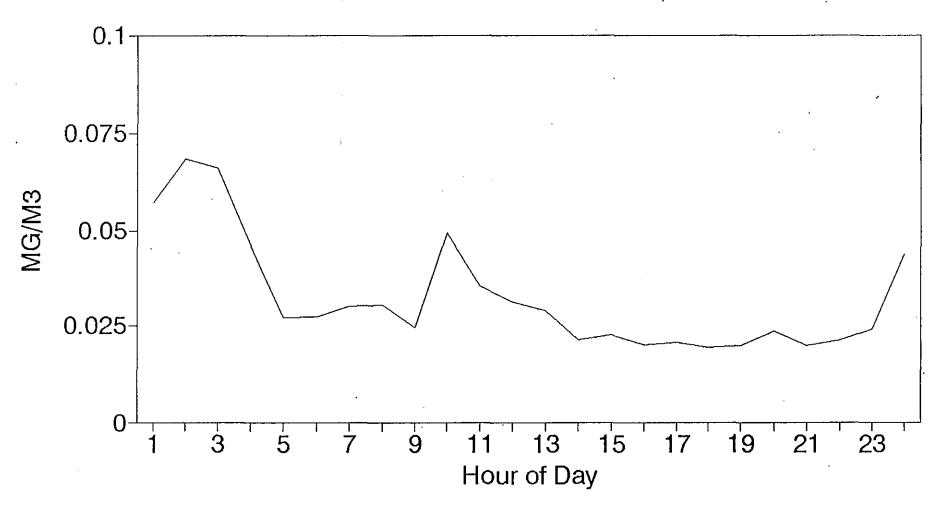
Operating Efficiency = 44.3 percent

Hourly Particulate - April, 1991



Particulate

Diurnal Particulate - April, 1991



--- Particulate

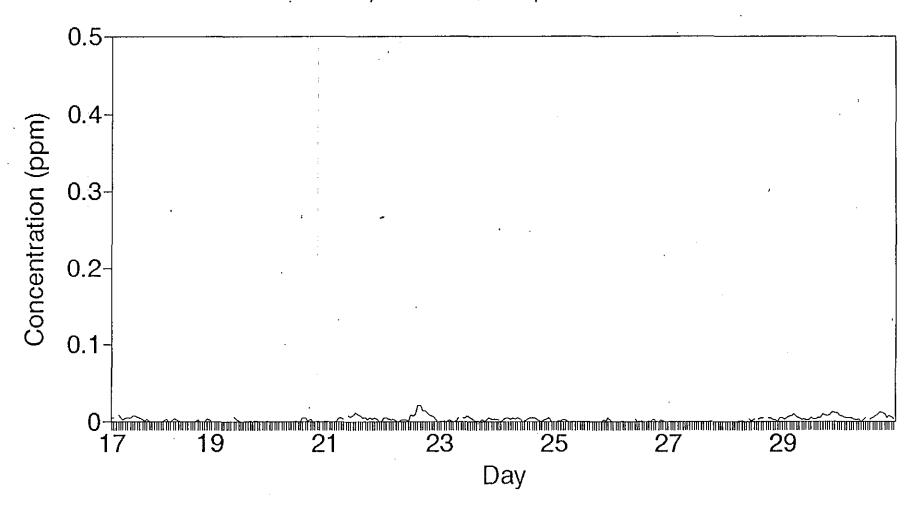
MEPA - Kuwait April 1991 Hourly Averages for NH3 in ppm

Daily Average	***	***	****	****	****	****	****	****	****	***	***	****	***	***	****	***	0.0043	0.0007	0.0007	0.0007	0.0038	0.0062	0.0023	0.0028	9000.0	0.0007	0.0002	0.0018	0,000.0	0.0054	0.0025
Т	- *	-	¥			-	-		-	-		•			*						_	_	_		_				_		·.
24	문	2	2	S.	윤	욮	S	₽	2	Ş	₽	S	웆	₽	운	₽	0000	0.003	0.000	0.000	0.000	0.000	0.003	000.0	0.002	0.000	00000	0.004	0.011	0.003	и 9
23	Q.	모	윷	₽	Ş	웊	웆	2	₽	2	웆	읒	웆	유	Q	Q.	0.003	0.000	0.000	0.000	0.003	0.006	0.003	0.004	0.001	0.001	0.000	0.001	0.011	0.006	Monthly Average
22	9	용	₽	읒	Ş	웊	2	S	웊	S	웆	웊	£	2	₽	₽	0.001	0.000	0.000	0.001	0.005	0.007	0.004 (0.003	0.002	0,002 (0.000	0.002	0.012	0.007	onthly
21	욧	2	웊	웆	욧	웆	웆	₽	₽	웊	⊋	ş	웊	2	2	9	0.002	0.000	0.001	0.000	0.003	0.008	0.002 (0.002 (0.000	0.000	0.000	0,002	0.009	0.005 0.007	ž T
20	웊	₽	⊋	2	웊	9	ð	웆	2	웆	₽	ş	皇	2	윤	웊	0.004	0.002	0.001	0.000	0.005	0.011	0,001	0.001	0.000	0.001	0.003	0.004	0.007	0.010	
19	Ş	⊋	웆	욮	윷	윤	윷	웆	₽	욧	웃	Ş	웆	웆	S	2	0.006 0	0.000.0	0.000 0	0.003 0	0.002 0	0.013 0	0.002 0	0.0010	0.000.0	0.003 0	0.0010	0.004 0	0.008 0	0.011 0	
18	9	₽	2	욮	윺	2	Ş	웆	Ş	S	웆	웆	웆	2	웆	웆	0.007	0.000	0.001	0.001	0.004 0	0.013 0	0.000.0	0.003 0	0.000.0	0.001	0.000.0	Ş	0.010 0	0.012 0	
17	9	2	2	욯	₽	₽	읒	₽	윷	Ş	Ş	2	2	윺	윷	웆	0.007	0.000.0	0.000.0	0.005 0	0.004 0	0.020.0	0.0010	0.005 0	0.000.0	0.001	0.000	0.005	0.005 0	0.008 0	
16	욮	₽	웆	Ş	S	웆	웆	웆	옾	웊	웊	물	8	윷	웊	윷	0.005 0	0.000.0	0.000.0	0.004 0	0.007 0	0.020.0	0.0010	0.005 0	0.000.0	0.000 0	0.000.0	0,000,0	0.005 0	0.0070	
15	Ş	웆	웆	운	오	윤	웊	₽	용	æ	웆	æ	₽	₽	Q	Q	0.005 0	0.000.0	0.000.0	0.0010	0.008 0	0.010 0	0.003 0	0.005 0	0.000	0.000.0	0.000.0	0.003 0	0.003 0	0.004 0	
14	Ş	£	웆	윤	웆	문	윷	윷	욧	·S	읒	읖	웆	웆	ð	S	0.004 0	0.000.0	0.000.0	0.000.0	0.011 0	0.007 0	0.005 0	0.003 0	0.000.0	0.0010	0.000.0	₽	0.003 0	0.003 0	
13	ð	웆.	ş	₽	2	ş	2	₽	S	S	₽	Ş	₽	₽	웆	웆	0.002 0	0.000.0	0.001	0.001	0.009	0.000	0.007	0.001	0.000.0	0.0010	0.000.0	0.003	0.004 0	S O	
12	2	2	윺	웊	웊	₽	身	₽	Q	읒	ş	2	2	웆	욯	웆	0.005 0	0.0010	0.003 0	0.000.0	0.006.0	0.0010	0.005 0	0.000.0	0.000.0	0.000	0.000.0	0.0010	0.002 0	0.004	
٦.	£	₽	웆	웆	2	2	2	웆	웊	윷	웊	웊	£	웆	웆	웆	0.009	0.003 0	0.006 0	0.000 0	0.0070	0.002 0	0.005 0	0.003 0	0.000.0	0.003 0	0.000.0	0.003 0	0.002 0	0.002 0	
01	Ş	욷	웆	웆	읖	⊋	2	2	웊	Ş	웆	웆	웆	웆	R	NO	CAL 0	.003	CAL 0	000	CAL 0	.002	CAL 0	0.004 0	0.000 0	오 오	900.	CAL 0	0.003 0	0.000.0	
٥	ą	웆	오	9	오	身	2	웊	읒	웆	웊	2	웆	2	웆	웆	0.004	0.000.0	CAL	0.000.0	0.003	0.002 0	0.004	0.003 0	0.000	000.0	0.000.0	0.000	0.002 0	0.003 0	
బ	SN	S	옾	2	웊	2	8	ş	욧	S	윷	Ş	웃	£	웆	Ŗ	0.005 0	0.000.0	000.0		0.004 0	0.000.0	0.001 0	0,004 0	0.000.0	0.000.0	0.000.0	0.0010	0.004 0	0.002 0	
7	æ	₽	웆	웆	웆	웆	용	웆	읒	웆	æ	웆	웆	웊	웆	웆	S 문	0.003 0	0,000,0	0,000	0.004	0.0010	0.000 0	0.003 0	0.000 0	0.000 0	0.000.0	0.0010	0.006 0	0.003 0	
9	9	윷	윤	₽	身	₽	웊	ş	Ş	웃	ş	읒	윷	웆	웆	웆	웆	0.0010	0,000,0	0.000.0	0.001 0	0.003 0	0.0010	0.004 0	0.002 0	0.0010	0.000.0	0.000 0	0.010 0	0.004 0	
5	Q.	2	웆	テ	윤	웆	웆	욧	읒	읒	웃	읒	웃	웆	읒	Ş	2	0.000.0	0.000.0	0,000,0	0.000.0	0.002 0	0.002 0	0.004 0	0.002 0	0.000 0	0.000.0	0.000.0	0.007 0	0.005 0	
7	Q.	₽	웊	웆	윷	윤	2	₽	₽	웆	웆	웊	웆	읖	욷	2	2		0.000	0.000.0	0.000.0	0.003 0	0.000.0	0.003 0	0.0010	0.000	0 000 0	0.000.0	0.007 0	0.004 0	
3	S.	₽	윷	ð	ş	⊋	웆	₽	웆	용	웆	웆	읒	윷	2	2	윷	0.000	0.000	0 000 0	0.000.0	0.004 0	0,001 0	0.000.0	0.001 0	0.000.0	0.000	0.000.0	0.004 0.	0,006 0	
2	2	욷	QN QN	2	웊	웆	웆	웊	Ş	S	Q.	Ş	Q	유	유	2	웊	0.000.0	0.000.0	0.000.0	0.001 0.	0.005 0.	0.001 0.	0.002 0.	0.000.0	0.000 0.	0.000 0.	0.000 0.	0.003 0.	0.007 0.	
-	æ	2	8	£	윷	₽	웆	웆	웆	Ş	Q	웆	9	Q.	8	9	S	000	0.002 0.	0.001 0.	0.0010.	0.0010.	0.000.0	0.003 0.	0.000.0	0.001 0.	0.000.0	0.000 0.	0.005 0.	0.008 0.	
Hour	<u>.</u>	2	M	7	'n	9	7	Ø	٥	. 10	=	12	13	14	5	16	17	18 0.	19 0.	20 0.	21 0.	22 0.	23 0.	24 0.	25 0.	26 0.	27 0.	28 0.	29 0.	30 0.	1

Maximum Hourly Average was 0.020 at Hour 16 on Day 22 with 2 occurences Maximum Daily Average was 0.0062 on Day 22 with 1 occurences

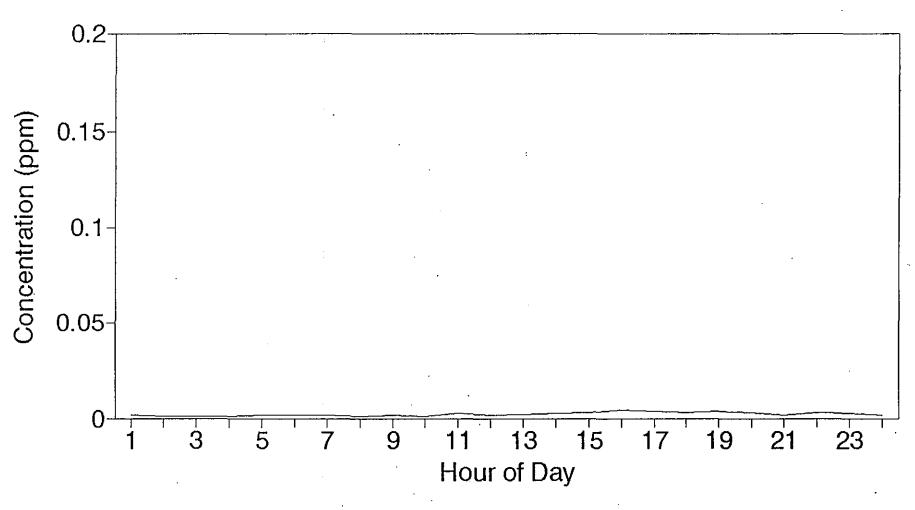
Operating Efficiency = 45.1 percent

Hourly NH3 - April, 1991



--- NH3

Diurnal NH3 - April, 1991



— NH3

MEPA - Kuwait
April 1991
Hourly Averages for 03 in ppm

Hour	1	Z	3	4	5	6	, 7	8	9	10	11	12	13	14	15	5 16	17	18	19	20	21	22	23	24	Daily
ay - 1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	{ Average *****
2	ND	_	*								ND					-		ND	ND	ND		ND	ND	ND	****
3	ND										ND							ND	ND	ND		ND	ND	_	****
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND.	ND	ND	ND	ND	ND	ИD	ND	****
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ŅD	ND	ND.	ND	ND	ND	ND	ND	ND	ND	****
6	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	****
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	: ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	****
8	ND	DM	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	****						
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	****						
11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	****						
12	ND	•	ND	ND	ND	ND	••-	ND			ND	ND	ND	ND	ND	ND.	ND	ND	****						
13	ND		,		ND	ND					ND				ND			ND	ND	ND	ND	ND	ND	ND	****
14	ND		ND		ND	ND					ND				ND		*	ND	ND	ND		ND	ND	ND	****
15	ND		ND	ND		ND					ND	•			ND			ND	ND	ND	ND	ND	ND	ИD	****
16 17	ND DN	ND DN		ND ND	ND ND	ND ND	ND	ND 0.024		ND	ND 0.017			ND 0.000	ND 0.030	-	ND 0.033	ND O OOR	ND 0.077	ND O OZZ	ND 0.074	ND C C C	ND 0.071	ND	***** 0.0235
				***	***												0.005							- •	0.0233
				0.018						*							0.015								0.0077
																	0.021								
				0.010			-		_								0.020					-			
22	0.000	0.001	0.002	0.005	0.006	0.008	0.012	0.013	0.018	0.022	0.022	0.022	0.023	0.020	0.018	0.016	0.015	0.010	0.004	0.011	0.015	0.018	0.011	0.012	0.0127
23	0.010	0.019	0.020	0.016	0.017	0.016	0.013	0.020	0.030	CAL	0.025	0.029	0.032	0.027	0.026	0.018	0.013	0.013	0.006	0.007	0.004	0.018	0.020	0.019	0.0182
24	0.016	0.012	0.005	0.003	0.009	0.005	0.011	0.015	0.013	0.014	0.023	0.020	0.026	Q.026	0.027	0.025	0.022	0.018	0.010	0.003	0.005	0.004	0.020	0.017	0.0145
25	0.008	0.013	0.019	0.020	0.019	0.018	0.018	0.015	0.010	0.000	0.000	0.002	0.006	0.005	0.008	0.011	0.008	0.008	0.003	0.001	0.001	0.002	0.000	0.012	0.0086
26	0.019	0.014	0.012	0.014	0.014	0.017	0.019	0.017	0.017	ND	0.019	0.021	0.022	0.024	0.022	0.023	0.028	0.025	0.022	0.013	0.002	0.021	0.024	0.024	0.0188
27	0.025	0.024	0.021	0.009	0.015	0.009	0.015	0.022	0.023	0.024	0.023	0.024	0.021	0.023	0.022	0.021	0.018	0.008	0.020	0.023	0.025	0.024	0.017	0.006	0.0193
28	0.007	0.006	0.008	0.006	0.019	0.017	0.020	0.022	0.025	CAL	0.025	0.026	0.028	ND	0.028	0.029	0.026	ND	0.020	0.017	0.021	0.019	0.005	0.011	0.0183
29	0.003	0.005	0.004	0.004	0.006	0.005	0.009	0.018	0.024	0.019	0.030	01035	0.031	0.027	0.024	0.022	0.021	0.011	0.015	0.010	0.004	0.000	0.001	0.001	0.0137
30	0.003	0.002	0.010	0.008	0.012	0.012	0.014	0.024	0.029	0.018	0.016	0.014	ND	0.036	0.026	0.014	0.005	0.001	0.002	0.001	0.015	0.005	0.009	0.014	0.0126
}					•		· · · · · · · · · · · · · · · · · · ·														!	ionthly	/ Avera	age =	0.0151
•																					•				

Maximum Hourly Average was 0.036 at Hour 14 on Day 30 with 1 occurences and there were no Hourly Violations

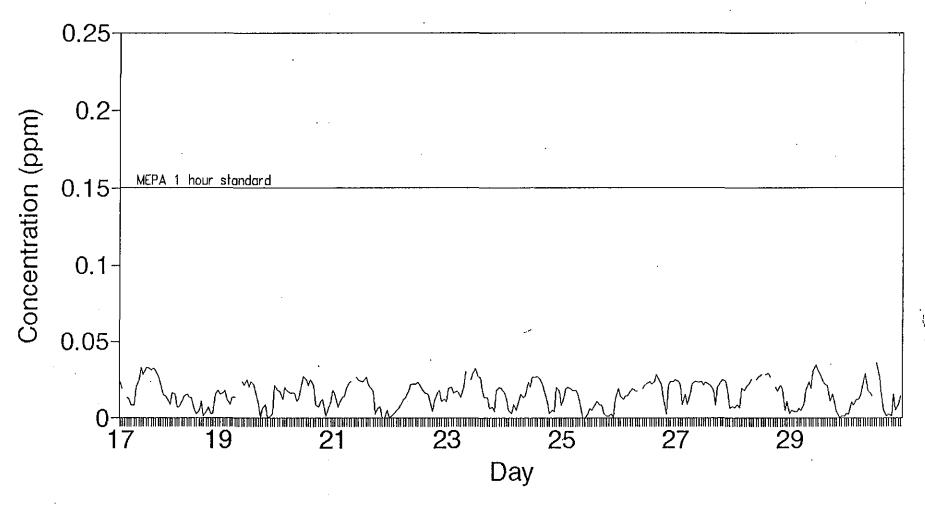
Maximum Daily Average was 0.0235 on Day 17 with 1 occurences and there were no Daily Violations

Operating Efficiency = 45.1 percent

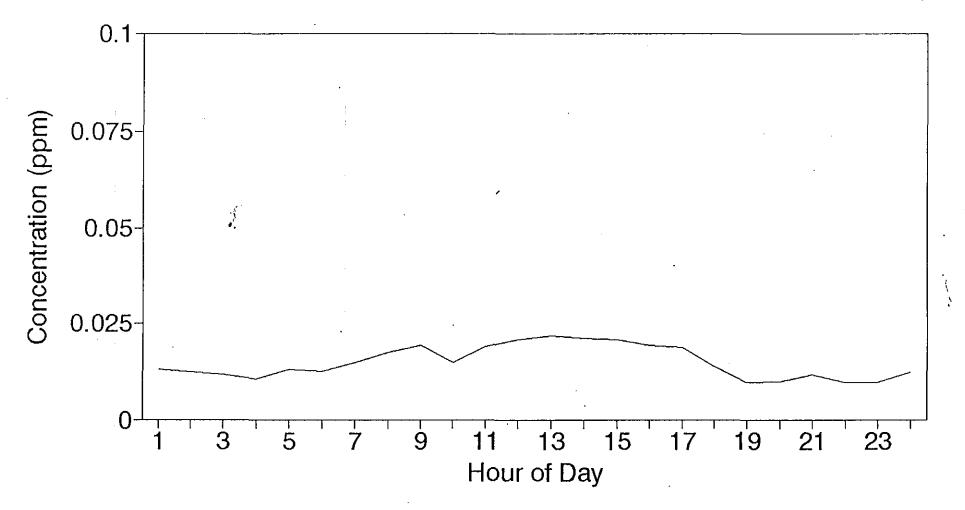
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

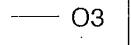
[CEM 1990]

Hourly 03 - April, 1991



Diurnal 03 - April, 1991





MEPA - Kuwait April 1991 Hourly Averages for NOx in ppm

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day																								-1-17	⊢ Average
1	ND) ND	ND	ND	ND	ND	ND.) ND	ND	ND	ND	ND	ND	ND	ND	ND	****								
2	ND	ИD	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ИĐ	ND	ND	ND	****									
3	ND		ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
4	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	NO	· ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	****
5	ND		ИD	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****								
6	ND	, ND	ND	NĐ	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	ND	****							
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****											
8	ИD	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	****										
9	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****										
10	ND	ND	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ND	ND	****											
11	ИD	ND	ND	ND	ND	ŅD	ND	ND	ND	ND	ND	ND	ND	ND	****										
12	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****										
13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****											
14	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	****											
15	ND	ИD	ND			•		ND				ND	ND	ND	ND	ND	ND	ND	****						
16	ND	-11-	ND			ND			ND	ND	ND	ND	ND	ND	ND	ND	****								
17	ND	ND	ND	ND	ND	ND		0.010			•					0.030				- •					0:0259
																0.090									0.0500
							0.034									0.050									0.0510
											-			-		0.015					- •				0.0408
							0.015									0.021									0.0432
							· ·									0.021									0.0459
							0.053				_					0,048		-							0.0394
												• • • • •		- • •		0.013		•							0.0421
									-					-		0.027				-					0.0425
				-			0.009				-					0.031				-			-		0.0271
											0.023	0.024	0.031	0.033	0.034	0.033	0.032	0.054	0.027	0.017	0.011	0.011	0.035	0.089	0.0311
							0.014						0.017			0.020				_				0.077	0.0411.
														-		0.039		-							0.0748
30	0.049	0.053	0.027	0.030	0.024	0.027	0.028	0.019	0.024	0.060	0.070	0.078	ND	0.075	0.040	0.073	0.084	0.135	0.104	0.091	0.047	0.084	0.066	0.034	0.0575
	·							_													≀	Monthly	/ Avera	age =	0.0442

Maximum Hourly Average was 0.140 at Hour 23 on Day 21 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0748 on Day 29 with 1 occurences and there were no Daily Violations

Operating Efficiency = 45.1 percent

MEPA - Kuwait April 1991 Frequency Distribution Hourly Averages for NOx in ppm

Concentration	# of Hours	Percentage
0.000 - 0.050	218	. 889
0.051 - 0.110	89	27.9
0.111 - 0.210	12	3.8
0.211+	- 0	0.0

MEPA - Kuwait April 1991 Hourly Averages for NO2 in ppm

Hour	1	2	: 3	4	5	6	, 7	8	9	10	11	12	13	14	15	16	5 17	18	19	20	21	22	23	24	Daily
Day -	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	, un	. UD	ND	NO.	NO.	ИD	. UO	NO.	Average
2	ND ND	ND ND							ND			ND	ND ND	ND	ND			ND ND	**-						****
3	ND	ND			ND			ND	ND				ND.	ND ND	ND			ND ND					•		****
4	ND	ND			ND			ND	ND			ND		ND	ND			ND	ND			ND			****
5	ND	ND			ND			ND	ND		ND	NO	ND	ND	ND			ND	ND	ND		ND	ND		****
6	ND	ND			ND			ND	· ND		ND	ND	ND	ND	ND			ND	ND	ND		ND	ND		****
7	ND	ND			ND			ND	ND	ND	מא	ND	ND	ND	ND			ND	ND	ND		ND	ND		****
8	ND	ND			ND			ND	ND		DN	ND	ND	ND	ND			ND	ND	ND		ND	ND		****
9	ND	ND		•	ND			ND	ND	ND	ND	ND	ND	ND	ND	***		ND	ND	_	-	ND	ND		****
10	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND	ND		****
11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		****
12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
13	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	****
15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	MD	ND	ND	ND	ND	ND	ND	ND	****
16	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ŅD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
17	ND	ND	ND	ND	ND	ND	ND	0.008	0.010	CAL	0.020	0.023	0.031	0.032	0.025	0.026	0.022	0.030	0.023	0.021	0.021	0.022	0.017	0.019	0.0219
18	0.028	0.037	0.023	0.030	0.035	0.019	0.017	0.031	0.027	0.021	0.016	0.022	0.032	0.036	0.050	0.056	0.048	0.035	0.049	0.046	0.039	0.053	0.047	0.021	0.0341
19	0.021	0.019	0.022	0.018	0.027	0.032	0.023	0.033	CAL	CAL	0.017	0.019	0.019	0.036	0.029	0.030	0.042	0.043	0.055	0.052	0.046	0.057	0.056	0.055	0.0341
20	0.018	0.026	0.027	0.029	0.013	0.018	0.025	.0.028	0.028	0.042	0.037	0.030	0.019	0.023	0.029	0.013	0.018	0.041	0.046	0.043	0.043	0.062	0.052	0.039	0.0312
21	0.024	0.027	0.038	0.032	0.024	0.022	0.012	0.011	0.019	CAL	0.015	0.012	0.010	0.010	0.008	0.017	0.021	0.023	0.052	0.049	0.041	0.060	0.058	0.048	0.0275
. 22	0.058	0.048	0.043	0.032	0.034	0.028	0.018	0.031	0.020	0.014	0.021	0.021	0.019	0.020	0.021	0.021	0.019	0.029	0.043	0.029	0.021	0.025	0.038	0.028	0.0284
23	0.030	0.012	0.011	0.022	0.025	0.025	0.032	0.027	0.019	CAL	0.029	0.019	0.014	0.022	0.025	0.039	0.041	0.042	0.050	0.044	0.051	0.022	0.019	0.018	0.0277
. 24	0.023	0.029	0.046	0.053	0.030	0.038	0.030	0.018	0.031	0.039	0.030	0.038	0.029	0.029	0.013	0.010	0.014	0.024	0.036	0.050	0.046	0.048	0.016	0.020	0.0308
25	0.037	0.012	0.005	0.004	0.003	0.006	0.014	0.022	0.026	0.037	0.039	0.034	0.023	0.019	0.022	0.020	0.026	0.030	0.043	0.048	0.052	0.052	0.049	0.024	0.0270
26	0.013	0.025	0.031	0.023	0.010	0.006	0.007	0.009	0.014	ND	0.024	0.022	0.021	0.019	0.020	0.020	0.014	0.023	0.027	0.040	0.054	0.020	0.013	0.009	0.0202
27	0.007	0.008	0.014	0.037	0.029	0.037	0.029	0.017	0.016	0.020	0.017	0.019	0.025	0.024	0.028	0.026	0.025	0.040	0.022	0.016	0.009	0.009	0.019	0.038	0.0221
28	0.034	0.037	0.033	0.039	0.014	0.015	0.008	0.010	0.014	CAL	0.018	0.016	0.012	ND	0.016	0.018	0.015	ND	0.023	0.027	0.017	0.023	0.051	0.044	0.0230
29	0.060	0.056	0.060	0.059	0.056	0.056	0.050	0.034	0.026	0.028	0.025	0.019	0.022	0:025	0.025	0.027	0.031	0.047	0.038	0.043	0.055	0.061	0.060	0.046	0.0420
30	0.041	0.041	0.025	0.027	0.023	0.024	0.023	0.015	0.020	0.041	0.043	0.051	ЙD	0.040	0.032	0.052	0.067	0.082	0.080	0.068	0.042	0.058	0.047	0.032	0.0423
-																						Monthl	/ Aver	age =	0.0297

Maximum Hourly Average was 0.082 at Hour 18 on Day 30 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0423 on Day 30 with 1 occurences and there were no Daily Violations

Operating Efficiency = 45.1 percent

MEPA - Kuwait April 1991 Frequency Distribution Hourly Averages for NO2 in ppm

Concentration	# of Hours	Percentage
0.000 - 0.050	284	89.0
0.051 - 0.110	35	11.0
0.111 - 0.210	0	0.0
0.211+	0	0.0

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MEPA - Kuwait April 1991 Hourly Averages for NO in ppm

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	. 14	15	16	17	18	19	20	21	22	23	24	Daily —∣ Average
Day -	ND.	ND	ND	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	#####						
2	ND ND	טא מא	טא סא		ND ND	ИD		ND	ND ND	ND ND	ND		ND	ND	ND			ND	ND	ND	. ND	ND	ND		****
3	ND.	ND ND	ND ND		ND	ND		ND	ND	ND	ND		ND	ND	ND			ND	ND	ND	ND	ND	ND		****
4	ND	ND	ND		ND	ND		ND	ND	ND	ND		ND	ND	ND.			ND	ND	ND	ИD	אם	ND		****
5	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND		ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	****
6	ND	ND	ND		ND	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	·ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
9	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
10	ND	LND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	****
13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		****
15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		****
16	ND	ИD	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	*****
17	ND	ND	ND	ND	ND	ND		0.002																0.002	0.0041
				0.029				_																0.040	0.0160 0.0174
				0.010																					0.0174
				0.016								•												0.022	0.0146
																								0.004	
				0.021													0.012								0.0117
				0.050																					0.0113
				0.001																					0.0153
				0.002																				0.002	0.0068
																								0.051	0.0130
				0.046									0.005											0.033	
															0.013	0.012	0.014	0.035	0.024	0.025	0.026	0.048	0.028	0.022	0.0324
				0.003																					0.0152
<u> </u>								•					•*				••					Monthl			0.0149

Maximum Hourly Average was 0.082 at Hour 23 on Day 21 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0324 on Day 29 with 1 occurences and there were no Daily Violations

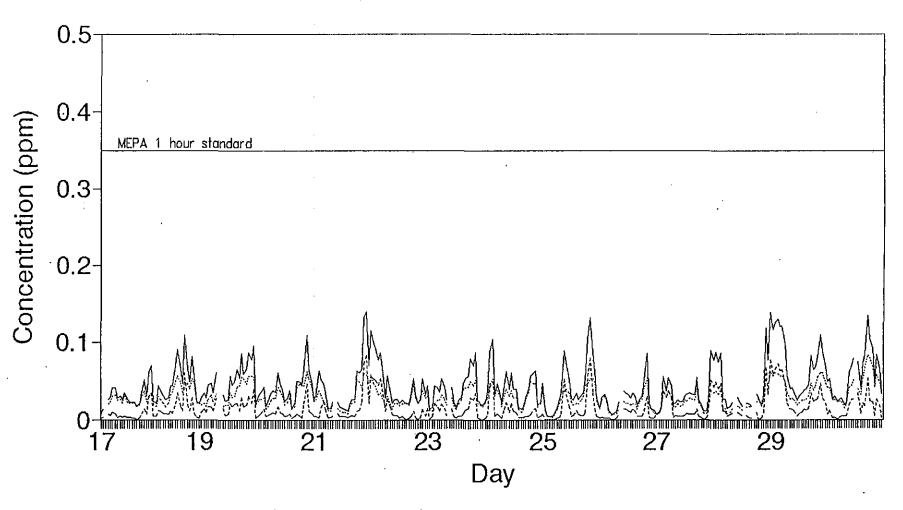
Operating Efficiency = 45.1 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = inc

April 1991 Frequency Distribution Hourly Averages for NO in ppm MEPA - Kuwait

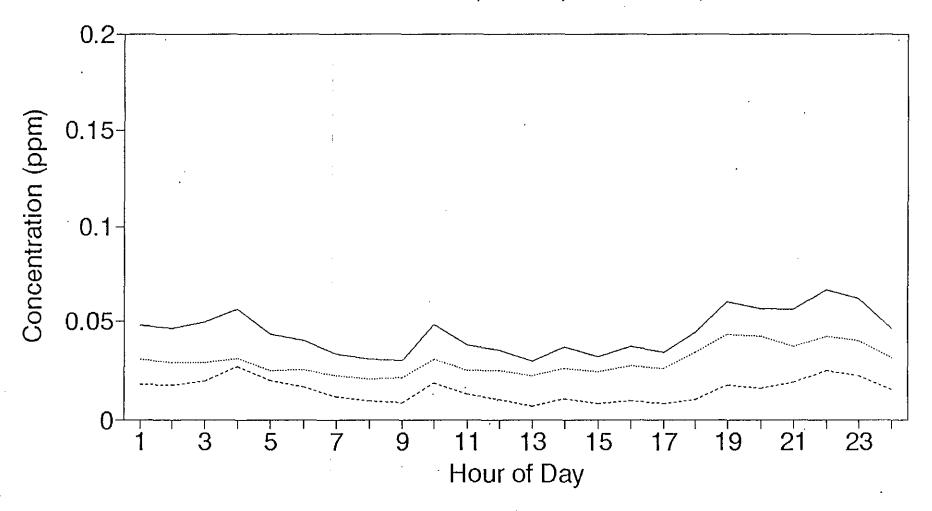
20 0 0	Concentration	# of Hours	Percentage
	0.051 - 0.110	50 Z	6.3
0	0.111 - 0.210	. 0	0.0
	0.211+	0	0.0

Hourly N0x/N02/N0 - April, 1991



— NOx — NO2 — NO

Diurnal N0x/N02/N0 - April, 1991



____ NOx ____ NO2 ____ NO

MEPA - Kuwait April 1991 Hourly Averages for H2S in ppm

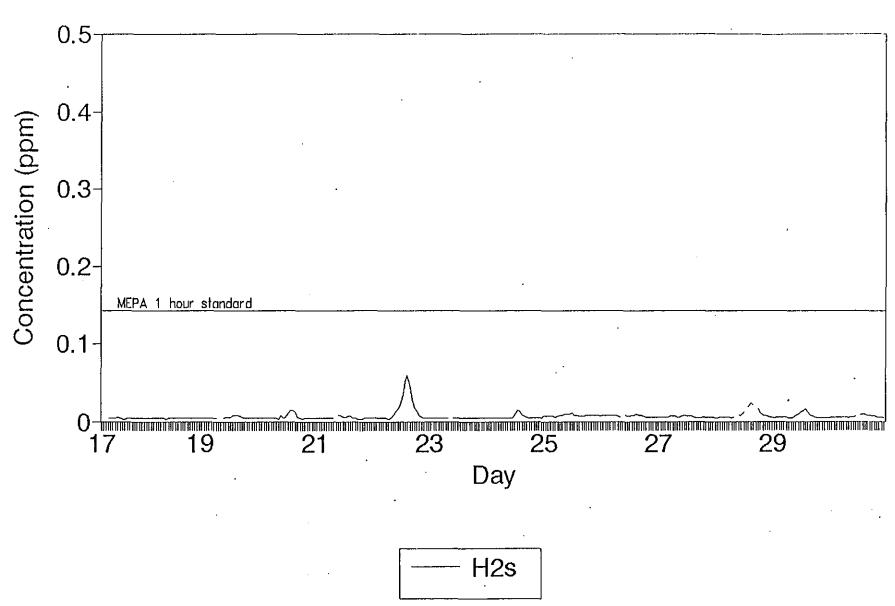
Kour	1	2	. 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
ay																							···	•	- ⊢ Average
1	ND	ND	ND	ND	ND	ND	ND	ND	ND	· ND	ND	ŃD	ND	ND	. ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	****
2	ND	ND	ND	ND	ND	ND	ND	ND	NĐ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
3	ND	NO	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND.	ND	ND	ND	ND	ND	ND	ND	****
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ИD	ND	ND	ND	****
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	. ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	****
8	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	DIA	ND		ND			ND	ND	ND	ND	ND	ND	ND	****
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND			ND	ND	ND	ND	ND	ND	ND	****
10	ND	ND	ND	ND	ИD	ND	ND		ND	ND	ND	ND			ND			ND	ND	ND	ND	ND	ND	ND	****
11	ND	ND	ND	ND	ND	ND		ND.	ND	ND	ND	ND			ND			ND	ND	ND	ND	ND	ND	ND	****
12	ND	ND	ND	ND	ИD	ND			ND	ND	ND	ND			ND			ND	ND	ND	ND	ND	ND	ND	****
13	ИD	ND		ND	ή. ViD	ND			ND	ND	ND	ND			ND			ND	ND	ND	ND	ND	ND	ND	****
14	ND	ND		ND	Ą'n	ND		ND	ND.		ND	ND		ND	ND			ND	ND	ND	ND	ND	ND	ND	****
15	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND			ND	ND	ND	ND	ND	ND	ND	****
16	ND	ND		ND	ND	ND	ND	•••	OM	ND	ND	ND			ND			ND	ND 0.004	ND 0.00E	ND 0.004	ND O OO	ND 0.007	ND 0.00/	0.0037
17	ND	ND		ND	· ND	ND C CCE		0.000									0.003								0.0037
			0.005														0.005								0.0047
			0.004						CAL																0.0054
			0.004														0.005								0.0050
			0.004																						0.0050
			0.004														0.004								0.0045
			0.005																						0.0057
			0.007																						0.0081
			0.007																					0.006	
			0.009										,												0.0063
			0.006										0.007				0.022							0.006	0.0096
			0.006								• •														0.0076
			0.006														0.009								0.0074
JU 1	0.003	0.000	0.000	0.000	0.000	0.000	0.000	V.VVD	0.003	0.000		0.007		0.010	0.010	0.010	0.007	0.000	0.007	0.007		o.000 Monthl			0.0069
_																						HOHELIE	AVE	-9¢ -	0.0007

Maximum Hourly Average was 0.059 at Hour 16 on Day 22 with 1 occurences and there were no Hourly Violations

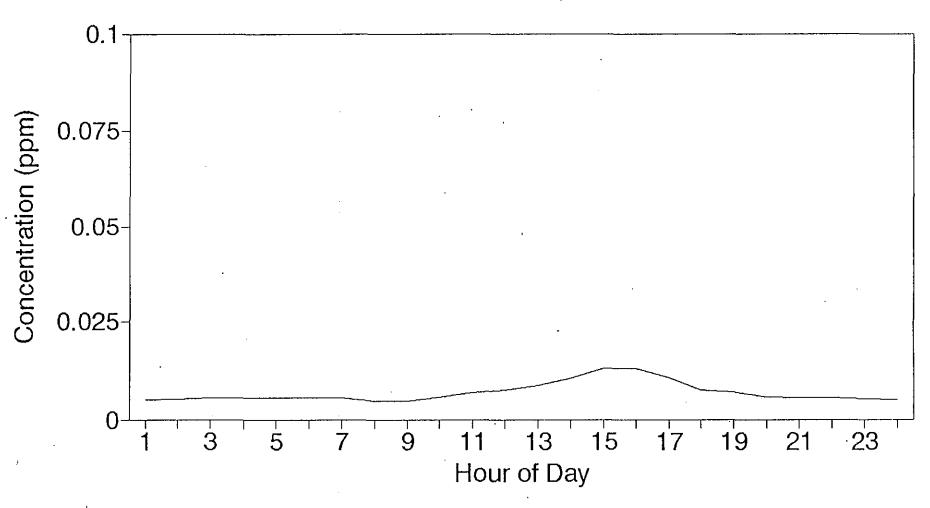
Maximum Daily Average was 0.0152 on Day 22 with 1 occurences and there were no Daily Violations

Operating Efficiency = 45.1 percent

Hourly H2S - April, 1991



Diurnal H2S - April, 1991



-- H2s

MEPA - Kuwait
April 1991
Hourly Averages for SO2 in ppm

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily → Average
Day - 1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ИD	МD	ND D	ND	ND	****							
2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
3	ND	ND	ND	ND	ND	ИD	ND	ND	ИD	ND	ND	ND	DИ	ND	ND	ND	ND	****							
4	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	****													
5	ND	· ND	ND.	ND	ND	ND	ND	ND	· ND	ND	ND	ND	ND	ND	****										
6	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****						
7	ND	- ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	****
8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****													
11	ИĎ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****												
12	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****												
13	ND	ND	ИD	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	МD	****						
14	ND	, ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****										
15	ND	ND	ND	ND	ИĎ	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	****
16	ND	ND	ND	ND	ND	ND		ND				ND	ND	ND		ND	ND		****						
17	ND	ND	ND	ND	ND	ND		0.008									0.006								0.0122
		- +	- +					• • •	- •				• .				0.014								0.0274
								0.019									0.020								0.0171
				•							-						0.007								0.0265
						•		0.004									0.019								0.0107
																	0.022								0.0190
								0.010						• • • •	- • •		0.022								0.0122
																•	0.001								0.0125
-																								0.010	0.0544
	-	-					-	0.009																0.030	
																	0.016								0.0422
						-		0.011					0.003				0.006								0.0089
																	0.012								0.0142
30	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.011	0.013	0.016	ND	0.025	0.010	0.013	0.003	0.012	0.013	0.014				0.002	
							-															Monthl	y Aver	age =	0.0227

Maximum Hourly Average was 0.326 at Hour 3 on Day 26 with 1 occurences and the Number of Hourly Violations were 1

Maximum Daily Average was 0.0544 on Day 25 with 1 occurences and there were no Daily Violations

Operating Efficiency = 45.1 percent

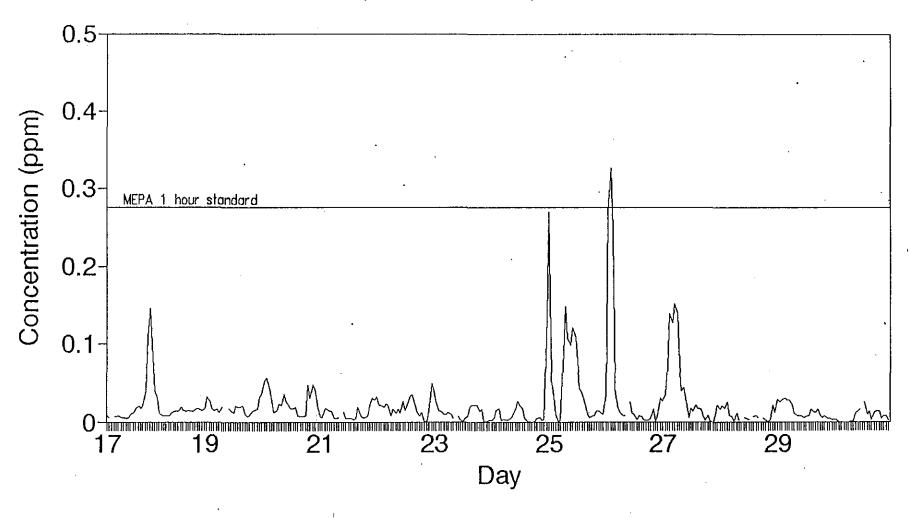
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

[CEM 1990]

MEPA - Kuwait April 1991 Frequency Distribution Hourly Averages for SO2 in ppm

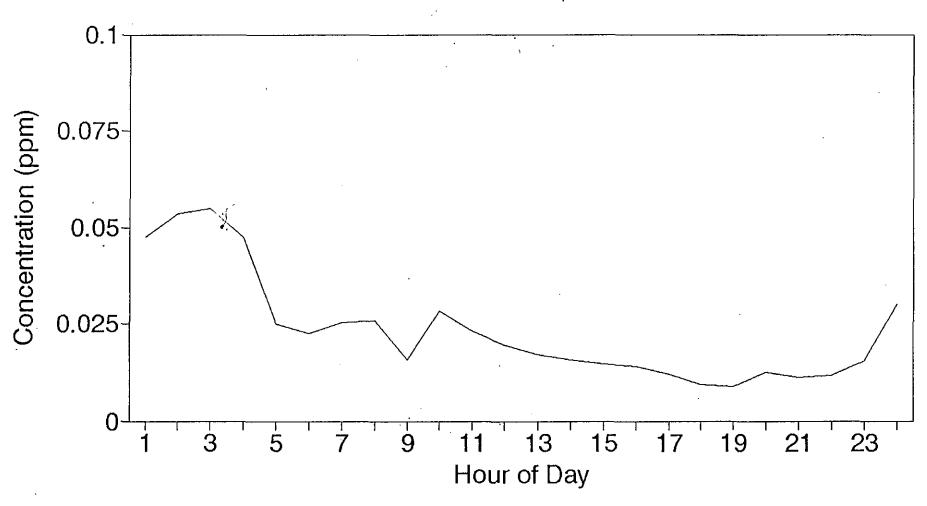
Concentration	# of Hours	Percentage
0.000 - 0.020	230	72.1
0.021 - 0.060	68	21.3
0.061 - 0.110	9	2.8
0.111 - 0.170	8	2.5
0.171 - 0.340	4	1.3
0.341+	0 ;	0.0

Hourly SO2 - April, 1991



--- SO2

Diurnal SO2 - April, 1991



- SO2

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MEPA - Kuwait

May 1991

Hourly Averages for Direction(degrees)

Hour Day -	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17.	18	19	20	21	22	23	24	Daily → Average
1	282	277	284	287	286	278	272	279	294	312	340	333	338	349	74	94	126	0	0	354	11	329	278	284	316.70
. 2	240	241	241	238	253	255	254	269	283	306	307	328	355	301	298	317	329	330	328	322	316	310	311	315	294.47
3	318	325	328	329	329	326	329	331	332	0	334	332	330	331	338	335	333	333	343	334	328	315	304	320	329.86
4	325	322	324	329	330	318	308	313	312	314	312	306	307	308	311	312	323	318	321	328	307	287	280	271	312.12
5	284	295	273	268	270	279	284	282	289	302	0	309	311	316	310	311	314	313	313	311	298	273	290	292	297.43
6	283	264	258	264	268	269	275	277	292	304	310	308	314	309	305	308	0	0	0	0	0	0	0	0	311.46
7	0	0	0	0	0	0	0	0	0	U	0	0	0	0	0	. 0	0	0	0	0	0	0	0	0	0.00
8	0	0	0	0	0	0	0	' 0	0	0	0	0	299	218	172	99	130	147	162	172	213	229	243	251	340.27
9	242	268	276	276	272	288	304	322:	358	9	0	22	56	73	87	115	125	146	149	189	203	208	230	244	264 97
10	246	249	270	306	315	312	315	308	308	0	313	328	329	326	321	323	319	324	325	332	330	330	317	284	313.15
11	265	277	285	258	276	298	304	309	312	315	. 315	311	315	315	314	317	326	328	332	333	330	326	325	308	308.55
12	278	281	259	265	271	277	286	316	341	0	314	315	306	308	309	316	335	332	349	106	50	45	91	114	318.94
13	227	266	264	260	256	259	269	269	282	321	347	349	330	325	290	198	107	85	230	245	254	- 267	276	248	272.39
14	265	261	262	262	249	240	248	252	261	262	294	319	80	72	107	123	124	147	153	156	168	179	206	237	217.51
15	240	248	239	247	250	241	241	255	253	0	358	43	47	47	66	75	90	101	119	133	151	160	124	108	145.60
16	109	114	124	144	184	205	196	330	140	. 337	339	345	345	340	343	346	348	339	336	351	346	333	334	327	345.96
17	328	330	335	333	334	332	333	330	0	337	339	345	345	349	343	346	348	339	336	351	346	335	334	327	338.94
18	328	330	335	333	334	332	333	328	339	338	335	337	338	333	336	338	332	334	335	336	333	331	329	326	333.46
19	324	321	320	306	295	294	312	324	330	329	0	333	330	333	336	340	342	344	344	341	344	329	324	315	328.00
20	304	305	310	301	272	266	270	285	305	319	310	311	317	334	335	336	341	12	8	8	3	353	328	292	319.23
21	282	278	260	253	245	239	245	263	274	752	39	111	73	101	127	137	140	144	151	129	199	223	286	297	216.37
22	288	284	291	306	330	332	334	339	347	352	352	359	6	8	11	11	12	11	355	345	11 -	770	357	344	345.85
23 24	349 286	8 279	7	352	338	316	355	345	10	8	359	774	335	343	339	324	320	321	324	333	320	338	341	306	341.30
25	200 321	323	280 318	279 310	276 312	279 318	318 326	321 325	323 314	355 0	347 320	336 311	331 317	332 327	333 324	337 326	337 334	342 333	353 333	345 344	335 337	326 318	322 304	325 309	321.34 323.41
26	313	323	305	289	272	274	282	301	311	317	322	337	348	330	348	63	103	333 104	124	139	337 167	196	226	252	302.09
27	251	242	245	242	234	233	225	225	262	0	319	312	319	321	340 N	03	321	314	317	319	311	312	315	311	294.20
28	319	320	317	323	321	320	325	326	330	335	336	332	326	326	327	331	335	334	335	333	333	332	327	328	327.96
29	329	328	329	332	329	329	329	329	330	0	328	331	325	329	332	339	343	344	340	339	344	329	327	328	333.37
30	329	329	330	329	330	328	326	315	319	334	337	332	333	333	341	347	352	359	333	352	346	336	328	328	334.38
31	327	327	339	357	342	337	344	334	336	343	350	350	355 355	333	ا بەر 1	356	351	345	332	325	327	324	326	328	340.65
J.		JLI		100	J4C	100	J44	JJ4	0.00			330			'		ا دد	347	332	323			y Aver		321
						.,																nonent	7 AVEL	uye -	261

Operating Efficiency for Wind Direction = 100.0 percent Last Instrument Calibration Date - unknown [CEM] ** = missing or no data

MEPA - Kuwait

May 1991

Hourly Averages for Wind Speed(meters/sec)

lour y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	D.
, L	2.7	2.4	2.7	2.4	3.0	2.5	2.4	2.6	2.6	2.2	2.4	2.5	1.3	1.4	0.9	1.1	1.5	0.0	0.0	0.0	0.7	0.9	0.8	0.0	1
2	0.4	0.4	0.9	0.6	1.0	2.2	3.0	3.0	3.6	4.2	1.3	2.3	2.7	1.9	2.2	3.3	4.8	6.3	4.9	4.5	4.3	5.7	6.2	5.6	3
3	5.5	4.9	5.6	6.3	6.2	6.1	6.5	6.7	7.1	0.0	5.0	6.8	6.8	7.1	6.2	6.3	6.2	4.8	3.8	3.5	2.9	2.5	4.0	3.5	5
4	3.8	3.1	3.4	4.5	4.6	3.7	4.8	4.7	6.0	5.9	7.0	7.6	7.1	7.2	7.2	6.6	5.5	4.5	3.3	2.8	2.2	2.3	2.5	2.3	4
5	3.1	3.4	2.9	2.3	2.2	2.9	3.8	4.0	4.6	4.9	0.0	6.5	6.4	5.7	5.8	6.2	5.8	4.7	3.1	2.5	2.5	2.1	2.3	1.8	3
6	2.4	2.7	2.9	3.5	3.7	3.7	4.4	3.9	4.6	5.9	6.5	6.2	5.3	5.1	5.7	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0:0	0.0	0.0	0.0	1.5	1.0	2.4	4.2	4.1	4.3	3.2	3.8	3.0	3.3	3.2	3.0	1
9	3.8	3.7	2.4	1.8	1.9	2.1	1.9	1.6	1.8	2.4	1.8	2.7	3.3	4.1	3.8	3.3	3.7	3.3	3.0	4.1	4.0	3.9	3.9	5.1	3
10	4.7	4.9	6.6	6.1	4.7	6.0	5.0	7.3	.7.9	0.0	6.4	6.5	6.5	6.9	6.7	6.8	5.7	4.7	4.2	3.5	3.9	3.4	2.6	2.4	5
11	2.3	2.6	3.3	2.2	2.8	3.9	4.8	4.6	6.2	6.1	7.6	7.9	7.7	8.1	7.4	7.2	6.5	6.4	5.9	4.5	4.0	3.5	2.7	3.1	5
12	2.1	2,5	2.9	2.8	2.6	2.5	3.6	4.2	3.8	0.0	4.3	5.3	6.0	6.4	5.8	5.3	4.6	4.4	2.5	1.1	1.3	1.7	0.8	0.3	3
13	1.3	2.3	3.1	3.2	3.2	3.4	3.3	3.4	2.9	2.0	1.9	2.5	2.3	2.6	3.0	3.5	2.9	2.7	2.3	2.4	2.0	1.9	1.7	1.6	2
14	2.4	3.2	3.3	3.1	3.3	3.6	3.7	3.5	4.6	3.4	2.9	2.7	3.8	4.2	3.9	4.4	5.5	4.7	3.6	3.1	3.6	2.3	0.2	2.6	3
15	2.4	2.4	3.4	3.2	3.0	2.5	3.5	3.3	2.1	0.0	2.1	3.6	5.0	5.6	5.9	5.3	4.7	4.4	3.7	2.9	2.4	1.8	1.4	1.8	3
16	1.7	0.5	0.4	0.6	1.3	2.5	2.1	7.0	2.7	7.7	7.4	6.7	6.9	7.2	6.8	6.6	6.0	5.6	4.7	4.2	3.8	4.2	3.7	3.7	4
17	3.6	3.8	4.6	3.7	3.7	4.1	4.6	7.0	0.0	7.7	7.4	6.7	6.9	7.2	6.8	6.6	6.0	5.6	4.7	4.2	3.8	4.2	3.7	3.7	5
18	3.6	3.8	4.6	3.7	3.7	4.1	4.6	5.0	5.7	8.3	7.4	7.8	8.3	8.1	7.9	7.7	6.8	6.1	5.2	5.1	4.7	4.7	4.2	4.2	5
19	4.3	3.8	3.7	3.6	3.3	4.0	5.5	6.0	6.5	7.1	0.0	8.6	8.6	8.8	8.1	8.0	7.9	7.0	5.2	4.2	3.4	3.7	3.3	3.0	5
20	3.9	4.5	4.3	4.0	3.2	3.8	3.8	5.0	5.6	6.0	6.3	6.2	6.3	5.9	6.1	6.1	5.6	5.0	4.8	3.3	2.8	1.9	1.2	1.8	4
21	1.9	2.3	3.3	3.8	4.1	4.2	4.2	4.1	4.4	0.0	2.8	4.4	4.6	5.6	6.1	6.2	5.7	4.9	4.1	1.6	1.0	2.0	2.2	2.0	' 3
22	1.6	0.6	1.4	2.6	3.1	3.8	3.6	3.9	4.4	5.1	5.1	5.4	6.5	6.5	6.6	7.0	6.3	5.9	3.9	4.5	4.3	3.3	3.0	3.3	4
23	2.7	2.5	2.1	1.6	1.7	2.1	3, 5	4.1	4.9	4.8	4.9	0.0	4.8	5.2	5.4	5.8	5.5	5.7	4.7	3.9	3.1	3.2	1.8	2.0	3
24	2.8	2.9	3.2	2.7	2.4	2.6	2.4	2.8	3.0	2.3	4.2	5.8	6.9	7.2	7.8	7.2	7.0	5.8	4.9	4.3	4.2	3.6	3.6	3.7	4
25	3.7	3.6	3.5	4.0	4.3	4.3	5.5	5.2	6.6	0.0	7.9	8.3	8.6	7.5	7.2	6.5	5.9	5,2	3.7	3.0	3.2	2.5	3.2	3.1	4
26	2.4	2.2	2.5	2.5	2.4	3.2	3.6	4.1	3.9	4.4	4.6	4.6	4.1	4.5	4.3	4.5	3.5	2.0	2.1	2.0	1.4	2.1	2.1	3.2	3
27	3.4	4.2	3.5	3.8	3.6	3.8	3.9	4.2	4.4	.0.0	5.6	5.6	6.0	6.4	0.0	.0.0	7.0	6.5	5.4	4.9	6.1	6.3	5.7	6.0	4
28	5.1	4.6	5.1	4.5	4.3	4.6	4.9	5.0	5.8	6.8	7.9	8.1	7.8	8.1	8.0	7.1	7.4	6.3	5.7	4.7	4.2	4.6	5.1	5.5	5
29	5.7	5.8	5.5	5.0	4.6	5.0	5.9	6.8	6.7	0.0	7.9	7.9	8.1	7.3	7.7	6.8	6.5	5.8	5.2	4.8	3.2	2.6	3.2	4.7	5
30	5.0	5.1	5.6	4.7	4.3	4.3	3.9	4.3	4.2	5.0	6.7	7.2	6.9	7.3	7.4	7.1	5.9	5.1	5.2	5.4	4.4	4.1	3.8	4.1	5
31	4.7	5.0	5.0	4.9	4.1	4.0	3.4	5.7	5.8	5.0	5.4	4.9	5.2	5.6	5.6	5.0	4.3	3.5	3.1	3.7	3.8	3.1	3.6	3.7	4
																						Monthl	y Aver	age =	3

Maximum Hourly Average Wind Speed was 8.8 meters/sec at Hour 14 on Day 19

Maximum Daily Average Wind Speed was 5.88 meters/sec on Day 28

Operating Efficiency for Wind Speed = 100.0 percent ** = missing or no data Last Instrument Calibration Date - unknown

[CEM]

MEPA - Kuwait

May 1991

Hourly Averages for Wind Speed(meters/sec) and Direction

Kour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
ау 🖵																				······································					Average
1	3WNW	2W	3MMM	SMMM	3WNW	2W	SM	3W	3NNM	2NW	2NNW	ZNNW	1NNW	1N	1ENE	1E	2SE	ON	ON	ON	1N	1nnw	1W	OWNW	2NW
2	OWSW	OWSW	1WSW	1WSW	1WSW	2WSW	3WSW	3W	4WNW	4NW	1พพ	2000	3N	2WNW	2WNW	3NW	5NNW	6NNW	5NNW	4NW	4NW	6NW	6NW	6NW	3WNW
3	6NW	5NW	6nnw	6NNW	6NNW	6NW	биии	7NNW	7nnw	ON	5NNW	7NNV	7NNW	7nnw	6NNW	6NNW	6NNW	5NNV	4884	4NNW	3NNW	2NW	4NW	4NW	5NNW
4	4NW	3NW	3พพ	4nnW	5NNW	4NW	5พพ	5NW	6NW	6NW	7NV	8NW	7N₩	7NW	7NW	7NW	6NW	4NW	3NW	3NNW	SHM	SMNM	2W	2W	5NW
5	3พพพ	3WNW	3W	2W	2W	3₩	4WNW	4WNW	5WNW	5WNW	ON	6NW	6NW	6NW	6NW	6NW	6NW	5NW	3NW	2NW	2WNW	2W	2WNW	2WNW	4WNW
6	ZWNW	3W	3WSW	4W	4W	4 U	4W	4W .	5WNW	6NW	6NW	6NW	5NW	5NW	6NW	4NW	ON	ON	ON	ON	ON	ON	ON	ON	3NW
7	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
8	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	2WNW	1sw	25	4E	4SE	4SSE	3SSE	45	3SSW	35W	3WSW	3WSW	2000
9	4WSW	4W	2W	2W	2₩	SHNM	SNM	2NW	2N	2N	2N	3NNE	3NE	4ENE	4E	3ESE	4SE	3SE	3SSE	4\$	4SSW	4SSW	4\$W	5WSW	3W
10	5WSW	5WSW	7W	6NM	5พพ	6NW	5พ₩	7NW	8NW	ON	6NW	6NNW	6NNW	7NW	7NW	7NW	6NW	5NW	4NW	4NNW	4NNW	3NNW	3NW	2WW	5หพ
11	2W	3W	3WWW	2WSW	3W	4WNW	5NW	5NW	6NW	6NW	8NW	8NW	8NW	8NW	7NW	7NW	6NW	6NNW	6NNW	4NNW	4NNW	4NW	3NW	3NW	5NW
12	2W	2₩	3W	3W	3W	2W	4WNW	4NW	4NNW	ON	4NW	5NW	6NW	6NW	6NW	5NW	5พพพ	4NNW	2พ	1ESE	1NE	2NE	1E	OESE	3NW
13	1sw	2W	3W	3W	3 u sw	3W	3₩	3W	3WNW	2NW	2NNW	2N	2NNW	3NW	3WNW	4SSW	3ESE	3E	2SW	SMSM	2WSW	2W -	SM	2WSW	3W
14	2W	3W	3W	3W	3 W \$W	4WSW	4WSW	4WSW	5W	3W	3WNW	3NW	4E	4ENE	4ESE	4ESE	6SE	5sse	4SSE	3\$\$E	4SSE	2\$	OSSW	3WSW	3SW
15	2WSW	2WSW	3WSW	3W\$W	3W\$W	2WSW	4WSW	3WSW	2WSW	ON	2N	4NE	5NE	6NE	6ENE	5ENE	5E	4E	4ESE	3SE	2SSE	2SSE	1SE	SESE	3SE
16	2ESE	0ESE	0SE	1SE	18	2SSW	2ssw	7nnw	3SE	8หหพ	7NNW	7NNW	7NNW	7พพพ	7nnw	7nnu	МИИ	6NNW	5NNW	4N	4NNW	4NNW	4NNW	4NNW	4NNW
17	4ทท₩	4NNW	SNNW	4NNW	4NNW	4NNW	5NNW	7nnw	ON	WNN8	7NNW	7nnu	7NNW	7N	7nnw	7nnu	6NNW	6NNW	5NNW	4N	4NNW	4NNW	4NNW	4NNW	5NNW
18	4NNW	4nnw	5NNW	4NNW	4NNW	4NNW	5NNW	5NNW	6NNW	8NNW	7NNW	WHH8	8NNW	8NNW	BNNW	BNNW	7NNW	6NNW	5NNW	5NNW	5NNW	5NNW	4NNW	4NW	6NNW
19	4NW	4 NW	4NW	4NW	3WWW	4WNW	6NW	6NW	6NNM	7nnw	ON	9NNW	9NNW	9NNW	8NNW	8NNW	WNN8	7NNW	5NNW	4NNW	3NNW	4NNW	3NW	3NW	5มหพ
20	4NW	4 N W	4NW	4WNW	3W	4W	4W	5พหพ	6NW	6NW	6NW	6NW	6NW	6nnw	6NNW	6NNW	6NNW	5NNE	5N	3N	3N	2N	1NNW	2WWW	4NW
21	2WNW	2W	3₩	4WSW	4WSW	4WSW	4W\$W	4W	4W	ON	3NE	4ESE	5ENE	6E	6SE	6SE	6SE	5SE	4SSE	2SE	1SSW	2sw	2WNW	ZWNW	4SW
22	SMNM	1WNW	1WNW	3NW	3ททพ	4NNW	4NNW	4NNW	4NNW	5N	5N	5N	6N	6N	7N	7N	GNNE	6N	4N	4NHW	4N	3N	3N	3NNW	4NNW
23	3ห	2N	2N	2N	2ททพ	2NW	4N	4NNW	5N	5N	5N	ON	5NNW	5พพพ	5NNW	6NW	6NW	6NW	5NW	4NNW	3NW	3NNW	ZNNW	2NW	4NNW
24	3WNW	3W	3W	3W	24	3W	2NW	3NW	3NW	2N	4NNW	6NNW	7NNV	7nnw	8NNW	7NNW	7nnw	6NNW	5N	4nnu	4NNW	4N₩	4NW	4NW	4NW
25	4NW	4NW	4NW	4NW	4NW	4NW	6nW	5NW	7NW	ON	8NW	8NW	9NW	WNN8	7NW	6NW	6NNW	5พพพ	4NNW	3NNV	3NNW	2NW	3NW	3NW	5NW
26	2NW	2NW	2NW	2WNW	2W	3W	4WNW	4WNW	4NW	4NW	5 พ พ	5พพพ	4NNV	4NNW	4NNW	4ENE	4ESE	ZESE	2SE	2SE	1SSE	2ssw	2sw	3WSW	3WWM
27	3WSW	4WSW	4WSW	4WSW	4SW	4SW	4 SW	4sw	4W	ON	6NW	6NW	6NW	6NW	ON	ON	7NW	6NW	5NW	5NW	6NW	6NW	6NW	6ии	4UNW
28	5พพ	5NW	5NW	4NW	4NW	5NW	5NW	5NW	6NNW	7NNW	WAN8	8NNW	8NW	8NW	NNN8	7nnw	7nnw	6NNW	6NNW	5หหพ	4NNW	5NNW	5NNW	. GNNM	6NNW
29	6NNW	6NNW	6NNW	5NNW	5NNW	5NNW	6NNW	7NNW	7NNW	ON	8NNW	BNNW	8NW	7NNW	8NNW	7ทท₩	6NNW	6NNW	5NN₩	5พพพ	3NNW	3NNW	3NNW	5NNW	6иии
30	5พพ₩	5NNW	6NNW	5NNW	4NNW	4NNW	4NW	4NW	4NW	5NNW	7NNW	7NNV	7NNW	7NNV	7nnw	7NNW	6N	5N	5NNW	5N	4NNW	4NNW	4NNW	4NNW	5ทพพ
31	5NNW	5NNW	5NNW	5N "	4NNW	4NNW	3NNW	6NNW	6NNW	5NNW	5N	5N	5N	6N	6N	5ท	4N	4NNW	3NNW	4NW	4NNW	3NW	4NW	4NNW	5ทพพ
	ä									/												Monthl	y Aver	age =	4 N W

Maximum Hourly Average Wind Speed was

Maximum Daily Average Wind Speed was

6 meters/sec on Day 28 and Wind Direction was from the NNW

Operating Efficiency for Wind Speed = 100.0 percent Operating Efficiency for Wind Direction = 100.0 percent

** = missing or no data.

⁹ meters/sec at Hour 14 on Day 19 and Wind Direction was from the NNW.

MEPA - Kuwait

May 1991

Hourly Averages for Pressure in millibars

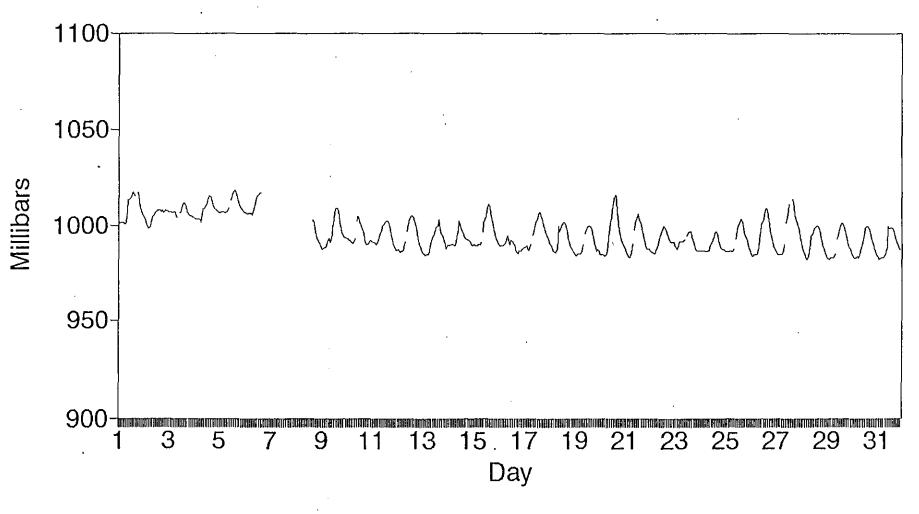
Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day -																									- √ Average
1	1003	1001	1001	1001	1001	1001	1001	1001	1002	1008	1014	1014	1014	1016	1018	1017	1016	ND	ND	1018	1013	1010	1008	1006	1008.4
2	1005	1004	1003	1002	1000	999	999	1000	1002	1005	1006	1007	1007	1008	1008	1008	1008	1007	1008	1007	1007	1008	1008	1008	1005.2
3	1008	1007	1007	1007	1007	1007	1007	1005	1004	ND	1007	1007	1008	1011	1011	1012	1011	1010	1008	1006	1005	1005	1005	1005	1007.4
4	1004	1004	1004	1004	1003	1004	1003	1002	1006	1009	1009	1010	1012	1014	1015	1016	1015	1014	1011	1009	1009	1008	1008	1007	1008.3
5	1007	1007	1007	1007	1007	1007	1007	1007	1008	1009	ND	1013	1016	1017	1018	1019	1018	1016	1014	1011	1009	1009	1008	1007	1010.8
6	1007	1007	1006	1006	1007	1006	1007	1006	1007	1009	1012	1014	1015	1016	1017	1017	ND	ND	ND	ND	ND	ND	ND	ND	1009.9
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
8	ND	· ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1002	1003	1002	998	995	994	993	992	990	996.6
9	989	987	988	989	989	989	991	994	991	992	995	1000	1004	1007	1009	1010	1009	1006	1002	998	996	995	995	994	996.6
10	994	993	992	993	992	991	991	992	993	ND	1003	1005	1005	1002	1001	999	996	993	990	990	990	991	992	993	994.8
11	992	992	992	991	991	990	991	993	997	998	1000	1000	1001	1002	1003	1003	1002	1001	998	995	993	991.	989	988	995.5
12	987	987	987	986	986	987	987	990	992	ND	997	1001	1003	1004	1005	1005	1005	1003	1000	996	993	991	989	988	994.3
13	986	986	985	985	985	985	985	986	990	992	995	995	997	999	1000	1000	1003	999	996	995	995	992	990	988	992.0
14	990	990	990	990	990	990	990	990	992	994	998	1003	1001	998	997	997	995	993	994	993	992	992	991	990	993.3
15	990	, 990	990	990	990	990	990	990	992	ND	997	1002	1005	1008	1011	1012	1010	1007	1003	1001	998	996	994	993	997.8
16	991	990	990	990	990	990	991	992	994	995	993	990	993	992	992	991	990	988	986	985	987	987	988	988	990.1
17	988	989	989	989	988	987	989	990	ND	995	997	1000	1002	1004	1006	1007	1007	1005	1002	1000	998	997	996	994	996.5
18	993	991	990	989	988	986	986	987	988	1000	997	999	1000	1001	1002	1002	1002	1000	997	994	992	990	988	987	993.7
19	986	985	985	985	985	985	985	958	987	990	ND	996	997	998	1000	1000	1000	998	996	993	991	989	987	988	989.7
20	987	985	985	985	985	985	984	986	990	995	999	1002	1005	1008	1012	1015	1016	1013	1007	1002	998	995	993	991	996.8
21	989	988	986	985	984	983	984	986	991	ND	998	1002	1003	1004	1006	1004	1001	998	995	993	991	989	988	988	992.9
22	988	987	987	986	986	986	986	987	989	993	995	996	997	998	1000	999	998	996	994	993	992	991	991	991	991.9
23	991	989	987	989	991	992	992	992	992	992	993	ND	995	996	997	997	997	994	992	989	987	987	987	987	991.5
24	987	. 987	987	987	987	987	987	987.	987	987	989	991	993	995	996	997	997	995	992	990	989	988	988	988	989.9
25	987	987	987	987	987	987	987	987	988	ND	993	996	1000	1001	1002	1004	1003	1001	999	995	993	991	989	987	993.0
26	986	985	.984	985	985	985	985	986	989	993	997.	1001	1004	1006	1009	1010	1008	1005	1001	998	994	992	990	988	994.4
27	988	986	985	985	985	985	985	987	990	ND	1001	1005	1008	1011	ND	ND	1014	1014	1010	1006	1003	1000	997	994	997.1
28	991	989	987	986	984	983	983	984	987	990	995	996	997	999	1000	1000	1000	998	996	993	991	989	987	986	991.3
29	985	983	983	983	983	984	984	984	985	ND	994	995	997	999	1001	1002	1002	1000	998	996	993	991	989	988	991.3
30	986	985	984	983	983	984	984	983	985	987	989	991	993	996	999	1000	1000	998	997	994	992	990	989	987	990.0
31	986	984	983	982	983	984	983	984	985	987	989	1000	998	999	999	999	998	997	995	993	991	990	989	988	990.3
																					M	onthly	Avera	ge =	996.2

Maximum Hourly Average was 1019 at Hour 16 on Day 5 with 1 occurences

Maximum Daily Average was 1010.8 on Day 5 with 1 occurences

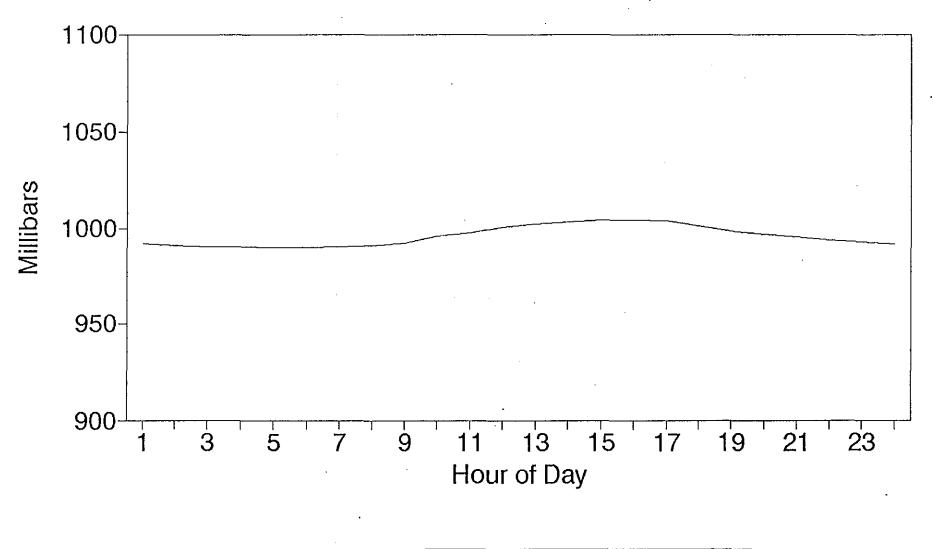
Operating Efficiency = 91.5 percent

Hourly Barometric Pressure — May, 1991



Pressure

Diurnal Pressure - May, 1991



Barometric Pressure

MEPA - Kuwait

May 1991

Hourly Averages for Solar Radiation in Watts/ M2.

Hour Day ├─	1 .	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily ➡ Average
1 (PO	0	0	0	0	0	 8	39	72	134	357	293	289	~ 250	270	239	129	75	ND	ND	0	0	0	0	0	98.0
2	0	0	0	0	0	7	30	70	41	0	0	1	6	10	4	34	44	15	0	0	0	0	0	0	10.9
3	0	0	0	0	1	45	105	165	202	ND	277	383	449	496	- 508	317	157	42	1	0	0	0	0	0	136.9
4	0	0	0	0	1	58	97	126	434	568	670	710	693	645	549	403	235	72	1	0	0	0	0	0	219.3
5	0	0	0	0	2	59	117	178	440	585	ND	717	696	647	549	408	241	74	1	0	0	0	0	0	205.0
6	0	0	0	0	5	86	68	108	464	551	634	701	667	618	458	276	ND	ND	ND	ND	ND	ИD	ND	ND	289.8
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NĐ	ND	****
8	ND	ND	ND	ND	ND	ND	ND	3	108	195	ND	326	357	325	361	393	242	85	4	0	0	0	0	0	149.9
9	0	0	0	0	1	29	60	92	221	299	540	642	621	553	454	333	190	52	1	0	0	0	0	0	170.3
10	0	0	0	0	4	45	136	272	423	ND	571	629	571	487	469	268	118	36	2	0	0	0.	0	0	175.3
11	0	0	0	0	4	25	64	123	427	540	609	649	638	597	483	374	219	54	1	0	0	0	0	0	200.3
12	0	0	0	0	4	76	52	443	491	ND	637	606	633	597	417	346	208	71	1	0	0	0	0	0	199.2
13	0	0	0	0	2	49	129	175	209	223	224	268	273	271	205	157	101	1	0	0	0	0	0	0	95.3
14	0	0	0	0	0	24	69	141	153	320	452	582	516	533	485	298	115	24	0	0	0	0	0	0	154.7
15	0	0	0	0	5	46-	75	59	185	ИD	476	644	663	618	516	390	222	77	4	0	0	0	0	0	173.0
16	0	0	0	0	2	37	84	118	83	80	.85	63	124	278	145	68	118	65	5	0	0	0	0	0	56.5
17	0	0	0	0	0	18	50	80	ND	272	342	439	456	438	363	257	150	54	3	0	0	0	0	0	127.0
18	0	0	0	0	1	37	51	103	408	649	581	653	649	582	540	409	205	72	5	0	0	0	0	0	206.0
19	0	0	0	0	2	63	153	236	528	632	ND	815	701	666	614	446	260	104	6	0	0	0	0	0	227.2
20	0	0	0	0	3	70	160	115	538	669	746	799	778	709	610	455	257	74	4	. 0	0	0	0	0	249.5
21 22	0	0	0	0	5 1	66	147 60	181 168	362 190	ND 233	580	640	633	613	356	187 148	52 63	10	1	0	0	0	0	, 0	166.7 89.5
23	0	0	0	0	2	14 18	47	159	315	311	197 454	256 ND	290 674	276 652	229 57	398	238	22 88	2 6	0	0	0	0	0	148.7
24	0	0	0	0	5	29	98	134	203	375	525	562	556	642	590	432	225	68	3	0	0	0	0	0	185.3
25	0	0	0	0	12	97	22	103	367.	ND	709	757	755	734	654	507	356	137	10	. 0	0	0	0	0	227.0
26	0	0	0	0	2	39	48	141	434	548	636	693	703	672	585	428	262	89	5	0	0	0	0	0	220.2
27	0	0	0	0	2	16	13	98	355	ND	640	637	695	669	ND	ND	551	62	9	0	0	0	0	0	178.4
28	0	0	0	0	3	52	122	124	453	588	634	704	728	715	636	482	271	80	5	0	Ō	0	0	0	233.2
29	0	0	0	0	8	71	172	202	470	ND	699	749	754	712	629	484	291	105	7	Ō	0	0	0	0	232.7
30	0	0	0	0	2	34	91	110	153	270	356	429	561	675	559	376	193	51	4	0	0	0	0	0	161.0
31	0	0	0	0	2	20	82	142	273	366	382	420	424	386	338	213	125	52	6	0	0	0	0	0	134.6
	<u> </u>																				Mo	nthly	Averag	e =	169.5

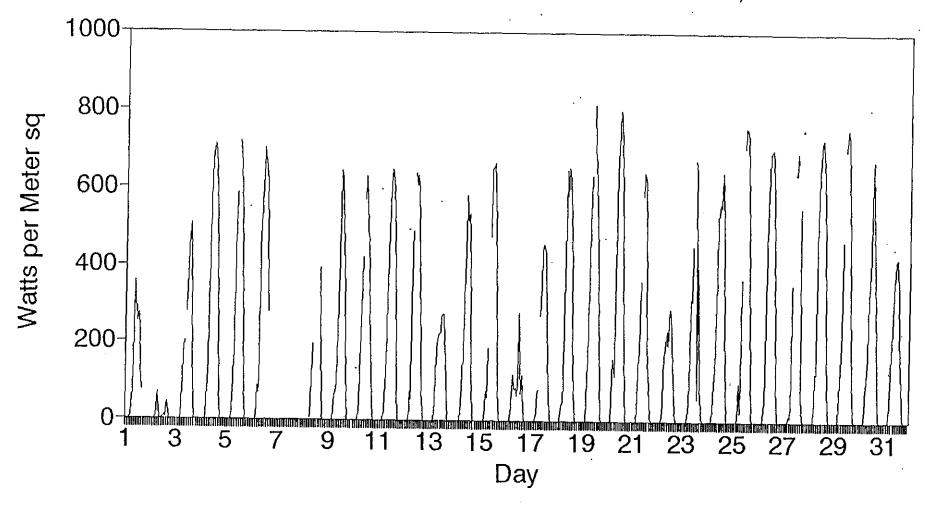
Maximum Hourly Average was 815 at Hour 12 on Day 19 with 1 occurences

Maximum Daily Average was 289.8 on Day 6 with 1 occurences

Operating Efficiency = 92.5 percent

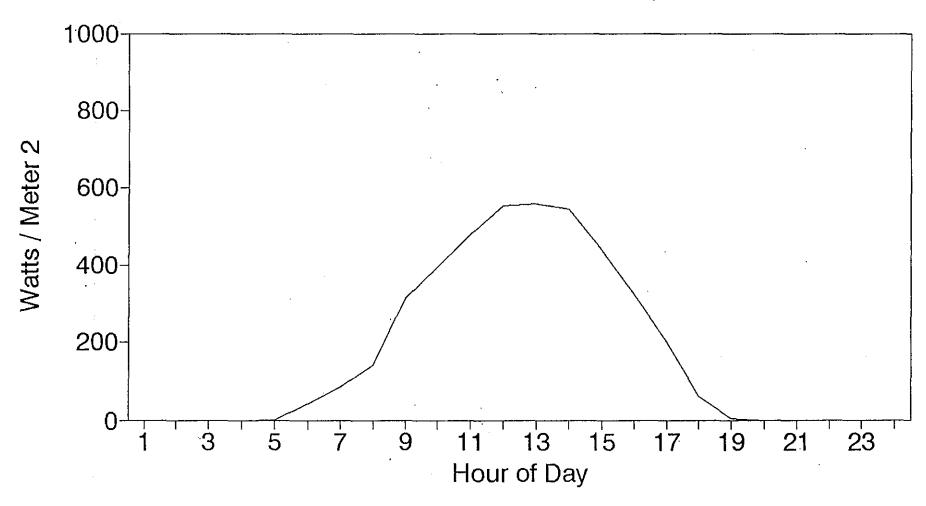
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

Hourly Solar Radiation - May, 1991



Solar Radiation

Diurnal Radiation - May, 1991



Solar Radiation

MEPA - Kuwait

May 1991

Hourly Averages for Relative Humidity in Per Cent

Hour	1	2	3	4	5	6	7	8	9	· 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day -	15 1	15 6	16.5	17 8	18 0	10.7	20.2	10 9	19.2	17 7	15 '7	1/, 5	14.0	17 1	12.0	17 7	1/, 2	ND	ND	16.7	15.9	15 7	16.6	17 6	-{ Average 16.34
									17.5																22.61
	28.0						30.9														21,2				23.91
	22.9								20.9					•											18.06
5	16.5								15.8												13.5				14.23
6	15.4	15.8							15.1		13.6	13.1	12.6	12.0	11.6	11.6	ND	ND	ND	ND	ND	ND	ND	ND	14.78
7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NO	ND	ND	ND	ND	ND	****
8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.9	2.6	1.4	4.2	12.9	13.3	13.6	14.1	14.6	14.2	14.6	15.0	15.4	10.68
9	15.6	15.9	16.1	16.5	17.1	17.4	17.8	18.5	18.5	17.2	15.3	13.6	12.8	13.3	14.4	15.2	14.8	14.7	14.9	15.2	15.1	15.0	14.9	14.7	15.60
10							17.1														13.3			14.2	13.85
									15.2															15.2	13.62
•							16.5													20.9		22.3		22.6	16.03
13									18.1														20.2		19.09
									19.1																19.58
		•					21.6		19.5												21.7				19.61 29.64
							32.4														22.0				29.04
									26.3															18.6	19.95
									18.7												15.5				17,28
20									16.6																15.93
21	17.4	18.2					17.7														17.6				17.57
22	19.5	19.6	19.8	19.8	19.8	19.6	19.5	20.2	20.6	21.1	20.8	19.6	18.7	17.6	17.0	18.4	19.3	20.2	20.0	19.1	20.2	21.2	21.2	20.7	19.73
23	21.0	21.6	22.9	24.2	24.6	26.2	27.3	27.0	25.6	25.5	23.5	ND	19.6	18.3	18.2	17.8	17.5	17.3	17.8	18.9	19.2	20.0	22.0	23.3	21.71
24	25.3	23.1	22.9	23.6	24.4	25.0	26.9	26.2	25.5	23.4	20.5	18.6	17.7	17.0	16.5	16.3	16.7	17.1	18.0	18.5	19.4	19.8	20.2	21.5	21.00
25	22.4						20.5													12.0	12.5	15.0	16.8	16.3	15.90
	17.1								16.8				•							15.1			16.3	16.5	15.62
27	16.5			16.2				14.9			11.9			11.3	ND						15.4			19.2	14.72
28	20.1								20.3															19.7	18.25
29	20.4						23.2														14.8				17.51
									21.4																17.40
. 31 L	19.3	۵.0	22.3	22.3	ري. ري 	23.1	23.0	22.0	19.5	17.4	10.0	12.9	14.5	15.7	13.8	13.9	12.9	14.4	14.7	14.5		12.0 onthly			17.58 18.38
ļ																					M	onthry	wasi.9	ge -	10.30

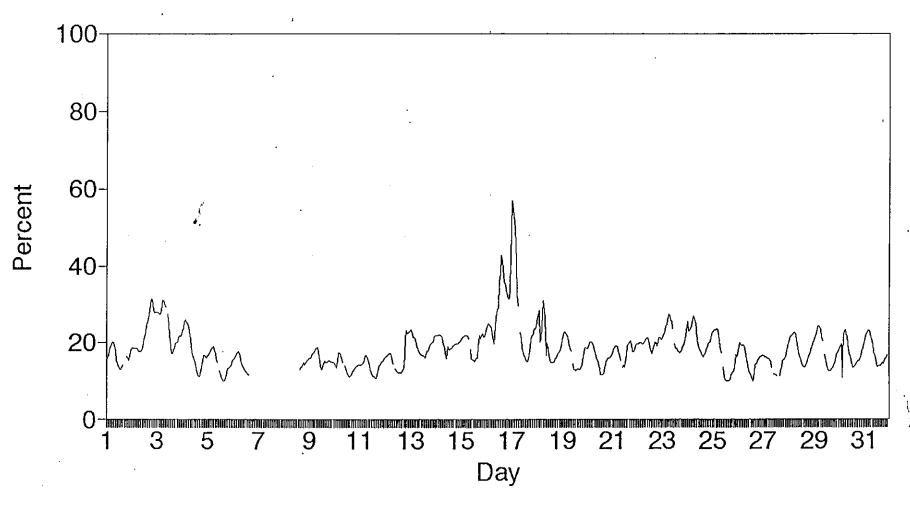
Maximum Hourly Average was 56.9 at Hour 2 on Day 17 with 1 occurences

Maximum Daily Average was 29.64 on Day 16 with 1 occurences

Operating Efficiency = .92.1 percent

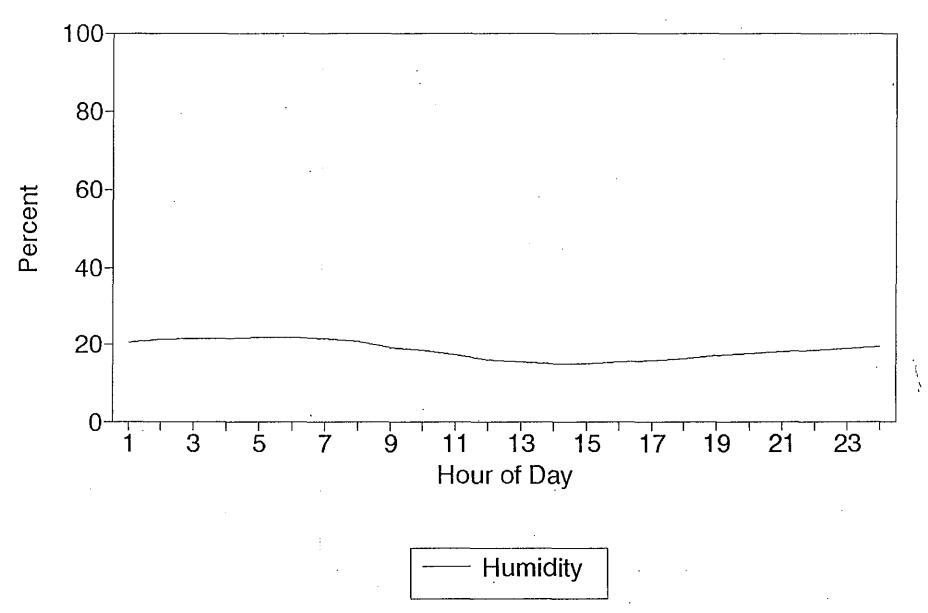
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

Hourly Humidity - May, 1991.



Humidity

Diurnal Humidity - May, 1991



MEPA - Kuwait

May 1991

Hourly Averages for Temperature in Degrees C

Hou	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day																			~~~						- Average
1	27.9	26.7	26.7	26.6	26.2	25.5	25.7	27.6	29.6	33.5	35.8	36.5	37.2	38.5	38.7	37.3	36.0	ND	ND	31.1	32.3	33.1	31.1	30.6	31.55
7	29.7	29.0	29.0	28.8	28.6	28.3	29.2	29.7	29.4	29.5	29.5	29.3	30.5	30.4	29.5	30.9	30.9	29.3	27.7	26.9	26.5	26.4	26.0	25.5	28.77
3	25.1	24.7	24.4	24.0	22.9	22.5	23.5	24.4	25.2	ND	26.9	28.9	30.7	32.2	33.6	33.1	32.1	30.8	29.4	28.6	27.5	26.8	26.2	25.2	27.33
1	24.4	23.6	22.8	22.8	22.6	22.5	23.3	24.9	26.8	29.1	30.6	31.6	32.7	33.6	34.2	34.4	34.0	32.6	30.9	29.3	28.2	26.7	26.0	24.2	27.99
	24.2	24.0	22.7	21.2	20.6	21.9	24.2	26.8	29.4	31.6	ND	34.1	35.2	36.1	36.4	36.3	35.7	34.4	32.7	31.3	30.2	28.5	27.7	27.0	29.23
. 6	25.6	25.1	23.7	22.6	22.3	23.4	26.0	28.3	31.5	33.2	33.9	34.9	35.8	36.4	36.3	36.7	ND	ND	ND	ND	ND	ND	ND	ND	29.73
7	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****										
8	ND	34.0	34.1	34.8	36.7	37.8	37.3	35.7	33.8	33.0	33.4	32.6	31.9	30.8	34.30										
ć	30.2	29.1	28.6	28.3	27.7	28.4	29.3	30.3	32.8	34.5	38.5	40.9	41.4	40.7	39.1	37.9	37.1	35.3	33.8	33.1	33.2	33.3	33.3	33.2	33.75
10	33.2	32.4	33,2	32.0	31.0	30.9	31.3	32.3	33.6	ND	35.7	37.7	38.7	38.8	39.1	38.4	37.1	35.7	34.4	33.1	32.2	31.1	30.1	29.0	33.96
11	27.7	27.8	27.1	25.0	25.0	26.2	26.8	28.4	31.3	33.4	34.3	35.2	36.4	37.0	37.4	37.6	37.0	35.2	33.3	32.3	31.4	30.6	29.8	29.4	31.48
12	27.9	27.5	26.3	25.3	24.9	26.1	27.8	33.1	34.6	ND	36.7	37.5	38.2	39.0	38.6	38.6	38.3	36.8	35.0	30.6	30.2	30.1	29.7	29.1	32.26
13	28.1	27.8	27.0	27.0	26.9	27.3	29.9	32.3	33.7	35.0	36.0	36.6	36.8	36.9	37.0	37.1	35.5	34.5	33.4	32.6	32.4	32.0	30.5	29.9	32.34
14	29.3			28.3																					32.84
15	30.8	30.3	29.9	29.7	29.6	30.1	30.8	30.4	32.1	ND	38.5	41.1	40.8	40.6	39.6	38.8	37.8	34.7	33.6	33.6	32.7	32.4	32.1	31.9	34.00
16	31.4	30.0	29.3	29.3	29.9	30.5									•										31.21
17	28.0	27.9	28,2	28.3	28.6	29.5	30.6	31.0	ND	32.3	33.1	34.8	35.7	36.0	36.3	35.7	34.5	32.9	31.6	30.8	30.3	30.0	28.9	28.7	31.47
18	28.2	27.7	27.1	26.3	25.6	25.4	25.5	26.3	28.8	34.9	32.6	33.9	34.9	35.4	35.7	35.4	34.5	33.3	32.0	31.1	30.1	29.3	28.9	28.1	30.46
19	27.4	26.8	26.1	26.0	25.7	25.8	27.9	29.7	31.1	32.6	ND	35.6	36.5	36.9	37.2	36.8	35.8	34.5	32.9	32.0	31.1	30.2	29.3	28.7	31.16
20	28.2	27.8	27.2	26.4	24.8	24.3	27.1	30.2	32.8	34.6	35.9	37.1	38.9	40.0	40.5	40.2	39.4	36.9	35.0	33.6	33.0	32.7	32.1	31.6	32.93
21	30.7	30.0	28.5	27.8	27.5	28.4	30.9	33.7	36.0	ND	40.0	38.2	39.3	37.0	34.2	32.3	32.0	31.6	31.5	32.0	31.4	30.9	31.4	32.1	32.50
22	31.8	30.9	31.0	30.9	30.6	30.3	30.4	31.3	31.4	31.8	31.9	32.7	33.1	33.5	33.4	32.5	31.5	30.5	30.1	29.9	28.9	28.2	28.1	28.0	30.95
23	27.6	27.0	26.2	25.6	25.2	25.0	24.9	25.6	26.9	27.7	29.3	ND	32.2	33.2	32.9	32.6	32.0	31.1	29.7	28.8	28.1	27.3	26.1	25.3	28.27
24	24.4	23.9	23.3	22.4	21.8	22.0	24.2	26.0	26.6	29.0	31.6	32.5	32.7	33.8	34.0	33.6	32.5	31.2	29.8	29.0	28.3	27.6	26.8	26.1	28.05
25	25.4	24.6	23.7	23.1	22.7	24.6	27.4	28.4	29.7	ND	33.7	34.7	36.2	36.8	37.2	37.5	37.2	35.6	33.6	32.2	31.5	30.0	29.4	29.0	30.62
26	28.3	27.7	27.5	26.7	25.3	25.1	27.8	30.6	33.5	35.9	38.0	40.3	41.9	42.0	42.3	40.5	37.1	36.3	35.3	33.6	31.9	31.0	30.7	30.0	33.30
27				29.5						•	41.4				ND		42.4								34.95
28	30.4	29.8																				30.5			32,10
20		27.4															37.1								31.74
30	29.2																								32.23
	29.1																								32.76
L																J ,			U-10-7			onthly			31.44

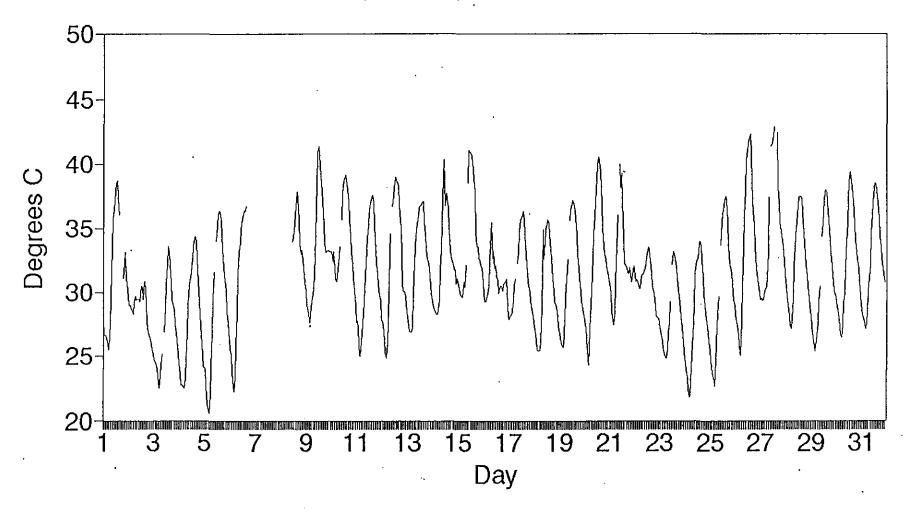
Maximum Hourly Average was 42.9 at Hour 14 on Day 27 with 1 occurences

Maximum Daily Average was 34.95 on Day 27 with 1 occurences

Operating Efficiency = 92.1 percent

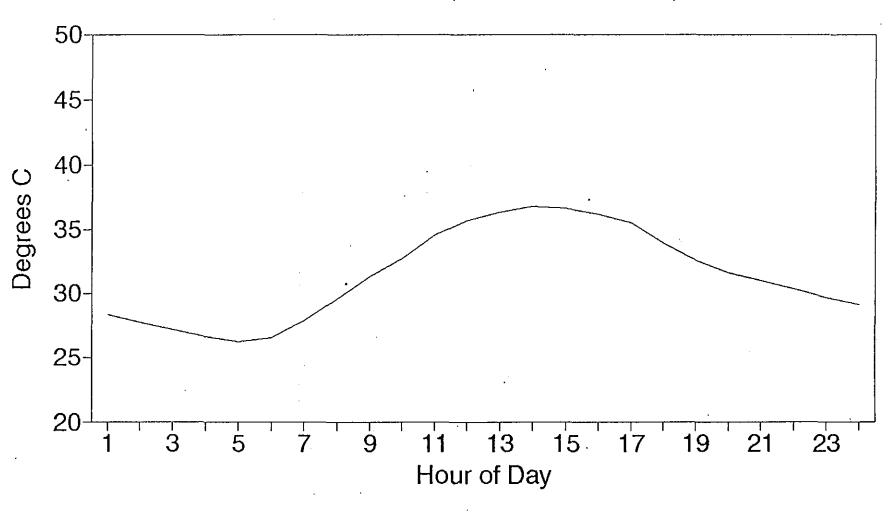
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

Hourly Temperature - May, 1991



— Temp

Diurnal Temperature - May, 1991



Temperature

MEPA - Kuwait

May 1991

Hourly Averages for Total Particulate in MG/M3

Kour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day																									⊣ Average
1	0.014	0.013	0.014	0.014	0.016	0.017	0.015	0.015	0.015	0.018	0.013	0.012	0.013	0.015	0.017	0.018	0.019	ND	ND	0.022	0.017	0.019	0.044	0.041	0.0182
2	0.056	0.070	0.057	0.066	0.091	0.045	0.051	0.016	0.070	0.096	0.100	0.055	0.036	0.038	0.059	0.056	0.043	0.041	0.045	0.052	0.063	0.070	0.042	0.020	0.0558
																									0.0337
																									0.0193
			•	0.015																0.014	0.015	0.014	0.015	0.014	0.0153
6	0.018	0.017	0.017	0.018	0.015	0.013	0.012	0.013															ND		0.0136
	ND		ND																						0.0168
																									0.0462
												•													0.0588
																									0.0407
							-	-				-												0.019	
				0.014					÷																0.0238
				0.057																					0.0303
				0.036																		-			0.0558
																									0.0672
																								0.021	
																									0.0893 0.0309
																									0.0354
																									0.0165
																									0.0233
																									0.1075
																									0.0514
																									0.0255
																									0.0157
26	0.018	0.018	0.018	0.024	0.023	0.023	0.017	0.016	0.015	0.016	0.015	0.015	0.015	0.015	0.017	0.020	0.020	0.018	0.018	0.020	0.018	0.017	0.056	0.097	0.0229
27	0.054	0.036	0.020	0.017	0.032	0.063	0.159	0.131	0.031	CAL	0.021	0.020	0.019	0.019	ND	ND	0.019	0.048	0.063	0.083	0.053	0.043	0.035	0.031	0.0475
28	0.036	0.031	0.032	0.026	0.019	0.019	0.021	0.025	0.031	0.029	0.025	0.023	0.022	0.019	0.020	0.022	0.024	0.027	0.031	0.031	0.033	0.032	0.026	0.023	0.0261
																									0.0187
																									0.0260
31	0.015	0.017	0.058	0.211	0.182	0.296	0.162	0.076	0.020	0.030	0.037	0.029	0.030	0.028	0.024	0.026	0.023	0.019	0.019	0.018	0.015	0.015	0.014	0.015	0.0575
·			•													-						onthly	Avera	ge =	0.0372

Maximum Hourly Average was 0.400 at Hour 5 on Day 15 with 1 occurences

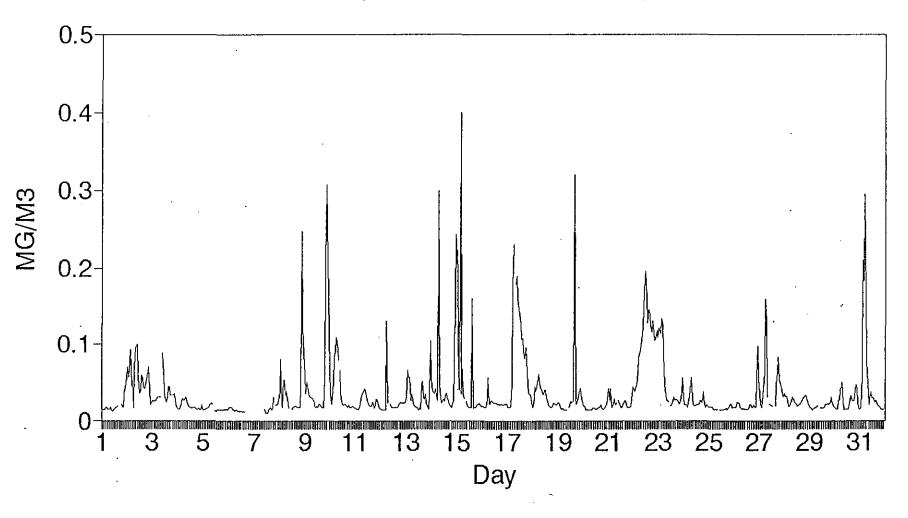
Maximum Daily Average was 0.1075 on Day 22 with 1 occurences

Operating Efficiency = 97.0 percent

ND = no data, ZS = zero/span, CAL = calibration, 1R = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

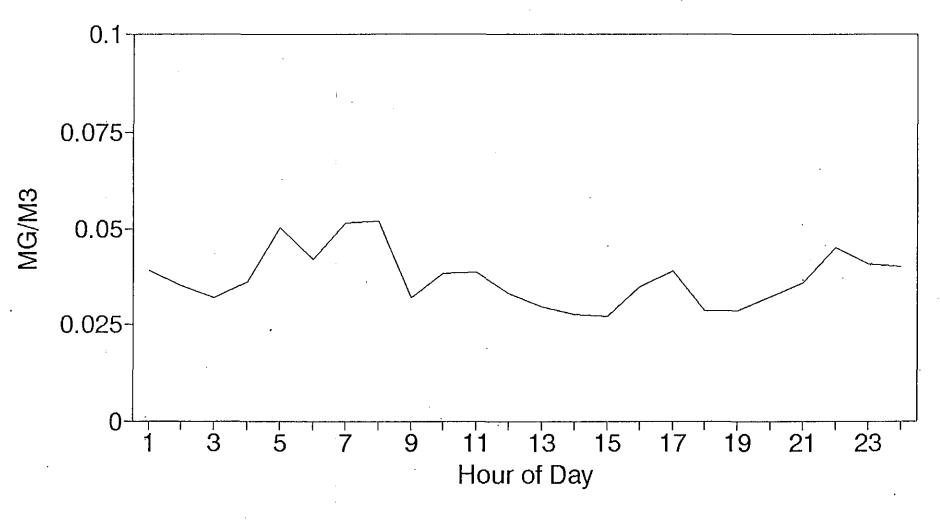
[CEM 1990]

Hourly Particulate - May, 1991



Particulate

Diurnal Particulate - May, 1991



—— Particulate

MEPA - Kuwait May 1991 Hourly Averages for NH3 in ppm

Hour 11 12 13 15 2 10 14 16 17 20 21 22 23 24 Daily Day |-Average 1 0.003 0.003 0.003 0.002 0.000 0.000 0.000 0.000 0.001 0.001 0.004 0.002 0.001 0.003 0.003 0.004 0.006 ND 0.003 0.014 0.026 0.029 0.016 0.0056 2 0.012 0.005 0.004 0.003 0.002 0.000 0.001 0.000 0.001 3 0.000 0.003 0.004 0.004 0.004 0.003 0.004 0.005 0.001 CAL 0.005 0.004 0.002 0.001 0.001 0.002 0.003 0.001 0.000 0.003 0.001 0.000 0.003 0.001 0.000 0.002 0.000 0.002 4 0.002 0.000 0.000 0.003 0.005 0.000 0.002 0.002 0.002 0.002 0.002 0.002 0.004 0.004 0.003 0.004 0.004 0.002 0.001 0.006 0.003 0.007 0.003 0.003 0.006 0.0029 5 0.004 0.005 0.003 0.004 0.004 0.004 0.003 0.004 0.001 0.000 CAL 0.005 0.003 0.003 0.003 0.004 0.003 0.004 0.013 0.017 0.007 0.004 0.004 0.009 0.0048 6 0.006 0.004 0.004 0.004 0.002 0.003 0.003 0.003 0.002 0.000 0.001 0.002 0.003 0.003 0.003 0.000 ND ND ND 0.0027 ND ND ND ND ND ND ND ND ND 0.003 0.004 0.005 0.001 0.008 0.000 0.029 0.006 0.005 0.016 CAL 0.006 0.014 0.014 0.0085 CAL CAL 0.001 0.001 0.005 0.001 0.000 0.001 0.001 0.003 0.000 0.000 0.000 0.000 0.0023 8 0.009 0.017 0.008 0.002 0.001 0.000 0.000 0.000 0.000 0.000 9 0.000 0.000 0.003 0.001 0.003 0.000 0.000 0.000 0.000 0.001 0.000 0.000 0.000 0.000 0.000 0.000 0.002 0.004 0.006 0.002 0.000 0.000 0.000 0.000 0.0009 10 0.000 0.000 0.002 0.000 0.000 0.001 0.000 0.000 0.002 CAL 0.002 0.002 0.002 0.002 0.004 0.005 0.007 0.006 0.008 0.004 0.001 0.002 0.010 0.006 0.0029 11 0.008 0.006 0.004 0.008 0.007 0.003 0.001 0.003 0.005 0.004 0.005 0.003 0.004 0.004 0.004 0.005 0.005 0.005 0.005 0.001 0.002 0.002 0.002 0.004 0.004 0.004 12 0.002 0.002 0.002 0.002 0.001 0.003 0.003 0.001 0.002 CAL 0.006 0.001 0.001 0.003 0.003 0.004 0.003 0.005 0.006 0.000 0.002 0.005 0.006 0.007 0.0030 13 0.006 0.006 0.007 0.005 0.004 0.002 0.000 0.000 0.002 0.000 0.002 0.001 0.002 0.003 0.004 0.003 0.001 0.005 0.002 0.000 0.000 0.002 0.000 0.008 0.0027 0.0002 14 0.000 0.000 0.000 0.000 0.000 0.000 0.002 0.000 16 0.001 0.000 17 0.002 0.001 0.003 0.000 0.000 0.001 0.003 0.002 CAL 0.006 0.003 0.004 0.004 0.005 0.006 0.007 0.007 0.004 0.005 0.004 0.003 0.004 0.006 0.004 0.003 18 0.005 0.003 0.004 0.003 0.001 0.002 0.000 0.000 0.000 0.005 0.003 0.004 0.005 0.004 0.005 0.004 0.005 0.005 0.004 0.005 0.004 0.003 0.003 0.003 0.003 0.001 0.0032 19 0.001 0.003 0.002 0.005 0.003 0.002 0.000 0.001 0.003 0.004 CAL 0.006 0.005 0.005 0.005 0.005 0.004 0.005 0.007 0.009 0.010 0.012 0.019 0.017 0.0058 20 0.010 0.005 0.010 0.003 0.004 0.004 0.004 0.004 0.004 0.003 0.005 0.004 0.004 0.005 0.005 0.006 0.009 0.009 0.009 0.006 0.007 0.006 0.007 0.007 0.007 0.011 0.008 0.0061 21 0.007 0.005 0.011 0.004 0.005 0.003 0.000 0.000 0.001 CAL 0.006 0.004 0.005 0.004 0.003 0.004 0.003 0.003 0.005 0.004 0.009 0.008 0.008 0.006 22 0.003 0.003 0.006 0.007 0.003 0.004 0.001 0.003 0.000 0.002 0.002 0.004 0.000 0.000 0.001 0.003 0.001 0.002 0.004 0.003 0.002 0.005 0.005 0.005 0.005 23 0.004 0.001 0.003 0.003 0.000 0.000 0.000 0.002 0.002 0.003 0.001 0.004 CAL 0.002 0.003 0.004 0.003 0.003 0.004 0.004 0.003 0.012 0.009 0.007 0.002 0.0034 24 0.002 0.005 0.004 0.004 0.005 0.004 0.000 0.000 0.000 0.000 0.000 0.001 0.003 0.003 0.003 0.003 0.004 0.004 0.004 0.004 0.014 0.003 0.003 0.003 0.005 0.005 0.005 0.005 CAL 0.015 0.005 0.004 0.005 0.007 0.006 0.007 0.007 0.008 0.022 0.019 0.018 0.012 0.019 0.0082 25 0.006 0.003 0.002 0.003 0.004 0.002 0.003 0.005 0.007 26 0.019 0.012 0.008 0.005 0.007 0.007 0.004 0.004 0.004 0.004 0.004 0.001 0.004 0.004 0.005 0.005 0.005 0.002 0.003 0.007 0.022 0.032 0.016 0.008 0.000 0.0078 27 0.000 0.002 0.002 0.002 0.004 0.002 0.000 0.000 0.000 CAL 0.011 0.002 0.002 0.002 ND ND 0.005 0.012 0.012 0.007 0.012 0.012 0.008 0.006 0.0049 28 0.003 0.005 0.003 0.004 0.007 0.001 0.002 0.003 0.003 0.003 0.004 0.002 0.005 0.004 0.005 0.004 0.005 0.004 0.006 0.006 0.006 0.007 0.006 0.003 0.002 0.0040 CAL 0.008 0.004 0.002 0.003 0.004 0.005 0.004 0.004 0.004 0.007 0.008 0.004 0.009 0.004 0.0037 29 0.003 0.004 0.003 0.003 0.001 0.001 0.000 0.001 0.000 30 0.003 0.005 0.004 0.003 0.003 0.000 0.000 0.000 0.000 0.001 0.003 0.002 0.003 0.004 0.003 0.001 0.000 0.000 0.002 0.002 0.002 0.003 0.000 0.002 0.0019 0.0016 31 0.003 0.002 0.000 0.00 0.0035 Monthly Average =

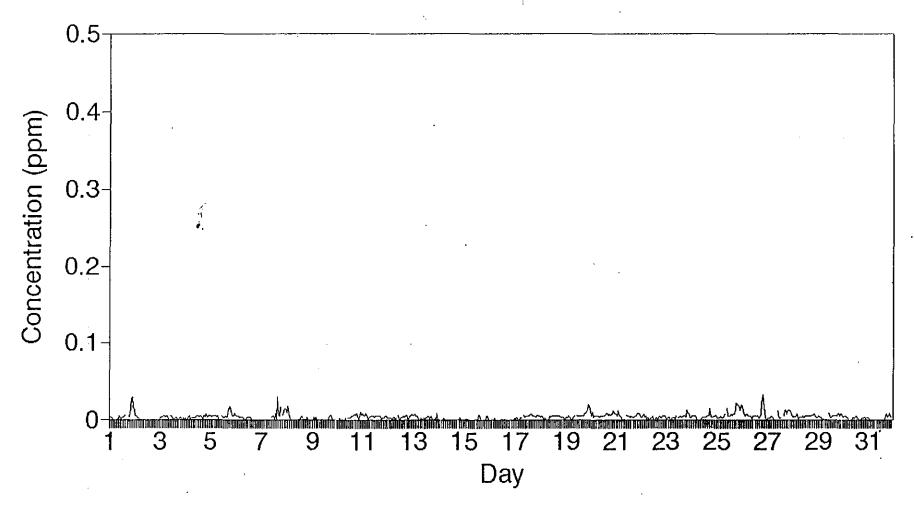
Maximum Hourly Average was 0.032 at Hour 21 on Day 26 with 1 occurences

Maximum Daily Average was 0.0085 on Day 7 with 1 occurences

Operating Efficiency = 97.0 percent

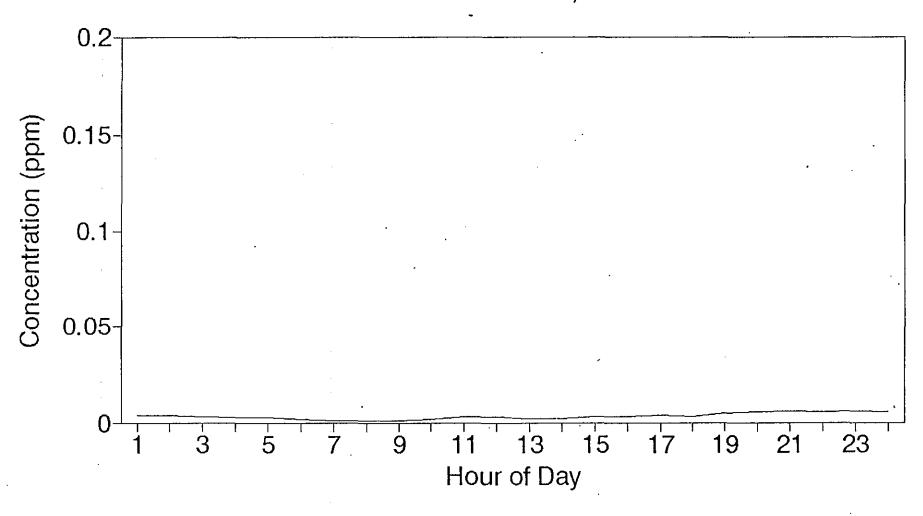
ND = no data, ZS = zero/span, CAL = calibration, 1R = repair, RL = relocation, OFF = off, AZS = daily zero/span, 1NS = insufficient data [CEM 1990]

Hourly NH3 - May, 1991



— NH3

Diurnal NH3 - May, 1991



— NH3

MEPA - Kuwait

May 1991

Hourly Averages for 03 in ppm

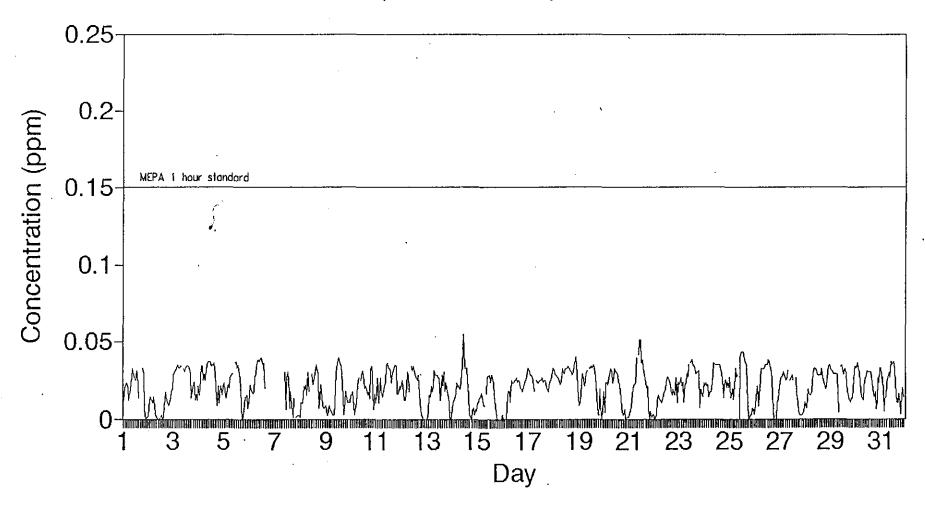
Hour	1		2 3	3	4	5 6	5 7	8	9	10	11	12	13	14	15	16	. 17	18	19	20	21	22	23	24	Daily
Day	0.017	0.01	2 0 020	. 0 02	2 0 03	3 0.020	0 012	0.017	0.010	0 027	0 032	0 028	0.026	0.025	0 031	0 020	0.013	ND	ND.	0 033	0 020	0 006	0.000	0.001	— Average 0.0199
													-								- +				0.0179
																•									0.0277
						4 0.025																			0.0262
						2 0.020																•			0.0216
6	0.011	0.02	2 0.019	0.018	B 0.01	6 0.017	0.027	0.029	0.035	0.038	0.037	0.038	0.039	0.035	0.036	0.020	ND	ND	0.0273						
7	ND	N) NE) NI) N	D NO	DI ND	ND	ND	ND	0.030	0.006	0.027	0.030	0.025	0.007	0.018	0.009	0.001	0.013	CAL	0.001	0.002	0.002	0.0132
8	0.001	0.01	1 0.010	0.01	0.02	1 0.019	0.022	0.015	0.030	0.018	CAL	CAL	0.029	0.022	0.029	0.035	0.033	0.029	0.007	0.014	0.022	0.014	0.008	0.007	0.0185
9	0.008	0.00	9 0.002	2 0.00	2 0.00	9 0.007	0.005	0.002	0.003	0.010	0.030	0:033	0.038	0.039	0.036	0.034	0.029	0.014	0.003	0.011	0.018	0.013	0.011	0.011	0.0157
10	0.015	0.01	0.017	0.00	3 0.00	3 0.008	0.010	0.022	0.026	CAL	0.025	0.028	0.031	0.028	0.020	0.021	0.015	0.018	0.013	0.032	0.034	0.028	0.006	0.016	0.0191
11	0.010	0.01	5 0.026	0.010	0.01	5 0.026	0.018	0.014	0.021	0.024	0.034	0.036	0.033	0.033	0.030	0.023	0.030	0.031	0.034	0.035	0.034	0.016	0.016	0.021	0.0244
						2 0.021																			0.0188
						4 0.021																			0.0178
						6 0.023																			0.0178
						4 0.016			:																0.0128
						0 0.015																			0.0173
						8 0.027									_										0.0247
						8 0.027																			0.0302
						9 0.029 4 0 022																			0.0209 0.0183
						6 0.022																			0.0103
						0.022 2 0.015																			0.0207
						4 0.011																			0.0154
						2 0.014																			0.0253
						2 0.021																			0.0234
						8 0.015																			0.0203
						0 0.026												0.016							0.0193
						6 0.015																			0.0230
						9 0.029																			0.0252
						0 0.023																			0.0233
						5 0.013																			0.0218
}-																· · · · ·							y Avera		0.0208

Maximum Hourly Average was 0.055 at Hour 13 on Day 14 with 1 occurences and there were no Hourly Violations

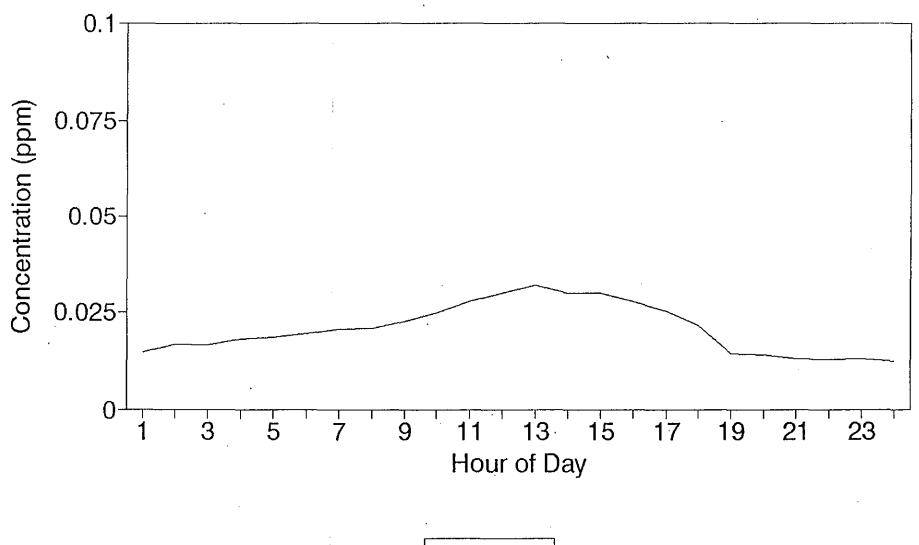
Maximum Daily Average was 0.0302 on Day 18 with 1 occurences and there were no Daily Violations

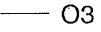
Operating Efficiency = 97.0 percent

Hourly 03 - May, 1991



Diurnal 03 - May, 1991





MEPA - Kuwait May 1991

Hourly Averages for NOx in ppm

Kour 11 12 14 15 21 22 23 Daily Day **√** Average 1 0.036 0.033 0.022 0.021 0.013 0.018 0.032 0.032 0.030 0.031 0.024 0.030 0.033 0.033 0.041 0.034 0.099 ND ND 0.197 0.084 0.156 0.182 0.139 0.0600 2 0.102 0.042 0.016 0.012 0.015 0.014 0.011 0.022 0.035 0.051 0.063 0.085 0.085 0.087 0.052 0.072 0.038 0.013 0.028 0.053 0.065 0.066 0.064 0.051 0.0472 3 0.044 0.016 0.008 0.007 0.004 0.006 0.006 0.005 0.010 CAL 0.016 0.011 0.015 0.013 0.015 0.012 0.011 0.017 0.054 0.032 0.027 0.059 0.045 0.074 0.0220 4 0.035 0.053 0.038 0.005 0.004 0.022 0.012 0.025 0.022 0.002 0.019 0.014 0.016 0.014 0.020 0.021 0.039 0.055 0.106 0.046 0.088 0.027 0.024 0.027 0.0306 5 0.014 0.013 0.015 0.020 0.005 0.015 0.010 0.011 0.014 0.023 CAL 0.020 0.019 0.030 0.025 0.036 0.048 0.069 0.169 0.182 0.057 0.034 0.035 0.093 0.0416 6 0.025 0.013 0.011 0.012 0.020 0.019 0.006 0.008 0.012 0.022 0.024 0.019 0.015 0.026 0.022 0.020 ND ND 0.0171 ND 0.025 0.061 0.024 0.010 0.010 0.044 0.024 0.065 0.057 0.095 CAL 0.063 0.132 0.108 0.0552 8 0.073 0.030 0.015 0.008 0.005 0.005 0.007 0.022 0.015 0.034 CAL CAL 0.027 0.045 0.021 0.011 0.015 0.022 0.077 0.045 0.034 0.052 0.080 0.088 0.0332 9 0.076 0.089 0.075 0.078 0.097 0.028 0.058 0.084 0.111 0.090 0.044 0.049 0.028 0.015 0.013 0.013 0.017 0.047 0.072 0.055 0.026 0.041 0.052 0.057 0.0548 10 0.049 0.051 0.042 0.073 0.111 0.081 0.068 0.025 0.031 CAL 0.036 0.035 0.025 0.033 0.061 0.057 0.076 0.066 0.090 0.021 0.017 0.027 0.128 0.055 0.0547 11 0.073 0.039 0.021 0.070 0.049 0.018 0.050 0.070 0.060 0.056 0.030 0.028 0.035 0.037 0.042 0.061 0.039 0.030 0.013 0.016 0.023 0.066 0.065 0.056 0.0436 12 0.030 0.019 0.026 0.031 0.034 0.026 0.017 0.041 0.012 CAL 0.033 0.037 0.028 0.032 0.036 0.034 0.031 0.024 0.061 0.059 0.061 0.081 0.087 0.083 0.0401 13 0.075 0.078 0.036 0.012 0.012 0.009 0.027 0.037 0.018 0.029 0.035 0.031 0.039 0.037 0.040 0.025 0.031 0.036 0.029 0.017 0.018 0.015 0.045 0.087 0.0341 14 0.060 0.027 0.015 0.012 0.010 0.004 0.006 0.010 0.023 0.034 0.016 0.022 0.025 0.012 0.011 0.014 0.018 0.032 0.062 0.080 0.053 0.056 0.055 0.051 0.0291 15 0.036 0.014 0.009 0.005 0.006 0.005 0.009 0.012 0.027 CAL 0.061 0.031 0.018 0.027 0.009 0.008 0.016 0.025 0.035 0.065 0.084 0.085 0.133 0.104 16 0.074 0.054 0.067 0.060 0.082 0.020 0.014 0.013 0.049 0.089 0.089 0.038 0.022 0.016 0.015 0.013 0.020 0.023 0.027 0.023 0.022 0.027 0.024 0.049 0.049 0.0386 17 0.013 0.016 0.011 0.021 0.050 0.034 0.007 0.010 CAL 0.012 0.016 0.020 0.018 0.016 0.016 0.022 0.021 0.021 0.024 0.024 0.024 0.310 0.025 0.130 0.210 0.0455 18 0.110 0.006 0.009 0.008 0.007 0.007 0.013 0.026 0.028 0.015 0.014 0.022 0.015 0.017 0.017 0.017 0.017 0.016 0.016 0.016 0.019 0.015 0.017 0.014 0.032 0.0197 19 0.063 0.107 0.090 0.085 0.016 0.017 0.046 0.051 0.026 0.025 CAL 0.022 0.026 0.019 0.020 0.016 0.028 0.044 0.063 0.095 0.101 0.048 0.130 0.165 0.0567 20 0.090 0.049 0.132 0.028 0.011 0.012 0.012 0.011 0.027 0.055 0.039 0.025 0.028 0.021 0.021 0.026 0.025 0.053 0.047 0.052 0.050 0.058 0.098 0.078 0.0437 21 0.073 0.035 0.029 0.013 0.003 0.002 0.007 0.015 0.013 CAL 0.046 0.032 0.029 0.014 0.015 0.020 0.031 0.040 0.042 0.074 0.096 0.067 0.074 0.063 0.0362 22 0.055 0.059 0.071 0.073 0.026 0.026 0.033 0.031 0.039 0.024 0.023 0.017 0.017 0.020 0.029 0.029 0.032 0.039 0.049 0.038 0.052 0.054 0.022 0.060 0.0382 23 0.028 0.029 0.015 0.020 0.017 0.062 0.027 0.029 0.025 0.036 0.023 CAL 0.200 0.013 0.020 0.022 0.033 0.040 0.037 0.048 0.112 0.053 0.057 0.056 0.0436 24 0.018 0.019 0.015 0.011 0.012 0.029 0.040 0.044 0.036 0.024 0.017 0.021 0.019 0.020 0.019 0.015 0.018 0.026 0.028 0.056 0.036 0.031 0.052 0.040 0.0269 25 0.062 0.038 0.072 0.051 0.079 0.047 0.022 0.042 0.043 CAL 0.095 0.021 0.019 0.016 0.017 0.029 0.028 0.030 0.054 0.134 0.111 0.156 0.089 0.132 0.0603 26 0.151 0.110 0.079 0.023 0.051 0.035 0.016 0.024 0.043 0.042 0.041 0.036 0.034 0.017 0.013 0.015 0.020 0.028 0.073 0.173 0.181 0.107 0.044 0.022 0.0574 ND 0.032 0.115 0.118 0.121 0.127 0.126 0.097 0.092 0.0514 27 0.009 0.004 0.002 0.003 0.002 0.008 0.016 0.016 0.014 CAL 0.077 0.029 0.030 0.041 ND 28 0.066 0.077 0.082 0.040 0.025 0.052 0.051 0.052 0.038 0.024 0.019 0.020 0.023 0.030 0.029 0.031 0.019 0.025 0.031 0.031 0.036 0.034 0.021 0.019 0.0365 29 0.014 0.013 0.013 0.013 0.016 0.016 0.023 0.024 0.004 CAL 0.023 0.019 0.026 0.032 0.022 0.017 0.026 0.051 0.054 0.056 0.061 0.051 0.096 0.016 0.0298 30 0.010 0.013 0.002 0.004 0.004 0.004 0.020 0.052 0.057 0.064 0.042 0.034 0.026 0.023 0.020 0.020 0.021 0.033 0.042 0.042 0.034 0.078 0.057 0.026 0.021 0.0310 31 0.011 0.008 0.026 0.016 0.082 0.053 0.051 0.027 0.020 0.038 0.019 0.021 0.019 0.013 0.010 0.019 0.037 0.071 0.050 0.040 0.054 0.102 0.044 0.023 0.0356 0.0402 { Monthly Average =

Maximum Hourly Average was 0.310 at Hour 21 on Day 17 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0603 on Day 25 with 1 occurences and there were no Daily Violations

Operating Efficiency = 97.0 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

(CEM 1990)

MEPA - Kuwait

Hay 1991

Frequency Distribution

Hourly Averages for NOx in ppm

Concentration	# of Hours	Percentage
0.000 - 0.050	509	72.0
0.051 - 0.110	167	23.6
0.111 - 0.210	30	. 4.2
0.211+	1 :	0.1

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MEPA - Kuwait May 1991 Hourly Averages for NO2 in ppm

22 Hour 11 12 13 15 16 17 23 24 Daily Day -Average 1 0.034 0.031 0.021 0.020 0.012 0.016 0.028 0.028 0.027 0.027 0.020 0.024 0.029 0.028 0.038 0.031 0.064 ND ND 0.082 0.057 0.064 0.080 0.078 0.0381 2 0.061 0.033 0.014 0.010 0.013 0.013 0.009 0.018 0.030 0.038 0.037 0.041 0.052 0.050 0.037 0.039 0.024 0.011 0.020 0.030 0.038 0.039 0.039 0.033 0.030 3 0.030 0.012 0.006 0.005 0.003 0.006 0.004 0.004 0.008 CAL 0.013 0.008 0.011 0.010 0.011 0.010 0.009 0.014 0.042 0.027 0.022 0.038 0.030 0.042 0.0159 4 0.024 0.033 0.024 0.003 0.003 0.016 0.009 0.018 0.017 0.016 0.014 0.011 0.012 0.011 0.015 0.017 0.029 0.041 0.060 0.038 0.051 0.027 0.024 0.026 0.0225 5 0.013 0.012 0.014 0.020 0.005 0.014 0.008 0.008 0.011 0.016 CAL 0.014 0.014 0.021 0.018 0.024 0.032 0.042 0.072 0.072 0.039 0.031 0.030 0.045 0.0250 6 0.023 0.013 0.011 0.011 0.019 0.016 0.004 0.006 0.010 0.016 0.018 0.014 0.012 0.019 0.017 0.036 ND ND ND ND ND 0.0153 ND ND 0.027 0.047 0.029 0.016 0.007 0.029 0.028 0.000 0.046 0.062 CAL 0.057 0.068 0.066 0.0371 ND ND ND 8 0.049 0.028 0.014 0.007 0.004 0.004 0.005 0.017 0.015 0.023 CAL CAL 0.021 0.028 0.015 0.010 0.013 0.020 0.059 0.042 0.025 0.037 0.044 0.043 0.0238 9 0.038 0.038 0.036 0.036 0.041 0.023 0.036 0.048 0.059 0.058 0.035 0.040 0.023 0.014 0.012 0.012 0.016 0.043 0.058 0.039 0.023 0.033 0.036 0.031 10 0.027 0.026 0.023 0.030 0.044 0.037 0.033 0.016 0.019 CAL 0.021 0.024 0.018 0.023 0.039 0.034 0.047 0.041 0.048 0.019 0.015 0.021 0.056 0.034 0.0280 11 0.040 0.025 0.015 0.034 0.028 0.014 0.030 0.040 0.038 0.038 0.021 0.019 0.023 0.025 0.028 0.039 0.026 0.023 0.012 0.015 0.020 0.043 0.043 0.033 12 0.029 0.018 0.024 0.028 0.032 0.023 0.016 0.028 0.008 CAL 0.022 0.025 0.019 0.021 0.023 0.022 0.023 0.017 0.045 0.047 0.049 0.060 0.058 0.062 0.0304 13 0.057 0.050 0.029 0.011 0.012 0.008 0.021 0.029 0.015 0.023 0.031 0.026 0.029 0.027 0.074 0.093 0.085 0.065 0.045 0.038 0.031 0.021 0.020 0.049 0.0370 14 0.035 0.020 0.014 0.011 0.008 0.004 0.005 0.008 0.019 0.025 0.012 0.018 0.023 0.010 0.009 0.012 0.016 0.028 0.052 0.054 0.044 0.042 0.042 0.032 0.0226 15 0.027 0.012 0.007 0.004 0.005 0.004 0.006 0.010 0.018 CAL 0.041 0.022 0.013 0.016 0.007 0.007 0.014 0.021 0.031 0.048 0.058 0.061 0.063 0.061 0.0242 16 0.056 0.047 0.053 0.051 0.057 0.017 0.012 0.005 0.034 0.010 0.013 0.016 0.015 0.013 0.015 0.020 0.019 0.019 0.022 0.022 0.022 0.027 0.022 0.012 0.014 0.0246 17 0.009 0.004 0.008 0.006 0.006 0.005 0.009 0.005 CAL 0.010 0.013 0.016 0.015 0.013 0.015 0.020 0.019 0.019 0.019 0.022 0.022 0.027 0.022 0.012 0.014 0.0135 18 0.009 0.004 0.008 0.006 0.006 0.005 0.009 0.016 0.022 0.012 0.011 0.017 0.012 0.013 0.014 0.011 0.014 0.015 0.016 0.018 0.016 0.014 0.016 0.013 0.025 0.0128 19 0.036 0.052 0.044 0.039 0.014 0.013 0.028 0.031 0.016 0.016 CAL 0.015 0.018 0.014 0.016 0.013 0.023 0.038 0.050 0.066 0.064 0.039 0.058 0.066 0.0334 20 0.044 0.029 0.053 0.018 0.010 0.011 0.010 0.008 0.018 0.033 0.025 0.017 0.020 0.015 0.015 0.020 0.021 0.040 0.042 0.047 0.047 0.046 0.061 0.056 0.0294 21 0.052 0.031 0.026 0.012 0.002 0.001 0.005 0.012 0.009 CAL 0.026 0.028 0.026 0.013 0.014 0.018 0.029 0.037 0.041 0.067 0.077 0.060 0.063 0.052 0.0305 22 0.048 0.048 0.044 0.036 0.022 0.021 0.027 0.024 0.027 0.019 0.018 0.014 0.014 0.016 0.022 0.021 0.025 0.031 0.040 0.033 0.039 0.039 0.039 0.021 0.046 0.0290 23 0.022 0.020 0.012 0.017 0.014 0.037 0.024 0.023 0.016 0.025 0.019 CAL 0.015 0.010 0.016 0.017 0.026 0.031 0.028 0.036 0.036 0.041 0.041 0.044 0.038 0.0259 24 0.018 0.019 0.015 0.011 0.010 0.026 0.026 0.026 0.030 0.026 0.019 0.015 0.016 0.015 0.015 0.015 0.015 0.012 0.016 0.024 0.026 0.045 0.032 0.026 0.034 0.027 0.0216 25 0.036 0.027 0.042 0.030 0.044 0.030 0.018 0.029 0.030 CAL 0.019 0.015 0.012 0.012 0.014 0.024 0.025 0.027 0.048 0.085 0.076 0.070 0.059 0.050 0.0357 26 0.061 0.053 0.044 0.022 0.035 0.028 0.014 0.021 0.032 0.032 0.032 0.032 0.027 0.026 0.014 0.011 0.013 0.019 0.027 0.057 0.076 0.076 0.074 0.038 0.020 0.0355 27 0.008 0.003 0.002 0.002 0.002 0.006 0.015 0.016 0.012 CAL 0.039 0.022 0.020 0.027 ND ND 0.023 0.076 0.062 0.060 0.061 0.056 0.047 0.046 0.0288 28 0.036 0.039 0.040 0.023 0.030 0.029 0.029 0.030 0.025 0.018 0.014 0.015 0.016 0.018 0.019 0.022 0.016 0.022 0.028 0.030 0.034 0.033 0.019 0.018 0.0251 29 0.012 0.012 0.012 0.012 0.014 0.013 0.016 0.017 0.002 CAL 0.016 0.013 0.018 0.021 0.015 0.014 0.022 0.041 0.045 0.046 0.045 0.037 0.040 0.013 0.0216 30 0.008 0.009 0.002 0.004 0.004 0.004 0.014 0.031 0.036 0.041 0.034 0.027 0.020 0.017 0.014 0.016 0.017 0.028 0.038 0.040 0.031 0.050 0.043 0.022 0.018 0.0235 31 0.010 0.006 0.001 0.015 0.049 0.037 0.037 0.022 0.017 0.030 0.016 0.017 0.017 0.012 0.010 0.017 0.031 0.049 0.045 0.033 0.040 0.049 0.033 0.019 0.0255 ┥ Monthly Average = 0.0268

Maximum Hourly Average was 0.093 at Hour 16 on Day 13 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0381 on Day 1 with 1 occurences and there were no Daily Violations

Operating Efficiency = 97.0 percent

NO = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

MEPA - Kuwait May 1991

Frequency Distribution Hourly Averages for NO2 in ppm

Concentration	# of Hours	Percentage
0.000 - 0.050	638	90.2
0.051 - 0.110	69	9.6
0.111 - 0.210	0	0.0
0.211+	a	0.0

MEPA - Kuwait May 1991 Hourly Averages for NO in ppm

[CEM 1990]

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day - 1	0.002	0.002	0.002	0.001	0.001	0.002	0.004	0.004	0.003	0.004	0.004	0.007	0.005	0.005	0.005	0.003	0.035	ND	ND	0.115	0.028	0.092	0.102	0.061	— Average 0.0221
	-												0.033							-			-		0.0167
3	0.014	0.004	0.003	0.002	0.001	0.001	0.002	0.001	0.002	CAL	0.003	0.003	0.004	0.004	0.003	0.002	0.002	0.003	0.012	0.005	0.005	0.021	0.015	0.032	0.0063
4	0.011	0.020	0.014	0.002	0.001	0.006	0.003	0.001	0.004	0.006	0.005	0.003	0.004	0.003	0.004	0.005	0.009	0.014	0.046	0.008	0.037	0.001	0.001	0.001	0.0087
5	0.001	0.000	0.001	0.001	0.000	0.001	0.002	0.002	0.003	0.007	CAL	0.005	0.005	0.009	0.007	0.012	0.016	0.027	0.097	0.109	0.017	0.003	0.005	0.048	0.0164
6	0.002	0.001	0.000	0.001	0.001	0.003	0.002	0.001	0.002	0.006	0.006	0.005	0.004	0.007	0.005	0.018	ND	ND	ND	ND	ND	ND	ND	ND	0.0040
7	ND	0.015	0.024	0.001	0.007	0.007	0.015	0.000	0.000	0.004	0.036	CAL	0.006	0.063	0.042	0.0169									
8	0.025	0.002	0.001	0.001	0.001	0.001	0.001	0.005	0.000	0.011	CAL	CAL	0.005	0.017	0.006	0.001	0.002	0.002	0.019	0.002	0.008	0.015	0.036	0.045	0.0094
9	0.038	0.051	0.039	0.042	0.056	0.005	0.022	0.037	0.051	0.033	0.009	0.009	0.005	0.002	0.001	0.001	0.001	0.005	0.014	0.017	0.003	0.007	0.016	0.025	0.0204
10	0.022	0,025	0.019	0.042	0.067	0.044	0.035	0.009	0.012	ÇAL	0.014	0.011	0.007	0.010	0.022	0.023	0.029	0.025	0.042	0.002	0.001	0.006	0.071	0.021	
													0.012										+		0.0157
												•	0.009												0.0095
					-								0.010												0.0154
													0.001												0.0065
										•			0.005												0.0116
													0.003												
-													0.003												0.0052
													0.003												0.0029
			-						-				0.009					_							0.0232
													0.008												
													0.003												
																									0.0093
									-				0.005												0.0219
													0.004												0.0052
													0.006												0.0243
												-						-							0.0214
													0.010							0.061					0.0225
													0.007												0.0123
													0.008												0.0083
													0.006							· · · · ·					0.0075
31	0.001	0.002	0.005	0.001	0.033	0.016	0.014	0.005	0.003	0.008	0.003	0.003	0.001	0.001	0.001	0.002	0.006	0.022	0.006						0.0092
 - -																				<u>-</u>	{ !	10nthly	/ Avera	ege =	0.0130

Maximum Hourly Average was 0.180 at Hour 24 on Day 23 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0243 on Day 10 with 2 occurences and there were no Daily Violations

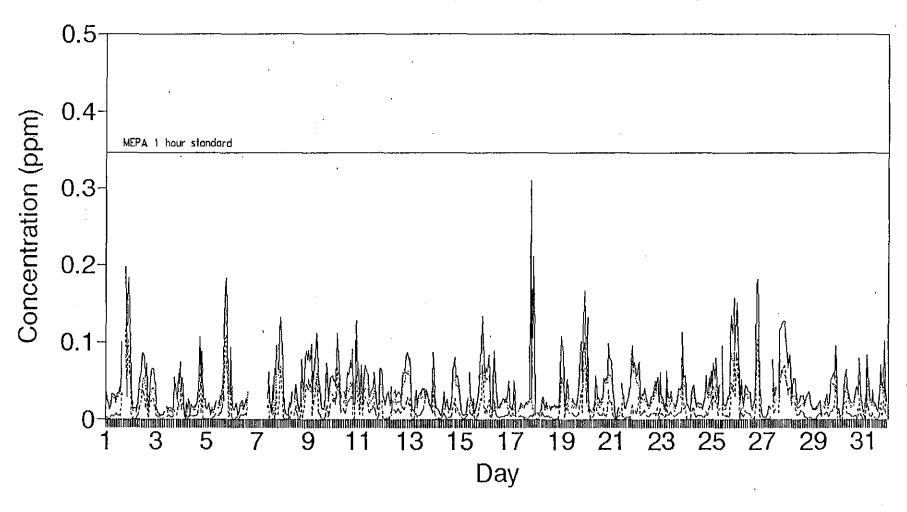
Operating Efficiency = 97.0 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

MEPA - Kuwait May 1991 Frequency Distribution Hourly Averages for NO in ppm

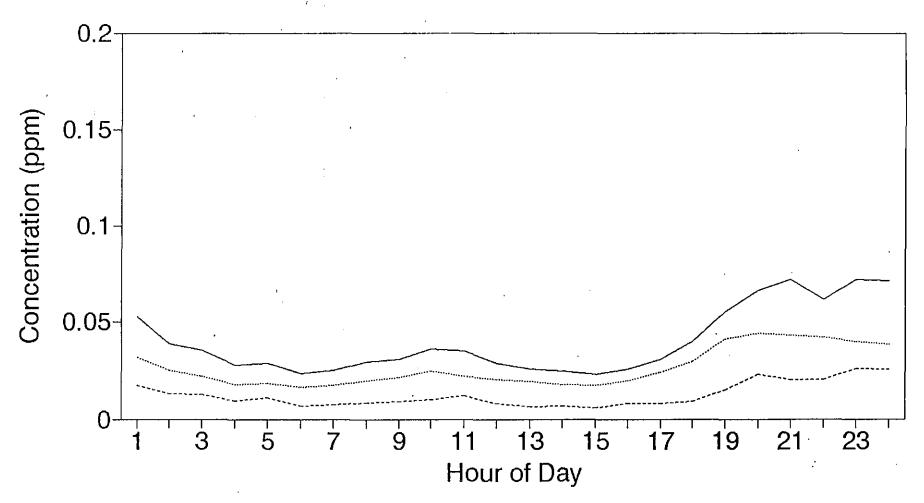
Concentration	# of Hours	Percentage
0.000 - 0.050	675	95.5
0.051 - 0.110	29	4.1
0.111 - 0.210	3	0.4
0.211+	0	0.0

Hourly N0x/N02/N0 - May, 1991



— NOx — NO2 — NO

Diurnal N0x/N02/N0 - May, 1991



____ NOx ____ NO2 ---- NO

MEPA - Kuwait May 1991 Hourly Averages for H2S in ppm

Hour	-	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day }		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.009	ND	ND	0.007	0.008	0,007	0.008	0.008	- Averag 0.0066
																			0.012	0.012	0.012	0.012	0.012	0.012	0.0144
3	0.011	0.011	0.011	0.010	0.010	0.010	0.010	0.008	0.007	CAL	0.008	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.007	0.006	0.007	0.007	0.007	0.007	0.0083
4	0.007	0.007	0.007	0.006	0.006	0.007	0.006	0.005	0.007	0.007	0.007	0.007	0.008	0.009	0.010	0.010	0.010	0.009	0.008	0.008	0.008	0.008	0.008	0.008	0.0076
5	0.008	0.008	0.008	0.008	0.009	0.009	0.008	0.007	0.007	0.007	CAL	0.009	0.009	0.010	0.011	0.011	0.011	0.010	0.009	0.008	0.007	0.008	0.008	0.008	0.0086
6	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.006	0.006	0.007	0.008	0.009	0.010	0.011	0.011	0.012	ND	ND	ND	ND	ND	ND	ND	ND	0.0085
7	ND	ИD	ND	0.013	0.013	0.015	0.019	0.013	0.011	0.009	0.008	0.008	0.007	CAL	0.008	0.007	0.007	0.0106							
8	0.006	0.006	0.006	0.005	0.006	0.006	0.006	0.006	0.008	0.010	CAL	CAL	0.015	0.015	0.014	0.013	0.014	0.013	0.012	0.009	0.008	0.009	0.011	0.012	0.0095
9	0.012	0.011	0.011	0.011	0.011	0.010	0.011	0.012	0.010	0.009	0.010	0.012	0.015	0.019	0.023	0.025	0.025	0.021	0.016	0.013	0.012	0.012	0.013	0.014	0.0141
					0.010																				0.0107
. 11	0.009	0.009	0.009	0.009	0.008	0.008	0.009	0.009	0.011	0.011	0.012	0.012	0.012	0.013	0.014	0.014	0.014	0.013	0.011	0.009	0.008	0.007	0.006	0.006	0.0101
12	0.006	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.007	CAL	0.009	0.011	0.012	0.013	0.015	0.015	0.015	0.014	0.012	0.010	800.0	0.007	0.007	0.006	0.0091
					0.006																				0.0092
					0.008																				0.0079
					0.014																				0.0158
16	0.009	0.008	0.008	0.009	0.009	0.009	0.010	0.008	0.011	0.010	0.010	0.011	0.013	0.015	0.017	0.020	0.020	0.018	0.016	0.014	0.012	0.011	0.010	0.009	0.0120
17	0.009	0.008	0.008	0.007	0.007	0.007	0.007	0.008	CAL	0.010	0.010	0.011	0.013	0.015	0.017	0.020	0.020	0.018	0.016	0.014	0.012	0.011	0.010	0.009	0.0116
18	0.009	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.011	0.010	0.010	0.011	0.012	0.012	0.013	0.013	0.012	0.011	0.010	0.008	0.008	0.007	0.007	0.0092
19	0.007	0.007	0.006	0.007	0.007	0.007	0.006	0.006	0.006	0.007	CAL	0.010	0.010	0.011	0.012	0.012	0.012	0.012	0.011	0.009	0.009	0.008	0.007		0.0086
					0.007																				0.0136
					0.008																				0.0191
					0.009																				0.0113
-	-			-	0.011																				0.0101
					0.008																				0.0083
					0.008																				0.0100
					0.007							,													0.0118
					0.007													0.027							0.0154
					0.006																				0.0086
					0.006																				0.0082
					0.006					•															0.0075
31	0.006	0.006	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.007	0.009	0.010	0.011	0.011	0.012	0.011	0.011	0.010	0.009					0.0078
} -			·																		^	fonthly	/ Avera	ige =	0.0105

Maximum Hourly Average was 0.041 at Hour 11 on Day 21 with 1 occurences and there were no Hourly Violations

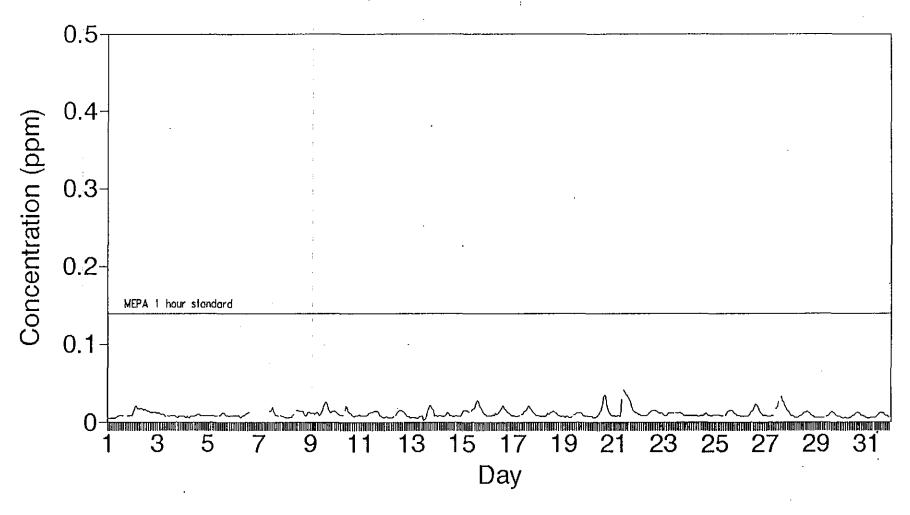
Maximum Daily Average was 0.0191 on Day 21 with 1 occurences and there were no Daily Violations

Operating Efficiency = 97.0 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

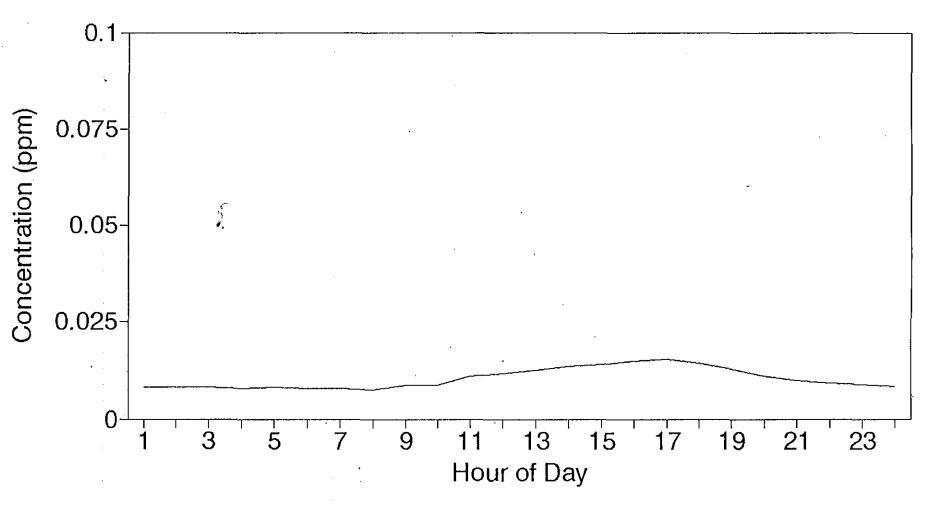
[CEM 1990]

Hourly H2S - May, 1991



— H2S

Diurnal H2S - May, 1991



— H2S

MEPA - Kuwait May 1991 Hourly Averages for SO2 in ppm

Average 1,0,001 0,002 0,001 0,002 0,002 0,004 0,004 0,003 0,003 0,006 0,006 0,008 0,008 0,005 0,005 0,005 0,007 0,012 ND ND 0,034 0,013 0,018 0,025 0,020 0,002 0,002 0,003 0,004 0,004 0,003 0,002 0,002 0,002 0,003 0,004 0,004 0,003 0,002 0,002 0,003 0,004 0,004 0,004 0,003 0,	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
2 0.025 0.037 0.043 0.056 0.078 0.049 0.052 0.054 0.074 0.111 0.107 0.052 0.030 0.025 0.018 0.023 0.019 0.007 0.010 0.016 0.021 0.022 0.025 0.019 0.007 0.006 0.006 0.006 0.006 0.008 0.007 0.007 0.006 0.006 0.006 0.008 0.005 0.007 0.007 0.007 0.007 0.007 0.007 0.007 0.007 0.007 0.007 0.008 0.006 0.008 0.00	Day			- N-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-										-		· - · · ·						-		,	·	⊣ Average
3 0.015 0.007 0.004 0.003 0.002 0.002 0.002 0.002 0.002 0.007 0.008 0.007 0.007 0.003 0.004 0.005 0.003 0.003 0.007 0.004 0.004 0.003 0.010 0.001 0.008 0.004 0.008 0.007 0.006 0.005 0.007 0.007 0.007 0.012 0.016 0.024 0.007 0.008 0.003 0.003 0.003 0.003 0.003 0.008 0.008 0.008 0.008 0.009 0.002 0.002 0.002 0.002 0.001 0.001 0.001 0.001 0.004 0.016 0.025 0.007 0.006 0.007 0.009 0.003 0.00	1	0.001	0.002	0.001	0.002	0.002	0.004	0.004	0.003	0.003	0.006	0.006	0.008	0.006	0.005	0.005	0.005	0.012	ND	ND	0.034	0.013	0.018	0.025	0.028	0.0088
4 0.010 0.016 0.012 0.002 0.001 0.008 0.004 0.008 0.007 0.007 0.007 0.006 0.006 0.010 0.005 0.007 0.007 0.012 0.016 0.024 0.007 0.018 0.003 0.003 0.008 0.0104 0.010 0.025 0.009 0.010 0.002 0.001 0.002 0.000 0.003 0.008 0.0108 0.012 0.007 0.006 0.000 0.006 0.017 ND ND ND ND ND ND ND ND ND ND ND ND ND	2	0.025	0.037	0.043	0.056	0.078	0.049	0.052	0.054	0.074	0.111	0.107	0.052	0.030	0.025	0.018	0.023	0.019	0.007	0.010	0.016	0.021	0.022	0.019	0.017	0.0402
5 0.002 0.002 0.002 0.002 0.002 0.001 0.001 0.001 0.001 0.004 0.016 0.025 CAL 0.006 0.007 0.009 0.013 0.014 0.017 0.037 0.038 0.010 0.003 0.005 0.019 0.010 6 0.003 0.003 0.003 0.003 0.004 0.005 0.005 0.004 0.005 0.00	3	0.015	0:007	0.004	0.003	0.002	0.002	0.002	0.002	0.005	CAL	0.007	0.003	0.004	0.005	0.003	0.003	0.002	0.003	0.007	0.004	0.004	0.013	0.010	0.021	0.0057
6 0.003 0.003 0.002 0.001 0.002 0.002 0.002 0.002 0.003 0.008 0.018 0.012 0.007 0.006 0.008 0.006 0.017 NO NO NO NO NO NO NO NO NO NO NO NO NO	4	0.010	0.016	0.012	0.002	0.001	0.008	0.004	0.008	.0.007	0.007	0.006	0.006	0.010	0.005	0.007	0.007	0.012	0.016	0.024	0.007	0.018	0.003	0.003	0.003	0.0084
8 0.019 0.008 0.005 0.006 0.038 0.035 0.038 0.036 0.038 0.036 0.038 0.036 0.038 0.036 0.038 0.036 0.038 0.036 0.038 0.036 0.038 0.036 0.038 0.03	5	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.004	0.016	0.025	ÇAL	0.006	0.007	0.009	0.009	0.013	0.014	0.017	0.037	0.038	0.010	0.003	0.005	0.019	0.0106
8 0.019 0.008 0.005 0.006 0.036 0.036 0.036 0.036 0.034 0.035 0.034 0.037 0.038 0.032 0.018 0.023 0.039 0.019 0.012 0.009 0.010 0.008 0.015 0.009 0.031 0.215 0.128 0.001 0.0357 0 0.066 0.038 0.056 0.029 0.030 0.023 0.029 0.009 0.010	6	0.003	0.003	0.002	0.001	0.002	0.002	0.002	0.003	0.008													ND	ND	ND	0.0063
9 0.072 0.048 0.047 0.038 0.032 0.018 0.025 0.029 0.025 0.023 0.011 0.015 0.011 0.013 0.016 0.016 0.014 0.012 0.012 0.015 0.183 0.267 0.283 0.100 0.0575 10 0.066 0.038 0.056 0.022 0.030 0.023 0.020 0.099 0.010 CAL 0.015 0.018 0.013 0.013 0.018 0.015 0.018 0.013 0.010 0.004 0.003 0.004 0.007 0.031 0.014 0.021 11 0.018 0.011 0.007 0.015 0.014 0.007 0.015 0.016 0.019 0.013 0.014 0.005 0.006 0.005 0.006 0.005 0.012 0.004 0.015 0.016 0.010 0.010 0.012 0.013 0.014 0.019 0.013 0.010 0.004 0.003 0.004 0.007 0.031 0.014 0.012 0.013 0.014 0.015 0.006 0.005 0.006 0.005 0.006 0.005 0.012 0.004 0.015 0.016 0.019 0.017 0.015 0.014 0.012 0.009 0.011 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.006 0.005 0.005 0.006 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.006 0.005 0.005 0.005 0.006 0.005	7	ND	ИD	ND	ND	ND	ИD	ND	ИD	ИD	ND	0.010	0.021	0.008	0.011	0.008	0.010	0.006	0.014	0.009	0.062	CAL	0.008	0.017	0.015	0.0153
10 0.066 0.038 0.056 0.022 0.030 0.023 0.020 0.009 0.010	8	0.019	0.008	0.005	0.006	0.036	0.066	0.030	0.036	0.044	0.030	CAL	CAL	0.023	0.019	0.012	0.009	0.010	0.008	0.015	0.009	0.031	0.215	0.128	0.001	0.0345
11 0.018 0.011 0.007 0.019 0.013 0.007 0.016 0.019 0.017 0.016 0.019 0.010 0.010 0.012 0.013 0.014 0.019 0.013 0.010 0.004 0.003 0.004 0.012 0.013 0.014 0.012 12 0.007 0.005 0.006 0.005 0.006 0.005 0.007 0.009 0.007 0.009 0.014 0.025 0.005 0.006 0.005 0.007 0.009 0.014 0.020 0.014 0.012 0.009 0.014 0.005 0.005 0.006 0.005 0.007 0.009 0.014 0.020 0.014 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.017 0.017 0.024 0.022 0.022 0.013 0.024 0.023 0.018 0.023 0.019 0.015 0.023 0.018 0.023 0.023 0.019 0.015 0.023 0.018 0.023 0.024 0.011 0.012 0.013 0.013 0.013 0.015	9	0.072	0.048	0.047	0.038	0.032	0.018	0.025	0.029	0.025	0.023	0.011	0.015	0.011	0.013	0.016	0.016	0.014	0.012	0.012	0.051	0.183	0.287	0.283	0.100	0.0575
12 0.007 0.005 0.004 0.005 0.006 0.006 0.006 0.005 0.012 0.004 CAL 0.016 0.016 0.019 0.017 0.015 0.014 0.012 0.009 0.011 0.005 0.005 0.006 0.005 0.007 0.0024 13 0.009 0.011 0.022 0.022 0.013 0.024 0.023 0.018 0.023 0.018 0.023 0.019 0.017 0.013 0.013 0.019 0.033 0.035 0.027 0.018 0.020 0.019 0.017 0.024 0.022 14 0.025 0.030 0.029 0.012 0.019 0.017 0.054 0.019 0.017 0.014 0.011 0.019 0.020 0.014 0.022 0.030 0.012 0.011 0.017 0.070 0.211 0.015 0.035 0.035 0.027 0.021 0.011 0.010 0.015 0.022 0.033 0.002 0.012 0.011 0.017 0.024 0.018 0.021 0.016 0.014 0.018 0.015 0.015 0.013 0.011 0.010 0.010 0.015 0.012 0.014 0.010 0.015 0.012 0.014 0.011 0.019 0.017 0.024 0.018 0.015 0.013 0.011 0.010 0.010 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.011 0.019 0.015 0.012 0.014 0.013 0.011 0.010 0.015 0.012 0.014 0.011 0.010 0.015 0.012 0.014 0.011 0.010 0.005 0.005 0.005 0.005 0.005 0.005 0.004 0.002 0.004 0.001 0.002 0.005 0.005 0.003 0.002 0.002 0.001 0.004 0.002 0.004 0.002 0.004 0.003 0.005 0.005 0.005 0.005 0.005 0.005 0.005 0.005 0.005 0.004 0.002 0.005 0.00	10	0,066	0.038	0.056	0.022	0.030	0.023	0.020	0.009	0.010	CAL	0.015	0.018	0.013	0.013	0.018	0.016	0.020	0.015	0.019	0.005	0.004	0.007	0.031	0.014	0.0210
13 0.009 0.014 0.021 0.022 0.022 0.013 0.024 0.023 0.018 0.023 0.010 0.013 0.013 0.019 0.033 0.048 0.053 0.035 0.027 0.018 0.020 0.019 0.017 0.024 0.022 14 0.063 0.041 0.029 0.032 0.032 0.032 0.032 0.032 0.032 0.012 0.017 0.067 0.054 0.019 0.017 0.014 0.011 0.019 0.020 0.014 0.022 0.030 0.012 0.011 0.017 0.070 0.217 0.0353 15 0.023 0.018 0.035 0.025 0.005 0.	11	0.018	0.011	0.007	0.019	0.013	0.007	0.016	0.019	0.017	0.016	0.010	0.010	0.012	0.013	0.014	0.019	0.013	0.010	0.004	0.003	0.004	0.012	0.013	0.014	0.0123
14 0.063 0.041 0.029 0.032 0.033 0.022 0.012 0.017 0.067 0.054 0.019 0.017 0.014 0.011 0.019 0.020 0.014 0.022 0.030 0.012 0.011 0.017 0.070 0.217 0.0360 15 0.023 0.159 0.084 0.030 0.027 0.021 0.051 0.023 0.018	12	0.007	0.005	0.004	0.005	0.006	0.006	0.005	0.012	0.004	CAL	0.016	0.016	0.019	0.017	0.015	0.014	0.012	0.009	0.011	0.005	0.005	0.006	0.005	0.007	0.0092
15 0.203 0.159 0.084 0.030 0.027 0.021 0.051 0.023 0.018	13	0.009	0,014	0.021	0.022	0.022	0.013	0.024	0.023	0.018	0.023	0.010	0.013	0.013	0.019	0.033	0.048	0.053	0.035	0.027	0.018	0.020	0.019	0.017	0.024	0.0224
16 0.009 0.008 0.009 0.009 0.015 0.020 0.042 0.011 0.012 0.013 0.013 0.009 0.010 0.006 0.007 0.009 0.008 0.007 0.005 0.005 0.005 0.004 0.002 0.004 0.002 0.004 17 0.002 0.001 17 0.002 0.001 0.004 0.025 0.020 0.012 0.009 0.008 0.003 0.003 0.005 0.005 0.006 0.007 0.009 0.008 0.007 0.005 0.005 0.005 0.004 0.002 0.004 0.002 0.004 18 0.002 0.001 0.004 0.025 0.020 0.012 0.009 0.008 0.008 0.004 0.003 0.005 0.005 0.004 0.005	14	0.063	0.041	0.029	0.032	0.033	0.022	0.012	0.017	0.067	0.054	0.019	0.017	0.014	0.011	0.019	0.020	0.014	0.022	0.030	0.012	0.011	0.017	0.070	0.217	0.0360
17 0.002 0.001 0.004 0.025 0.020 0.012 0.009 0.003	15.	0.203	0.159	0.084	0.030	0.027	0.021	0.051	0.023	0.018	CAL	0.021	0.016	0.014	0.018	0.015	0.015	0.013	0.011	0.010	0.010	0.015	0.012	0.014	0.013	0.0353
18 0.002 0.001 0.004 0.025 0.020 0.012 0.009 0.008 0.008 0.004 0.003 0.005 0.004 0.005 0.004 0.005 0.003 0.002 0.002 0.001 0.001 0.002 0.005 0.005 19 0.013 0.013 0.026 0.021 0.023 0.009 0.012 0.012 0.014 0.007 0.007 CAL 0.006 0.006 0.005 0.005 0.005 0.007 0.009 0.013 0.019 0.015 0.007 0.028 0.040 0.013 0.014 0.022 0.015 0.037 0.008 0.004 0.001 0.002 0.006 0.009 0.014 0.011 0.008 0.010 0.009 0.013 0.018 0.020 0.028 0.012 0.006 0.003 0.006 0.011 0.012 0.011 0.012 0.011 0.022 0.022 0.015 0.037 CAL 0.070 0.043 0.040 0.040 0.027 0.026 0.025 0.018 0.013 0.018 0.017 0.013 0.011 0.016 0.022 0.022 0.015 0.01	16	0.009	800.0	0.009	0.009	0.015	0.020	0.042	0.011	0.012	0.013	0.013	0.009	0.010	0.006	0.007	0.009	0.008	0.007	0.005	0.005	0.005	0.004	0.002	0.004	0.0101
19 0.013 0.026 0.021 0.023 0.009 0.012 0.012 0.014 0.007 0.007 CAL 0.006 0.006 0.005 0.005 0.005 0.007 0.009 0.013 0.019 0.015 0.007 0.028 0.040 0.013 20 0.022 0.012 0.035 0.009 0.044 0.001 0.002 0.006 0.009 0.014 0.011 0.008 0.010 0.009 0.013 0.018 0.020 0.028 0.012 0.006 0.003 0.006 0.011 0.012 0.011 0.022 0.015 0.022 0.015 0.037 CAL 0.070 0.043 0.040 0.040 0.027 0.026 0.025 0.018 0.013 0.018 0.017 0.013 0.011 0.016 0.022 0.023 0.015 0.015 0.018 0.008 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.026 0.022 0.016 0.021 0.011 0.009 0.011 0.015 0.021 0.011 0.004 0.015 0.015 0.018 0.008 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.026 0.022 0.016 0.021 0.011 0.009 0.011 0.015 0.021 0.011 0.004 0.015 0.015 0.018 0.008 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.026 0.022 0.016 0.021 0.011 0.009 0.011 0.015 0.021 0.011 0.004 0.015 0.015 0.018 0.028 0.019 0.029 0.014 0.023 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.027 0.008 0.007 0.008 0.007 0.008 0.007 0.008 0.009 0.014 0.027 0.013 0.011 0.028 0.015 0.014 0.029 0.029 0.015 0.014 0.029 0.029 0.015 0.014 0.029 0.029 0.015 0.014 0.029 0.029 0.015 0.014 0.029 0.029 0.015 0.014 0.029 0.029 0.015 0.014 0.029 0.02	17	0.002	0.001	0.004	0.025	0.020	0.012	0.009	0.003	CAL	0.003	0.003	0.005	0.005	0.006	0.007	0.009	0.008	0.007	0.005	0.005	0.005	0.004	0.002	0.004	0.0067
20 0.022 0.012 0.035 0.009 0.004 0.001 0.002 0.006 0.009 0.014 0.011 0.008 0.010 0.009 0.013 0.018 0.020 0.028 0.012 0.006 0.003 0.006 0.011 0.012 0.011 21 0.022 0.010 0.004 0.003 0.004 0.012 0.022 0.015 0.037 CAL 0.070 0.043 0.040 0.040 0.027 0.026 0.025 0.018 0.013 0.018 0.017 0.013 0.011 0.016 0.0220 22 0.023 0.015 0.015 0.018 0.008 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.026 0.022 0.016 0.021 0.011 0.009 0.011 0.015 0.021 0.011 0.004 0.015 0.015 23 0.013 0.020 0.006 0.009 0.014 0.023 0.010 0.013 0.011 0.010 0.007 CAL 0.010 0.006 0.007 0.008 0.010 0.012 0.007 0.010 0.027 0.013 0.011 0.028 0.012 24 0.009 0.005 0.004 0.004 0.004 0.005 0.024 0.044 0.049 0.018 0.005 0.006 0.006 0.007 0.008 0.010 0.012 0.007 0.010 0.027 0.013 0.011 0.028 0.011 25 0.019 0.013 0.023 0.017 0.026 0.016 0.006 0.012 0.013 CAL 0.046 0.008 0.009 0.007 0.008 0.010 0.009 0.007 0.007 0.016 0.017 0.033 0.012 0.029 0.015 26 0.035 0.030 0.024 0.007 0.008 0.007 0.005 0.005 0.012 0.033 0.037 0.010 0.010 0.009 0.010 0.014 0.013 0.010 0.009 0.012 0.015 0.014 0.029 0.057 0.0173 27 0.044 0.027 0.010 0.008 0.022 0.056 0.150 0.144 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 0.0412 28 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.008 0.010 0.009 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.004 0.005 0.005 0.004 0.004 0.002 29 0.004 0.004 0.005 0.005 0.005 0.006 0.008 0.008 0.004 CAL 0.009 0.007 0.008 0.007 0.008 0.009 0.007 0.008 0.009 0.009 0.008 0.010 0.016 0.023 0.005 0.008 30 0.005 0.006 0.005 0.016 0.015 0.036 0.053 0.028 0.034 0.009 0.007 0.008 0.007 0.008 0.004 0.024 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 0.009 0.009	18	0.002	0.001	0.004	0.025	0.020	0.012	0.009	0.008	0.008	0.004	0.003	0.005	0.004	0.004	0.005	0.004	0.005	0.003	0.002	0.002	0.001	0.001	0.002	0.005	0.0058
21 0.022 0.010 0.004 0.003 0.004 0.012 0.022 0.015 0.037 CAL 0.070 0.043 0.040 0.040 0.027 0.026 0.025 0.018 0.013 0.018 0.017 0.013 0.011 0.016 0.0220 0.023 0.015 0.015 0.018 0.008 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.026 0.022 0.016 0.021 0.011 0.009 0.011 0.015 0.021 0.011 0.004 0.015 0.015 0.015 0.018 0.008 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.006 0.002 0.016 0.007 0.008 0.010 0.015 0.021 0.011 0.004 0.015 0.015 0.015 0.015 0.011 0.004 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.016 0.006 0.007 0.008 0.010 0.007 0.008 0.010 0.012 0.007 0.010 0.027 0.013 0.011 0.028 0.012 0.009 0.005 0.004 0.004 0.004 0.004 0.005 0.024 0.044 0.049 0.018 0.005 0.006 0.006 0.007 0.006 0.005 0.005 0.005 0.005 0.004 0.020 0.014 0.005 0.014 0.010 0.0116 0.0116 0.016 0.017 0.026 0.016 0.006 0.012 0.013 CAL 0.046 0.008 0.009 0.007 0.008 0.010 0.009 0.007 0.007 0.007 0.016 0.017 0.033 0.012 0.029 0.0158 0.035 0.030 0.024 0.007 0.008 0.007 0.005 0.005 0.005 0.005 0.005 0.005 0.005 0.005 0.014 0.029 0.015 0.014 0.029 0.015 0.014 0.029 0.015 0.014 0.029 0.017 0.018 0.014 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 0.0412 0.018 0.020 0.022 0.015 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.008 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.005 0.005 0.004 0.004 0.005 0.005 0.006 0.008 0.004 CAL 0.009 0.007 0.008 0.007 0.008 0.009 0.009 0.009 0.009 0.009 0.008 0.010 0.016 0.023 0.005 0.008 0.000 0.008 0.009 0.009 0.009 0.009 0.009 0.009 0.009 0.008 0.010 0.006 0.008 0.009 0.009 0.008 0.006 0.010 0.006 0.009 0.009 0.009 0.009 0.009 0.009 0.009 0.009 0.008 0.006 0.006 0.008 0.009 0.009 0.009 0.009 0.009 0.009 0.009 0.008 0.006 0.009 0.009 0.009 0.009 0.009 0.008 0.006 0.010 0.006 0.009 0.009 0.009 0.009 0.009 0.009 0.009 0.008 0.006 0.009	19	0.013	0.026	0.021	0.023	0.009	0.012	0.012	0.014	0.007	0.007	CAL	0.006	0.006	0.005	0.005	0.005	0.007	0.009	0.013	0.019	0.015	0.007	0.028	0.040	0.0134
22 0.023 0.015 0.015 0.018 0.008 0.010 0.027 0.029 0.021 0.007 0.005 0.018 0.026 0.022 0.016 0.021 0.011 0.009 0.011 0.015 0.021 0.011 0.004 0.015 0.0157 23 0.013 0.020 0.006 0.009 0.014 0.023 0.010 0.013 0.011 0.010 0.007 CAL 0.010 0.006 0.007 0.008 0.010 0.012 0.007 0.010 0.027 0.013 0.011 0.028 0.0124 24 0.009 0.005 0.004 0.004 0.004 0.005 0.024 0.044 0.049 0.018 0.005 0.006 0.006 0.007 0.006 0.005 0.005 0.005 0.005 0.004 0.002 0.014 0.005 0.014 0.010 0.016 25 0.019 0.013 0.023 0.017 0.026 0.016 0.006 0.012 0.013 CAL 0.046 0.008 0.009 0.007 0.008 0.010 0.009 0.007 0.007 0.016 0.017 0.033 0.012 0.029 0.0158 26 0.035 0.030 0.024 0.007 0.008 0.007 0.005 0.005 0.012 0.033 0.037 0.010 0.010 0.009 0.010 0.014 0.013 0.010 0.009 0.012 0.015 0.014 0.029 0.057 0.0173 27 0.044 0.027 0.010 0.008 0.022 0.056 0.150 0.144 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 0.0412 28 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.008 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.005 0.004 0.004 0.0012 29 0.004 0.004 0.005 0.005 0.005 0.006 0.008 0.008 0.004 CAL 0.009 0.007 0.008 0.007 0.008 0.026 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 0.038 30 0.005 0.006 0.005 0.016 0.015 0.036 0.053 0.062 0.034 0.009 0.007 0.008 0.008 0.007 0.008 0.024 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 0.029 31 0.005 0.007 0.057 0.133 0.131 0.155 0.109 0.088 0.015 0.028 0.030 0.027 0.012 0.021 0.021 0.014 0.012 0.012 0.009 0.000 0.008 0.009 0.009 0.039	20	0.022	0.012	0.035	0.009	0.004	0.001	0.002	0.006	0.009	0.014	0.011	0.008	0.010	0.009	0.013	0.018	0.020	0.028	0.012	0.006	0.003	0.006	0.011	0.012	0.0117
23 0.013 0.020 0.006 0.009 0.014 0.023 0.010 0.013 0.011 0.010 0.007 CAL 0.010 0.006 0.007 0.008 0.010 0.012 0.007 0.010 0.027 0.013 0.011 0.028 0.0124 0.009 0.005 0.005 0.004 0.004 0.004 0.004 0.005 0.024 0.044 0.049 0.018 0.005 0.006 0.006 0.007 0.006 0.005 0.005 0.005 0.005 0.004 0.020 0.014 0.005 0.014 0.010 0.0116 0.017 0.013 0.013 0.013 0.023 0.017 0.026 0.016 0.006 0.012 0.013 CAL 0.046 0.008 0.009 0.007 0.008 0.010 0.009 0.007 0.007 0.016 0.017 0.033 0.012 0.029 0.0158 0.035 0.030 0.024 0.007 0.008 0.007 0.005 0.005 0.012 0.033 0.037 0.010 0.010 0.009 0.010 0.014 0.013 0.010 0.009 0.012 0.015 0.014 0.029 0.057 0.0173 0.014 0.027 0.010 0.008 0.022 0.056 0.150 0.144 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 0.0412 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.008 0.010 0.009 0.010 0.006 0.005 0.005 0.004 0.005 0.005 0.004 0.005 0.005 0.004 0.004 0.012 0.012 0.012 0.012 0.014 0.012 0.014 0.013 0.014 0.013 0.014 0.015 0.00	21	0.022	0.010	0.004	0.003	0.004	0.012	0.022	0.015	0.037	CAL	0.070	0:043	0.040	0.040	0.027	0.026	0.025	0.018	0.013	0.018	0.017	0.013	0.011	0.016	0.0220
24 0.009 0.005 0.004 0.004 0.004 0.005 0.024 0.044 0.049 0.018 0.005 0.006 0.006 0.007 0.006 0.005 0.005 0.005 0.005 0.004 0.020 0.014 0.005 0.014 0.010 0.0116 25 0.019 0.013 0.023 0.017 0.026 0.016 0.006 0.012 0.013 CAL 0.046 0.008 0.009 0.007 0.008 0.010 0.009 0.007 0.007 0.007 0.016 0.017 0.033 0.012 0.029 0.0158 26 0.035 0.030 0.024 0.007 0.008 0.007 0.005 0.005 0.012 0.033 0.037 0.010 0.010 0.009 0.010 0.014 0.013 0.010 0.009 0.012 0.015 0.014 0.029 0.057 0.0173 27 0.044 0.027 0.010 0.008 0.022 0.056 0.150 0.144 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 0.0412 28 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.008 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.005 0.005 0.004 0.004 0.004 0.012 0.012 0.012 0.014 0.012 0.006 0.008 0.010 0.009 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.005 0.005 0.004 0.004 0.005 0.0	22	0.023	0.015	0.015	0.018	0.008	0.010	0.027	0.029	0.021	0.007	0.005	0.018	0.026	0.022	0.016	0.021	0.011	0.009	0.011	0.015	0.021	0.011	0.004	0.015	0.0157
25 0.019 0.013 0.023 0.017 0.026 0.016 0.006 0.012 0.013 CAL 0.046 0.008 0.009 0.007 0.008 0.010 0.009 0.007 0.007 0.016 0.017 0.033 0.012 0.029 0.015 26 0.035 0.030 0.024 0.007 0.008 0.007 0.005 0.005 0.012 0.033 0.037 0.010 0.010 0.009 0.010 0.014 0.013 0.010 0.009 0.012 0.015 0.014 0.029 0.057 27 0.044 0.027 0.010 0.008 0.022 0.056 0.150 0.144 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 28 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.008 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.005 0.005 0.004 0.004 29 0.004 0.005 0.005 0.005 0.005 0.006 0.008 0.008 0.004 CAL 0.009 0.007 0.009 0.010 0.009 0.007 0.008 0.009 0.009 0.008 0.010 0.016 0.023 0.005 30 0.005 0.006 0.005 0.016 0.015 0.036 0.053 0.062 0.034 0.009 0.007 0.008 0.008 0.007 0.008 0.024 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 31 0.005 0.007 0.057 0.133 0.131 0.155 0.109 0.088 0.015 0.028 0.030 0.027 0.017 0.012 0.021 0.021 0.014 0.012 0.012 0.009 0.008 0.006 0.008 0.019 0.0398	23	0.013	0.020	0.006	0.009	0.014	0.023	0.010	0.013	0.011	0.010	0.007	CAL	0.010	0.006	0.007	0.008	0.010	0.012	0.007	0.010	0.027	0.013	0.011	0.028	0.0124
26 0.035 0.030 0.024 0.007 0.008 0.007 0.005 0.005 0.012 0.033 0.037 0.010 0.010 0.009 0.010 0.014 0.013 0.010 0.009 0.012 0.015 0.014 0.029 0.057 0.0173 27 0.044 0.027 0.010 0.008 0.022 0.056 0.150 0.144 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 0.0412 28 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.006 0.009 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.005 0.005 0.004 0.004 0.004 0.005 0.005 0.006 0.008 0.004 0.004 0.005 0.005 0.005 0.005 0.006 0.008 0.009 0.007 0.009 0.010 0.009 0.007 0.008 0.009 0.009 0.009 0.009 0.008 0.010 0.016 0.023 0.005 0.008 0.008 0.005 0.005 0.006 0.005 0.005 0.005 0.006 0.008 0.009 0.009 0.007 0.008 0.009 0.009 0.009 0.009 0.008 0.010 0.016 0.023 0.005 0.008 0.009 0.009 0.007 0.008 0.005 0.005 0.005 0.005 0.006 0.010 0.006 0.009 0.009 0.008 0.009 0.009 0.009 0.009 0.008 0.009 0.009 0.009 0.008 0.009 0.0	24	0.009	0.005	0.004	0.004	0.004	0.005	0.024	0.044	0.049	0.018	0.005	0.006	0.006	0.007	0.006	0.005	0.005	0.005	0.004	0.020	0.014	0.005	0.014	0.010	0.0116
27 0.044 0.027 0.010 0.008 0.022 0.056 0.150 0.144 0.028 CAL 0.028 0.035 0.028 0.032 ND ND 0.029 0.037 0.037 0.033 0.034 0.032 0.026 0.025 0.0412 28 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.006 0.009 0.010 0.009 0.010 0.006 0.005 0.005 0.005 0.005 0.005 0.004 0.004 0.001 0.012 0.006 0.008 0.009 0.007 0.009 0.010 0.009 0.007 0.008 0.009 0.009 0.009 0.008 0.010 0.016 0.023 0.005 0.008 0.005 0.005 0.006 0.035 0.025 0.034 0.009 0.007 0.008 0.007 0.008 0.024 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 0.020 0.020 0.0398	25	0.019	0.013	0.023	0.017	0.026	0.016	0.006	0.012	0.013	CAL	0.046	0.008	0.009	0.007	0.008	0.010	0.009	0.007	0.007	0.016	0.017	0.033	0.012	0.029	0.0158
28 0.018 0.020 0.022 0.012 0.016 0.017 0.018 0.016 0.012 0.006 0.006 0.006 0.008 0.010 0.009 0.010 0.006 0.005 0.005 0.004 0.005 0.005 0.004 0.004 0.004 0.004 0.001 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.016 0.023 0.005 0.008 0.010 0.016 0.023 0.005 0.008 0.005 0.006 0.005 0.016 0.015 0.036 0.053 0.062 0.034 0.009 0.007 0.008 0.008 0.007 0.008 0.024 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 0.019 0.020 0.038 0.010 0.010 0.038 0.0398	26	0.035	0.030	0.024	0.007	0.008	0.007	0.005	0.005	0.012	0.033	0.037	0.010	0.010	0.009	0.010	0.014	0.013	0.010	0.009	0.012	0.015	0.014	0.029	0.057	0.0173
29 0.004 0.005 0.005 0.005 0.005 0.006 0.008 0.008 0.008 0.004 CAL 0.009 0.007 0.009 0.010 0.009 0.007 0.008 0.009 0.009 0.009 0.008 0.010 0.016 0.023 0.005 0.0082 30 0.005 0.006 0.005 0.016 0.015 0.036 0.053 0.062 0.034 0.009 0.007 0.008 0.008 0.007 0.008 0.024 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 0.0200 31 0.005 0.007 0.057 0.133 0.131 0.155 0.109 0.088 0.015 0.028 0.030 0.027 0.017 0.012 0.021 0.021 0.014 0.012 0.012 0.009 0.000 0.008 0.006 0.019 0.0398	27	0.044	0.027	0.010	0.008	0.022	0.056	0.150	0.144	0.028	CAL	0.028	0.035	0.028	0.032	ND	ND	0.029	0.037	0.037	0.033	0.034	0.032	0.026	0.025	0.0412
30 0.005 0.006 0.005 0.016 0.015 0.036 0.053 0.062 0.034 0.009 0.007 0.008 0.008 0.007 0.008 0.024 0.026 0.026 0.019 0.022 0.032 0.036 0.010 0.006 0.0200 31 0.005 0.007 0.057 0.133 0.131 0.155 0.109 0.088 0.015 0.028 0.030 0.027 0.017 0.012 0.021 0.021 0.014 0.012 0.012 0.009 0.020 0.008 0.006 0.019 0.0398	28	0.018	0.020	0.022	0.012	0.016	0.017	0.018	0.016	0.012	0.006	0.006	0.006	0.008	0.010	0.009	0.010	0.006	0.005	0.005	0.004	0.005	0.005	0.004	0.004	0.0102
31 0.005 0.007 0.057 0.133 0.131 0.155 0.109 0.088 0.015 0.028 0.030 0.027 0.017 0.012 0.021 0.021 0.014 0.012 0.012 0.012 0.009 0.020 0.008 0.006 0.019 0.0398	29	0.004	0.004	0.005	0.005	0.005	0.006	0.008	0.008	0.004	CAL	0.009	0.007	0.009	0.010	0.009	0.007	0.008	0.009	0.009	0.008	0.010	0.016	0.023	0.005	0.0082
Monthly Average = 0.0190	31	0.005	0.007	0.057	0.133	0.131	0.155	0.109	0.088	0.015	0.028	0.030	0.027	0.017	0.012	0.021	0.021	0.014	0.012	0.012	0.009	0.020	0.008	0.006	0.019	0.0398
	}-																					 +	donthly	/ Avera	age =	0.0190

Maximum Hourly Average was 0.287 at Hour 22 on Day 9 with 1 occurences and the Number of Hourly Violations were 2

Maximum Daily Average was 0.0575 on Day 9 with 1 occurences and there were no Daily Violations

Operating Efficiency = 97.0 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

MEPA - Kuwait

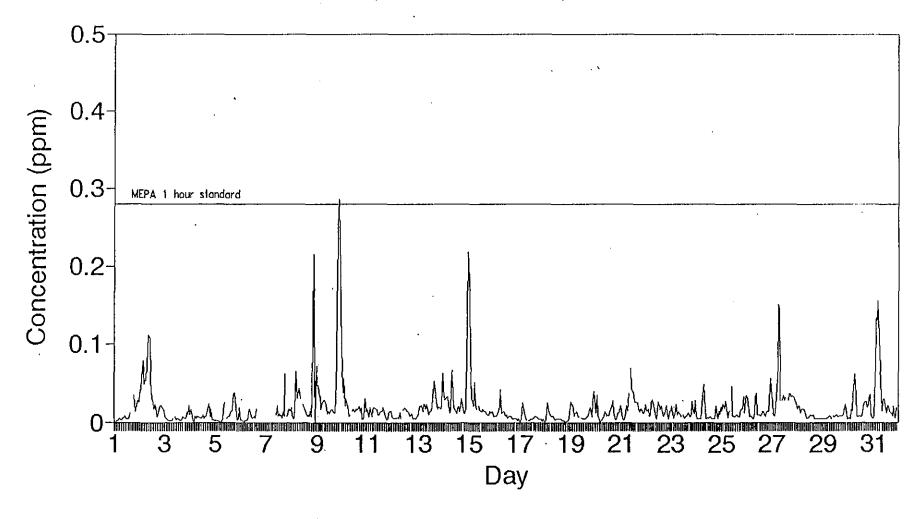
May 1991

Frequency Distribution

Hourly Averages for SO2 in ppm

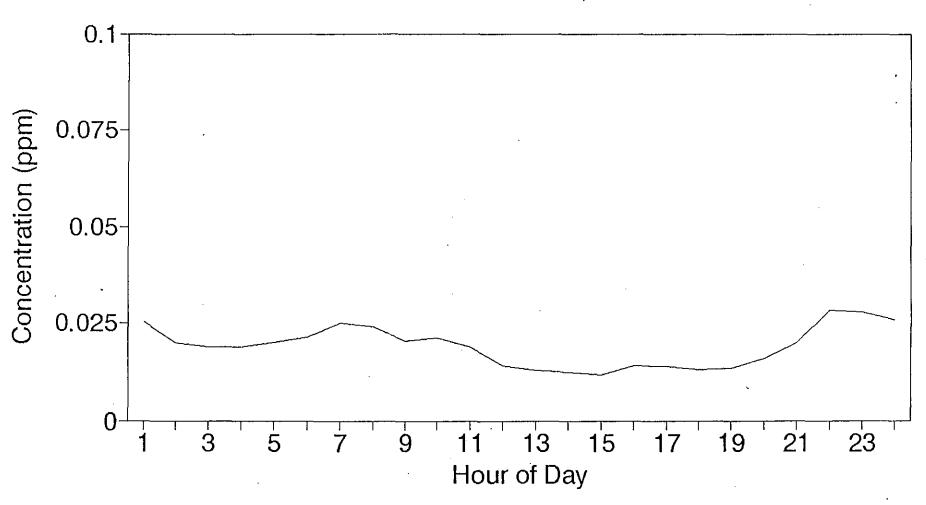
Concentration	# of Hours	Percentage (
0.000 - 0.020	527	. 74.5
0.021 - 0.060	150	21.2
0.061 - 0.110	16	2.3
0.111 - 0.170	8	1.1
0.171 - 0.340	6	0.8
0.341+	0	0.0

Hourly SO2 - May, 1991



--- SO2

Diurnal SO2 - May, 1991



- SO2

MEPA - Kuwait

June 1991

Hourly Averages for Direction(degrees)

Kour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day [-O-F-				·																	······································	********	→Average
1	325	328	326	324	326	322	323	328	337	0	16	15	21	21	15	16	19	8	325	309	309	324	320	307	341.43
. 2	304	319	355	330	327	321	331	336	348	354	1	338	341	312	307	326	322	320	317	307	305	308	315	323	326.00
3	323	324	328	328	328	325	323	320	324	0	323	329	331	333	331	329	335	338	339	338	329	323	322	322	329.32
4	322	322	317	310	299	304	319	323	321	328	327	326	324	326	328	333	332	332	339	339	333	326	319	313	
5	287	291	309	313	311	314	319	323	327	0	330	333	328	330	332	334	334	338	337	327	332	330	325	318	324.34
6	318	322	325	322	321	316	313	327	323	335	342	341	341	337	338	343	341	349	6	10	17	18	17	357	340.55
7	349	323	320	329	331	332	330	312	320	326	330	333	334	334	338	336	334	331	328	329	327	323	317	312	328.25
8	315	319	319	320	317	319	319	327	332	0	333	. 337	332	337	332	330	328	333	337	336	329	333	321	324	328.66
9	325	332	342	329	323	276	283	300	324	313	314	324	325	338	333	336	340	337	337	332	330	325	319	314	323,29
10	311	288	279	289	279	292	311	313	311	0	315	318	322	328	325	323	322	320	322	326	333	349	352	349	318.25
11	312	289	280	303	317	313	302	323	342	344	341	340	333	340	338	325	323	322	326	328	330	337	347	356	325.69
12	1	0	353	354	341	359	5	5	9	0	18	22	23	20	12	341	340	346	16	15	14	12	14	36	5.69
13	25	33	9	304	287	291	1	327	284	336	0	15	15	15	16	28	47	51	17	300	248	278	7	5	350.91
14	337	326	.267	324	337	297	318	334	339	344	341	21	42	43	91	138	130	172	218	302	256	261	260	262	316.63
15	261	268	272	251	265	260	261	266	277	0	358	354	96	80	128	123	123	134	136	128	153	160	188	266	211.71
16	242	242	253	271	275	288	279	280	290	332	338	22	47	63	118	145	140	141	172	264	281	281	280	315	276.59
17	326	329	327	327	328	326	327	325	327	0	332	325	331	328	326	332	331	333	333	325	323	310	308	306	326.84
18	306	301	303	294	294	309	309	314	313	309	317	331	333	333	318	331	334	337	335	324	315	303	285	275	313.55
19	283	286	283	283	280	292	303	306	309	310	309	349	26	61	91	119	102	143	151	197	247	232	247	238	280.90
20	284	326	317	308	307	327	331	340	19	0	45	80	131	145	144	139	141	127	131	162	179	200	253	246	239.79
21	238	186	168	131	171	173	183	207	213	232	239	137	126	149	149	160	158	161	159	165	174	179	186	198	175.90
22	219	243	249	229	148	161	171	234	277	0	104	121	128	113	122	134	140	137	112	92	112	103	100	102	141.59
23	111	126	150	196	··134	268	288	11	41	34-	53	66	84	92	111	124	99	124	146	167	191	225	225	165	125.61
24	195	184	169	210	244	255	275	272	264	0	283	106	112	12	86,	129	132	129	146	177	196	230	232	245	199.05
25	240	229	130	137	192	227	248	241	257	288	330	67	0	126	151	155	176	181	167	167	175	198	215	212	195.59
26	210	164	126	179	138	142	137	125	102	115	121	134	125	132	135	92	74	107	111	126	121	113	117	117	126.55
27	119	104	131	131	94	84	78	78	65	0	65	57	70	75	79	88	96	111	109	338	286	281	3	31	74.72
28	315	335	18	310	307	357	71	32	4	346	340	12	25	45	81	94	100	127	154	184	242	272	267	260	0.92
29	254	251	253	261	269	265	267	269	283	318	347	331	339	334	324	326	338	341	341	337	329	314	310	322	306.08
30	327	324	322	323	311	295	291	310	312	0	318	326	332	333、	336	333	336	334	331	327	329	331	329	304	323.96
<u> </u>		_																			⊣	Monthl	y Aver	age =	326

Operating Efficiency for Wind Direction = 100.0 percent Last Instrument Calibration Date - unknown [CEM] ** = missing or no data

MEPA - Kuwait

June 1991

Hourly Averages for Wind Speed(meters/sec)

Hour ay —	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily ⊢ Average
1	3.5	3.6	3.1	3.6	3.4	3.3	2.5	3.2	3.6	0.0	6.4	8.1	8.2	7.8	8.1	7.8	8.0	5.8	2.4	2.5	2.7	2.9	2.3	2.6	4.39
2	3.6	2.2	2.6	2.5	2.7	2.1	2.6	2.1	2.5	2.6	3.5	, 2.9	2.5	3.9	4.1	2.7	2.3	3.2	2.5	3.6	4.3	4.6	5.0	6.3	3.20
3	6.7	7.1	8.4	8.4	7.3	6.9	7.4	7.6	8.2	0.0	8.6	8.7	8.6	8.6	9.0	8.4	7.5	6.3	5.2	5.0	5.4	4.6	4.7	4.1	6.78
4	4.0	4.0	3.8	4.3	4.0	4.5	5.8	6.7	6.9	7.6	8.6	9.2	9.2	8.6	9.3	8.7	7.9	6.7	5.9	5.5	5.1	4.6	4.2	5.0	6.25
5	4.5 .	4.8	5.7	5.6	6.3	6.3	6.2	7.4	8.6	0.0	9.3	8.2	9.1	9.5	9.3	8.9	8.2	6.6	5.8	4.9	5.3	4.9	3.7	3.7	6.37
6	4.3	4.7	4.2	5.3	4.9	5.4	6.1	4.4	3.2	4.3	5.0	5.2	5.8	6.2	6.8	6.4	5.7	4.6	2.9	2.7	3.3	2.5	2.2	1.2	4.47
7	1.3	1.4	2.4	3.7	4.2	3.9	3.8	6.5	7.0	8.6	9.0	9.1	8.7	8.4	8.2	8.3	8.1	7.8	6.9	5.9	5.4	5.3	5.2	6.1	6.05
8	6.0	6.2	5.6	6.0	5.0	5.0	5.0	4.3	4.6	0.0	7.1	7.0	6.8	6.3	7.5	7.8	7.2	6.4	5.0	4.8	4.1	3.6	3.6	4.0	5.37
9	4.0	5.1	4.6	4.2	3.8	4.1	4.7	5.8	6.5	7.7	7.9	8.3	7.7	7.7	8.0	8.2	7.3	6.4	6.1	5.4	4.7	4.1	4.0	4.5	5.87
10	4.1	4.1	3.4	3.3	3.4	4.9	5.5	6.3	7.2	0.0	8.0	10.0	10.6	9.5	9.5	9.2	8.2	6.3	4.9	3.8	3.6	3.2	2.4	2.2	5.57
11	1.8	2.8	2.6	3.3	3.5	3.9	4.1	3.5	3.5	3.4	5.8	6.3	6.5	5.8	6.2	7.1	6.6	6.2	4.7	4.6	4.2	3.4	2.2	2.3	4.35
12	3.2	3.2	4.0	3.3	2.7	2.8	2.7	3.3	4.0	0.0	4.5	5.0	4.7	4.3	4.4	4.6	5.0	5.1	4.1	4.9	5.4	4.7	3.4	2.3	3.82
13	2.4	1.7	2.0	1.1	1.4	1.2	2.1	1.7	3.0	2.4	4.4	5.2	5.4	5.9	5.3	4.1	3.8	2.5	3.9	2.6	2.4	1.9	2.7	2.7	2.99
14	1.9	1.6	2.4	2.3	2.4	2.2	1.6	2.2	2.7	2.7	3.7	6.9	4.9	3.9	2.3	1.2	1.4	1.0	1.0	0.9	2.4	3.7	3.8	3.8	2.62
15	3.5	2.7	2.7	3.8	3.6	3.8	4.0	2.4	3.5	0.0	3.4	2.2	1.0	2.2	2.8	2.8	2.5	2.2	2.4	1.6	1.7	1.7	2.8	3.7	2.62
16	4.3	5.4	5.1	3.7	3.8	2.8	2.7	2.8	2.7	3.0	2.4	3.0	2.1	1.6	1.6	0.9	1.4	1.5	1.5	2,4	2.7	2.6	3.4	3.9	2.80
17	5.1	5.4	5.3	5.6	5.1	4.5	4.5	4.1	6.3	0.0	7.5	9.0	8.9	8.7	8.8	8.6	8.4	7.4	7.6	6.8	5.9	7.0	7.6	7.8	6.50
18	7.5	6.9	7.7	6.0	5.5	7.5	8.8	8.6	9.4	10.5	9.1	9.1	8.0	8.0	7.3	7.4	6.8	6.4	5.6	3.8	3.7	4.9	4.8	4.3	6.98
19	4.9	5.4	6.2	6.1	5.4	4.8	6.1	6.8	8.5	7.6	6.1	4.4	3.9	4.9	4.0	3.7	3.2	3.6	2.5	2.0	2.7	2.5	2.9	3.7	4.66
20	3.5	2.3	2.5	3.7	0.0	2.2	2.2	2.6	2.3	0.0	2.8	3.4	6.1	6.2	6.5	4.9	4.5	2.6	2.2	3.0	4.2	4.2	3.3	4.1	3.30
21	3.5	2.1	1.4	1.8	1.0	2.0	2.3	2.1	2.2	2.6	2.8	0.7	1.2	2.5	4.5	6.5	6.5	6.2	5.9	6.7	6.0	5.7	4.5	5.9	3.61
22	5.3	5.4	4.2	3.9	3.1	2.3	2.0	1.8	1.4	0.0	2.5	1.5	1.6	2.0	3.2	4.9	4.8	3.9	3.5	3.5	2.5	2.0	2.2	3.0	2.94
23	3.0	3.4	2.0	0.9	0.0	0.0	0.1	0.1	2.2	3.3	3.0	3.5	4.6	5.0	3.1	1.2	2.8	3.0	3.1	2.6	2.2	1.9	2.0	0.7	2.24
24	1.5	1.0	0.2	1.1	0.4	1.5	2.3	2.6	2.3	0.0	2.4	8.0	1.8	1.1	2.2	1.5	1.3	4.0	3.7	3.5	3.2	2.9	3.1	4.2	2.03
25 24	3.7	4.0	4.2	2.4	1.3	1.8	3.1	3.3	3.3	1.6	0.1	2.0	0.0	5.1	5.7	6.0	5.9	6.0	6.7	5.8	5.6	2.9	3.2	4.4	3.67
26 27	4.7	1.6	2.9	3.5	1.3	3.0	3.3	1.8	3.9	3.1	5.3	5.1	5.2	5.7	6.7	5.0	4.6	4.9	4.3	4.3	4.1	2.5	1.7	1.7	3.76
27 28	2.3	2.0	1.2	1,2	1.7 2.4	1.2	1.8	1:8	1.3	0.0	0.6	1.1	2.2	2.8	3.2	3.3	3.5	3.3	1.2	0.0	0.5	0.0	0.0	0.0	1.51
28 29	3.6	0.1 3.7	0.0 3.7	1.0 4.0	2.4 3.7	0.2	0.1 3.6	2.0 3.4	2.3	2.9	2.6	3.8	4.5	4.0	1.9 7.7	1.7	1.5	0.5	0.0	0.0	0.0	1.0 3.7	1.9 4.9	3.0	1.56 4.72
30	5.9	5.3	5.1	4.0		4.1			3.1	2.8	4.0	5.7	5.9	7.3		7.5	6.7	6.3	4.9	4.7	3.8	5.0		4.6	4.72 5.84
J	7.7	J.J	2.1	4.9	4.6	4.0	5.6	6.9	7.1	0.0	7.3	8.3	8.3	7.7	8.3	7.9	7.2	6.2	5.6	5.3	5.6 —	و.د Monthl	4.1 y Aver	4.3 age =	4.23

Maximum Hourly Average Wind Speed was 10.6 meters/sec at Hour 13 on Day 10

Maximum Daily Average Wind Speed was 6.98 meters/sec on Day 18

Operating Efficiency for Wind Speed = 100.0 percent ** = missing or no data - Last Instrument Calibration Date - unknown

[CEM]

Last Instrument Calibration Date - unknown

Operating Efficiency for Wind Direction = 100.0 percent

** = missing or no data

Operating Efficiency for Wind Speed = 100.0 percent

Maximum Daily Average Wind Speed was Maximum Hourly Average Wind Speed was

7 meters/sec on Day 18 and Wind Direction was from the NW

. WM and mort sew noitoanid bnik bns Of yed no If now to section was from the WM .

wonthly Average ≈ MNNY WNN8 WNNB WN8 MNZ NO MNZ MNZ MNM9 MNM5 MNS MN7 MNS MNS MNN9 OE MNNS MNN9 MNNS MNN9 MNN2 WNNB WNNB MN9 MNMS MNB MNNO MNN9 לאאא MNS MΣ ለታ 'n۶ Mb M۶ MSM5 MSM5 MSM5 MNN9 MNR MNNZ MNS MNNS MNNS MNNZ MNS MNNE SN SAME OENE NO MNL ONNE MNNO MNO S0 OSSE BSO SE 32 32 **THE** THINE 2NNM CHNE SNM NZ MΣ MZ ML. MSMO JENE ΒL 383Z 22 BNBL NO SEME SENE 32 **3SL** 12E 383Z NO MO MNMO MNNO JEZE 3E2E 37 3£ 3E 3ENE SENE JENE SENE ONNE SEZE **TESE** 2EZE PERE 36 **SEE 3S9 2SE** SESE SSE **ZEZE** 3S37 SZE **32E** 32E 3SL 57 32E SSSE MSSS 92 SESE **TESE TRE** 3S7 SERE MNNO SMMM MSMS MSME NSZ MSSL SZE **TSP** MST MSM7 SZ MSE MSSE **S9** 3889 **JSSL S9 S9** 9SS9 BSS9 **PSE** NO SENE MSME MSS7 MSS7 SΕ SESE JEZE NO MΖ MΣ SM MSMZ MSMO MSSL S0 SI St SSSM MSSS **3**S5 3S7 J SE SSE JUNE MNMZ MSM7 MSΣ MSΣ S۶ MSSZ NO MO 3SO MSSL SSSE 38£ S2 RESE 3E2E 3NE 2NE SNE MNMO MSZ SZ 32SE 3SΣ 3SE 3Ε 1SE 35 35 4ENE SSE **JSSE** SZM SS 3ESE SESE SZE SER SESE NO ML MSZ SZ SZZE **322E** MST MSM7 MSMS MSS 38£ **ZEZE** SE SER SESE 37 **TESE 3**57 **22E** 2SE SZ SZ SĮ SZE **BSSL** SZ MSM5 ız **JSSZ** 9SSE **3889 9889 2889** 3SS7 SSSE 1SE 38 L MSME SSSM 3SM MSSZ MSS9 57 59 59 57 355´ **3**\$9 **92E 92E** 36 **3NE** NO ZNNZ MNNS SNNM MNNZ MNO MN7 MNZ MNZ MNM5 ∃SS£ SZE 38£ **BSS** MSM7 MSMS MSS7 57 MSMS MNM9 MNMS MS MNM9 MNM9 MNMS MNMS MSMS MSSZ SSSE ∃S'n **ZEZE** #ESE 37 **2ENE** THIS N'n MN9 WN8 MN8 MNZ MSMS MSZ. MS MSM7 MN6 MN6 MNR MNM9 MNM9 MNM8 MNMZ WN8 81 MNNZ MNNZ MNZ WNN8 WNNS MNN6 MN6 MNOL MN6 MNZ MNMS MNMS MN7 ለዘታ WNN3 MNN9 MN7 MNNS MNS MN9 MNZ WNNB MNNZ WNNB MNNA MN6 MNN6 MNN6 MN6 WNN8 NO MNN9 MN7 MNN7 MNNS MNN9 MNNS MNN9 WNB MNR MNZ MNNS MNMS MΣ MΣ MNMS Mb MT MSMS MSMS MSM7 9٤ МΣ MZ SZ SSE **JSL** 381 SESE SENE SNE SNNM 3NNE MΣ MΣ MΣ SSE SE 31 SN NΣ NO Mb MZ Мħ Mt Mb MSM7 MΣ MΣ Mħ S١ SSSE SZE SZE SEZE RESE 3\$£ SΣ SSSE MSSE SNNM ZMMM SKNM ΜZ SNM カレ MNML MSL SL 3SL **JSE** SE HIP PNE THAM YANE MNNS ZNNM SNNM NNZ NNZ MNS ሸን M'n SMSM MNNZ SM MNL SN SNNE JZ SNNE NΣ ΝZ MSMZ MNMS **THIRE** SNE 3N7 THIS SNNS PNN9 **SNNE** PANE N۶ ZNNM MNMS MNML MNML NΣ NΣ マルハケ **THANE** SNNE PANE THIRE NO NΣ NΣ NΣ NΣ N۶ NΣ NS SI **SNNE 2NNE THANE** MNNS MNNS MNNS N۶ SNE **ZNNE SNNE** SNM MND MN7 MNME MΣ MNMS LL MNN5 MNS MN9 MNZ MNZ MNN9 MNN9 MNN9 MNN9 MNN9 MNNS MNN7 MN7 MNM5 NZ SNNN MNNS MNNS MN7 MN9 MN9 MNMS MΣ MNMS MΣ ለለለታ MN7 01 MN6 MNOL MNNOL MNLL MNOL WN8 NO MNZ NZ NZ NΣ MNN5 MN7 MNS MN9 WN8 MN9 M'n MNNS MN7 MN7 MNT MNNS MNNS MNN9 MNN9 MNNZ SNNN. WNNB WNN8 WNB WNB WNB MNO MN9 MNM9 MNMS MN7 לאאא MNNS MN9 MN5 MN9 MN9 MNN7 MNS MNS MNS MN9 MN9 MN7 MNN5 MNN MNNS MNNS MNN9 MNNZ MNN8 WNNB MNN9 MNNZ MNNZ MNNZ ИO MNNS MN7 MNNS MNN7 MNN7 NNZ MNL NL Z MN6 MN9 MNN7 MNN7 MNS WWW WNN8 WNN8 WNNB WNN8 MNN6 MNN6 MNN6 MNZ MNN9 MN9 MNS MNNS MNN9 MN7 MNS MN7 Nς MNN9 MNNS MNNS **MNN**り MNS MNN7 MN9 MNS MNS MNS SAME 3NNE NΣ Nς MNN9 MNNZ MNN9 MNN7 NL SAME MNZ MN9 MN9 MN9 MN9 MNMS MNM7 S NO MNN6 MN9 MN9 MN7 MN7 MNNS MNNS MNN9 MNNZ WNNB MNN6 MNN6 MNNOL MNN6 BNNW MNN6 MNN9 MNN9 MNNZ WNNB MNN6 MNN6 MN6 MN6 MN6 MNN6 WNN8 MNZ MNZ MN9 MN7 למאמ MN7 MN7 MN5 MN7 MN9 MNS MN7 NO MN8 WNB MNZ MNZ MNNZ **BNNW** WNN8 MNZ MNZ E MNNS MNN9 WNN8 MNN6 MNN6 MNN6 MNN6 MN6 MNNZ MNS MNS MNNS MNNZ NNNZ MNNS MNZ MNNS ZNNM NΣ MNZ ለበን SHM MNS MN7 SNNM MNNE NΣ MNS MN9 MNS MNS MN7 MN7 ハハケ 8NNE NO MNN7 MNNE MNZ MNS MNS MNT MNS MNN5 MN7 NNZ SMM N9 SNNE SNNE SNNE 8NNE **PANE SUNE** MNN7 MNE NNS MNΣ MNΣ Yed Average Hour Ylisd 57 52 ZZ ız 50 61 81 2١ 91 S١ ٦l Σ١ Z١ 10 6

Nourly Averages for Wind Speed(meters/sec) and Direction

1661 anut MEPA - Kuwait

MEPA - Kuwait

June 1991

Hourly Averages for Pressure in millibars

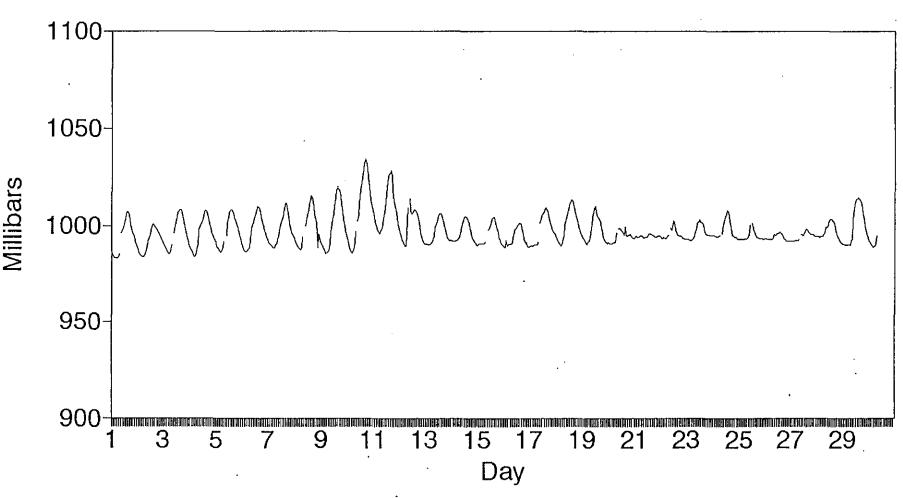
Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	- 21	22	23	24	Daily
Day } 1	986	985	984	983	983	984	984	984	986	ND	997	998	1001	1004	1006	1007	1007	1006	1003	999	996	994	992	990	→ Average 993.9
2	989	988	986	985	984	984	984	984	986	989	992	994	996	998	1000	1007	1007	1000	998	997	996	995	994	993	992.2
3	992	990	989	988	987	986	986	988	990	ND	996	1000	1002	1005	1007	1008	1008	1007	1005	1002	999	997	995	993	996.5
4	991	989	987	986	985	984	985	988	991	998	1000	1000	1002	1005	1007	1008	1007	1006	1003	1001	999	997	994	993	996.1
5	991	990	988	987	987	987	988	989	994	998	1000	1002	1004	1006	1008	1010	1009	1007	1004	1002	999	997	996	994	997.4
6	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	ND	NĐ	ND	****								
7	993	992	991	990	989	988	989	990	991	993	995	998	1001	1004	1006	1009	1011	1011	1008	1004	1001	999	997	995	997.7
8	993	992	990	989	989	988	988	988	994	ND	1000	1004	1006	1008	1011	1014	1015	1014	1010	1006	1002	989	996	994	999.1
9	992	990	989	988	986	985	986	987	991	997	1000	1004	1006	1010	1015	1018	1019	1018	1015	1011	1007	1003	1000	997	1000.6
10	995	993	990	988	986	986	987	991	997	ND	1003	1006	1012	1018	1024	1029	1032	1034	1033	1030	1025	1020	1016	1012	1009.0
11	1008	1005	1002	1000	998	997	996	997	998	999	1004	1009	1013	1020	1025	1026	1027	1028	1026	1018	1013	1008	1005	1001	1009.3
12	999	997	995	993	992	990	990	990	1009	ND	1014	1008	1006	1007	1008	1008	1008	1007	1004	1000	997	994	993	991	1000.0
13	991	991	991	991	990	991	991	992	993	995	999	1001	1003	1005	1006	1006	1005	1003	1000	998	996	995	993	993	996.6
14	993	993	992	992	992	992	993	993	994	996	998	1001	1004	1005	1005	1004	1003	1001	998	996	994	993	991	991	996.4
15	990	990	991	991	991	991	991	991	992	ND	998	998	999	1002	1004	1004	1005	1003	1000	997	994	993	991	990	995.5
16	990	989	989	993	990	990	990	991	991	994	997	. 998	999	999	1000	1002	1001	999	996	993	992	991	990	989	993.9
17	989	990	990	990	990	990	990	990	992	ND	1001	1004	1006	1008	1009	1009	1008	1007	1005	1002	1000	998	997	996	998.3
18	995	993	992	991	990	990	991	992	995	1001	1005	1007	1010	1011	1013	1014	1013	1011	1008	1005	1002	1000	998	997	1001.0
19	995	994 991	993	992	991	990	991	992	996	1000	1005	1007	1010	1010	1007	1005	1004	1002	998	996	994	993	992	991	997.8
20 21	991 994	991 994	991 995	991 994	991 994	991	991	991 995	997 995	ND	998	999	998	998	997	995	999	996	995	995	995	996	995	994	994.6
22	995	994	994	994	994	994 994	995 994	994	996	994 ND	994 999	994 998	994 1000	995 1003	996 1001	996 998	996 997	995 995	995 995	995 995	995 994	994 994	995 994	995 994	994.7 995.9
23	993	993	993	993	993	993	993	994	996	997	999	1002	1000	1003	1001	1002	1001	998	996	996	995	995	995	995	996.6
24	995	995	995	994	994	994	995	995	995	ND	996	1002	1002	1005	1002	1002	1005	1001	997	995	995	994	994	993	997.8
25	993	993	994	993	993	993	994	994	994	994	997	1001	ND	1002	999	997	996	995	994	994	994	994	994	993	995.0
26	993	994	994	993	993	993	993	993	994	996	996	995	996	996	996	997	996	995	994	993	993	992	992	992	994.1
27	992	992	992	992	992	993	993	992	993	ND	996	996	995	997	998	999	998	997	996	996	996	996	995	995	994.8
28	995	995	995	995	995	995	995	996	997	999	1000	1002	1003	1004	1003	1003	1003	1001	999	996	994	992	992	991	997.5
29	991	991	991	990	990	990	990	990	993	993	1004	1009	1012	1013	1014	1014	1014	1013	1010	1006	1003	1000	998	996	1000.6
30	994	993	992	990	989	989	990	991	995	ND	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	991.4
-																						onthly		•	997.5

Maximum Hourly Average was 1034 at Hour 18 on Day 10 with 1 occurences

Maximum Daily Average was 1009.3 on Day 11 with 1 occurences Operating Efficiency = 92.9 percent

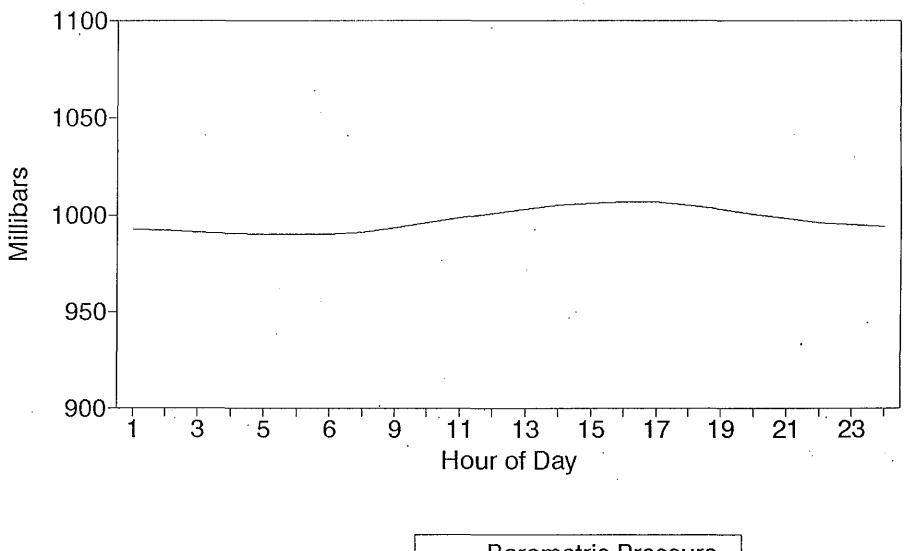
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

Hourly Barometric Pressure — June, 1991



Pressure

Diurnal Pressure - June, 1991



Barometric Pressure

MEPA - Kuwait

June 1991

Hourly Averages for Solar Radiation in Watts/ M2

Hour	1	2	3	4	. 5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day					······································																				- Average
1	0	0	0	0	1	29	70	142	368	ND	692	736	740	622	479	320	185	60	5	0	0	0	0	0	193.4
2	0	0	0	0	4	34	61	76	179	289	299	301	378	340	228	140	78	33	2	0	0	0	0	0	101.8
3	0	0	0	0	13	85	193	313	589	ND	780	843	852	798	703	560	357	109	8	0	0	0	0	0	269.7
4	0	0	0	0	11	78	201	293	565	666	775	827	813	716	486	356	232	86	6	0	0	0	0	0	254.6
5	0	0	0	0	12	85	196	265	434	517	575	554	568	552	443	270	119	50	5	0	0	0	0	0	193.5
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND -	ND	ND	****
.7	0	0	0	0	11	59	153	167	248	307	417	457	488	571	547	494	327	129	11	0	0	0	0	0	182.8
8	0	0	0	0	5	36	90	117	208	ND	714	803	825	788	688	550	323	121	10	0	0	0	0	0	229.5
9	0	0	0	0	6	.59	137	105	405	661	757	815	830	783	677	501	284	99	7	0	0	0	0	0	255.3
10	0	0	0	0	13	63	204	327	603	ND	797	840	763	748	670	548	369	158	11	0	0	0	0	0	265.8
11	0	0	0	0	6	39	121	135	170	521	776	841	872	812	724	599	415	206	29	0	0	0	0	0	261.1
12	0	0	0	0	1	30	107	124	497	ND	662	729	805	780	704	592	425	203	19	0	0	0	0	0	246.9
13	0	0	0	0	18	112	207	155	308	509	660	795	781	752	499	273	130	49	7	0	0	0	0	0	219.0
14	0	0	0	0	3 ,5	53	125	183	351	572	677	788	515	353	292	186	97	28	3	0	0	0	0	0	176.2
15	0	0	0	0	0	4	26	95	199	ND	402	315	494	511	423	295	163	50	5	0	0	0	0	0	129.7
16	0	0	0	0	0	7	24	47	142	384	258	244	272	302	281	168	92	36	7	0	0	0	0	0	94.3
17	0	0	0	0	1	23	47	112	459	ND	726	792	799	756	602	289	131	56	9	0	0	0	0	0	208.8
18	0	0	0	0	4	51	184	211	516	630	719	781	768	718	665	495	266	82	11	0	0	0	0	0	254.2
19	0	0	0	0	5	47	194	169	448	628	720	705	673	437	379	463	301	68	7	0	0	0	0	0	218.5
20	0	0	0	0	3	33	110	148	370	ND	421	441	481	346 -	13	0	0	0	0	0	0	0	0	0	102.9
21	0	0	0	0	0	0	0	0	0	6	15.	35	58	203	307	261	102	28	0	0	0	0	0	0	42.3
22	0	0	0	0	0	16	55	94	187	ND	265	227	397	270	219	271	146	48	8	0	0	0	0	0	95.8
23	0	0	0	0	2	38	142	202	450	558	649	657	687	701	585	363	200	84	20	0	0	0	0	0	222.4
24	0	0	0	0	0	6	25	48	145	ND	169	508	525	421	342	200	100	43	9	0	0	0	0	0	110.5
25	0	0	0	0	0	1	0	23	60	299	365	289	ND	210	113	71	9	4	1 -	0	0	0	0	0	62.8
26	0	0	0	0	0	0	2	7	3	3	8	59	41	95	178	109	83	29	5	0	0	0	0	0	25.9
27	0	0	0	0	0	0	11	61	195	ND	182	101	73	149	269	249	127	30	4	0	0	0	0	0	63.1
28	0	0	0	0	2	37	141	216	408	433	419	552	592	408	213	322	133	49	14	.0	0	U	0	0	164.1
29	0	0	0	0	0	16	46	103	230	321	788	863	852	779	668	503	325	144	24	0	0	0	0	0	235.9
30	Ō	0	0	0	3	42	236	236	575	ND	782	830	813	709	566	435	265	90	12	0	0	0	. 0	0	243.2
																					Mo	nthly.	averag	e =	176.8

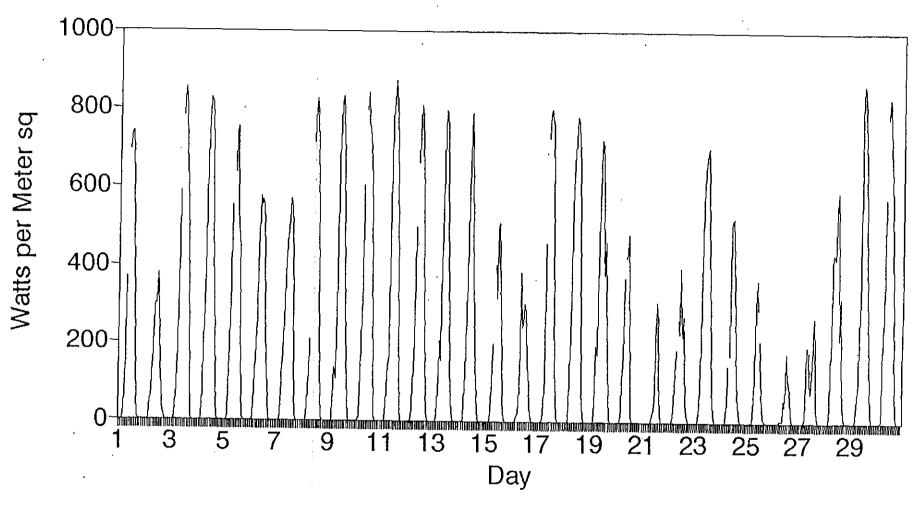
Maximum Hourly Average was 872 at Hour 13 on Day 11 with 1 occurences

Maximum Daily Average was 269.7 on Day 3 with 1 occurences

Operating Efficiency = 94.9 percent

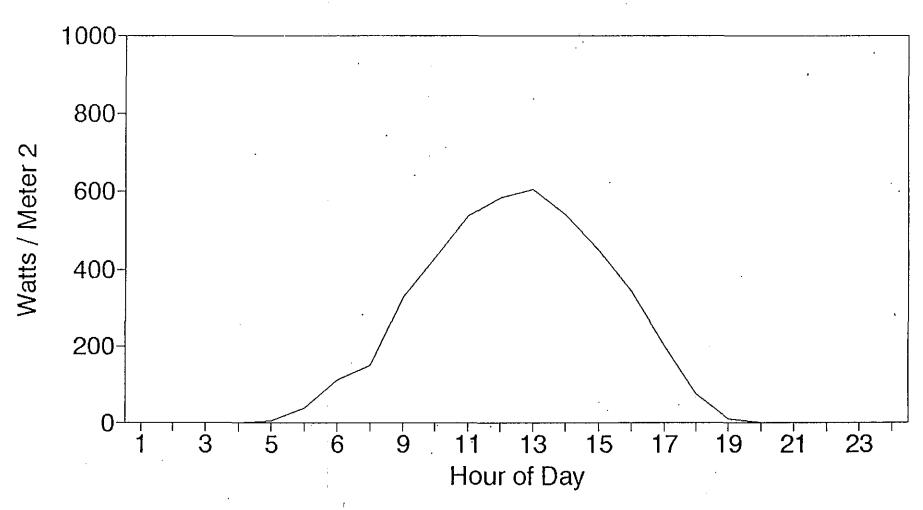
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

Hourly Solar Radiation - June, 1991



Solar Radiation

Diurnal Radiation - June, 1991



Solar Radiation

MEPA - Kuwait

June 1991

Hourly Averages for Relative Humidity in Per Cent

Hour Day ⊨	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily —∣ Average
1	18.5	18.8	19.2	19.6	19.5	19.3	19.6	19.4	18.1	ND	15.6	14.5	13.5	12.9	12.0	12.0	12.6	13.1	14.1	14.8	15.2	15.6	16.4	17.3	16.16
2	18.1	19.2	20.3	20.0	19.9	21.2	20.8	19.8	18.4	17.5	16.9	16.7	16.3	14.6	13.6	13.1	13.3	13.7	14.6	15.0	15.2	15.8	16.5	17.9	17.02
	18.9																				14.4			16.1	16.00
4	16.7	17.3	17.8																	14.6	14.7	15.3	15.6	15.9	15.10
5	16.8	17.3	17.6	18.0	18.2		18.1	17.7	17.0		15.1		13.4	13.0	13.0	13.8		15.7	16.4	16.8	17.3	18.2	18.7	19.3	16.45
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	20.4	21.6	22.4			23.1	22.3	21.7			17.7											19.4	20.4	21.3	18.86
	21.6		23.0	24.0			22.9	22.2			15.4											15.2		16.5	16.85
	17.2																				13.6			15.6	14.50
	15.8			16.5																	12.2			14.1	13.12
	14.8																								14.57
12				18.2							15.3											18.1		19.8	16.37
13	21.2			21.8																		18.2		19.3	18.76
15	19.8																				13.8			15.6	16.52
	15.6 18.8			16.6																	12.9 14.9			16.3	14.19 14.42
17				19.2																	13.6			13.6	14.42
18	13.6																				12.9			13.5	12.92
19																									16.27
20	18.9	19.0																			26.9				24.88
21	21.9			33.6																				25.2	25.12
22	25.2	26.9						31.8			32.3										86.2		91.6	93.3	52.04
23	94.2	94.3	94.4	94.6	94.6	93.7	93.6	87.0	58.1												53.6	49.8	45.4	58.9	62.59
24	59.7	56.8	60.1	64.2	53.2	42.9	36.5	34.1	27.1	ND	21.1	19.5	23.3	13.8	22.9	33.7	29.9	47.7	50.0	37.3	27.9	25.7	26.6	23.3	36.40
25	19.7	17.8	34.6	49.9	39.9	26.2	23.7	22.4	19.3	16.1	12.5	13.5	ŃD	30.1	30.5	28.4	27.8	27.2	25.5	23.7	20.4	19.2	19.9	21.2	24.76
26	20.3	23.4	53.6	50.6	46.7	51.5	57.4	48.3	66.2	86.1	84.3	76.4	67.8	66.6	56.8	57.2	8.03	56.9	59.0	52.3	48.1	58,2	61.2	69.9	57.48
27	76.6	82.7	81.6	78.1	86.3	84.6	84.5	85.0	82.6	ND	63.9	65.5	70.0	72.4	59.8	58.6	59.4	73.5	76.4	75.5	72.6	67.7	69.1	74.9	73.97
28	76.9	68.5	78.4	85.9	81.1	85.6	84.4	69.9	45.0	39.1	29.0	24.7	21.3	19.6	24.0	21.8	21.2	19.7	19.4	20.9	21.2	20.9	21.1	22.8	42.60
29	23.5	22.6	21.8	22.0	20.8	20.2	20.0	19.4	17.9	16.4	12.8	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.2	11.3	11.6	12.9	14.76
30	13.3	14.1	14.8	15.9	17.1	17.5	16.4	15.9	15.1	ND	12.5	10.4	10.1	10.1	10.1	10.1	10.2	10.1	10.3	10.1	10.1	11.1	12.4	12.9	12.63
—			-								· ·										—— M	onthly	Avera	ge = '	24.47

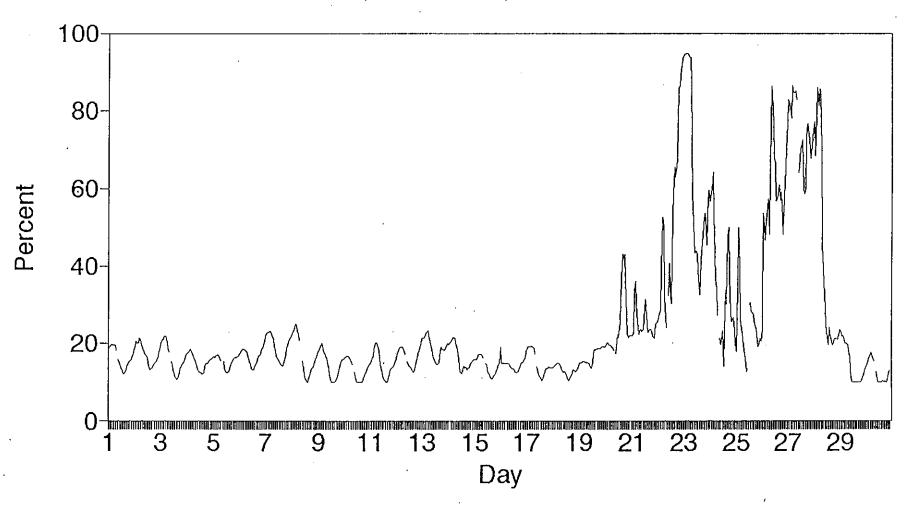
Maximum Hourly Average was 94.6 at Hour 4 on Day 23 with 2 occurences

Maximum Daily Average was 73.97 on Day 27 with 1 occurences

Operating Efficiency = 94.9 percent

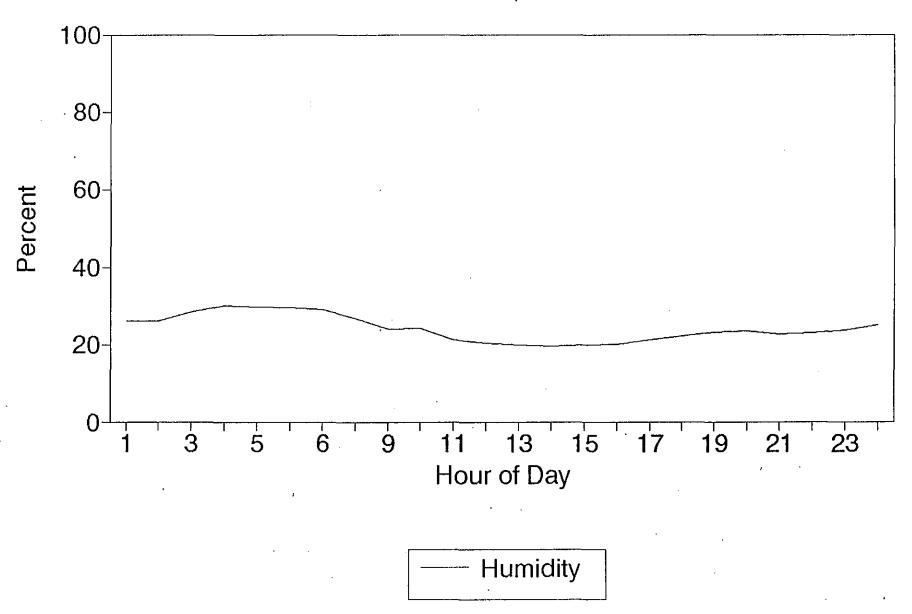
NO = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

Hourly Humidity - June, 1991



Humidity

Diurnal Humidity — June, 1991



MEPA - Kuwait

June 1991

Hourly Averages for Temperature in Degrees C

Hour Day ⊢	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	、Daily ⊶ Average
, i	30.1	29.6	29.1	28.9	28.6	28.9	29.9	31.5	34.2	ND	38.7	39.8	41.0	41.6	41.5	40.7	39.7	38.5	37.3	35.9	35.1	34.0	33.1	32.5	34.79
2	32.0								33.6																34.89
3	31.5	30.4	29.6	29.0	28.0	28.5	30.3	32.1	33.6	ND	35.8	37.2	38.4	39.5	40.0	40.1	39.2	37.4	35.9	34.8	33.9	33.0	32.3	31.1	33.98
4	29.9	29.1	28.5	28.0	27.6	28.6	30.6	32.7	34.3	35.5	37.2	38.7	39.8	40.6	40.4	39.8	39.0	37.2	36.2	35.4	34.6	33.7	33.0	32.5	34.29
5	31.7	30.6	30.1	29.8	29.9	30.6	31.7	33.0	35.2	37.0	38.6	40.0	41.0	41.9	42.1	41.2	39.9	38.5	37.4	36.8	36.0	35.2	34.5	34.0	35.70
6	ND	ND	ND	****																					
7	33.2	32.4	31.7	31.6	31.4	32.1	33.4	34.5	35.9	37.9	40.0	41.3	42.2	43.3	43.6	43.7	43.3	41.8	39.2	37.2	36.3	35.8	35.0	34.3	37.13
8	33.8	33.1	32.5	31.9	31.1	31.2	32.4	33.3	34.5	ND	39.9	41.4	42.4	43.2	43.2	42.9	42.2	40.2	38.3	37.1	36.1	34.8	34.1	33.1	36.64
9	32.2	31.7	31.8	30.7	29.7	30.0	32.0	33.1	35.2	37.9	39.9	41.8	43.3	44.1	44.2	43.4	42.3	40.9	39.5	38.5	37.3	36.2	35.4	34.5	36.90
10	33.3	32.0	29.9	29.8	30.0	31.9	34.5	36.7	38.1	ND	41.4	43.6	44.9	45.4	45.7	45.4	44.9	43.4	41.3	39.6	38.6	38.3	37.3	36.5	38.37
11	35.2	34.2	32.8	32.3	32.Ó	31.6	32.3	34.1	34.6	37.6	42.0	43.7	44.2	44.8	44.8	44.4	43.6	42.4	40.2	38.7	37.7	36.7	35.4	34.6	37.91
12	33.8	32.9	32.5	31.8	31.2	30.9	31.1	31.9	36.0	ND	38.3	39.7	41.0	41.9	42.5	42.3	41.7	40.4	37.0	35.3	34.4	33.8	33.1	32,1	35.90
13	31.6	31.1	30.9	29.8	29.1	30.1	32.7	34.6	34.5	37.2	39.2	40.6	41.4	42.5	42.0	40.8	38.9	36.6	36.8	36.0	34.6	33.7	33.6	33.8	35.50
14	33.1	32.5	30.8	31.2	30.8	31.1	32.4	34.4	35.7	39.1	41.0	43.3	43.1	41.6	41.2	41.5	41.1	38.9	36.7	36.3	35.6	33.4	33.1	32.9	36.28
15	32.7	33.1	32.9	30.3	30.2	29.8	30.1	31.7	34.5	ND	39.2	39.3	42.9	43.9	42.7	42.9	42.4	40.2	37.9	36.3	35.7	34.8	33.8	33.4	36.12
16	32.4	32.6	32.9	32.3	32.3	32.0	32.2	33.0	34.5	40.4	40.8	41.5	41.9	42.9	43.5	43.1	41.9	39.6	36.9	36.1	36.6	35.7	34.8.	35.3	36.88
17				33.5									43.8												38.47
18	36.6	35.8	35.4	34.3	33.5	34.8	36.2	37.8	39.3	41.5	43.9	44.9	45.8	46.4	46.9	46.4	45.3	43.6	42.3	40.5	39.9	39.2	38.8	37.8	40.29
19									38.9																37.93
20	35.7			34.4						-			35.8									-		36.2	35.71
21									34.2											36.5		37.1	36.7	37.0	35.32
22				32.6									39.4										27.8		33.04
									35.7																32.70
24				30.4									42.9									34.8		35.3	35.54
25	35.3								34.8								35.1								36.06
26									29.3																31.21 ′
27				29.3				-					31.3												30.53
	29.0																								34.92
29									34.5																38.03
30	35.9	34.8	34.1	33.1	32.7	32.8	34.4	36.4	37.8	ND	41.8	43.6	44.5	45.8	45.8	45.4	44.8	43.3	41.6	40.6					39.26
													*								— н	onthly	Avera	ge =	35.87

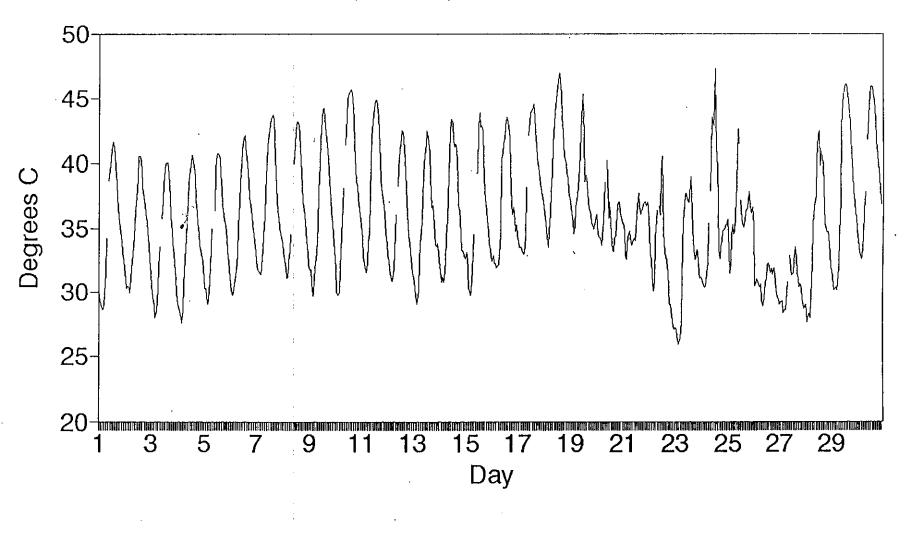
Maximum Hourly Average was 47.2 at Hour 14 on Day 24 with 1 occurences

Maximum Daily Average was 40.29 on Day 18 with 1 occurences

Operating Efficiency = 94.9 percent

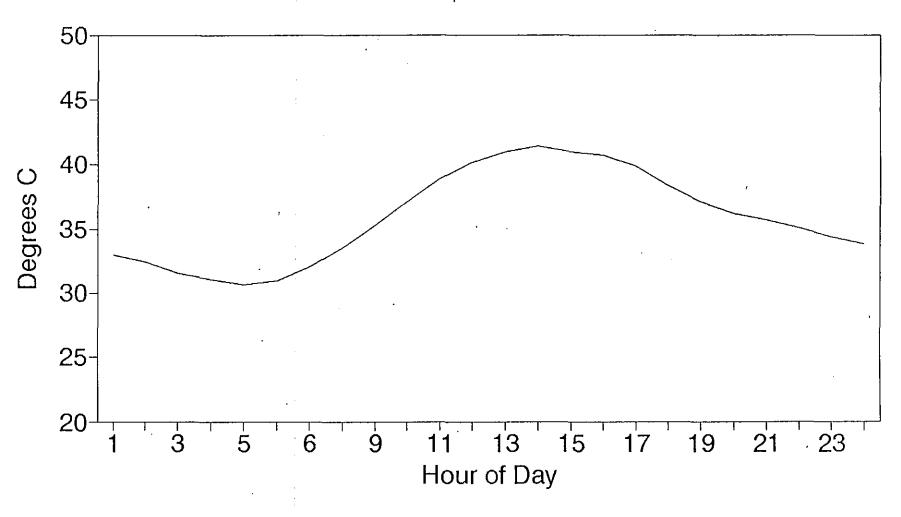
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

Hourly Temperature - June, 1991



— Temp

Diurnal Temperature - June, 1991



Temperature

MEPA'- Kuwait

June 1991

Hourly Averages for Total Particulate in MG/M3

24 Daily
Averag
16 0.0226
21 0.0386
24 0.0253
33 0.0288
24 0.0267
4**** OV
24 0.0237
16 0.0287
22 0.0264
48 0.0222
3 0.0300
17 0.0218
13 0.0228
23 0.0214
98 0.0283
24 0.0403
25 0.0336
24 0.0225
0.0499
10 0.0357
76 0.0483
19 0.0401
74 0.0357
14 0.1160
75 0.0618
28 0.0400
39 0.0298
35 0.0335
15 0.0217
26 0.0213
= 0.0344
0.03 0.08 0.01

Maximum Hourly Average was 0.377 at Hour 23 on Day 24 with 1 occurences

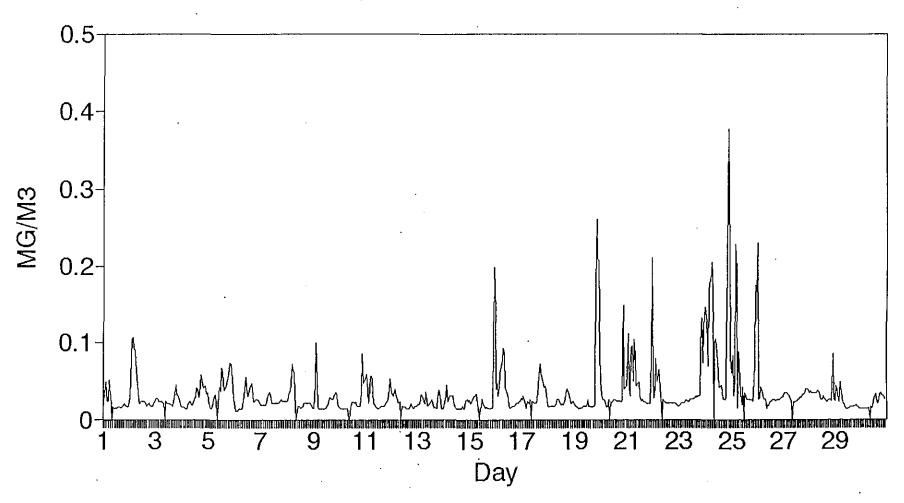
Maximum Daily Average was 0.1160 on Day 24 with 1 occurences

Operating Efficiency = 94.7 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

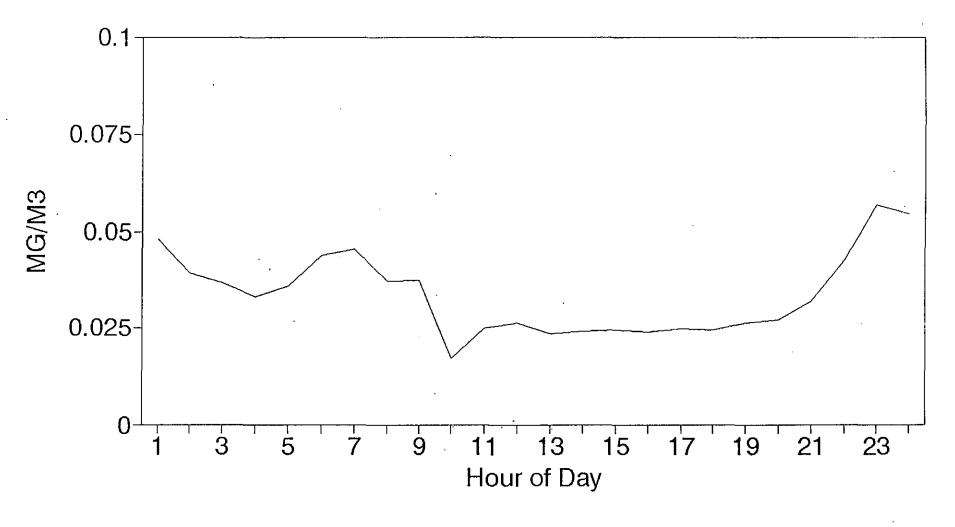
[CEM 1990]

Hourly Particulate - June, 1991



Particulate

Diurnal Particulate - June, 1991



— Particulate

MEPA - Kuwait June 1991 . Hourly Averages for NH3 in ppm

1 0.004 0. 2 0.004 0. 3 0.001 0. 4 0.010 0. 5 0.016 0. 6 ND 7 0.005 0. 8 0.006 0. 9 0.002 0. 11 0.005 0. 12 0.002 0.	.014 0.0			0.000	0.000	0 001																	
2 0.004 0. 3 0.001 0. 4 0.010 0. 5 0.016 0. 6 ND 7 0.005 0. 8 0.006 0. 9 0.002 0. 10 0.005 0. 11 0.005 0.	.014 0.0						0.000	CAL	0.002	0.002	0.004	0.006	0.004	0.005	0.005	0.006	0.007	0.009	0.016	0.016	0.028	0.016	—∤ Average 0.0057
4 0.010 0. 5 0.016 0. 6 ND 7 0.005 0. 8 0.006 0. 9 0.002 0. 10 0.005 0. 11 0.005 0.	.000 0.0		0.000	0.006	0.000																		0.0092
5 0.016 0. 6 ND 7 0.005 0. 8 0.006 0. 9 0.002 0. 10 0.005 0. 11 0.005 0. 12 0.002 0.		04 0.004	0.002	0.001	0.002	0.004	0.003	CAL	0.011	0.005	0.006	0.005	0.004	0.004	0.006	0.009	0.007	0.005	0.005	0.006	0.007	0.007	0.0047
6 ND 7 0.005 0. 8 0.006 0. 9 0.002 0. 10 0.005 0. 11 0.005 0. 12 0.002 0.	.012 0.0	18 0.014	0.005	0.003	0.008	0.007	0.009	0.005	0.004	0.005	0.005	0.004	0.003	0.005	0.006	0.006	0.006	0.005	0.005	0.004	0.014	0.015	0.0074
7 0.005 0. 8 0.006 0. 9 0.002 0. 10 0.005 0. 11 0.005 0. 12 0.002 0.	.000 0.0	05 0.004	0.005	0.007	0.005	0.006	0.008	0.003	0.003	0.006	0.008	0.016	0.007	0.008	0.003	0.004	0.002	0.002	0.001	0.000	0.002	0.006	0.0053
8 0.006 0. 9 0.002 0. 10 0.005 0. 11 0.005 0. 12 0.002 0.	ND	ND ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	. ND	ND	ND	ND	ND	ND	, ND	ND	ND	ND	****
9 0.002 0. 10 0.005 0. 11 0.005 0. 12 0.002 0.	.003 0.0	03 0.002	0.003	0.004	0.004	0.003	0.004	0.003	0.003	0.007	0.008	0.010	0.005	0.005	0.005	0.002	0.001	0.004	0.007	0.008	0.013	0.008	0.0050
10 0.005 0. 11 0.005 0. 12 0.002 0.	.002 0.0	02 0.001	0.001	0.000	0.000	0.000	0.000	CAL	0.003	0.004	0.005	0.007	0.007	0.006	0.007	0.009	0.004	0.002	0.001	0.000	0.022	0.000	0.0039
11 0.005 0. 12 0.002 0.																							0.0034
12 0.002 0.																							0.0080
														-									0.0067
																							0.0030
		01 0.003																					0.0018
14 0.001 0.																							0.0021
15 0.001 0.										-													0.0103
16 0.006 0.																							0.0144
17 0.009 0.																							0.0111
18 0.014 0. 19 0.005 0.																	•						0.0120\ 0.0061
20 0.000 0.									•														0.0093
21 0.014 0.																							0.0073
22 0.002 0.																							0.0268
23 0.077 0.																							0.0200
24 0.058 0.																							0.0300
25 0.020 0.													•										0.0139
26 0.000 0.																							0.0194
27 0.037 0.																							0.0695
28 0.088 0.																							0.0412
29 0.007 0.													_										0.0107
30 0.006 0.		06 0.003	0.004	0.005	0.011	0.009	0.007	0.010	0.010	0.007	U.UIU	0.010	0.010	V.U12	0.010	0.007		0.000	0.000	0.000			
	.007 0.00															-							0.0049

Maximum Hourly Average was 0.133 at Hour 16 on Day 27 with 1 occurences

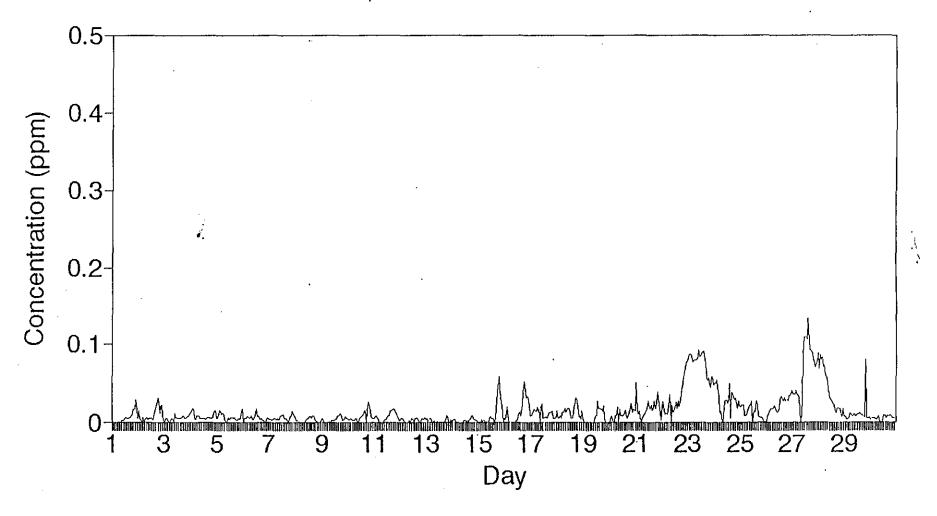
Maximum Daily Average was 0.0746 on Day 23 with 1 occurences

Operating Efficiency = 96.7 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

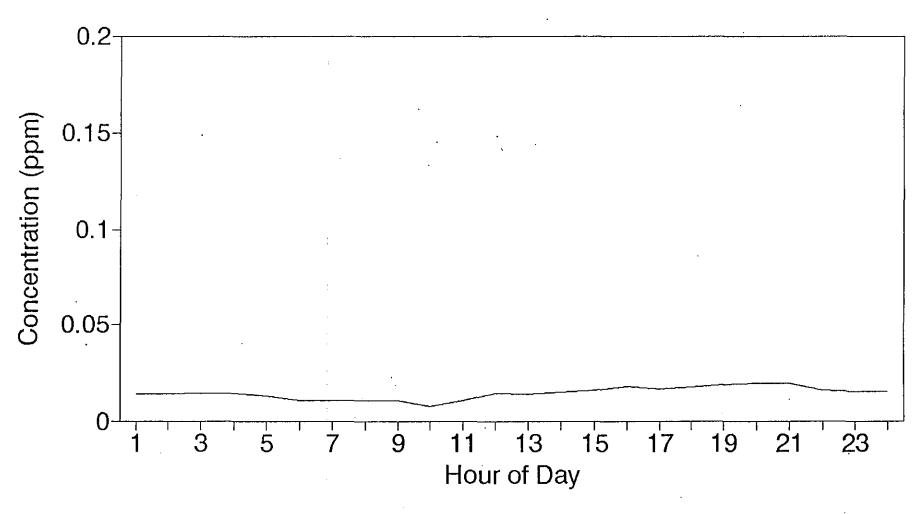
[CEM 1990]

Hourly NH3 - June, 1991



--- NH3

Diurnal NH3 - June, 1991



— NH3

MEPA - Kuwait June 1991 Hourly Averages for 03 in ppm

Hour	1	2	3	4	5	6	7	- 8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
рау -									•••																⊶ Average
1	0.014	0.019	0.016	0.012	0.021	0.021	0.005	0.009	0.018	CAL	0.025	0.030	0.023	0.022	0.023	0.020	0.012	0.008	0.000	0.000	0.000	0.000	0.000	0.001	0.0130
2	0.009	0.000	0.004	0.009	0.011	0.002	0.005	0.001	0.004	0.010	0.013	0.007	0.008	0.017	0.018	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.0057
3	0.023	0.022	0.029	0.031	0.031	0.025	0.021	0.021	0.029	CAL	0.057	0.037	0.040	0.039	0.040	0.036	0.039	0.037	0.035	0.031	0.032	0.011	0.014	0.016	0.0303
4	0.006	0.006	0.002	0.008	0.025	0.024	0.013	0.015	0.019	0.022	0.028	0.029	0.023	0.024	0.030	0.032	0.031	0.032	0.028	0.029	0.027	0.017	0.001	0.000	0.0196
5	0.000	0.011	0.015	0.016	0.009	0.010	0.011	0.006	0.002	0.015	0.020	0.019	0.020	0.019	0.021	0.021	0.020	0.014	0.001	0.000	0.000	0.000	0.000	0.000	0.0104
6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	· ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ND	ND	****
7	0.002	0.002	0.003	0.009	0.012	0.012	0.014	0.012	0.012	0.021	0.029	0.031	0.033	0,033	0.034	0.032	0.027	0.023	0.022	0.021	0.017	0.007	0.000	0.000	0.0170
8	0.002	0.003	0.003	0.004	0.001	0.003	0.003	0.012	0.015	CAL	0.029	0.034	0.034	0.034	0.034	0.031	0.024	0.028	0.024	0.024	0.022	0.015	0.003	0.018	0.0174
9	0.021	0.036	0.037	0.023	0.015	0.027	0.033	0.033	0.031	0.027	0.031	0.031	0.034	0.040	0.038	0.039	0.035	0.030	0.026	0.024	0.027	0.019	0.001	0.004	0.0276
10	0.012	0.026	0.023	0.022	0.027	0.029	0.017	0.016	0.019	CAL	CAL	0.027	0.032	0.035	0.032	0.029	0.026	0.019	0.006	0.003	0.003	0.003	0.002	0.008	0.0189
11	0.003	0.006	0.006	0.007	0.003	0.007	0.015	0.006	0.012	0.018	0.033	0.036	0.035	0.034	0.034	0.025	0.020	0.015	0.007	0.006	0.007	0.007	0.002	0.005	0.0145
12	0.015	0.020	0.026	0.027	0.023	0.026	0.021	0.018	0.017	CAL	0.024	0.026	0.029	0.032	0.036	0.036	0.037	0.034	0.007	0.004	0.006	0.002	0.000	0.002	0.0203
13	0.004	0.012	0.012	0.009	0.011	0.010	0.012	0.018	0.024	0.034	0.039	0.038	0.037	0.036	0.036	0.030	0.023	0.014	0.000	0.008	0.017	0.018	0.001	0.010	0.0189
14	0.018	0.023	0.015	0.018	0.025	0.022	0.022	0.027	0.030	0.040	0.044	0.036	0.037	0.033	0.032	0.020	0.016	0.001	0.003	0.011	0.015	0.018	0.016	0.021	0.0226
15	0.021	0.024	0.019	0.020	0.019	0.016	0.018	0.015	0.019	CAL	0.015	0.004	0.019	0.036	0.039	0.031	0.010	0.000	0.000	0.000	0.000	0.000	0.001	0.016	0.0149
16	0.015	0.020	0.021	0.022	0.022	0.014	0.005	0.000	0.000	0.015	0.011	0.008	0.015	0.028	0.030	0.023	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.0106
17	0.022	0.029	0.031	0.035	0.037	0.035	0.033	0.027	0.035	CAL	0.042	0.044	0.044	0.044	0.044	0.042	0.040	0.037	0.037	0.037	0.037	0.038	0.038	0.039	0.0368
									0.041																0.0394
								-	0.033					-											0.0256
									0.015																0.0172
									0.017																0.0101
									0.014																0.0039
						-			0.000																0.0013
									0.002																0.0070
									0.007																0.0147
									0.002		-														0.0091
									CAL																0.0059
									0.018																0.0107
									0.019	,															0.0240
30	0.033	0.033	0.033	0.034	0.032	0.030	0.030	0.036	0.037	CAL	0.077	0.047	0.049	0.051	0.051	0.050	0.047	0.039							0.0399
\vdash					······						·										(1	ionthly	/ Avera	age =	0.0175

Maximum Hourly Average was 0.077 at Hour 11 on Day 30 with 1 occurences and there were no Hourly Violations

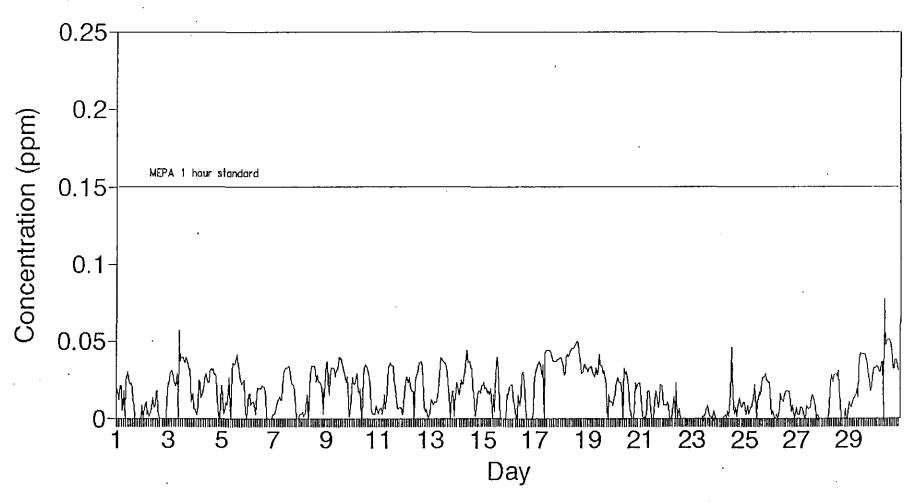
Maximum Daily Average was 0.0399 on Day 30 with 1 occurences and there were no Daily Violations

Operating Efficiency = 96.7 percent

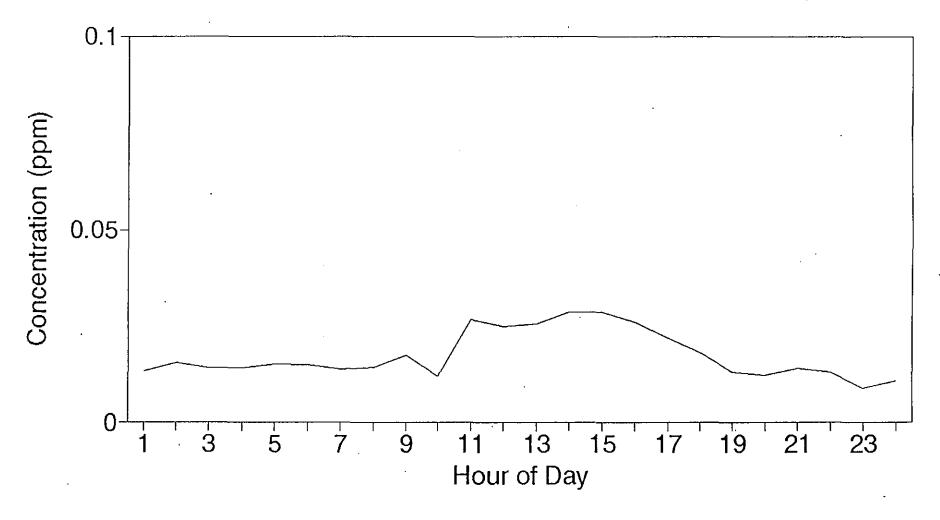
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

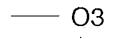
[CEM 1990]

Hourly 03 - June, 1991



Diurnal 03 - June, 1991





MEPA - Kuwait June 1991 Hourly Averages for NOx in ppm

Hour 21 Daily 10 11 12 15 17 18 19 20 16 Day Average 1 0.071 0.031 0.039 0.055 0.025 0.029 0.099 0.072 0.043 CAL 0.049 0.038 0.044 0.041 0.035 0.036 0.060 0.054 0.086 0.087 0.150 0.109 0.181 0.101 0.0667 2 0.037 0.142 0.079 0.051 0.060 0.117 0.059 0.090 0.079 0.056 0.053 0.081 0.076 0.063 0.044 0.091 0.134 0.136 0.217 0.170 0.080 0.147 0.161 0.074 0.0957 3 0.029 0.026 0.005 0.003 0.005 0.024 0.047 0.056 0.044 CAL 0.080 0.027 0.018 0.017 0.015 0.022 0.014 0.012 0.014 0.018 0.018 0.090 0.073 0.061 0.0312 4 0.113 0.123 0.154 0.115 0.033 0.033 0.079 0.077 0.058 0.039 0.032 0.031 0.045 0.041 0.021 0.015 0.018 0.013 0.014 0.013 0.018 0.051 0.165 0.193 0.0623 5 0.182 0.085 0.058 0.052 0.081 0.082 0.076 0.071 0.077 0.046 0.025 0.020 0.012 0.007 0.007 0.008 0.013 0.017 0.018 0.018 0.026 0.059 0.127 0.137 0.0543 **** 7 0.107 0.079 0.078 0.075 0.103 0.084 0.085 0.060 0.084 0.019 0.010 0.008 0.006 0.011 0.007 0.008 0.008 0.018 0.069 0.094 0.128 0.014 0.132 0.071 0.0566 8 0.030 0.038 0.045 0.008 0.006 0.012 0.022 0.032 0.030 CAL 0.025 0.013 0.016 0.017 0.015 0.018 0.030 0.017 0.019 0.021 0.024 0.045 0.127 0.047 0.0286 9 0.038 0.006 0.007 0.028 0.063 0.020 0.011 0.019 0.027 0.050 0.038 0.036 0.029 0.011 0.013 0.005 0.008 0.009 0.013 0.018 0.019 0.039 0.114 0.098 0.0300 10 0.067 0.011 0.008 0.014 0.009 0.013 0.066 0.076 0.062 CAL CAL 0.039 0.022 0.014 0.016 0.015 0.019 0.030 0.075 0.072 0.060 0.039 0.043 0.031 0.0364 11 0.058 0.033 0.027 0.033 0.087 0.063 0.027 0.078 0.039 0.037 0.015 0.008 0.010 0.011 0.007 0.022 0.029 0.035 0.059 0.039 0.036 0.033 0.039 0.030 0.030 0.035 12 0.017 0.010 0.005 0.005 0.007 0.008 0.017 0.033 0.075 CAL 0.053 0.041 0.037 0.032 0.020 0.009 0.006 0.010 0.060 0.065 0.062 0.072 0.087 0.078 0.0352 13 0.073 0.041 0.040 0.039 0.024 0.036 0.052 0.049 0.032 0.029 0.026 0.023 0.024 0.021 0.019 0.023 0.033 0.042 0.088 0.050 0.021 0.019 0.084 0.045 0.0389 14 0.027 0.017 0.017 0.017 0.010 0.016 0.017 0.019 0.022 0.023 0.016 0.022 0.014 0.015 0.015 0.036 0.043 0.075 0.083 0.070 0.038 0.012 0.012 0.009 0.0269 15 0.008 0.008 0.016 0.004 0.004 0.009 0.009 0.009 0.031 0.032 CAL 0.050 0.076 0.046 0.025 0.021 0.024 0.045 0.144 0.234 0.135 0.000 0.069 0.108 0.029 0.0490 16 0.014 0.004 0.006 0.000 0.003 0.016 0.032 0.059 0.059 0.053 0.057 0.076 0.054 0.020 0.013 0.026 0.123 0.255 0.250 0.200 0.121 0.146 0.099 0.051 0.0739 17 0.010 0.005 0.005 0.003 0.002 0.004 0.007 0.017 0.015 CAL 0.007 0.005 0.004 0.004 0.004 0.006 0.009 0.013 0.013 0.012 0.012 0.012 0.009 0.008 0.0081 18 0.005 0.007 0.005 0.013 0.012 0.005 0.006 0.008 0.008 0.008 0.007 0.008 0.007 0.006 0.003 0.003 0.008 0.014 0.016 0.024 0.023 0.021 0.019 0.018 0.0105 19 0.014 0.014 0.010 0.008 0.006 0.013 0.022 0.028 0.018 0.029 0.026 0.011 0.022 0.016 0.011 0.017 0.018 0.038 0.077 0.099 0.024 0.027 0.016 0.015 0.0241 20 0.024 0.024 0.018 0.028 ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND 0.0235 **** 21 ND ND ND ND ND ND ND ND ND ND ND ND ND ND' ND ND 22 ND ND ND ND ND , ND ND ND ND ND ND ND ND ND ND ND ND **** ND *** 23 ND ND ND ND ND ND ND ND ND ND ND . ND ND ND ND ND ND ND ND ND ИÐ ND **** 24 ND **** 25 ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND. ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND ND 0.033 0.038 0.039 0.029 0.026 0.026 0.038 0.043 0.057 0.063 0.045 0.060 0.081 0.0445 CAL 0.019 0.019 0.023 0.020 0.015 0.015 0.023 0.028 0.040 0.066 0.049 0.059 0.089 0.201 27 0.049 0.030 0.036 0.036 0.016 0.013 0.013 0.024 CAL 0.0401 28 0.235 0.126 0.252 0.244 0.245 0.133 0.170 0.039 0.032 0.027 0.016 0.030 0.026 0.014 0.009 0.003 0.000 0.007 0.140 0.131 0.121 0.044 0.061 0.046 0.0896 29 0.025 0.010 0.007 0.006 0.006 0.012 0.013 0.021 0.042 0.060 0.036 0.012 0.006 0.007 0.006 0.005 0.007 0.012 0.019 0.023 0.028 0.030 0.020 0.011 0.'0177 30 0.005 0.004 0.004 0.004 0.006 0.009 0.013 0.011 0.012 CAL 0.058 0.008 0.006 0.005 0.005 0.006 0.007 0.014 0.020 0.019 0.017 0.018 0.015 0.017 0.0123 { Monthly Average = 0.0421

Maximum Hourly Average was 0.255 at Hour 18 on Day 16 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0957 on Day 2 with 1 occurences and there were no Daily Violations

Operating Efficiency = 75.7 percent

ND = no data 75 = zero/span CAL = calibration IR = repair RL = relocation OFF = off A75 = daily zero/span

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

MEPA - Kuwait June 1991 Frequency Distribution Hourly Averages for NOx in ppm

Concentration	# of Hours	Percentage
0.000 - 0.050	385	72.1
0.051 - 0.110	106	19.9
0.111 - 0.210	35	9.9
0.211+	80	1.5

MEPA - Kuwait June 1991 Hourly Averages for NO2 in ppm

Hour	1	2	3	4	5	6	7	' 8	9	10	11	12	13	14	. 15	16	17	18	19	20	21	22	23	24	Daily.
Day																									⊣ Average
1	0.030	0.018	0.023	0.029	0.017	0.020	0.048	0.042	0.032	CAL	0.031	0.026	0.027	0.026	0.023	0.024	0.038	0.042	0.054	0.059	0.064	0.057	0.052	0.043	0.0359
5	0.026	0.041	0.033	0.028	0.023	0.039	0.036	0.049	0.050	0.042	0.041	0.055	0.055	0.049	0.034	0.058	0.064	0.062	0.062	0.059	0.047	0.047	0.051	0.038	0.0454
3	0.019	0.016	0.004	0.001	0.003	0.015	0.028	0.034	0.028	CAL	0.028	0.020	0.013	0.013	0.013	0.016	0.011	0.011	0.015	0.018	0.017	0.052	0.045	0.037	0.0199
4	0.055	0.057	0.064	0.051	0.021	0.020	0.042	0.041	0.035	0.023	0.019	0.020	0.028	0.025	0.015	0.013	0.016	0.013	0.015	0.013	0.018	0.033	0.064	0.068	0.0320
5	0.065	0.042	0.031	0.028	0.038	0.038	0.036	0.027	0.035	0.014	0.009	0.007	0.005	0.008	0.005	0.006	0.008	0.016	0.040	0.047	0.050	0.052	0.051	0.047	0.0294
6	ND	•			ND	ND	ND		DM	ND			***		ND		ND	ND	ND	ND	ND	ND	ND	ND	****
				0.007																					0.0205
				0.031					_													0.034			0.0259
				0.018									•												0.0207
			-	0.014																					0.0270
				0.024														-						-	0.0270
				0.005					_																0.0273
				0.035	,																				0.0312
14	0.026	0.017	0.016	0.016	0.009	0.015	0.015	0.018	0.020	0.020	0.015	0.017	0.013	0.014	0.013	0.033	0.039	0.064	0.062	0.045	0.029	0.011	0.010	0.009	0.0227
				0.003																					0.0283
				0.000																					0.0379
				0.002									•												0.0077
				0.012																					0.0105
				0.006																					0.0210
		0.024			ND		ND			ND		ND	ND	ND	ND	ND	ND	ND	0.0170						
21	ND				ND	ND	ND		_	ND		ND	ND	ND	ND	ND	ND	ND	****						
22	ND				ИD	ND	ND		ND	ND		ND	ND	ND	ND	ND	ND	ND	****						
23	ND				ND	ND	ND		-	ND		ND	ŊD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
24	ND	ND			ND	ND	ND		ND	ND		ND	ND	ND	ND	ND	ND	ND	****						
25	ND	ND	ND		ND	ND	ND		ND	ND		ND	ND	ND	ND	ND	ND	ND	****						
26	ND	ND			ND	ND	ND		ND	ND			•									0.040			0.0374
				0.029					_													0.048			0.0267
				0.064																					0.0385
				0.002																					0.0140
30	0.003	0.001	0.001	0.001	0.003	0.006	0.009	0.008	0.009	CAL	0.007	0.007	0.004	0.004	0.003	0.003	0.005	0.013	0.017						0.0078
-										3.54								<u>,,</u>				Monthly	/ Avera	age =	0.0256

Maximum Hourly Average was 0.074 at Hour 20 on Day 19 with 1 occurences and there were no Bourly Violations

Maximum Daily Average was 0.0454 on Day 2 with 1 occurences and there were no Daily Violations

Operating Efficiency = 75.7 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient daily [CEM 1990]

MEPA - Kuwait June 1991

Frequency Distribution Hourly Averages for NO2 in ppm

Concentration	# of Hours	Percentage
0.000 - 0.050	694	87.8
0.051 - 0.110	92	12.2
0.111 - 0.210	0.	0.0
0.211+	0	0.0

MEPA - Kuwait June 1991 Hourly Averages for NO in ppm

Hour Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily —— Average
٠.	0.041	0.013	0.016	0.026	0.008	0.008	0.051	0.030	0.012	CAL	0.017	0.012	0.017	0.014	0.012	0.012	0.022	0.013	0.032	0.028	0.085	′0.051	0.127	0.057	
2	0.011	0.101	0.047	0.022	0.036	0.077	0.023	0.041	0.029	0.014	0.012	0.025	0.022	0.014	0.001	0.032	0.068	0.073	0.154	0.110	0.033	0.099	0.109	0.036	0.0495
3	0.010	0.010	0.001	0.001	0.005	0.009	0.019	0.022	0.016	CAL	0.052	0.007	0.004	0.004	0.002	0.006	0.003	0.001	0.000	0.000	0.001	0.038	0.028	0.024	0.0114
4	0.057	0.066	0.089	0.064	0.011	0.012	0.036	0.036	0.023	0.015	0.012	0.011	0.018	0.015	0.006	0.002	0.003	0.000	0.000	0.000	0.001	0.018	0.099	0.122	0.0298
5	0.117	0.043	0.027	0.024	0.043	0.044	0.040	0.036	0.039	0.020	0.009	0.005	0.002	0.000	0.000	0.000	0.002	0.002	0.001	0.001	0.005	0.027	0.081	0.090	0.0274
6	ND	ИD	ND	ND	ND	ND	****																		
7	0.066	0.047	0.046	0.044	0.067	0.051	0.051	0.033	0.049	0.005	0.001	0.001	0.001	0.004	0.002	0.002	0.000	0.002	0.029	0.047	0.078	0.090	0.080	0.023	0.0341
8	0.002	0.011	0.024	0.001	0.001	0.002	0.005	0.006	0.007	CAL	0.007	0.002	0.004	0.003	0.002	0.004	0.007	0.000	0.000	0.000	0.000	0.011	0.070	0.017	0.0081
9	0.011	0.001	0.001	0.010	0.031	0.006	0.001	0.003	0.006	0.016	0.012	0.010	0.007	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.057	0.048	0.0097
10	0.028	0.000	0.000	0.001	0.000	0,002	0.029	0.034	0.026	CAL	CAL	0.013	0.005	0.001	0.002	0.000	0.000	0.001	0.025	0.024	0.018	0.000	0.001	0.000	0.0095
11	0.019	0.003	0.002	0.009	0.045	0.027	0.006	0.033	0.005	0.006	0.001	0.001	0.001	0.000	0.000	0.004	0.007	0.007	0.017	0.007	0.005	0.002	0.000	0.001	0.0087
12	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.005	0.028	CAL	0.018	0.012	0.010	0.007	0.003	0.000	0.000	0.000	0.012	0.009	0.009	0.012	0.020	0.024	0.0075
13	0.025	0.010	0.007	0.003	0.001	0.009	0.015	0.010	0.005	0.005	0.003	0.003	0.002	0.003	0.003	0.003	0.003	0.003	0.025	0.006	0.001	0.002	0.030	0.002	0.0075
14	0.001	0.000	0.001	0.001	0.001	0,002	0.002	0.002	0.000	0.003	0.001	0.005	0.000	0.001	0.002	0.003	0.004	0.011	0.022	0.025	0.009	0.001	0.002	0.000	0.0041
15	0.001	0.000	0.011	0.000	0.000	0.000	0.000	0.003	0.003	CAL	0.010	0.025	0.009	0.001	0.001	0.000	0.004	0.077	0.160	0.097	0.000	0.035	0.047	0.002	0.0211
16	0.002	0.001	0.000	0.000	0.000	0.001	0.004	0.018	0.047	0.009	0.006	0.019	0.007	0.002	0.001	0.002	0.064	0.160	0.181	0.131	0.053	0.078	0.038	800.0	0.0347
17	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.002	CAL	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0004
18	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0,000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.0002
19	0.000	0.000	0.000	0.002	0.000	0.000	0.003	0.004	0.003	0.006	0.004	0.001	0.003	0.000	0.000	0.002	0.001	0.002	0.010	0.025	0.001	0.006	0.002	0.001	0.0032
20	0.002	0.000	0.001	0.023	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	DN	ND	ND	ND	0.0065
21	ND	ND	ND	ND	ND	****																			
22	ND	ND	ND	ND	ND	****																			
23	ND	ND	ND	ND	ND	****																			
24	ND	ND	ND	ND	ND	****																			
25	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	ND	ИD	ND	ND	ND	ND	ND	****						
26	ND	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.007	0.009	0.005	0.011	0.018	0.0072										
27	0.007	0.004	0.005	0.007	0.005	0.004	0.004	0.006	CAL	CAL	0.006	0.006	0.006	0.005	0.006	0.005	0.006	0.007	0.006	0.011	0.009	0.011	0.030	0.138	0.0134
28	0.166	0.067	0.190	0.180	0.180	0.075	0.102	0.009	0.008	0.008	0.005	0.007	0.007	0.003	0.002	0.000	0.000	0.000	0.075	0.065	0.051	0.007	0.012	0.007	0.0511
29	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.004	0.006	0.013	0.007	0.003	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.0037
30	0.002	0.003	0.003	0.003	0.003	0.002	0.004	0.003	0.003	CAL	0.051	0.001	0.002	0.002	0.001	0.002	0.002	0.001	0.003	0.001.	0.002	0.002	0.001	0.002	0.0043
 -																					t	4onthly	/ Avera	ige =	0.0166

Maximum Hourly Average was 0.190 at Hour 3 on Day 28 with 1 occurences and there were no Hourly Violations

Maximum Daily Average was 0.0511 on Day 28 with 1 occurences and there were no Daily Violations

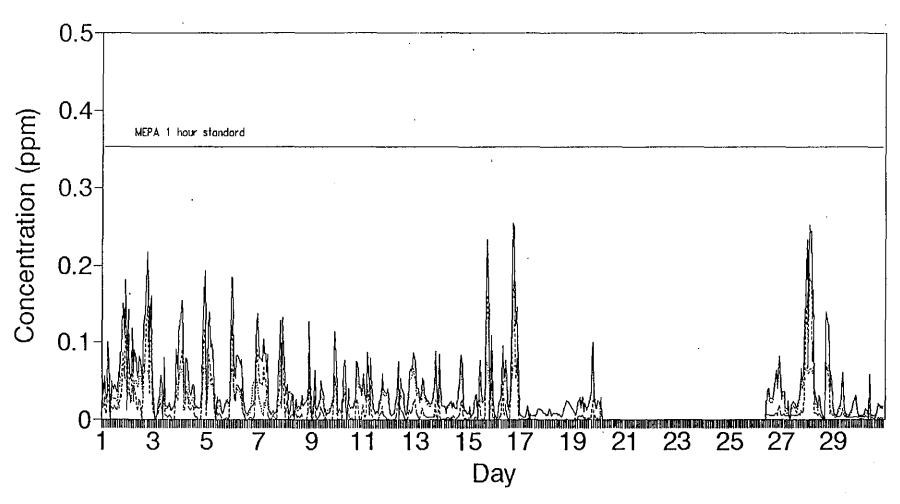
Operating Efficiency = 75.7 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data [CEM 1990]

MEPA - Kuwait June 1991 Frequency Distribution Hourly Averages for NO in ppm

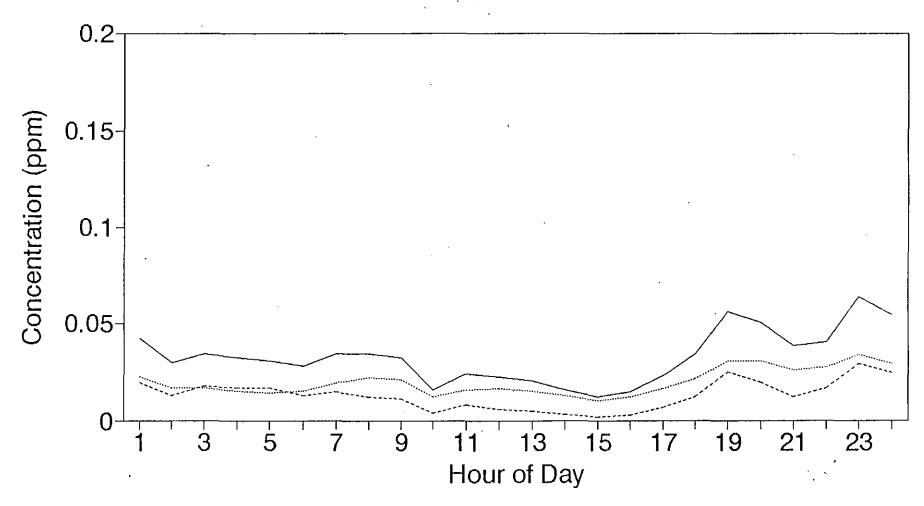
Concentration	# of Hours	Percentage					
0.000 - 0.050	. 481	90.1					
0.051 - 0.110	40	7.5					
0.111 - 0.210	13	2.4					
0.211+	0	0.0					

Hourly NOX/NO2/NO - June, 1991



NOx NO2 NO

Diurnal NOx/NO2/NO - June, 1991



— NOx — NO2 — NO

MEPA - Kuwait June 1991 Hourly Averages for H2S in ppm

Коцг	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Day -	0.006	0.006	0.006	0.005	0.005	0.005	0.006	0.005	0.006	CAL	0.009	0.010	0.012	0.015	0.018	0.020	0.021	0.019	0.016	0.013	0.011	0.010	0.009	0.008	Average 0.0105
2	0.007	0.007	0.006	0.006	0.006	0.006	0.005	0.006	0.006	0.006	0.007	0.008	0.009	0.010	0.011	0.012	0.012	0.012	0.011	0.010	0.009	0.009	0.009	0.008	0.0083
3	0.007	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.006	CAL	0.008	0.010	0.011	0.013	0.015	0.017	0.017	0.017	0.015	0.013	0.011	0.010	0.009	0.009	0.0099
4	0.008	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.006	0.008	0.009	0.010	0.011	0.013	0.015	0.016	0.016	0.015	0.013	0.012	0.010	0.009	0.008	0.008	0.0094
5	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.007	0.008	0.009	0.011	0.013	0.016	0.019	0.021	0.018	0.015	0.013	0.011	0.010	0.007	0.0098
6	, ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	****
7	0.008	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.006	0.007	0.009	0.010	0.012	0.014	0.016	0.018	0.019	0.017	0.014	0.012	0.010	0.009	0.009	0.008	0.0099 `
8	0.007	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.006	CAL	0.008	0.010	0.012	0.014	0.018	0.023	0.026	0.026	0.021	0.016	0.012	0.010	0.009	0.007	0.0115
9	0.006	0.006	0.005	0.005	0.005	0.005	0.004	0.005	0.005	0.006	0.008	0.009	0.012	0.015	0.022	0.029	0.032	0.032	0.028	0.021	0.015	0.012	0.010	0.008	0.0127
10	0.007	0.006	0.005	0.004	0.004	0.004	0.004	0.004	0.005	CAL	CAL	0.010	0.012	0.010	0.031	0.056	0.071	0.080	0.077	0.063	0.045	0.033	0.024	0.018	0.0260
11	0.014	0.011	0.010	0.008	0.008	0.007	0.006	0.006	0.007	0.007	0.008	0.011	0.014	0.024	0.034	0.038	0.039	0.046	0.043	0.027	0.018	0.013	0.010	0.008	0.0174
12	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.010	CAL	0.016	0.012	0.010	0.010	0.010	0.010	0.010	0.010	0.009	800.0	0.006	0.006	0.006	0.005	0.0079
13	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.007	0.007	0.008	0.009	0.009	0.009	0.008	0.007	0.007	0.006	0.005	0.005	0.005	0.0062
14	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.006	0.005	0.005	0.005	0.005	0.0060
15	0.005	0.005	0.005	0.006	0.007	0.006	0.005	0.005	0.005	CAL	0.006	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	800.0	0.006	0.006	0.005	0.005	0.0063
16	0.008	0.009	0.009	0.007	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.006	0.007	0.007	0.030	0.007	0.007	0.007	0.006	0.005	0.005	0.005	0.005	0.005	0.0075
17	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	CAL	0.005	0.006	0.007	0.009	0.010	0.010	0.010	0.010	0.009	0.008	0.006	0.006	0.005	0.004	0.0061
. 18	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.005	0.007	0.009	0.011	0.012	0.013	0.014	0.013	0.012	0.010	0.008	0.006	0.005	0.005	8800.0
19	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.005	0.007	0.008	0.009	0.008	0.007	0.007	0.006	0,005	0.004	0.005	0.005	0.006	800.0	0.0051
20	0.008	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005	CAL	0.005	0.006	0.006	0.006	0.006	0.005	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.0055
21	0.005	0.005	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.012	0.014	0.016	0.016	0.013	0.012	0.011	0.010	0.009	0.009	0.008	0.007	0.007	0.007	0.007	0.0091
																									0.0086
23	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.002	0.000	0.000	0.008	0.009	0.009	0.009	0.008	0.007	0.007	0.007	0.009	0.013	0.016	0.0073
24	0.015	0.014	0.014	0.013	0.013	0.015	0.015	0.014	0.013	CAL	0.012	0.012	0.013	0.015	0.017	0.013	0.011	0.009	0.007	0.006	0.006	0.006	0.009	0.012	0.0119
25	0.017	0.025	0.013	0.012	0.011	0.010	0.011	0.012	0.011	0.011	0.010	0.012	CAL	0.013	0.012	0.010	0.009	0.008	0.008	0.007	0.007	0.007	0.008	0.011	0.0111
26	0.013	0.014	0.015	0.013	0.012	0.012	0.011	0.011	0.011	0.010	0.010	0.009	0.009	0.009	0.009	0.009	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.0098
27	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	CAL	CAL	0.007	0.007	0.007	0.007	0.008	0.009	0.008	0.008	800,0	0.009	0.009	0.009	0.009	0.010	0.0078
28	0.011	0.011	0.011	0.012	0.012	0.011	0.012	0.011	0.011	0.076	0.011	0.011	0.012	0.013	0.013	0.013	0.012	0.011	0.010	0.009	0.008	0.007	0.007	0.007	0.0134
29	0.007	0.008	0.013	0.017	0.009	0.007	0.007	0.007	0.007	0.007	0.011	0.015	0.021	0.023	0.025	0.026	0.027	0.025	0.022	0.018	0.014	0.011	0.010	0.008	0.0144
30	0.007	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	ÇAL	0.004	0.000	0.012	0.016	0.019	0.021	0.022	0.021	0.018	0.015	0.013	0.011	0.009	0.008	0.0103
									-				_								<u> </u>	Monthly	/ Avera	age =	0.0099

Maximum Hourly Average was 0.080 at Hour 18 on Day 10 with 1 occurences and there were no Hourly Violations

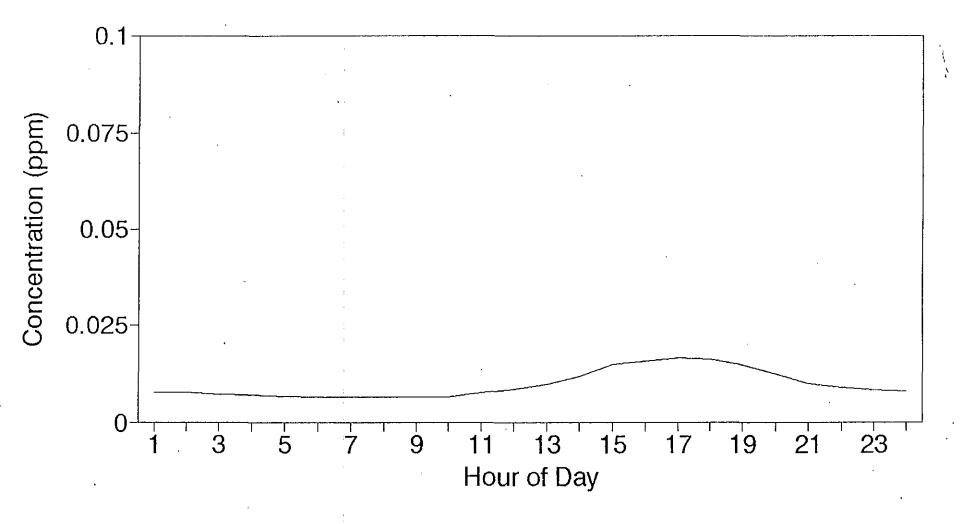
Maximum Daily Average was 0.0260 on Day 10 with 1 occurences and there were no Daily Violations

Operating Efficiency = 96.7 percent

ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data

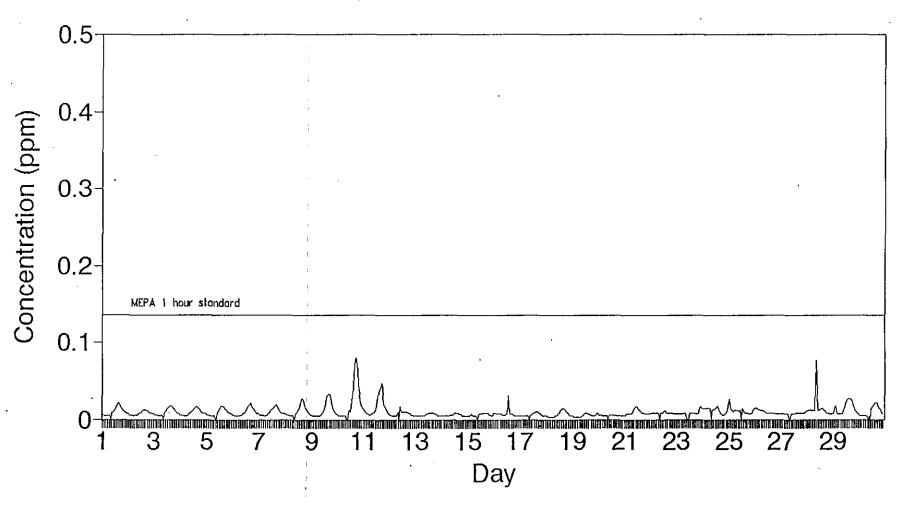
[CEM 1990]

Diurnal H2S - June, 1991



--- H2S

Hourly H2S - June, 1991



H2S

MEPA - Kuwait June 1991 Hourly Averages for SO2 in ppm

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	·20	21	22	23		Daily
Day }		<u> </u>			· ····						-17-14	~~~													≖ Average
																									0.0255
																									0.0370
				0.005																					0.0119
																									0.0174
5	0.038	0.019	0.014	0.014	0.022	0.023	0.021	0.018	0.023	0.016	0.014	0.004	0.004	0.006	0.006	0.008	0.009	0.011	0.015	0.017	0.023	0.029	0.023	0.006	0.0160
-	ND				ND											ND		ND	ND	ND	ND	ND	NĐ	ND	****
				0.020																					0.0173
																									0.0187
																									0.0214
																									0.0280
																									0.0244
																									0.0073
																									0.0101
																									0.0075
																									0.0160
																									0.0339
																									0.0080
																									0.0093
																									0.0494
																									0.0213
																									0.0378
																									0.0316
				0.007																					0.0094
				0.020																					0.0778
																								0.150	0.0589
																									0.0316
				0.016																				- •	0.0193
																									0.0370
																									0.0188
30	0.010	0.010	0.010	0.010	0.010	0.011	0.013	0.011	0.012	CAL	0.037	0.017	0.021	0.018	0.019	0.021	0.021	0.021	0.018	0.016	0.014	0.013	0.012	0.013	0.0156
j																					 1	donthly	/ Avera	age ≍	0.0247

Maximum Hourly Average was 0.288 at Hour 23 on Day 24 with 1 occurences and the Number of Hourly Violations were 1

Maximum Daily Average was 0.0778 on Day 24 with 1 occurences and there were no Daily Violations

Operating Efficiency = 96.7 percent

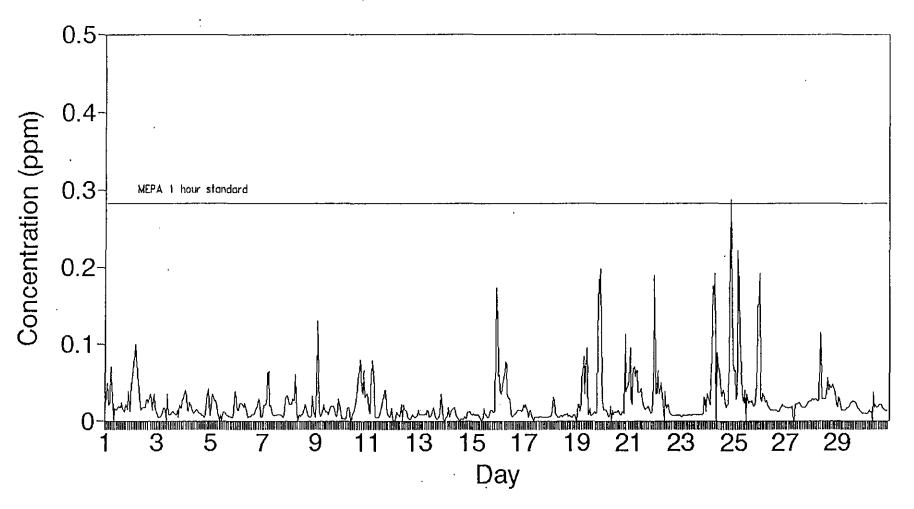
ND = no data, ZS = zero/span, CAL = calibration, IR = repair, RL = relocation, OFF = off, AZS = daily zero/span, INS = insufficient data
[CEM 1990]

MEPA - Kuwait June 1991 Frequency Distribution Hourly Averages for SO2 in ppm

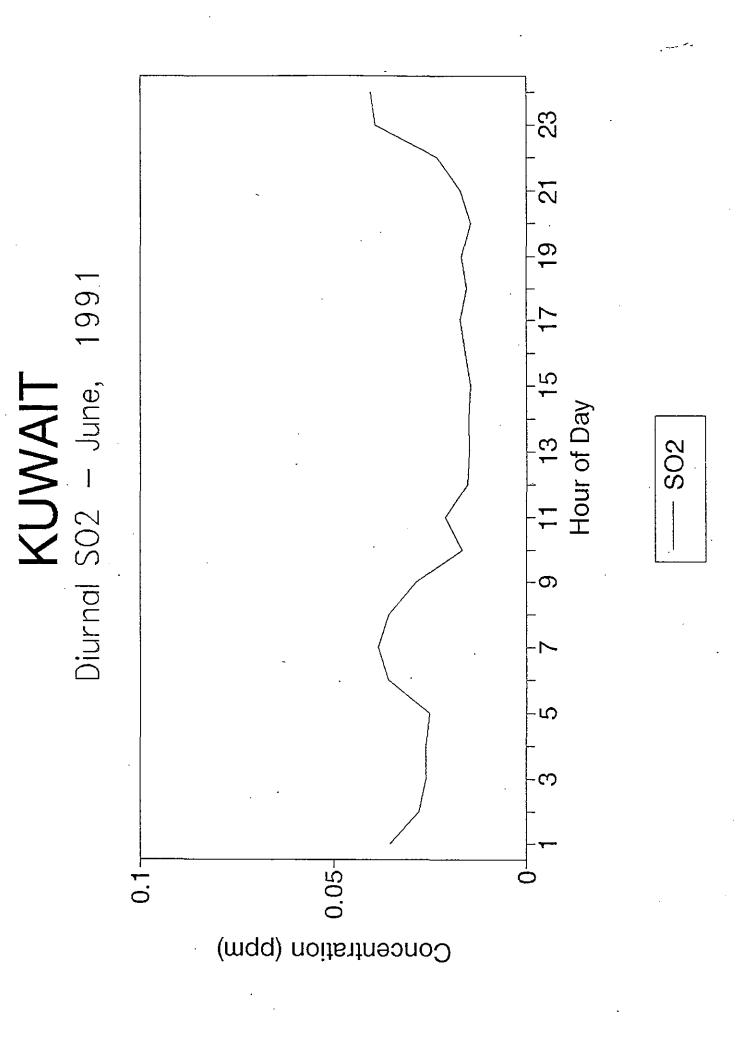
Concentration	# of Hours	Percentage
0.000 - 0.020	437	64.2
0.021 - 0.060	184	27.0
0.061 - 0.110	39	5.7
0.111 - 0.170	11	1.6
0.171 - 0.340	10	1.5
0.341+	0	0.0

KUWAIT

Hourly SO2 - June, 1991



___ SO2



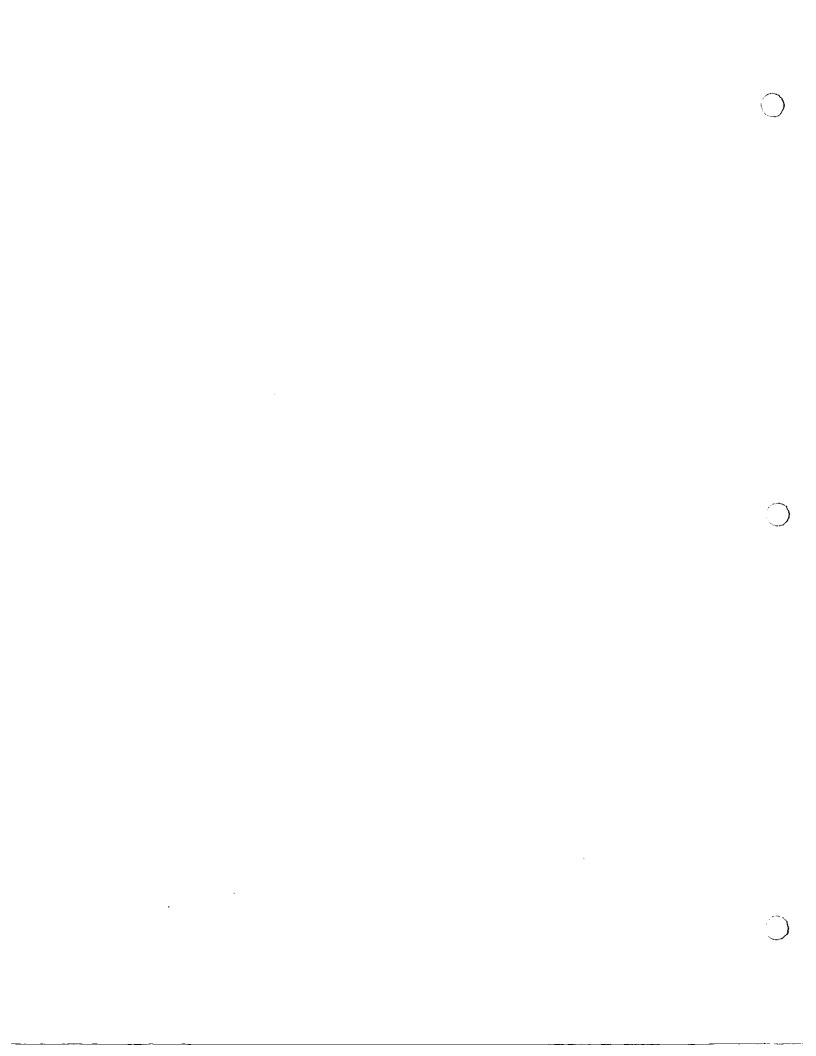
SEPTEMBER

DRAFT

AMBIENT AIR MONITORING DATA Dammam

KAFJI





	603	NO	MOO	170	03	37710	TIOG
,	SO2	NO	NO2	NOX .	03	NH3	H2S
11:00:00	ppm	ppm	ppm	ppm	ppm	ppm	ppm
12:00:00	0.000	0.003	0.006	0.009	0.044	0.00	0.001
13:00:00	0.000	0.001	0.013	0.014	0.053	0.00	0.001
14:00:00	0.000	0.001	0.010	0.011	0.053	0.00	0.002
	0.000	0.001	0.010	0.011	0.050	0.00	0.002
15:00:00	0.000	0.001	0.014	0.016	0.047	0.00	0.001
16:00:00	0.000	0.001	0.010	0.010	0.047	0.00	0.001
17:00:00	0.000	0.002	0.019	0.021	0.039	0.00	0.000
18:00:00	0.000	0.002	0.022	0.024	0.034	0.00	0.000
19:00:00	0.000	0.008	0.028	0.035	0.018	0.00	0.001
20:00:00	0.000	0.005	0.016	0.020	0.020	0.00	0.000
21:00:00	0.000	0.003	0.016	0.018	0.022	0.00	0.000
22:00:00	0.000	0.003	0.013	0.015	0.026	0.00	0.000
23:00:00	0.000	0.002	0.011	0.013	0.029	0.00	0.000
24:00:00	0.000	0.002	0.006	0.008	0.026	0.00	0.000
09 / 10 /							
01:00:00	0.000	0.001	0.005	0.006	0.031	0.00	0.000
02:00:00	0.000	0.001	0.006	0.007	0.032	0.00	0.000
03:00:00	0.000	0.001	0.006	0.007	0.031	0.00	0.000
04:00:00	0.000	0.001	0.006	0.007	0.031	0.00	0.000
05:00:00	0.000	0.001	0.005	0.006	0.030	0.00	0.000
06:00:00	0.000	0.001	0.005	0.006	0.029	0.00	0.000
07:00:00	0.000	0.003	0.008	0.010	0.029	0.00	0.000
08:00:00	0.000	0.003	0.010	0.014	0.031	0.00	0.000
09:00:00	0.000	0.002	0.011	0.013	0.038	0.00	0.000
10:00:00	0.000	0.004	0.014	0.019	0.034	0.00	0.000
11:00:00	0.000	0.002	0.009	0.011	0.041	0.00	0.000
12:00:00	0.000	0.003	0.014	0.017	0.052	0.00	0.001
13:00:00	0.000	0.002	0.013	0.015	0.051	0.00	0.002
14:00:00	0.000	0.002	0.010	0.011	0.054	0.00	0.001
15:00:00	0.000	0.002	0.007	0.009	0.048	0.00	0.001
16:00:00	0.000	0.002	0.012	0.014	0.038	0.00	0.001
17:00:00	0.000	0.011	0.036	0.047	0.022	0.00	0.001
18:00:00	0.000	0.012	0.034	0.046	0.020	0.00	0.001
19:00:00	0.000	0.008	0.042	0.050	0.012	0.00	0.001
20:00:00	0.000	0.014	0.050	0.063	0.006	0.00	0.001
21:00:00	0.000	0.003	0.029	0.032	0.020	0.00	0.001
22:00:00	0.000	0.004	0.027	0.030	0.020	0.00	0.001
23:00:00	0.000	0.008	0.035	0.042	0.010	0.00	0.002
24:00:00	0.000	0.002	0.009	0.011	0.022	0.00	0.001
09 / 11 /			•				
01:00:00	0.000	0.002	0.008	0.011	0.019	. 0.00	0.002
02:00:00	0.000	0.000	0.007	0.006	0.021	0.00	0.002
03:00:00	0.000	0.001	0.004	0.005	0.024	0.00	0.003
04:00:00	0.000	0.001	0.003	0.004	0.024	0.00	0.004
05:00:00	0.000	0.001	0.004	0.005	0.024	0.00	0.003
06:00:00	0.000	0.001	0.005	0.006	0.024	0.00	0.002
07:00:00	0.000	0.003	0.005	0.008	0.025	0.00	0.001
08:00:00	0.000	0.003	0.009	0.012	0.023	0.00	0.002

	SO2	NO	NO2	хОи	03	инз	H2S
	ppm	ppm	ppm	ppm	ppm	ppm	ppm
09:00:00	0.000	0.002	0.012	0.014	0.030	0.00	0.001
10:00:00	0.000	0.003	0.012	0.015	0.037	0.00	0.001
11:00:00	0.000	0.001	0.009	0.010	0.039	0.00	0.001
12:00:00	0.000	0.002	0.006	0.008	0.038	0.00	0.002
13:00:00	0.000	0.002	0.003	0.004	0.041	0.00	0.002
14:00:00	0.000	0.002	0.002	0.004	0.037	0.00	0.003
15:00:00	0.000	0.002	0.003	0.004	0.037	0.00	0.003
16:00:00	0.000	0.002	0.004	0.006	0.034	0.00	0.002
17:00:00	0.000	0.002	0.005	0.007	0.033	0.00	0.001
18:00:00	0.000	0.003	0.009	0.013	0.019	0.00	0.001
19:00:00	0.000	0.005	0.008	0.013	0.010	0.00	0.001
20:00:00	0.000	0.005	0.010	0.015	0.012	0.00	0.001
21:00:00	0.000	0.004	0.017	0.020	0.010	0.00	0.001
22:00:00	0.000	0.006	0.022	0.028	0.010	0.00	0.000
23:00:00	0.000	0.003	0.020	0.023	0.011	0.00	0.001
24:00:00	0.000	0.002	0.008	0.010	0.018	0.00	0.000
09 / 12 / 9	91						
01:00:00	0.000	0.001	0.005	0.006	0.024	0.00	0.000

	DUST mg/m3	WS	WD	TEMP	HUMIDITY %	RAD	PRESS
00 / 07 /		m/sec	degrees	С	8	watts	dm
09 / 07 /							
14:00:00	0.018	4.0	50	32.4	58.0	341.5	997.2
15:00:00	0.014	3.9	· 53	32.3	55.0	267.3	995.5
16:00:00	0.013	3.3	58	31.5	68.6	212.9	993.9
17:00:00	0.013	2.8	• 62	31.5	67.7	140.2	992.8
18:00:00	0.013	2.0	102	30.4	75.2	34.4	992.8
19:00:00	0.013	1.2	208	29.4	73.6	0.0	992.5
20:00:00	0.013	0.2	243	29.0	70.6	0.0	992.1
21:00:00	0.013	1.5	266	28.7	63.0	0.0	991.9
22:00:00	0.013	1.8	273	27.7	49.6	0.0	991.8
23:00:00	0.013	2.2	275	27.4	43.3	0.0	991.9
24:00:00	0.013	2.3	266	27.6	41.1	0.0	991.7
09 / 08 ,	/ 91						
01:00:00	0.013	2.5	265	27.2	37.1	0.0	991.6
02:00:00	0.013	2.5	272	26.8	33.5	0.0	991.5
03:00:00	0.014	3.4	276	26.1	31.8	0.0	991.2
04:00:00	0.015	4.1	286	25.7	30.8	0.0	991.1
05:00:00	0.014	3.8	292	24.9	31.2	0.0	990.8
06:00:00	0.015	3.9	293	25.0	30.4	3.7	990.4
07:00:00	0.016	3.8	291	26.0	28.6	16.1	990.4
08:00:00	0.017	3.9	290	26.4	27.5	8.2	990.7
09:00:00	0.017	3.8	292	27.2	26.9	23.6	990.9
10:00:00	0.015	4.2	313	29.1	25.7	81.2	991.0
11:00:00	0.023	4.9	332	31.2	23.3	41.6	992.2
12:00:00	0.017	5.7	359	34.0	21.6	57.9	992.8
13:00:00	0.014	5.8	10	34.5	26.5	192.0	993.2
14:00:00	0.014	5.7	12	35.4	28.6	385.4	
15:00:00	0.012	6.3	19	35.4	32.3	355.9	994.0
16:00:00	0.014	6.5	18	34.5		222.5	994.7
17:00:00	0.014	6.1	13	34.1	36.6		995.2
18:00:00	0.014	6.1	12		37.6	90.4	994.6
19:00:00	0.014	7.3	4	33.5	38.0	14.5	994.1
20:00:00	0.018	6.5	347	34.2	33.4 37.4	0.0	993.7
21:00:00	0.023	6.8	347	32.9		0.0	994.2
22:00:00	0.023			32.8	36.0	0.0	994.1
		6.2	1	32.6	35.6	0.0	993.9
23:00:00	0.018	3.3	323	29.1	39.9	0.0	993.6
24:00:00	0.015	4.6	327	28.7	30.3	0.0	992.8
09 / 09 ,							
01:00:00	0.015	5.8	331	29.1	26.2	0.0	992.8
02:00:00	0.016	5.0	328	28.2	26.4	0.0	992.6
03:00:00	0.015	4.9	322	27.0	27.3	0.0	992.1
04:00:00	0.016	5.3	329	26.9	27.6	0.0	991.2
05:00:00	0.015	4.6	322	26.1	27.8	0.0	990.8
06:00:00	0.015	4.0	317	24.7	29.2	6.1	990.2
07:00:00	0.016	5.0	328	26.7	27.7	63.4	990.4
08:00:00	0.015	6.7	330	31.1	24.1	239.3	992.7
09:00:00	0.016	8.7	344	34.7	21.4	526.6	995.3
10:00:00	0.016	9.3	340	37.4	17.5	627.8	997.6

					•		
	DUST	WS	WD.	TEMP	HUMIDITY	RAD	PRESS 🔍
	mg/m3	m/sec	degrees	С	8	watts	mb
11:00:00	0.022	8.1	320	38.1	15.8	531.4	998.9
12:00:00	0.016	6.1	356	38.8	16.3	591.6	999.8
13:00:00	0.014	4.2	5	37.7	19.4	336.8	1000.8
14:00:00	0.014	3.9	12	37.0	22.0	194.9	999.6
15:00:00	0.014	4.6	4	36.9	20.7	10.0	997.2
16:00:00	0.014	4.2	12	36.5	20.6	64.1	995.7
17:00:00	0.014	4.9	. 2	36.6	20.4	40.9	994.7
18:00:00	0.015	4.3	342	35.1	23.7	7.1	994.8
19:00:00	0.014	2.5	304	33.4	24.9	0.0	994.6
20:00:00	0.018	3.6	317	33.3	17.9	0.0	994.3
21:00:00	0.019	3.7	313	32.7	17.4	0.0	993.8
22:00:00	0.019	4.0	314	32.1	17.6	0.0	993.6
23:00:00	0.018	4.0	307	30.8	18.3	0.0	993.2
24:00:00	0.019	4.0	306	29.2	19.1	0.0	992.7
09 / 10 /							33211
01:00:00	0.020	4.4	309	28.9	20.1	0.0	992.4
02:00:00	0.024	5.2	315	28.8	20.2	0.0	992.2
03:00:00	0.028	6.3	318	28.6	19.5	0.0	992.2
04:00:00	0.031	6.6	322	28.0	19.0	0.0	992.1
05:00:00	0.031	6.0	. 318	26.9	19.4	0.0	991.8
06:00:00	0.024	5.1	315	26.0	20.1	5.0	991.3
07:00:00	0.029	6.4	318	27.0	20.3	55.8	991.2
08:00:00	0.030	6.5	320	29.9	18.7	188.9	992.6
09:00:00	0.028	6.9	329	34.4	16.6	410.3	995.0
10:00:00	0.017	5.2	21	35.9	21.8	609.9	996.2
11:00:00	0.014	4.3	24	36.4	29.3	712.1	996.7
12:00:00	0.015	5.0	34	34.1	38.8	669.8	997.4
13:00:00	0.014	3.9	50	33.7	44.4	530.2	997.1
14:00:00	0.014	3.3	47	34.1	41.3	369.4	997.1
15:00:00	0.013	3.5	66	33.2	47.1	220.8	995.9
16:00:00	0.013	2.0	122	33.4	41.3	110.7	994.4
17:00:00	0.013	- 1.1	190	33.3	35.5	49.0	994.3
18:00:00	0.013	1.7	207	31.7	40.4	7.9	994.1
19:00:00	0.013		237	30.9	37.4	0.0	993.8
20:00:00	0.014	2.2	247	30.6	34.5	0.0	993.5
21:00:00	0.014	3.0	249	30.0	33.8	0.0	993.3
22:00:00	0.014	3.0	259	29.9	31.2	0.0	993.3
23:00:00	0.015	3.3	276	29.7	26.7	0.0	993.3
24:00:00	0.016	3.6	298	28.8	24.3		993.3
09 / 11 /		3.0	230	20.0	24.3	0.0	993.0
01:00:00	0.016	3.7	303	27.7	24.1	0.0	002 6
02:00:00	0.018	4.0	309	27.8	24.1	0.0 0.0	992.6
03:00:00	0.021	5.3	321	27.8	24.9		992.3
04:00:00	0.021	5.4	321	27.3	26.1	0.0 0.0	992.3 992.3
05:00:00	0.022	5.1	322 319	26.6	27.3	0.0	992.3 992.1
06:00:00	0.023	4.9	319	26.2	27.3		
07:00:00	0.022	5.3	318	27.1	28.8	3.9	991.9
08:00:00	0.022	5.0	324	29.1	27.1	48.5	991.9
20.00.00	0.022	5.0	264	27.1	41.1	150.6	992.9

24 September, 1991

John Robinson, Director NOAA/Arabian Gulf Program

Re: Draft report on Kuwait PAH analyses.

Ground-level exposure to PAH was monitored on the road to Al-Wafra south of Al-Bergan oil field, at the International Hotel in Kuwait City, Doha, and the Ahmed Al-Jaber Air Base (abandoned) between august 4 and 9, 1991. A total of 16 samples were collected using standard methods (NIOSH METHOD 5515, TeflonTM filters and XAD-2). The samples along with 6 field blanks were returned to LSU for analysis. In addition to the filter samples, 6 sediment samples were collected along a transact on the road to Al-Wafra. Table 1 provides the sample collection dates, times, identification and sample location information. The samples were extracted and analyzed by a detailed gas chromatograph/mass spectrometer (GC/MS) technique which targets the pyrogenic (combustion)-sourced and petrogenic (oil)-sourced PAH. The sediment samples, in addition to the GC/MS analyses, were analyzed to determine total petroleum hydrocarbons (TPH) by a solvent extraction/gravimetric technique.

Attached are the quantitative results for these analyses. They have been proofed by myself for QA/QC. Earlier results for three of the samples released in a preliminary report (memo date 18, August, 1991) were found to be in error due to a data entry mistake in the formula used to calculate concentration. Sorry, but that's what happens when you rush to produce data of this complex nature. The correct values for those samples are incorporated into this report. The qualitative interpretation was not affected, only the absolute concentration value.

The samples collected south of the road to Al-Wafra were intended to be a "worse-case" ground level exposure in that I sought to located an area of high smoke concentration from an integrated plume

primarily sourced from the Al-Bergan field. What do the results mean? Most of the PAH detected is petrogenic in composition; resembling oil, not incomplete combustion products. Fingerprint comparisons of the PAH homolog profiles suggest that the oil collected at sites south of Al-Bergan is a positive match to oil collected at two lake sites within the Al-Bergan field. Samples collected within Kuwait City showed a different fingerprint suggesting that it was not sourced from the burning fields south of the city. No oil from the northern fields were available for source-fingerprinting (I was advised not to drive up in the northern fields due to mines, etc.). The composition of PAH in the samples collected in the city are probably from a combination of sources including automobile and truck exhaust, the desalination and power generation plants, burning trash, and the northern oil fields.

Expect a final report soon. I had hoped to have it completed sooner, but I've been really inundated since my return. If you have any questions please call.

Sincerely,

Charles B. Henry, Jr.

enclosures

SAMPLE ID	TYPE	XAD-2	DATE	S. TIME	E. TIME	PUMP 4	FLOW	S.TIME	S. VOL.	LOCATION
			m/d/y	hh:mm	hh:mm		L/min.	min.	 	
K01	G.FIL.	1	8/3/91	00:45	07:30	2	2	405	810	4th FLOOR BALCONY, RM 424, INTERNATIONAL HOTEL
K02	G.FIL.	1	-		•	-	-	-	•	FIELD BLANK
K03	G.FIL.	1	-		-			-	-	FIELD BLANK
K04	G.FIL.	1	8/4/91	11:05	13:15	2	2	130	260	AL-WAFRA ROAD, 6.45 km FROM MET.STATION TURN-OFF
K05	G.FIL.	1	8/4/91	11:05	13:15	1	2	130	260	AL-WAFRA ROAD, 6.45 km FROM MET.STATION TURN-OFF
K06	G.FIL.	1		-	-			•		FIELD BLANK
K07	G.FIL.	1	8/4/91	11:05	13:15	3	2	130	260	AL-WAFRA ROAD, 6.45 km FROM MET.STATION TURN-OFF
K08	TFE.FIL.	1	-		-	-	•	-	•	FIELD BLANK
K09	TFE.FIL	1	8/4/91	21:35	03:35		2	360	720	4th FLOOR BALCONY, RM 424, INTERNATIONAL HOTEL
	TFE.FIL	1	8/6/91	09:15	11:15	3	2	120		DOHA
	TFE.FIL	2	8/5/91	14:00	-	2	2	120	1000	COMPOUND, JUST NORTH OF WAFRA ROAD MET STATION
	TFE.FIL	1	8/5/91	11:30	•	2	2	500	1000	AIR BASE (CONTROL?)
	TFE.FIL	1	8/5/91	13:35	15:10	3	2	105	210	AL-WAFRA MET STATION #7
	TFE.FIL	2	8/5/91	-			-	-		FIELD BLANK
	TFE.FN.	1	8/8/91	12:00	13:10	2	2	70		4th FLOOR BALCONY, RM 424, INTERNATIONAL HOTEL
	TFE.FIL	1	8/8/91	08:30		2	2	164		4th FLOOR BALCONY, RM 424, INTERNATIONAL HOTEL
	TFE.FIL	1	8/7/91	16:00		2	2	332	664	41h FLOOR BALCONY, RM 424, INTERNATIONAL HOTEL
	TFE.FIL	1	8/9/91	12:25	13:40	3	2	75		AL-WAFRA ROAD, 16.1 km FROM MOTOTWAY
	TFE,FIL	1	8/9/91	12:25	13:40	2	2	75	150	AL-WAFRA ROAD, 16.1 km FROM MOTOTWAY
	TFE.FIL	1	8/8/91	23:00		3	. 2	480	960	4th FLOOR BALCONY, RM 424, INTERNATIONAL HOTEL
	TFE.FIL	1	8/8/91	19:00	20:06	2	2	66	132	AL-WAFRA MET STATION #7
	TFE.FIL	_		•			_			FIELD BLANK
	PUF	_ NA	8/9/91	12:25	13:40	1	2	. 75	150	AL-WAFRA ROAD, 16.1 km FROM MOTOTWAY
	PUF	NA	•	-	•	-	•	1 -	1	FIELD BALNK
	Surf.		8/4/91	12:00	NA	NA	NA	NA		AL-WAFRA ROAD, 6.45 km FROM MET.STATION TURN-OFF
	SURF.	NA	8/8/91	18:55	NA	NA	NA	NA	NA	AL-WAFRA ROAD, 10.0 km FROM MET.STATION TURN-OFF
	SURF.	NA	8/8/91	19:10	NA	NA	NA	NA	NA	AL-WAFRA ROAD, 10.7 km FROM MET.STATION TURN-OFF
	SURF.	NA	8/9/91	12:30	NA	NA	NA	NA	NA	AL-WAFRA ROAD
K55	SURF.	NA	8/9/91	12:45	NA	NA	NA	NA	NA	AL-WAFRA ROAD
	SURF.	NA	8/9/91	13:00	NA	NA	NA	_NA	NA	AL-WAFRA ROAD
K71	OIL	NA	8/5/91	11:00	NA	NA	NA	/NA	NA	LAKE IN SOUTHWESTERN PORTION OF BERGAN FIELD

SAMPLE ID: GC/MS TARGET	K01	K04	K05	1/07	1466
			1/03	K07	·K09
	ng/M3**	пд/М3**	ng/M3**	ng/M3**	ng/M3**
COMPOUND					
NAPHTHALENE	150.00	70.00	180.00	90.00	110.00
C-1 NAPHTHALENE	45.00	180.00	290.00	220.00	24.00
C-2 NAPHTHALENE	22.00	240.00	400.00	340.00	20.00
C-3 NAPHTHALENE	15.00	160.00	290.00	230.00	26.00
C-4 NAPHTHALENE	ND	59.00	71.00	110.00	ND
FLUORENE	ND	7.90	12.00	ND	ND
C-1 FLUORENE	ND	31.00	30.00	8.70	ND
C-2 FLUORENE	ND	13.00	16.00	11.00	ND
C-3 FLUORENE	ND	18.00	8.50	ND	ND
DIBENZOTHIOPHENE	ND	14.00	25.00	23.00	ND
C-1 DIBENZOTHIO.	. ND	31.00	52.00	38.00	ND
C-2 DIBENZOTHIO.	ND	52.00	17.00	33.00	ND
C-3 DIBENZOTHIO.	- ND	43.00	15.00	15.00	ND
PHENANTHRENE	2.40	19.00	30.00	19.00	3.80
C-1 PHENANTHRENE	ND	15.00	27.00	21.00	ND
C-2 PHENANTHRENE	ND	34.00	32.00	19.00	ND
C-3 PHENANTHRENE	ND	ND	- ND	ND	ND
ANTHRACENE	1.00	2.10	3.60	3.20	ND
FLUORANTHENE	ND	11.00	8.60	7.40	ND
PYRENE	ND	7.20	6.80	4.80	ND
C-1 PYRENE	ND	ND	ND	ND	ND
C-2 PYRENE	ND	ND	ND	ND	ND
BENZO(a)ANTHRACENE	ND	ND	ΝD	ND	ND
CHRYSENE	ND	9.10	8.90	3.20	ND
C-1 CHRYSENE	ND	ND	ND	ND	ND
BENZO(b)FLUORANT.*	. ND	19.00	6.10	6.80	ND
BENZO(e)PYRENE	ND	12.00	4.80	3.70	ND
BENZO(a)PYRENE	ND	11.00	3.10	2.60	ND
PERYLENE	ND	18.00	2.80	2.30	ND
INDENO(1,2,3-cd)PYR.	ND	20.00	ND	ND	ND
DIBENZO(a,h)ANTHR.	ND	17.00	ND	ND	ND
* (b) and (k) isomers comb.	ļ				
		14 = 2 = 2	45555		
TOTAL TARGET PAH:	240.00	1100.00	1500.00	1200.00	180.00

	AIR	AIR	AIR	AIR	AIR
SAMPLE ID:	K10	K12	K13	K15	K16
GC/MS TARGET	ng/M3**	ng/M3**	ng/M3**	ng/M3**	ng/M3**
COMPOUND					
NAPHTHALENE	760.00	5.10	420.00	560.00	390.00
C-1 NAPHTHALENE	150.00	12.00	170.00	130.00	99.00
C-2 NAPHTHALENE	140.00	12.00	200.00	110.00	120.00
C-3 NAPHTHALENE	170.00	26.00	160.00	140.00	110.00
C-4 NAPHTHALENE	ND	ND	31.00	70	ND
FLUORENE	15.00	1.60	8.80	8.80	11.00
C-1 FLUORENE	46.00	5.70	26.00	38.00	41.00
C-2 FLUORENE	ND		29	· ND	ND
C-3 FLUORENE	ND	ND	ND.	70	ND
DIBENZOTHIOPHENE	9.20	N D	8.80	11.00	3.30
C-1 DIBENZOTHIO.	ND	ND	29	13.00	2.20
C-2 DIBENZOTHIO.	ND	ND	Ŋ	45.00	20.00
C-3 DIBENZOTHIO.	ND	ŇĐ	29	20	ND
PHENANTHRENE	29.00	2.10	16.00	27.00	12.00
C-1 PHENANTHRENE	15.00	29	9	ND	12.00
C-2 PHENANTHRENE	ND	ND	9	- ND	ND
C-3 PHENANTHRENE	ND	9	2	29	ND
ANTHRACENE	ND	5	9	5.70	1.90
FLUORANTHENE	ND		9	9.00	3.20
PYRENE	ND	ND	29	5.50	2.10
C-1 PYRENE	ND	ND ND	ND	ND	ND_
C-2 PYRENE	ND	ND	ND	ND	ND.
BENZO(a)ANTHRACENE	ND ND	ND_ND	ND	ND	ND
CHRYSENE	ND	ND	ND	6.60	7.00
C-1 CHRYSENE	ND ND	ND	ND ND	ND ND	ND ND
BENZO(b)FLUORANT.*	ND	ND	ND	ND	5.00
BENZO(e)PYRENE	ND	ND	ND	ND	2.40
BENZO(a)PYRENE	ND	ND	ND	ND ND	5.70
PERYLENE	ND	ND		ND ND	3.40
INDENO(1,2,3-cd)PYR.	ND	ND ND	ND	ND	ND ND
DIBENZO(a,h)ANTHR.	ND	ND	ND	ND	ND
* (b) and (k) isomers comb.					
TOTAL TABOUT DAY	1000.00	05.00	4000 00	4400.00	050.00
TOTAL TARGET PAH:	1300.00	65.00	1000.00	1100.00	<u>850.00</u>
L				<u> </u>	

	AIR	AIR	AIR	AIR	AIR
SAMPLE ID:	K17	K18	K19	K20	K21
GC/MS TARGET	ng/ M3**	ng/M3**	ng/M3**	ng/M3**	ng/M3**
COMPOUND					
NAPHTHALENE	180.00	350.00	39.00	21.00	50.00
C-1 NAPHTHALENE	96.00	420.00	360.00	27.00	60.00
C-2 NAPHTHALENE	54.00	520.00	390.00	21.00	47.00
C-3 NAPHTHALENE	33.00	380.00	240.00	21.00	73.00
C-4 NAPHTHALENE	13.00	130.00	140.00	ND	ND
FLUORENE	4.90	16.00	14.00	2.70	9.00
C-1 FLUORENE	10.00	16.00	31.00	6.70	ND
C-2 FLUORENE	ND	20.00	22.00	ND	. ND
C-3 FLUORENE	ND	35.00	17.00	ND	ND
DIBENZOTHIOPHENE	3.70	29.00	21.00	0.98	3.60
C-1 DIBENZOTHIO.	4.90	88.00	49.00	1.40	ND
C-2 DIBENZOTHIO.	8.00	40.00	57.00	2.40	Ū/i
C-3 DIBENZOTHIO.	-ND	22.00	38.00	ND	ND
PHENANTHRENE	10.00	38.00	24.00	3.40	18.00
C-1_PHENANTHRENE	3.60	35.00	30.00	1.70	9.00
C-2 PHENANTHRENE	. ND	51.00	-28.00	ND	10
C-3 PHENANTHRENE	ND	20.00	ND	ND	ND
ANTHRACENE	ND	3.60	1.80	0.37	3.40
FLUORANTHENE	3.30	7.10	7.20	1.20	9.50
PYRENE	3.00	5.70	6.90	1.00	14.00
C-1 PYRENE	ND	ND	ND	ND	ND
C-2 PYRENE	ND	ND	ND	ND	ND
BENZO(a)ANTHRACENE	ND	ND	ND	ND	ND
CHRYSENE	2.30	4.40	4.70	0.72	7.00
C-1 CHRYSENE	ND	ND	ND	ND	ND.
BENZO(b)FLUORANT.*	2.50	7.60	9.00	1.30	15.00
BENZO(e)PYRENE	1.80	5.10	5.80	1.20	12.00
BENZO(a)PYRENE	1.40	3.60	2.00	0.50	11.00
PERYLENE	0.70	70	ND	0.38	3.70
INDENO(1,2,3-cd)PYR.	ND	5.50	ND	NO	ND
DIBENZO(a,h)ANTHR.	ND	ND	ND	ND	ND
* (b) and (k) isomers comb.					
TOTAL TARGET PAH:	440.00	2300.00	1500.00	120.00	350.00

,	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
SAMPLE ID:	K51	K52	K53	K54	K55
GC/MS TARGET	ug/g	ug/g	ug/g	ug/g	. ид/д
COMPOUND					
NAPHTHALENE	9	29	29	N D	G Z
C-1 NAPHTHALENE	ND	29	NO	ND	20
C-2 NAPHTHALENE	ND	20	2	ND	70
C-3 NAPHTHALENE	ND	ND	70	ND	9
C-4 NAPHTHALENE	ND	20	ND	20	2
FLUORENE	ND.	ND	29	ND	ND
C-1 FLUORENE	70	20	N D	ND	. 29
C-2 FLUORENE	ND	ND	ND	0.100	ND
C-3 FLUORENE	29	ND	0.680	0.590	ND.
DIBENZOTHIOPHENE	70	0.016	0.036	0.023	ND
C-1 DIBENZOTHIO.	0.089	0.190	0.410	0.310	0.014
C-2 DIBENZOTHIO.	0.650	1.200	2.700	2.200	
C-3 DIBENZOTHIO.	1.400	3.100	6.900	5.700	0.420
PHENANTHRENE	0.021	0.028	0.052	0.034	0.000
C-1 PHENANTHRENE	0.083	0.160	0.360	0.290	0.020
C-2 PHENANTHRENE	0.270	0.560	1.300	0.990	0.065
C-3 PHENANTHRENE	0.360	0.990	2.200	1.600	0.160
ANTHRACENE		ND	0.004	20	ND
FLUORANTHENE	0.036	0.068	0.160	0.099	0.011
PYRENE	0.044	0.085	0.200	0.140	0.013
C-1 PYRENE	0.023	0.150	0.320	0.220	0.017
C-2 PYRENE	0.160	0.350	0.790	0.450	0.052
BENZO(a)ANTHRACENE	0.013	0.024	0.063	0.031	0.012
CHRYSENE	0.054	0.082	0.170	0.098	0.028
C-1 CHRYSENE	0.076	0.210	0.340	0.170	0.028
BENZO(b)FLUORANT.*	0.012	0.027	0.046	0.025	0.027
BENZO(e)PYRENE	0.022	0.016	0.033	0.017	
BENZO(a)PYRENE	0.011	0.012	0.028	0.012	0.014
PERYLENE	ND	0.001	0.030	0.006	
INDENO(1,2,3-cd)PYR.	70			0.019	
DIBENZO(a,h)ANTHR.	ND	ND	0.001	70	0.009
* (b) and (k) isomers comb.					
TOTAL TARGET PAH:	3.300	7.300	17.000	13.000	1.100
· ·	l				

SAMPLE ID: GC/MS TARGET COMPOUND NAPHTHALENE	K56 ug/g	K56 (dup.)	K71 ug/g	N1183-1
COMPOUND NAPHTHALENE	29	ug/g	บg/a	
COMPOUND NAPHTHALENE	29	ug/g	ug/a	
NAPHTHALENE	29			ug/g
A A MADUTUAL CALC		9	3.500	210.000
C-1 NAPHTHALENE		29	91.000	1400.000
C-2 NAPHTHALENE	ND	ND	780.000	3500.000
C-3 NAPHTHALENE	NO	20	1500.000	4300.000
C-4 NAPHTHALENE	ND	ND	1300.000	2900.000
FLUORENE	29	70	47.000	110.000
C-1 FLUORENE	ND	ND	170.000	330.000
C-2 FLUORENE	9	ND	390.000	780.000
C-3 FLUORENE	0.068	ND	640.000	1200.000
DIBENZOTHIOPHENE	9	ND	160.000	350.000
C-1 DIBENZOTHIO.	0.023	, ND	620.000	1600.000
C-2 DIBENZOTHIO.	0.260	0.160	1700.000	3500.000
C-3 DIBENZOTHIO.	- 0.843	- 0.660	2300.000	4200.000
PHENANTHRENE	20	ND	110.000	210.000
C-1 PHENANTHRENE	0.025	0.012	400.000	730.000
C-2 PHENANTHRENE	0.130	0.076	630.000	
C-3 PHENANTHRENE	0.210	0.061	670.000	1200.000
ANTHRACENE	ND	ND	1.200	3.600
FLUORANTHENE	0.015	ND	2.300	7.800
PYRENE	0.010	ND	10.000	16.000
C-1 PYRENE	9	0.026	67.000	100.000
C-2 PYRENE	0.071	0.057	150.000	200.000
BENZO(a)ANTHRACENE	0.007	ND	15.000	0.440
CHRYSENE	0.054	0.036	22.000	28.000
C-1 CHRYSENE	0.180	0.099	79.000	0.260
BENZO(b)FLUORANT.*	0.018	0.016	6.600	5.400
BENZO(e)PYRENE	0.021	0.013	7.400	5.600
BENZO(a)PYRENE	0.010		4.100	
PERYLENE	10	ND	2.200	1.200
INDENO(1,2,3-cd)PYR.	<u></u>		<u>ND</u>	ND
DIBENZO(a,h)ANTHR.	ND	ND	ND	Ŋ
* (b) and (k) isomers comb.	<u> </u>	 		
TOTAL TARGET BALL	2 000	1 200	12000 000	28000 000
TOTAL TARGET PAH:	2.000	1.200	12000.000	28000.000

DATE:

September 19,1991

TO:

Charlie Henry, RA IV, Institute for Environmental Studies

W

FROM:

M. Michelle Mayfield, LA I, Institute for Environmental Studies

RE:

Kuwait sediment residual oil weights

Below are the residual oil weights for the Kuwait sediments as requested. Six samples and one duplicate sample were analyzed. High percentages of residual oil (.7 to almost 6%) were seen as expected from these highly contaminated soils.

FIELD ID	mg OIL/				
	g SAMPLE				
K51	7.4				
K52	32				
K53	56				
K54	22.0*				
K55	8.2				
K56	11				
K56DUP	9				

OX CENTRALIAN

^{*}Semiquantitative value due to lab accident. Actual value higher.

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			o de la composition de la composition de la composition de la composition de la composition de la composition La composition de la			
	*				•	
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SULTANATE OF OMAN

Ministry of Water Resources



سلطنية عميان وزارة مسوارد المساه

No. : MWR/WAS/26-5/627/471/91

Date: 9 November 1991

الرقم :

التاريخ : ﴿

الموافق :

Arabian Gulf Program Office 14th Constitution Ave. NW Rm. 5128 Washington D.C. 20230 U.S.A.

Vitie /

Attn: Mr. John H. Robinson, Chief Hazardous Materials Response Branch

After Compliments,

Sub: Rainfall Samples - Hydrocarbon Analyses

In response to your discussion with Don Davison, concerning pollution caused by Kuwait oil fires, the Ministry of Water Resources has taken 3 samples of rainfall for hydrocarbon analyses.

Attached are copies of Analytical Data Reporting Forms with lab analysis results from rainfall samples taken in Oman since March 1991. The Total Hydrocarbon is expressed in micrograms /liter.

I trust these samples will provide some information as to the extent of the effects of the oil fires. The people in this part of the world are thankful that the fires have now extinguished.

If you have any questions concerning these data, feel free to contact me.

Best regards,

Wayne C. Curry

Director, Surface Water Department

P.O. Box 5575 Ruwi

Tel.: 703552/703553

Telex: 3629 MWR ON

Fax: 706782 (Technical) - 701515 (Admin)

ص.ب ۲۵۵۵ روي

هاتف : ۷۰۲۰۰۲/۷۰۲۰۰۲

تلک س : ۱ MWR ON ۲۲۲۹

عَاكِس : ٧٠١٧٨٢ (الشؤون الغنية) ٥٠١٥١ (الشؤون الادارية)

WILTANATE OF OMAN Ministry of Water Resource Water Quality Laboratory Tel. 561905 / 561914



سيلطنة عميان وزارة موارد المياه منتبر نرعبة المياه لليفرن ١١١١٥٥ / ١١١٠٥

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	LABO	RATORY JOB No. 2	925	10.1	1110	SITE NUMBER DP 2	9318	7 AF
	Source	e 🗌 👍 Samplir	g dalo 🎗 🗓] වුයි	<u> </u>	[(26°08'30"N) 56°14'21"E)Time		MRUANN LLusab Town
	Reque	sted by <u>Newri</u>	Sampled by	AL: K	<u>Lg13</u>	Return Results to	5. w. lep	<i>9</i> -
	Field A	nalysis : Conductance	micro	S./cm.	To	тр с рн		Units
	Sample	Volume 1500 m.l.	Surface wate	er ; flow rate		L/s Gauge Heighl		
,	Ground	Water: Water Level		m		Pumping rate		
	Hours	pumped hours	mins. A	egion) /	Analysis Required Complete	Partial	Special
	Comm	nents & Sample of	Rainfal	l acc	ити	lation from 2-2	Z March	991
	Req.	Constituent	Value mg/L	me/L= mg/Lx	Req.	Constituent	Value mg/L	me/L= mg/Lx
		pH (Units).	6.39			Tot. Hardness, Ca CO ₂	5.0.	0.0200
	<u> </u>	Tot. Alkalin. Ca COa	48-	0.0200		Calcium Hardness, Ca CO ₃	28	0.0200
		Carb. Alkalin., CaCO ₃		0.0200		Magn. Hardness, Ca COs	22	0.0200
]	Bicarb. Alkalin., CaCO ₃		0.0200		Calcium, Ca ++	11	0.04990
i	<u> </u>	Hyd. Alkalin., CaCO ₃		0.0200		Magnesium, Mg++	5	0.08229
		Phenolph, Alkalin., CaCO ₃	•	0.0200		Sodium, Na+	18:	0.04350
		Conductance, (microS/cm.)	248			Potassium, K+	2-0	0,02556
,		Chloride, Cl	22-	0.02821		Boron, B		0.02775
		Sulphate, SO 4	15	. 0.02092		Soluble Iron, Fe		0,03581
•		Fluoride, F	(0,01	0,05264		Soluble Manganese, Mn		0.03640
		Bromide, Br		0.01252	<u> </u>	ion Balance (%error)	-3.27	
		Nitrate Nitrogen, NOs-N	.0:84	0.0714		Sodium Absorbtion Ratio	1.11	
		Nitrite Nitrogen, NO2 - N		0.0714		Sodium Equivalent Ratio	42.71	
į		Ammonia Nitrogen, NH ₃ - N	-	0.0714		Total Hydrocan bon.	1.46.42	16_
- {		Total Phosphate; PO 4 - P	0.112	0.0316				
		Orthophosphate, PO 1.P		0.0316				
		Tot, Solids at 180 °C				•		
}	1	Tot. Dis. Solids at 180 C	148		·			
İ		Sus. Solids at 103 °C						
•								

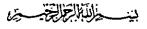
The higher than accorded and of Total Hydro carbon indicate, not william . He

Exappropriate sampling could have coursed less of some constituents.

ii.

SULTANATE OF OMAN Ministry of Water Resource

Water Quality Laboratory Tel. 561905 / 561914





مختبس نوعية المياه تليفون ١٩١٤ه / ٥٦١٩١٥

57° 15'41"E)

ANALYTICAL DATA REPORTING FORM

21231 ELZGTAOAAF 2 1 2 2 1 SITE NUMBER LABORATORY JOB No. 1 ALTITUDE: ZBZOM. (MASL) Source F Sampling date \ у у Field Analysis : Conductance microS. / cm. Temp. Sample Volume Surface water : flow rate Gauge Height Ground Water: Water Level Pumping rate Analysis Required Complete Partial Special Hours pumped hours Region CUMULATIVE Comments Jahe! Shams, rown water 27 MMR. 1991-9.0 mm., 25APR-0.2 mm. + 28 APR. 44.6 mm. (TOTAL: 53.8 mm) Value Value me/L= me/L= Reg. Constituent Req. Constituent mg/LX mg/L mg/L mg/Lx pН 7.70 Tot, Hardness, Ca CO3 0.0200 (Units) 100 Tot. Alkalin. Ca CO 3 98 0.0200 Calcium Hardness, Ca CO₃ 0.0200 90 Carb. Alkalin., CaCO₃ 0.0200 Magn, Hardness, Ca CO3 10 0.0200 0 36 Bicarb. Alkalin., CaCO3 0.0200 0.04990 98 Calcium, Ca++ 2 0.0200 Hyd. Alkalin., CaCO3 Magnesium, Mg++ 0 0.08229 0 0.0200 Phenoiph, Alkalin., CaCO₃ Sodium, Na+ 0.04350 193 Conductance, (microS/cm.) Potassium, K+ 0.02556 5.00 Chloride, 0.02821 Boron, B 0.02775 Sulphate. SÕ4 0.02082 Soluble Iron, Fe 0.03581 Fluoride, F 40.0 0.05264 0.03640 Solubie Manganese, Mn Bromide, Br - 1.75 0.01252 ion Balance (%error) Nitrate Nitrogen, NO3-N 1.45 0.0714 Sodium Absorbtion Ratio 0.35 Nitrite Nitrogen, NO2-N 0.0714 Sodium Equivalent Ratio Ammonia Nitrogen, NH₃-N 0.0714 Teco Hydrocail Total Phosphate, PO4-P <0.01 0.0316 Orthophosphate, PO4 P 0.0316 Tot. Solids at 180 °C Tot. Dis. Solids at 180 °C 100 Sus. Solids at 103 °C

	***	Approved		Date	27/////
LAB. NOTES					
			•	••••	
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SULTANATE OF OMAN

Council for Conservation of Environment and Water Resources

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			19 (·	5 7°	•	•3141 <u>4/</u> •31 <u>4</u>	
LABO	RATORY JOB NO	783			SITE NUMBER EL49	3057	AH
Source	ن ن ن		, -	0	9 / Y y		
Reques	ted by WASH Sai	mpled by	12H		Return Results to WAST	– Surfaci	EPT,
	nalysis: Conductance	umhos/cm.	Te	ımp. \Bigg	•°C pH	1111	its
Sample	Volume	Surface water:	flow rat		/s Gauge Height	T	
Ground	Water: Water Level		. .		Pumping rate	i/s	
Hours	pumped	District	\mathcal{B}		Analysis Required S P = Parti	lete al	
Commer	nts Make hydrocart	on ana	_ 		s well an chemica	analy	LO
	RUSTAQ MÉT, STATI	ON Analytic	al Data R	leportin	GUMULATIVE R g Form. ZBSEPT.1911—0.Zh	MIN FALLS	T,-46,
Req.	Constituent	Value mg/1	me/1= mg/1x	Dan		Value mg/1	me/1= mg/1x
	PH (Units)	7.16		٤	Tot. Hardness,Ca CO ₃	45	0.0200
	Tot. Alkalin. Ca CO3	20	0.0200	/	Caltium Hardness, Ca CO ₃	35	0.0200
	Carb. Alkalin., CaCO3	0	0.9200		Magn. Hardness, CaCO ₃	10	Biv.200
/	Bicarb. Alkalin., CaCO3	20	0.0200		Calcium, Ca++	-14	0.04,990
,	Hyd. Alkalin., CaCO3	0	9.0200	1	Magnesium. Mg++	2	0,08229
	Phenolph, Alkalini, CaCO3	0	0.0200	1	Sodium, Na+	. 2_	0.04350
_	Conductance, (umhos/cm.)	84		,,,	Potassium, K+	•3	0.02554
	Chloride, El	3.0	0.02821		Boron, B		0.02775
/	Sulfate, SO4	16	0,02082		Soluble Iron, Fe (ug/1)		0.03581
	Fluoride, F		9.05264		Soluble Manganese,Mn(µg/1)		0.03640
	Bromide, Br		0.01252		Ion Balance (%error)	3.41	
-	Nitrate Nitrogen, NO3—N	11.55	0.0714		Sodium Adsorbtion Ratio	0.13	
	Nitrite Nitrogen, NO ₂ —N		9.0714		Sodium Equivalent Ratio	8.75	
	Ammonia Nitrogen, NH3-N		0.0714		Total Hydrocorbon, 4911	0.36	
	Total Phosphate, PO4—P		0.0316				
	Orthophosphate, PO4—P		0.03%				
	Tot. Solids at 180°C						
	Tot. Dis. Solids 180℃	18				- <u>-</u> -	
	C . C . L' A 402.95				,		

ASSESSMENT OF EFFECTS ON HUMAN HEALTH FROM KUWAITI OIL FIRES

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ALTOCK COLLINS

MICH ON THE

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: March 29, 1991

John B. StewartDirector, Office of Foreign IntelligenceU.S. Department of Energy

from: Dennis Engi Strategic Technologies Division, 6601

subject: Assessment of Effects on Human Health from Kuwaiti Oil Field Fires

Introduction

The certainty of long-term smoke emissions (possibly one to two years based on estimates by well-control experts) from burning Kuwaiti oil wells has increased concerns regarding personnel exposure and acute and chronic health effects. Before the war, environmental scientists could only roughly estimate possible adverse environmental effects using pollutant dispersion models and limited source-term data. These estimates, though credible, had to be regarded with circumspection. Now, two complementary approaches to improved assessments of health effects can be taken. First, pollutants can be measured at various sites in the regions where exposure levels and health effects need to be assessed. This approach is currently being pursued by a contingent of the EPA. Second, with known numbers and locations of burning wells, better assessments of exposure levels can be made using pollutant dispersion models. Exposure levels from both approaches can be compared and used with known dose-response relationships to estimate short-term and long-term health effects. This memo describes follow-on efforts to the pre-war modeling studies of the threat to exposed populations. Estimates of the groundlevel concentrations for pollutants with potentially adverse effects on health have been made using an improved (two-dimensional, multi-source) dispersion model and the best data available to assess both short-term and long-term effects on exposed populations.

Background

Before the ignition of the Kuwaiti fields, SNL provided preliminary estimates of regional toxicological threats for a number of well-burning scenarios in Sandia Report, SAND91-0184, Potential Impacts of Iraqi Use of Oil as a Defensive Weapon. Burning wells in each of three principal production areas (Southeast, West, and North fields) were modeled as line sources oriented normal to the expected wind direction. Expected ground-level concentrations of NO_x, SO₂, CO, and soot were calculated at distances ranging from 1 to 100 kilometers downwind from each line source. Major population centers were not expected to be affected by the pollutants even for the worst-case scenario (a total of 720 wells ignited). Where some impact

appeared possible (in the vicinity of the Southeastern fields), no acute health effects were expected, except within a small sensitive population (infants, elderly, asthmatics) susceptible to SO₂ and soot. No computer calculations of exposure levels for representative volatile organic compounds (VOCs) and polynuclear aromatic compounds (PNAs) were made because their concentrations were expected to be too low to cause adverse health effects.

Multi-Source Dispersion Calculations

Dispersion Model

The Industrial Source Complex Short Term Dispersion Model was used to compute downwind ground-level concentration isopleths for pollutants (NO_x, SO₂, CO, soot, benzene vapor, and benzo(a)pyrene vapor) generated by 516 burning wells in eight fields in the principal oil production areas. This model is widely used in the U.S. to assess the effects of pollutants on local air quality. The model assumes that the downwind spread of a plume in both the horizontal and vertical directions behaves in a Gaussian manner that can be parameterized by dispersion coefficients that increase with downwind distance from the source. Values for the dispersion coefficients (standard deviations of plume width) are determined by direct meteorological measurements such as wind speed, the mixing depth of the atmosphere, and the temperature-altitude structure of the atmosphere. Input data can be obtained from routine measurements at a weather station in the locale of interest. Most useful in this analysis is the model's ability to account for multiple sources simultaneously so that the exposure level calculated for a specified pollutant at any given location is that from all sources.

Inputs

Two types of input to the model are needed to obtain reasonable estimates of pollutant concentrations:

- Source information, including realistic estimates of source location, size, oil blowout rate, plume injection height, and pollutant production rate,
- Meteorological information for the region of interest, including surface temperature, Pasquill stability category, wind speed and direction, and mixing height.

Source Information

Source location and size - Fields with burning wells and the number of these wells have been identified. The size (areal extent) of each oil field was approximated using satellite photos of the region. All fields are assumed to be 10 km on a side. A

map of Kuwait showing the locations of the eight oil fields with burning wells and the location of the densely populated Kuwait City area is shown in Figure 1.

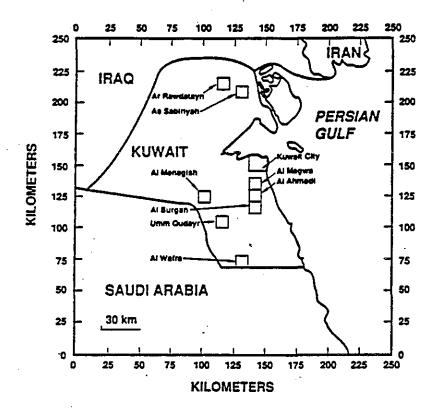


Figure 1. Locations of Burning Fields and Principal Population Center.

Oil blowout rate - The rate is dependent on many factors, including wellhead pressure, size of the well, extent of damage to plumbing, and inter-well pressure effects. Pre-war information provided by Kuwaiti engineers regarding well pressure, well size, subterranean geological formation, etc., was used in previous analyses to calculate expected oil blowout rates for completely breached wellheads. Because no new information is available, the blowout rates used here are unchanged from those in the pre-war calculations.

<u>Plume injection height</u> - Earlier calculations of buoyant rise of the smoke plume gave injection heights of about 200 to 450 meters for most wells in the affected oil fields. An average plume injection height of 300 meters is used for these calculations.

<u>Pollutant emission factors</u> - The emission factor for a pollutant is the mass of the pollutant that is released per unit mass of crude oil burned. An emission factor of 0.01 for nitrogen oxides would release 1 kilogram of NO_x for every 100 kilograms of

oil consumed. The values used for the pollutants examined in this analysis are based on work for the Nuclear Winter Source-Term Measurement Program on aviation fuel pool fires. Because there are few data for actual crude oil fires, these values are the best estimates at this time. The emission factor for each pollutant likely to cause adverse short-term or long-term health effects was used to calculate a total release rate for that pollutant for each affected oil field. Table 1 shows that the three southeastern fields (Al Burgan, Al Ahmadi, Al Magwa) have the highest release rates.

Table 1. Pollutant Release Rates

Oil Field	NO_x (g/s/m²)	SO_2 $(g/s/m^2)$	CO (g/s/m ²)	Soot (g/s/m²)	Benzene (μg/s/m²)	Benzopyrene (μg/s/m²)
Ar Rawdatayn	9.98E-05	4.99E-04	5.59E-05	5.99E-04	6.49E+00	9.98E-03
Al Sabiriyah	7.59E-05	379E-04	4.25E-05	4.55E-04	4.93E+00	7.59E-03
Al Magwa	1.53E-04	7.67E-04	8.59E-05	9.20E-04	9.97E+00	1.53E-02
Al Ahmadi	1.56E-04	7.79E-04	8.73E-05	9.35E-04	1.01E+01	1.56E-02
Al Burgan	4.52E-04	2.26E-03	2.53E-04	2.71E-03	2.94E+01	4.52E-02
Al Managish	3.13E-05	1.57E-04	1.75E-05	1.88E-04	2.03E+00	3.13E-03
Umm Qudayr	1.60E-05	7.98E-05	8.94E-06	9.57E-05	1.04E+00	1.60E-03
Al Wafra	1.02E-05	5.11E-05	5.72E-06	6.13E-05	6.64E-01	1.02E-03

Emission Factors:

 $NO_x = 0.01$; $SO_2 = 0.05$; CO = 5.6E-03; Soot = 0.06;

Benzene = 6.5E-04; Benzo(a)pyrene = 1E-06

Meteorological Information

Although the model can accept hourly meteorological data for an entire year, such data are not available for the region. Consequently, 10-year climatological summaries of meteorological data from Kuwait City airport have been used to provide a single average daytime (3PM Kuwait time) and a single average nighttime (3AM Kuwait time) summary for each month. The resulting set of data applies to 24 discrete meteorological periods (Table 2) for which the model calculates downwind pollutant concentrations. Specific meteorological parameters required for each period are discussed below.

<u>Surface temperatures</u> - These data are taken directly from the climatological summaries.

<u>Pasquill stability category</u> - This parameter characterizes the temperature-altitude structure, which affects the degree of vertical mixing in the plume. For these calculations, the daytime category selected is unstable (A) and the nighttime category selected is stable (D).

Wind speed and direction - These data are taken directly from the climatological summary and, as indicated above, provide an average daytime and nighttime speed and direction for each month. Note that the average wind direction is relatively constant throughout the year. Winds are typically from the northwest with little variation.

Mixing height - This parameter characterizes the height of the mixed layer into which the plume in injected. Atmospheric mixing-height data for each of the 24 periods were taken from a 10-year summary of atmospheric inversion data that excluded surface inversions. Surface inversions were excluded because the heat content of these plumes is considered to be great enough to penetrate any shallow surface inversion. Mixing heights (median inversion heights) in the Kuwaiti region range from a minimum of 800 meters during the winter season to a maximum of 4800 meters during the summer months.

Table 2. Kuwait City Airport Ten-year Climatological Summary

Per Month		Avg Temp (C)	Avg Press (mbar)	Avg Wspeed (m/s)	Avg Wdir (Deg)	Flow Vector ^a (Deg)	Median Invht ^b (m)
Jan	0300	9.4	1013.9	2.5	11.0	191.0	800
Jan	1500	17.5	1013.0	5.3	326.0	146.0	1000
Feb	0300	11.3	1011.8	2.5	11.0	191.0	1200
Feb	1500	20.0	1010.7	5.7	326.0	146.0	1200
Mar	0300	15.4	1008.1	2.9	11.0	191.0	1000
Mar	1500	24.3	1007.4	5.9	326.0	146.0	1600
Apr	0300	21.5	1004.9	3.0	11.0	191.0	1000
Apr	1500	31.3	1004.8	6.0	349.0	169.0	2000
May	0300	27.1	1001.6	3.3	11.0	191.0	1200
May	1500	37.9	1001.6	6.6	349.0	169.0	2200
Jun	0300	30.8	996.2	4.5	326.0	146.0	2000
Jun	1500	42.6	995.9	8.2	349.0	169.0	3800
Jul	0300	32.8	992.8	3.7	326.0	146.0	3400
Jul.	1500	44.9	992.2	7.5	349.0	169.0	4800
Aug	0300	31.9	993.9	3.3	11.0	191.0	2000
Aug	1500	43.6	993.7	7.2	326.0	146.0	4400
Sep	0300	27.6	999.9	2.2	11.0	191.0	3800
Sep	1500	41.0	999.6	5.7	349.0	169.0	4800
Oct	0300	22.4	1006.6	2.4	11.0	191.0	1200
Oct	1500	34.3	1006.1	5.5	349.0	169.0	1800
Nov	0300	16.5	1011.5	2.7	11.0	191.0	1000
Nov	1500	25.7	1010.7	5.5	349.0	169.0	1200
Dec	0300	10.7	1013.9	2.3	11.0	191.0	800
Dec	1500	19.1	1012.8	5.2	326.0	146.0	1000

^{*180} deg from the wind direction

bMedian inversion heights exclude surface-based inversions.

Results

Results of computations are given as downwind, ground-level concentration isopleths in Figures 2 to 8. The pollutants analyzed include nitrogen oxides ($NO_x = NO_2$, NO), sulfur dioxide (SO_2), carbon monoxide (CO), particulates (soot), VOCs (benzene), and PNAs (benzo(a)pyrene). Figures 2 through 4 show the second highest hourly concentration levels obtained for NO_x , SO_2 , CO, and soot during the 24 meteorological periods treated by the model. The highest hourly concentration levels are treated as unrepresentative and are discarded. Second highest hourly concentration levels represent short-term levels and are used as acute exposure levels. Figures 6 through 8 show average concentrations for soot, benzene, and benzo(a)pyrene averaged over all 24 periods examined by the model. These isopleths represent long-term, or chronic, exposure levels. In all cases, the highest exposure levels are immediately downwind of the Al Magwa, Al Ahmadi, and Al Burgan fields. This is not surprising because these oil fields have the highest wellhead pressures and the largest number of burning wells (70% of the total).

Nitrogen oxide levels (Figure 2) include nitric oxide (NO) and nitrogen dioxide (NO₂). Although most of the NO_x produced at the wellhead is NO, some fraction (about 25%) reacts with ambient oxygen to form NO₂. The rate of this reaction is proportional to the square of the NO concentration, so a high rate of conversion of NO to NO₂ occurs when the NO concentration is high. However, when the NO concentration falls as a result of plume dilution, this reaction pathway ceases to contribute to NO₂ formation. The highest NO_x level in the model calculations is 520 μ g m⁻³ (computed as NO₂). Assuming conservatively that 25% is NO₂, then hourly average levels of about 250 μ g m⁻³ of NO and 130 μ g m⁻³ of NO₂ would be expected in the region of high-level exposure southeast of the Al Burgan field. Levels along the more heavily populated coastal area would be lower by about a factor of two, and levels in the region of Kuwait City would be lower by about a factor of five. Ozone formation and ozone reactions with the nitrogen oxides are not examined in this analysis.

Hourly average sulfur dioxide levels (Figure 3) are among the highest encountered for any of the pollutants examined (Kuwaiti oil has a sulfur content near 2.5%). The SO₂ emission factor (0.05) and resultant downwind concentrations are correspondingly higher than those observed for NO_x (emission factor = 0.01). The highest level is about 2,200 μ g m⁻³ and occurs immediately southeast of the Al Burgan field. Levels drop off to about 1,000 μ g m⁻³ along the gulf coastal areas and to about 300 μ g m⁻³ in the region of Kuwait City.

Carbon monoxide levels are low in all areas (the emission factor for CO in these crude oil fires is about one-tenth that for SO_2). Background CO levels for clean air are typically about $100 \ \mu g \ m^{-3}$. Most of the downwind CO levels (Figure 4) are no more than a factor of two or three greater than the background level.

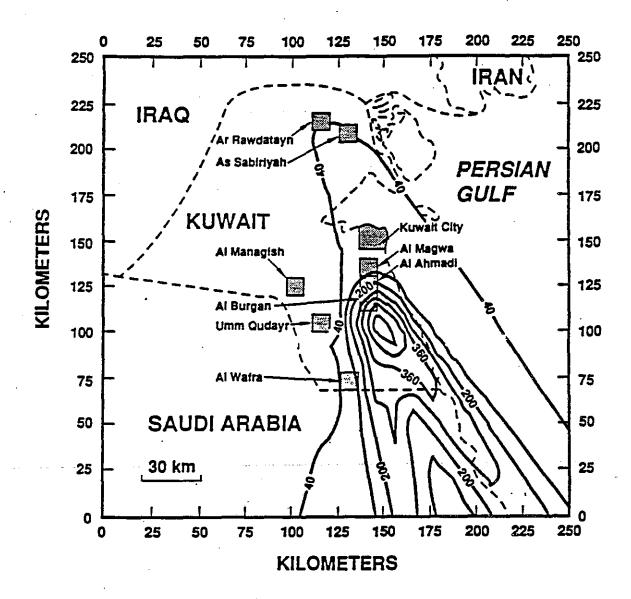


Figure 2. Downwind Ground-level Concentration Isopleths for NO_x Released from Burning Kuwaiti Oil Fields. The plot depicts the second highest hourly values in μg m⁻³ (as NO_2) calculated using a multi-source dispersion model run for 24 1-hour periods that represent average day and night meteorological conditions for each month. Contour interval is $80 \ \mu g$ m⁻³.

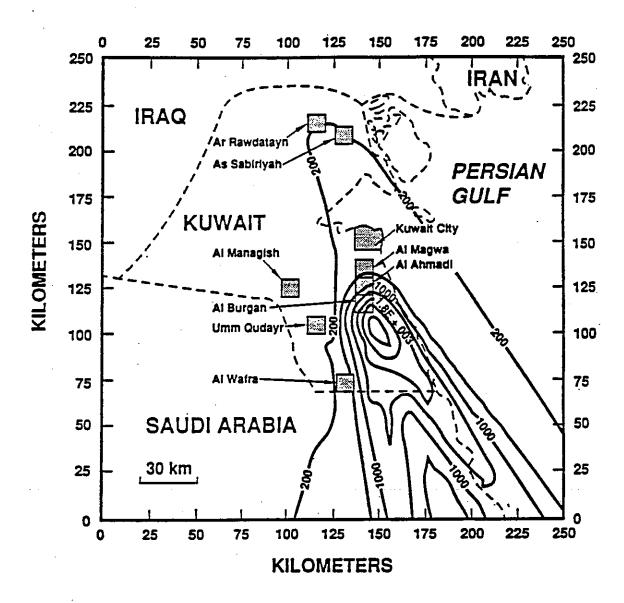


Figure 3. Downwind Ground-level Concentration Isopleths for SO₂ Released from Burning Kuwaiti Oil Fields. The plot depicts the second highest hourly values in μg m⁻³ calculated using a multi-source dispersion model run for 24 1-hour periods that represent average day and night meteorological conditions for each month. Contour interval is $400 \mu g$ m⁻³.

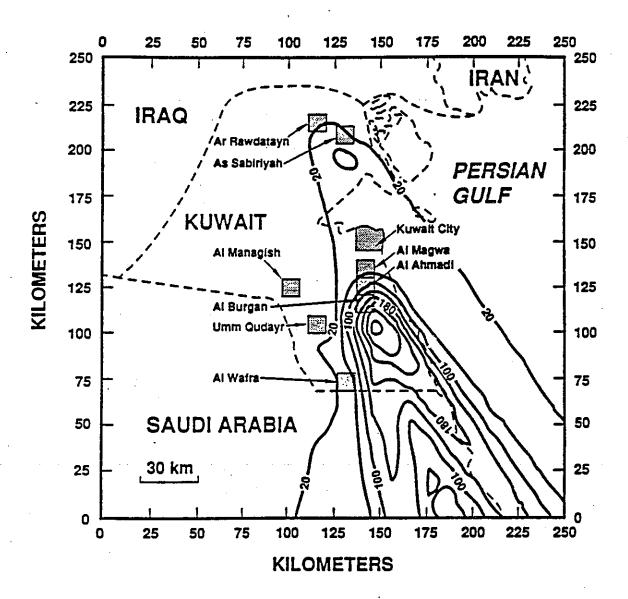


Figure 4. Downwind Ground-level Concentration Isopleths for CO Released from Burning Kuwaiti Oil Fields. The plot depicts the second highest hourly values in μg m⁻³ calculated using a multi-source dispersion model run for 24 1-hour periods that represent average day and night meteorological conditions for each month. Contour interval is $40 \ \mu g$ m⁻³.

Acute exposure levels for soot are shown as second highest hourly concentrations in the 3-D surface plot of Figure 5, and chronic exposure levels for soot are shown as annual average concentration isopleths in Figure 6. Hourly average values are in excess of 1,600 μ g m⁻³ immediately southeast of the Al Burgan field and drop to 800 to 1,000 μ g m⁻³ range near the Kuwait-Saudi border and along the gulf coastal region. Annual average soot levels, as shown in Figure 6, are lower than the second highest hourly values by about a factor of five.

Benzene is a typical VOC and is used here to represent this class of compounds. The benzene emission factor ($\sim 7 \times 10^{-4}$) was estimated in earlier SNL work involving smoke samples collected from large aviation fuel pool fires. Downwind annual average concentrations of benzene (Figure 7) range from a low of <1 μ g m⁻³ near the northern oil fields of Ar Rawdatayn and Al Sabiriyah to a high of about 9 μ g m⁻³ southeast of the Al Burgan field.

Benzo(a)pyrene is a typical PNA and is representative of the whole class of similar compounds many of which are either suspected or confirmed carcinogens. Emission factors for benzo(a)pyrene in crude oil or aviation pool fires are not well defined, so a value of 1×10^{-6} (obtained from published data on smoke samples collected from burning refuse piles) was used to provide an upper bound. Downwind exposure levels (Figure 8) range from a low of <1 ng m⁻³ in the north to a high of about >12 ng m⁻³ near the Al Burgan field.

Table 3 summarizes the hourly or annual average concentrations of pollutants that would be expected in the populated coastal region east of the Al Burgan field and in the vicinity of Kuwait City and, for comparison, lists typical values for these pollutants in urban areas of the U.S. In comparison to urban regions of the U.S., populated regions of Kuwait are likely to experience higher levels of SO₂ and soot.

Table 3. Comparison of Expected Hourly or Annual Average Concentrations of Selected Pollutants in Populated Areas of Kuwait with Levels Measured in Typical Urban Areas of the U.S.

Concentration Levels (µg m-3)

Species	Average Type	Coastal Areas	Kuwait City	Urban U.S.		
NO	Hourly	175	40	50-750		
NO ₂	Hourly	90	20	50-250		
SO ₂	Hourly	1,100	300	20-200		
co	Hourly	180	40	1,000-10,000		
Soot	Annual	180	80	10-30		
Benzene	Annual	3	1	40-1,000		
Benzo(a)Pyrene	Annual	5E-03	1E-03	2E-03 to 1E-02		

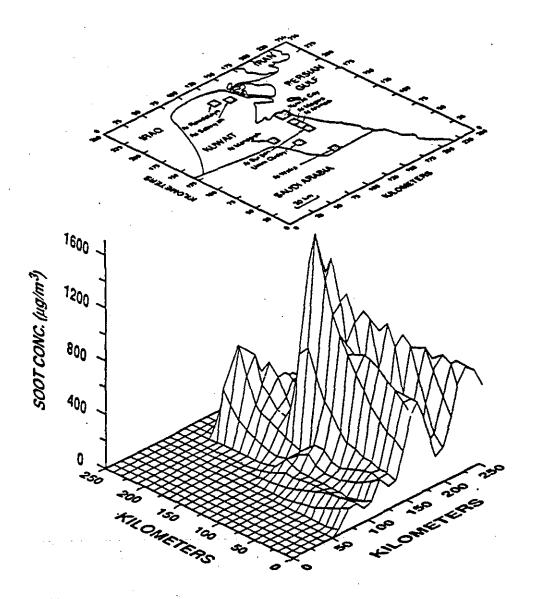


Figure 5. Three dimensional Surface Plot of Soot Concentrations Released from Burning Kuwaiti Oil Fields. The plot depicts the second highest hourly values in μ g m⁻³ calculated using a multi-source dispersion model run for 24 1-hour periods that represent average day and night meteorological conditions for each month. The viewer perspective is from the southwest. The grid shown is the same as that depicted in the map shown in Figure 1. Kuwait City is located at the grid point X=150 km, Y=150 km.

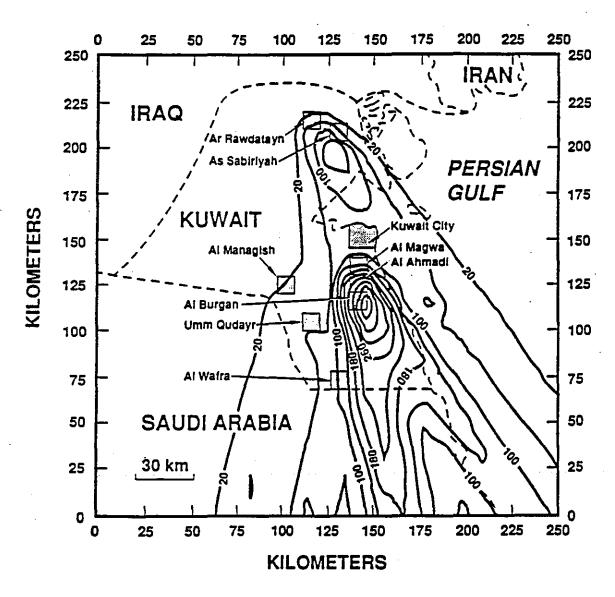


Figure 6. Downwind Ground-level Concentration Isopleths for Soot Released from Burning Kuwaiti Oil Fields. The plot depicts an annual average concentration in μ g m⁻³ calculated using a multi-source dispersion model run for 24 1-hour periods that represent average day and night meteorological conditions for each month. Contour interval is 40μ g m⁻³.

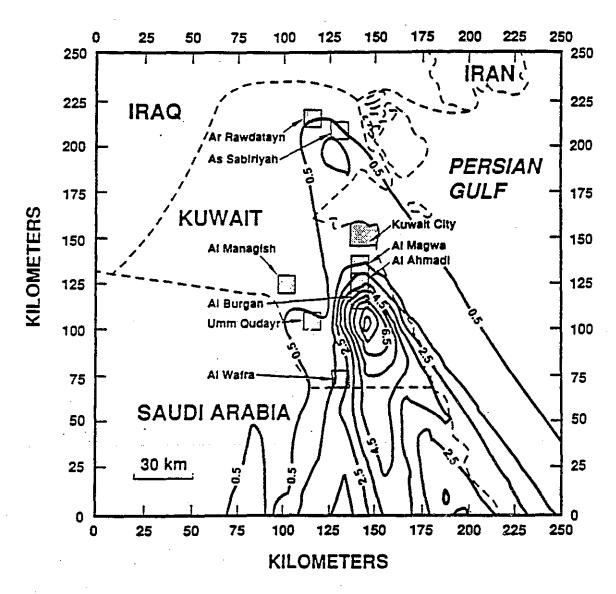


Figure 7. Downwind Ground-level Concentration Isopleths for Benzene Vapors Released from Burning Kuwaiti Oil Fields. The plot depicts an annual average concentration in μg m⁻³ calculated using a multi-source dispersion model run for 24 1-hour periods that represent average day and night meteorological conditions for each month. Contour interval is $1 \mu g$ m⁻³.

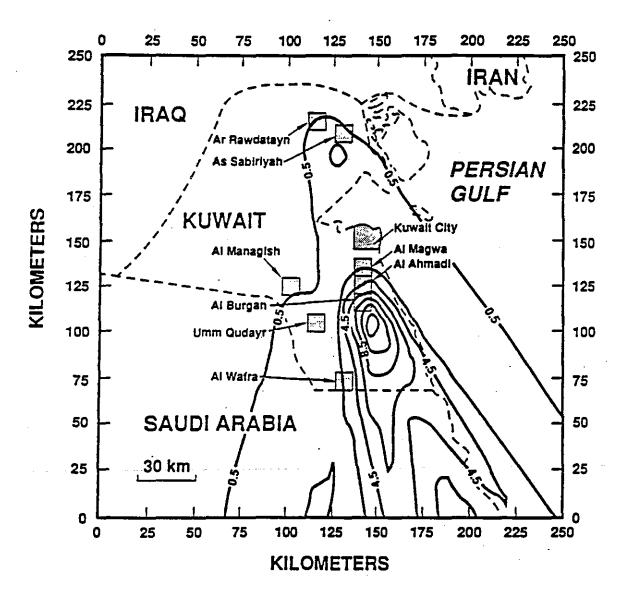


Figure 8. Downwind Ground-level Concentration Isopleths for Benzo(a)pyrene Vapors Released from Burning Kuwaiti Oil Fields. The plot depicts an annual average concentration in ng m-3 calculated using a multi-source dispersion model run for 24 1-hour periods that represent average day and night meteorological conditions for each month. Contour interval is 2 ng m-3.

Recommendations for Further Work

Now that access to the Kuwaiti oil fields is possible, there is opportunity to do experiments that will

- Generate actual concentration isopleths (and, collaterally, help to validate source-term/dispersion models),
- Establish legally unimpeachable exposure levels, and
- Explore means to alter the smoke plume so as to mitigate adverse health effects.
- Improve understanding of smoke source terms in oil well fires,
- Provide a well-characterized smoke environment in which to test the performance of military systems.

A data acquisition program should be carried out to measure pollutant concentrations at various locations and times in order to generate actual concentration isopleths that will provide a realistic picture of exposure hazards in the region. The program should be carefully designed and should take advantage of state-of-the-art instrumentation and sampling techniques.

Exposure levels should be carefully documented because the documentation may be especially useful should litigation arise from claims from military or U.S. civilian personnel exposed to oil fire smoke. The scientific uncertainties surrounding the nature and extent of exposure of personnel, as was the case with Agent Orange in Vietnam, should not be repeated.

Experiments should be done in conjunction with computer calculations of oil combustion to determine the feasibility and practicality of adding materials to the well fire that would alter the chemical composition or the dynamics of the plume so as to reduce the health hazard.

It should no longer be necessary to rely on estimates of oil blowout rates and pollutant emission factors. Insofar as possible, these quantities should be measured. Physical methods should be investigated to measure remotely the oil blowout rates at breached wellheads. Techniques using overhead doppler radar and ground-based passive thermal measurements of burning wellheads may be successfully developed to measure these rates. Measurements can be made using an instrumented aircraft platform and a technique known as the carbon balance method for determining emission factors. The availability of carefully measured emission factors for

pollutants in crude oil smoke would promote greater confidence in the results of dispersion model calculations.

Optically thick, well-characterized plumes could be used for realistic tests of various military targeting and tracking systems.

STATUS REPORT OF PUBLIC HEALTH IN KUWAIT AS OF MARCH 21, 1991

Prepared by John S. Andrews, Jr., M.D., M.P.H.

Associate Administrator for Science

Agency for Toxic Substances and Disease Registry

I. Background

I was attached to the Kuwait Task Force (KTF) of the U.S. Army's 352nd Civil Affairs Command beginning on January 30, 1991, to serve as liaison for additional U.S. Public Health Service personnel who were to be deployed from the United States. From January 30 until February 15, I trained with the U.S. Army at Fort Meade, Maryland. From February 16 until February 28, I was in Dammam, Saudi Arabia, working with the Kuwait Task Force and Dr. Saleh AL-Kandari from the Kuwaiti Ministry of Public Health. From March 1 through March 21, I was in Kuwait City working with Kuwaitis in the Ministry of Public Health (Dr. Jaffar Dawood, Dr. Rached AL-Owaish, Mr. Ibrahim Hadi).

Due to the short war, the small number of United States casualties, and the small number of civilian casualties, U.S. military personnel already in Saudi Arabia or Kuwait became available to carry out public health activities and they decreased the need to deploy public health personnel from the United States. Mr. Jorge Lambrinos, Chief of Staff for Congressman Edward Roybal of California and a member of the KTF, and I coordinated public health activities of these additional military personnel for the KTF.

The available public health personnel were divided into teams to work with personnel from the Kuwaiti Ministry of Public Health. Much of the work described in this report was carried out by military personnel or by personnel in the Kuwaiti Ministry of Public Health.

II. Persons Met

- A. Ministry of Public Health Kuwait
 - 1. Dr. Ali Saif, Undersecretary for Public Health
 - Dr. Rached AL-Owaish, Director of Department of Public Health
 - 3. Dr. Jaffar Dawood, Chief of Preventive Medicine
 - 4. Dr. Saleh AL-Kandari, Infectious Disease
 - 5. Dr. Mussab AL-Saleh, Preventive Medicine Physician
 - Mr. Ibrahim M. Hadi, Department of Environmental Health
 - 7. Dr. Ramsey Ishmael, Preventive Medicine Physician

B. Vector Control Team

CDR George Schultz, Navy Forward Medical Laboratory Team Leader
LT Manuel Lluberas, Navy Forward Medical Laboratory
HM1 Burger, Navy Forward Medical Laboratory
HM1 Richard Congo, Navy Forward Medical Laboratory
CPT Craft, Navy Forward Medical Laboratory
CAPT Steve Leonard, Navy Forward Medical Laboratory
Sgt Stone, British Army
Sgt Jones, British Army

C. Public Health Laboratory Team

CDR Jim Burans, Navy Forward Medical Laboratory - Team Leader LT Scott Thornton, Navy Forward Medical Laboratory HM1 Edna Bory, Navy Forward Medical Laboratory HM1 Avelino Cardwell, Navy Forward Medical Laboratory

D. Public Health Headquarters, Environmental Laboratory, Ministry of Municipalities Team

CDR Mary Anderson, Navy Forward Medical Laboratory - Team Leader
Major John Graham, British Army
CAPT Steve Wignall, Navy Forward Medical Laboratory
HM1 McMahon, Navy Forward Medical Laboratory
LCOL Jorge Lambrinos, KTF, 352nd Civil Affairs Command,
U.S. Army
CAPT John Andrews, KTF, 352nd Civil Affairs Command, U.S.
Public Health Service liaison

III. Public Health Situation Prior to August 2, 1990

- A. Organization. The Department of Health, under the Minister of Public Health, consisted of five divisions: (1) Preventive Medicine, (2) Ports and Borders Health, (3) Radiation Protection, (4) Rodent and Medical Insect Control, and (5) Public Health Laboratories.
- B. The country was divided into five health regions. Each region had its "Head of Public Health Office" who reported to both the national Preventive Medicine Division and the Director in the region.
- C. The Preventive Medicine Division consisted of three units: (1) Unit for Control of Epidemic Diseases, (2) Environmental Health Unit, and (3) Nutrition Unit. The main function of the Preventive Medicine Division was to plan, direct, and control the activities of the 23 Preventive Medicine Centers located in Kuwait City and

Preventive Medicine Centers located in Kuwait City and residential districts (Figure 1). These activities included the investigation and implementation of health regulations to control the spread of epidemic diseases. Through a mandatory reporting system, notifications of infectious diseases were investigated by the preventive medicine centers that were staffed with a preventive medicine doctor, two to three health inspectors, and a public health nurse for immunization activity. In addition, a preventive medicine center was located in each of the general regional hospitals, as well as the Hospital for Infectious Diseases and the Maternity Hospital. Attached to the Preventive Medicine Division was a center for the examination of food handlers.

D. Ports and Borders Division

The Ports and Borders Division was responsible for implementation of the international health regulations related to land, air, and sea movement; for preventive medical activities at the border areas; and for health control of arrivals to Kuwait from endemic areas through the International Airport. In addition, the Ports and Borders Division was responsible for the medical examination of expatriates for residency permits which included the examination for evidence of HIV infection, pulmonary tuberculosis, malaria, and leprosy.

E. Water

Prior to the occupation, 93-97 percent of Kuwait's water supply came from desalination plants. The rest of the water came from wells. All of Kuwait City was on municipal water. Results of drinking water testing for September 1989, January 1990, and June 1990 by the Environmental Protection Council are shown in Table 1.

F. Food

1. Food and Food Handler Testing

Legislation for food control was the responsibility of the Ministry of Commerce and the Ministry of Public Health. The municipalities were responsible for the control of distribution, as well as sampling imported food and the inspection of food stores and shops. The Division of Public Health Laboratories assisted in the examination of food and water and in the adoption of The Kuwaiti Specifications for Food.

Veterinary

This was done under the Department of Animal Health at the Public Authority for Agriculture and Fisheries.

G. Sewage

This was the responsibility of the Ministry of Public Works. Data on the quality of treated effluent for September 1989, and January and June 1990 are shown in Table 2.

H. Environmental

- 1. Garbage collection and disposal was the responsibility of the Ministry of Municipalities and their contractors.
- 2. Air quality monitoring was the responsibility of the Department of Environmental Protection of the Ministry of Public Health. The tables below are copied from three monthly reports of the Department of Environmental Protection (Environmental Protection Council).

The concentration of gases expressed as ppm and ppb for September 1989, January 1990, and June 1990 for Mansoria, Rabia, and Rega is shown in Table 3.

The distribution of settled dust in grams/square meter/day for January and June 1990 for the Shuwaikh Industrial area, Kuwait City, and Jahra is shown in Table 4.

The concentration of suspended particulate matter in daily samples for January and June 1955 in micrograms per cubic meter for the Schuwaikh Industrial area, Kuwait City, Shamieh, and Jahra is shown in Table 5.

The size distribution of suspended particulate matter for January and June 1990 for the Shuwaikh Industrial area, Kuwait City, and Shamiah is shown in Table 6.

I. Vector and Rodent Control was the responsibility of the Rodent and Insect Control Department of the Ministry of Municipalities.

J. Disease Surveillance

Disease surveillance in Kuwait covered the occurrence of disease and a watch on the risk factors that contribute to this occurrence. A list of reportable diseases is shown in Table 7. Reported communicable disease for 1988-1990 are shown on Tables 8-10, respectively.

Disease surveillance included active surveillance amongst population groups at risk, e.g., the expatriates for AIDS, tuberculosis, malaria, and leprosy and food handlers and others in high-risk vocations in the community. The reporting of disease included active case finding and looking at laboratory reports at all laboratories, as well as hospital admissions.

K. Immunizations

1. Childhood Immunizations

The last assessment of immunization in Kuwait (1989) showed a very good coverage of basic vaccines in infants and children. This reached about 95 percent for OPV, DPT, and measles. There were no cases of polio, neonatal tetanus, or diphtheria in Kuwait for a number of years. Measles control was well on its way to succeed in breaking the every other year increase in cases indicating success in the expanded program in immunization in Kuwait. The immunization schedule is shown in Table 11 and the number of immunizations given from 1977 through 1990 is shown in Tables 12-14.

2. Hepatitis B Vaccine

Hepatitis B vaccine was introduced in the Expanded Program of Immunization (EPI) in January 1990. The first dose of HBV is given the second day of birth; the second dose at 3 months of age; and a third dose at 6 months of age.

3. BCG Immunization

BCG vaccinations were one of the main functions of the Tuberculosis Control Unit. The section had four tuberculosis control units with static and mobile X-ray, tuberculin testing, and BCG. vaccination facilities. The units were distributed all over Kuwait. The BCG vaccination is conducted by a joint effort between the Tuberculosis Control Unit and the School Health Division. BCG vaccination is given at

the age of 4 years as part of the medical examination for school entry.

L. Laboratories

Public Health Laboratory

The Public Health Laboratories under the Division of Public Health Laboratories of the Department of Public Health, carried out bacteriological, chemical, and virological examinations. It examined food, water, and sewage, as well as stool samples. It was the only laboratory that handled examinations of stools for <u>Vibrio cholerae</u>. The Virology Laboratory was responsible for all viral disease identification, including AIDS and hepatitis.

2. Environmental Laboratory

The Environmental Laboratory had sections on air pollution, water pollution, occupational exposure, and oil. The air pollution program had three fixed stations to monitor the air every 5 minutes by computer and analyze the data. One mobile laboratory went to Iraq. The laboratories also could measure dust. The laboratory can also measure temperature inversions, noise at the airport, and sulfur dioxide pollution from cars.

When the environmental laboratory was working, seawater, drinking water, brackish water, and sewage were tested. Trihalomethanes were tested in the drinking water. Water was tested for total alkalinity, total dissolved solids, electrical conductivity, sulphates, residual chlorine, Ph, hardness, total chloride, and nitrate.

Nerve Gases

There was a laboratory to test for nerve gases during the Iran/Iraq war, but it was not felt to be sensitive enough to be of much use.

M. Other

The overall health status of the Kuwait population (about 2.1 million) was good, with a life expectancy of about 70 years and an infant mortality rate as low as 12/1,000. Health care was free in a welfare state system.

- IV. Public Health Situation August 2 January 15, 1991.
 - Organization. After the occupation the Iraqis tried to interfere with day-to-day operations of the Department of Public Health, but were constantly kept in the dark. Under the Iraqis, the Ministry of Public Health was headed by an Iraqi Public Health General. organization is shown in Figure 2. The Preventive Health and Environmental Control Section was one of the five sections under the Public Health General. During the occupation, the main concern of this section was health preservation, not health promotion. Special emphasis was given to water quality, immunization, disease reporting, and the implementation of control measures, examination of all expatriates for AIDS and pulmonary tuberculosis, inspection of food and food handlers, garbage collection, laboratory testing for food and water. Food handlers and contacts of cases of disease were given stool and serum examinations.

B. Manpower

The main problem was the continual decrease in manpower as workers left the country or stayed inside. Even though enough preventive health physicians, community nurses, and health inspectors continued to work during the occupation. However, they worked fewer days to give them the chance to wait in various long lines for bread, gas, and food.

Many of the decisions of the Iraqis were revoked and simply ignored, including decisions to require preventive medicine doctors to work as general practitioners or to make changes in the immunization schedule. This was the main reason that the high dropout percentage was highest among senior staff, since jail or death might be the punishment for such action. Some had stayed away from the decision-making process. Those who stayed to the last days were those showing strong will and courage.

Because of the war situation and the blockage, during the first days of occupation, all ports were closed. Fifty to sixty health inspectors with five physicians from the Ports and Border Health Department were transferred to preventive health centers. Most of them were Palestinians. This gave the preventive health centers a good boost, since most of those who used to work in PHS were Egyptian and many of them left Kuwait gradually during the occupation.

C. The water sources for the Iraqi solders located in Kuwait came from the distillation plants in Kuwait. Therefore, the Iraqis were keen to keep a safe water supply. To insure that the water supply was safe, the Iraqis dispatched some of their military health inspectors to join the Kuwait Ministry of Public Health team in military vehicles to make daily visits and water sampling for the desalination plants and main distribution centers. As an insurance for the Kuwaitis, personnel in the preventive health clinics were instructed to take water samples from nearby distribution centers to insure that the Kuwaiti citizens had a safe water supply. This was explained to the Iraqis as a routine procedure for disease control.

The water supply was checked for bacteriology and chemicals at the Public Health Laboratory. Most results were clear. An investigation was carried out on a water sample from the Chest Hospital that was tested as being unsatisfactory. An investigation showed that water had come from an infrequently used tank. The tank was cleaned and future specimens were satisfactory. All specimens from desalination plants and main distribution centers were satisfactory.

Water quality continued to be checked even after the air war started. One hundred sixty-five samples were taken from December 1990 until the beginning of February 1991.

D. Food

1. Food and Food Handler Testing

Most of the Iraqi soldiers obtained their food from Therefore, a lot of interest was given to Kuwait. keeping the food supply good. The health inspection unit was assigned the responsibility of inspecting food and food handlers. With the shortage of available transportation for the Public Health. Department (one car for all of Kuwait), districts were inspected every 2 weeks according to a prearranged time table. The main emphasis of inspection was on factories and main food suppliers to check food before it reached general stores and Food handlers were mainly inspected small shops. clinically since laboratory facilities were scarce. Priority was given for foods that were more likely to be contaminated, such as milk and dairy products, meat, poultry, and soft drinks like canned juice and Pepsi. About 400 food samples were collected. Only five of them that were not acceptable for human consumption were destroyed.

Small shops and food stores were mostly closed because of Iraqi hassling, including a tax and fee payment that was required by the Iraqi government. Therefore, persons started selling food and other items in stalls and on sidewalks, changing from one place to another each day or week. Despite that, food was inspected and samples were collected from that stalls to make sure expired such contaminated food was not sold to the public. However, it was difficult to obtain good results since most persons changed location, increasing the difficulty in enforcing public health laws under the occupation.

Fruits and vegetables came from Iraq and Jordan in large amounts for profit reasons since these goods were sold at prices more than five times higher than in Iraq and Jordan. Regular samples were taken of such food.

Veterinary

During the occupation, there were health inspectors and a veterinarian at the abattoir. Ill animals were isolated and treated, if possible. Remnants of animals were burned. Dead animals were regularly buried as a joint effort between the Ministry of Public Health and firemen. Although the Iraqis formed small teams of garbage collectors under their supervision, they were not able to carry out all of the activities that were needed.

E. Sewage

Just at the beginning of the invasion, sewage was directed to the sea via the rain drainage sewer system. This system continued for some time without any problems. However, due to the lack of maintenance, breakdowns did occur. A major breakdown occurred at the Istiqial Street (The Embassies Street) which continued for days. Other breakdowns occurred in the heavily populated provinces. The main reason for that was direct blockage which was mostly managed through local efforts by the people themselves.

F. Environmental

1. Garbage

During the occupation, there was a failure to collect garbage. There were piles of garbage all over the streets, mainly near expatriate

populations. These were ineffectively set ablaze. Fire and smoke were a public annoyance. However, in the mainly Kuwaiti districts, Kuwaitis managed to somehow succeed in setting up neighborhood collection of garbage from in front of houses and to burn it in large heaps which kept the residential streets fairly clean.

An effort was launched by the Iraqi government to clean all Kuwait through volunteer teams from inside Iraq. They called it the Kuwait Garbage Campaign. This campaign was merely for propaganda reasons. The real objective was not accomplished. The campaign ended and was not retried.

2. Air

During the occupation, there were minimal air monitoring activities because the mobile and several of the static stations were taken to Iraq.

G. Vectors

Anopheles mosquitoes are in Kuwait (in few numbers). But, there have been no cases of indigenous malaria in many years. There were no malaria investigations or malaria control activities since the occupation. Almost all insecticides were taken to Baghdad. In addition 80-90 cars of the Vector Control Program were taken to Baghdad. During the occupation there was limited spraying of garbage and spraying for rodents and vectors in and around hospitals. There was no other vector control.

H. Disease Surveillance.

1. Summary of Reported Diseases

The list of reportable diseases remained unchanged. However, notifications were mainly from the Infectious Disease Hospital. The cases reported from the hospital were relatively severe. It is believed that milder cases were treated at primary health clinics where reporting was omitted. This is supported by the greatly decreased reporting of diseases from August through December 1990 (Table 10).

So far, there is no knowledge of the occurrence of cases of polio, diphtheria, neonatal tetanus, or outbreaks of vaccine preventable diseases amongst infants or children. The high immunization level in

the last 5 years has shown its fruit during the occupation. In addition, the efforts that were made to make vaccine available and in good supply from the Preventive Health Centers during the occupation were helpful. There were no outbreaks of food poisoning during the occupation. - During the occupation, 130 cases of viral hepatitis were reported, mainly in children less than 10 years of age in the previously known endemic districts. These cases appeared in the January 1991 report of disease during the period when water supply was scarce and houses became crowded.

The number of notified cases could not be compared with previous periods due to the lack of a denominator. The notifications during the occupation served as a means of access to cases so that preventive health efforts could be carried out among contacts.

2. Diseases in Iraqi Troops

No outbreaks of disease occurred among Iraqi troops during the occupation. However, 37 cases of cholera were documented in Iraq in the 45-day period before the war. There was no spread to the rest of the population. Iraq continued to be concerned about the possibility of cholera. In addition, some cases of hepatitis A were detected in Iraqi soldiers. There were rumors of malaria in Iraqi troops, but no documented reports.

3. Cholera

Only one case of cholera was reported from a native Kuwaiti woman. She was one of a group of 3,000 Kuwaitis who tried to escape through the Iranian border who drank water from a contaminated stream because no other water was available. The management and control measures for the case and her contacts were implemented.

4. Dog Bites

Seven persons were reported to have been bitten by dogs. All persons bitten by dogs were treated with tetanus toxoid and with human diploid rabies vaccine.

5. Quarantine and Screening of Expatriates

Dr. AL-Owaish carried out inspections of non-Arabs wanting to work in Kuwait. Through December, persons were checked for HIV antibody and tuberculosis. Most of these persons were Filipinos, Indians, Bengali, other Asians, and Africans.

6. AIDS

During this time, one case of AIDS in an Ethiopian worker was found. She was sent to Baghdad.

I. Immunizations

1. Immunization Sites

During the occupation, the 29 centers attached to the Preventive Medicine Division were decreased to 17 immunization centers due to (i) looting and stealing of equipment from health centers, (ii) destruction of health centers from shooting, and (iii) loss of manpower, especially public health nurses.

2. Immunization Statistics

It was obligatory to report to the Iraqi officials. The provided statistics were the bare minimal information on total numbers from the functioning immunization centers. Information on age, sex, nationality, etc. (place, person, and time), were not reported. The statistics of the first and last month of occupation are not reliable since some of the 17 centers did not report, whereas others remained nonfunctional because of the war situation. However, from September to December, more people were willing to leave their homes and be immunized. The statistics provided to the Iraqis did not include the effort of some physicians to immunize children in their local area.

People who came from Iraq and Jordan (either bringing food or for work) frequently asked for immunizations against certain diseases (HBV and meningococcal vaccine), increasing the numbers of immunizations for such disease during certain months (October and November 1990).

Immunization Schedules

The Iraqi officials were keen to change the immunization schedule in Kuwait so that it would be in accordance with the Iraqi immunization schedule. Official memos circulated instructing the discontinuance of certain vaccine and booster doses of polio and DPT. These memos were ignored and the Kuwait immunization schedule continued without any changes. The change happened in statistical reporting only (Table 14).

4. BCG Vaccination

During the invasion, the Central Tuberculosis Unit and the School Health Division, organized under the supervision of physicians from the Preventive Medicine Department, were responsible for coming up with a plan to immunize Kuwaiti children who did not go to school. Palestinian and other children continued to go to school. However, most schools were occupied by Iraqi soldiers. Therefore, the plan included the assignment of the remaining staff for BCG vaccination to two mobile teams to cover highly populated residential districts at five Three static teams were different locations. present at previously identified BCG vaccination centers. Health officers and nurses went to the few opened schools to give BCG vaccination to the children to insure a good BCG vaccination coverage.

J. Laboratories

1. Public Health Laboratory

The laboratory continued to carry out bacteriological examinations on food, water, sewage, stool samples, and serum specimens. It was the only laboratory that handled the examination for <u>Vibrio cholera</u> because it had peptone water.

The virological disease laboratory facilities were taken to Baghdad so there was no way to carry out tests for virological disease. Hepatitis cases were diagnosed clinically. Serotyping was not possible since the virology laboratory became non-functioning.

2. Environmental Laboratory

During the occupation, the environmental laboratory continued to carry out water quality testing as

previously described, although the mobile monitoring unit was taken to Baghdad and the fixed monitoring stations gradually became nonfunctional.

K. Other

Public Health Education

There was great difficulty in informing the public. Health instructions were given at mosques and information was passed from family to family. about circulars Information and vaccination availability were passed out at mosques, informal community groups, and posted inside the mosques, supermarkets, primary health clinics, and hospitals. when a case of cholera was identified, information was given out through such routes for people not to panic or worry. Information was also given that cholera vaccinations were not needed even though people requested it because the Department of Public Health did not feel that vaccinations were needed or Such methods of health education were adopted since the Department of Public Health had no access to radio, TV, or other media.

2. Institute for Handicapped and Mentally Retarded

At the beginning of the occupation, there were some 1,300 children at the Institute. Some died because of lack of employees to take care of them (who left the country after the invasion.) During the first 1-2 months, entire families went to the Institute to volunteer and improvements were made. Later on, the Iraqis did not accept volunteers, unless new job contracts with the Iraqi government were signed. This was resented because non-compliance with the contract might lead to severe penalties by the Iraqi Therefore, many volunteers left the government. Accordingly, one outbreak of diarrhea Institution. occurred at the Institute. The impression was that the diarrhea was due to starvation. One hundred bacteriological samples were collected, but all reports were negative. The remaining working staff in the Institute brought their own families for help and the health situation improved to some extent.

3. Dead People

During the occupation, people were taken to the hospital morgues. At one time near the beginning of the occupation, there were so many bodies that they

were taken to the ice rink where they were kept cool. The Kuwaiti Red Crescent was burying people together. Most of the time, the Department of Public Health would try to wait a week before burying bodies so that families could come to identify relatives.

4. Kuwaiti Red Crescent

For a time, the Kuwaiti Red Crescent was receiving instructions from the Kuwaiti Government in Exile. This resulted in Kuwaiti Red Crescent people being put in jail.

V. March 4-21, 1991

A. Organization

The organization of the Ministry of Public Health, Departments, and Department Directors are shown in Figure 3. The organization of the Department of Public Health, the Division Chiefs, and the Units in the Preventive Medicine Division are shown in Figure 4. The Health Districts and District Directors are shown in Figure 5.

B. Manpower

Some public health personnel started returning to their offices on March 4. By March 9, public health inspectors and other workers returned to work. As of March 16, 1991, there were 16 Kuwaiti public health physicians and 8 non-Kuwaiti public health physicians in Kuwait. These physicians were assigned to five hospitals and five health centers. By March 16, 75 public health inspectors and other workers were available to work.

C. Hospitals and Clinics

The hospitals and clinics were beginning to function. From March 4 to 21, there were increasing numbers of persons coming to the outpatient and emergency rooms of the hospitals. The hospitals and hospital directors are shown in Figure 6.

D. Water

A report from the team that assessed the water situation is provided as Attachment 1. Municipal water was shut off from the time of the ground war (February 23) through March 21. Initially, the only water available to Kuwaitis was water that had been stored on roofs or in

cisterns or water (bottled and in tankers) that was brought by the Kuwait Task Force from Saudi Arabia. In early March, however, water became available by truck. The trucks were filling up with water from one of the three 500,000 million gallon reservoirs. These reservoirs had been tested. The reservoir supplying the Americans was being chlorinated at a level of 4 ppm by the U.S. Army. I was unable to find out the details of how much chlorine was being added to the water being trucked into Kuwait City, although one person complained to me that a residual of only 0.5 ppm was present in some of the water he had tested. Although I would have liked the level to be higher, the result indicated that chlorine was being added to the water. I recommended that U.S. Army personnel working with the Ministry of Electricity and Power increase the level of chlorine at the delivery point to 4 ppm.

Since liberation, radio messages telling people to boil water had been heard by my interpreter.

E. Food

1. Food and Food Handlers

The U.S. Army brought in many truckloads of rice, and staples had been obtained from approved food sources. However, as of March 21, inspection of food and food handlers by the Government of Kuwait had not yet been reinstated.

2. Veterinary

As of mid-March sheep were again being slaughtered at the slaughter house. KTF personnel worked with the Minister of Municipalities to have garbage picked up from the slaughter house. Although there were a few stray cats in Kuwait City, there were few if any stray dogs.

F. Sewage

During the Iraqi occupation, the Polish engineers who had been operating the sewage system protected the sewage system by having raw sewage bypass the system and flow directly into the Gulf. KTF personnel who assessed the sewage system in early March reported that the system would be operational as soon as electricity was available.

G. Environmental

1. Garbage

Garbage trucks were brought from Saudi Arabia to Kuwait in early March. In addition, a number of garbage trucks still in Kuwait were made operational by adding tires or batteries. There are contracts with four Saudi Arabian companies to provide garbage pickup. As of March 16, these four companies were reported to have had 4,000 workers in Saudi Arabia who were available to enter Kuwait and assist with cleaning up the city and collecting garbage. The United States company, Waste Management, Inc., was also cleaning up one area in Kuwait on speculation that they would be able to obtain future contracts.

2. Air

With the oil well fires, residents have had eye tearing, sore throats, sneezing, and coughing. Persons with a previous history of respiratory disease or asthma have reported increasing severity of symptoms. The British Royal Commission in Jubail, Saudi Arabia, examined the oil fire smoke and found that it contained carbon particles, but it did not have significant amounts of hydrocarbons, SO₂, or NO₂. The United States Interagency Air Assessment Team (USIAAT) from the EPA sampled for several days in Kuwait City. Paul Seligman, M.D., from the National Institute for Occupational Safety and Health was in Kuwait as a part of the team.

H. Vector

The reports of the Vector Control Team and the Entomology Team are shown as Atta hments 2 and 3, respectively. There were fewer mosquitoes and flies than expected, primarily because garbage had been burned or picked up throughout most of Kuwait City during the occupation. No spraying for vectors was done from January 15 until March 9. Beginning on March 9, vector control efforts were restarted. Anecdotally, there are reports of some increase in the numbers of domestic and Norwegian rats. Three hundred laborers have been contracted to carry out vector control. There are six ultralow-volume (ULV) sprayers as well as an inventory of pesticides and vehicles. A 3-month program of spraying was set up. Public health inspectors were to continue on the program that was in existence prior to the occupation.

I. Disease Surveillance

The report of the Epidemiology Team is shown as Attachment 4. The Report of the Team assisting the Mubarak Hospital laboratory is provided as Attachment 5.

The Department of Public Health continues to be notified of cases of infectious disease admitted to the Infectious Disease Hospital. Notifications come in every Sunday. Every health inspector comes to the headquarters each Sunday. The health inspectors are assigned to investigate cases of disease. The inspectors also check on the immunization level of children. The diseases reported in 1991 through March 9 are shown in Table 15.

Kuwaiti physicians were concerned about the possibility of a hepatitis A outbreak. Although there was no evidence of such an outbreak based on disease reporting (Table 9 above) or by reviewing hepatitis A reports from 1988 through March 9, 1991 (Table 16), Ministry of Public Health physicians were alerted to this concern.

The routine disease surveillance program is scheduled to be restarted as soon as the telephones are working and transportation is available.

J. Immunization

The routine immunization program had not been started by March 21. However, vaccine was available in the central warehouse and immunizations were being given by some physicians.

K. Laboratories

1. Public Health

Although the public health laboratory had some water, it did not yet have electricity. It cannot process specimens until it has electricity. Neither can the laboratory process food or cholera samples at the present time. A protocol for the identification of <u>Vibrio</u> cholerae 01 carriers is provided as Attachment 6.

The virological laboratory was destroyed and the equipment removed. In addition, the laboratories needed to be cleaned.

2. Environmental

Although only one piece of equipment was stolen from the Environmental Laboratory, specimens could not be processed until water and electricity were available.

L. Other

1. Injury

Two people have died from explosives taken to their house. The problem is that people have been in their houses for 7 months, without sports, games, or movies. They are delighted to be outside. Citizens have been instructed to inform their local police station if weapons or munitions are found. In addition, announcements telling people not to pick up explosives have been heard.

2. Biological and Chemical Weapons

I was told that no biological weapons had been found in Kuwait. There were reports of cases of anthrax occurring in Iraq, near to where a biological weapons facility was thought to exist.

I only heard one report of several chemical projectiles being found inside Kuwait.

3. Noise and Odors

There were reports of people breeding chickens in their yards which has caused an increase in noise and odors in communities.

4. Cattle

There were approximately 2,000 head of cattle in the Kuwait. Animals that died were buried in place by the municipalities with at least one meter of sand covering them. Some of them were disposed of in a landfill.

5. Zoo

The Iraqis opened the cages of many of the zoo animals. For a while there was a tiger and a leopard running lose.

VI. Summary

Prior to the Iraqi occupation, Kuwait had a very advanced public health system. The water, sewage, electricity, and garbage collection systems appear to be on the verge of functioning. However, the public health infrastructure that depends on people needs more attention. This other part of the public health system needs to be reinstated. When it is reinstated, the disease surveillance system needs to be computerized. It should be possible to have all of the hospitals and clinics with an on-line disease surveillance system that would provide data within hours to decision makers. It could even serve as a model for the system that needs to be set up in the United States.

The major upheavals that have occurred in Kuwait will necessitate intensive retraining and rebuilding of the public health infrastructure.

John S. Andrews, Jr., M.D., M.P.H.

Table(2) Drinking Water Quality

Table 1

جدول رقم (٦) نتائم مراقبة مواهفات مياه الشرب

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Source: Environment Protection Council/Environmental Protection Department, Kuwait

Table(2)
Drinking Water Quality

جدول رقم (٦) نتائج مراقبة موامقات مياه الشرب

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TANTE (2)
Thrinking Water Quality

جدول رقم (٦) تقالم مراقبة موامقات مياه الشرب.

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2 Table جدول رقم (٤) نتائج مراقبة مياه الصرف الصعي

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I TER I I	ı	1 1	·	1 1	t	l	ŧ	t	1	1	١.	1	1	1	1	1	1	1	1
1 1 1 JAHRA 1	32 1 2.	017.5	2000	l 168 i	360	:	1 399	1 13.64	1 4.70	1 12.94	7, 62	1.56	1 369	11280	1	!	1	!	1
I IARDEAH I	37 1 1.	B17. 7	2400	206 1	380	1	1 320	1 26.05	1 7, 90	1 27, 781	7, 95	1 1.65	1 258	11536	!	!	1	!	1
I IREGA I	29 1.	817.31	2800	1 76 1	420	1	1 455	1 1.26	1 3.90	3, 08	13.96	1.95	1 358	11792	1	1		1	:
111	1			11		!	I	-1	1	1		1			!	(1	t	- t

ISTAGE	1	•	-	-	Cu	_	_	-	_	TOTAL COLIFORM cfu/100ml	cfu/100ml	STREPTOCCOCII	V. V ·
I SEC					i	i		8	i i	•			1
	JAHRA	0.73	3. 93	2.00	1,501	115.9	400.0	4,70	2, 401	276000	258000	15000	184000 1
1	IARDEAH	0. 53	4, 80	2, 46	1.801	167. 8	500.0	4.00	1 2, 801	46000000	26000000	410000	12650 1
1	IREGA	0, 30	3, 301	1. 60	4. BOI	110.1	400.0	1.90	2, 401	132000000	430000	90000	0 1
1	IFAILAKA	0, 301	2, 931	16. 00	5. 401	81.2 1	550.0	1 10.30	l 2.401	5700000	18000	3000	0 1
!	1		l - 1		1			!	11		1		
I TER	1	1 (1	, !	t t	ı	!	ŧ	1 1		1	t :	1.1
ŀ	IJAHRA	0.301	2, 15	1, 40	1.301	144.7	200, 0	1 0.00	1 0.001	0	i o	0	0 1
t	IARDEAH 1	1.00	l 4, 10	3, 00	2.401	393. 0 1	550, 0°	1 7.50	1 5.401	5	1 0	0	3450 1
1	IREGA	0. 30	2, 801	1. 60	8. 301	300, 5 1	575, 0	1.90	1 4, 101	0	1 0	1 0	0 1
1			1					l	11		l	l	

Source: Environment Protection Council/Environment Protection Department, Kuwait



Table 2

Table(4)
Treated Effluent Quality

جدول رقم (1) دتائج مراقبة مياه الصرف الصحي

يناير 1990 - Ja nua ry

1		-			. 1	-1	1		l	1	1	1			1	- 	1		1	11
18TAGEL L	DC. ITE	EMP I (C12	PH	I E.C	IT. ALM	IT. HARD	l Br	1 C1	EHM-NI	1 N-NO3	10RQ. N. 1	P-P04	-8	1604	IT, D, S	l Na	K	l Ca :	1 B 1
t I												1 mg/1 1								
11		1		}	. [-	1	l	1	1	1	l			i i	l	1	l 		
I BEC I	1	1		ì	ŧ	1	l	t	1 '	1	1	1 1) :	l	1	l	l	ŀ	1	i 1
1 IJAH	IRA 1 2	24 1	0.0	17.7	1 4250	1 206	1 424	l	1 305	1 24, 82	1 - 6, 52	1 28. 621	9, 20	0.47	270	12720	1	t	1	1 1
1 IARD	EAH 1 2	24 1	0.01	7. 7	1 3400	1 318	1 376	1	1 ,320	1 33, 19	I 5.53	1 43, 901	13,70	0.35	1 125	12176	t	l	1	i i
1 IREG	A 1 2	24 1	0.01	7. 4	1 3480	1 80	1 404	ı	1 '460	4, 40	i 3.71	1 4.651	1 9.9 01	0.00	1 1621	12227	1	۱	1 1	1 1
I IFAI	LAKAI S	20 1	0. 01	17. 4	1 9980	1 268	1 980	I	13274	1 24, 50	1 6.31	1 30, 861	6, 301	0.00	400	16387	1	۱	1	1 1
		1			.	-	1	1		1	1	11				t	1	t	1	1
i ter i	1	1		l .	1	1	1	1	1	1	1 .	1 1	i I	'	t ·	1	ı	1	l	i :
I IJAH	IRA L 2	25 (2. 11	7. :	1 4100	1 168	1 460	i	l 415	1 17.77	1 6.37	1 24, 471	B. 50	0.00	1 285	12624	1	ı		l i
I IARD	EAH I 2	25	0. B	7, 3	1 3350	1 270	1 400	1	1 530	1 3.83	l 7.11	1 3.301	7. 50	0.00	1 189	12144	1			1 1
I IREG	A 1 2	25 1	1.4	17. 4	00EE 1	1 94	1 408	1	1 450		1 10.87		7.60						1	1 i
1	1	1		 -	.1	-!	·t	1	1	l	1	t			t	1	I	i	1	:i

I IBTAGE	i 1.00. (Cd mg/l	Pb mg/l	i Cr mg/l	l Gu mg/l	Zn mg/l	 Fe mg/l	i Ni mg/l	Mg/l	TOTAL COLIFORM	FAECAL COLIFORM cfu/100m1	FAECAL FAECAL BTREPTOCGOCII cfu/100ml	COLLEPHAGE : pfu/100ml
I SEC	I LJAHRA LARDEAH IREGA IFAILAKA	 	 	 	 	 	i ,	 	 	11000000 188000000 1 4000000 1 50000	1000000	310000	360000 1 122000 1 690000 1 2300 1
TER	IJAHRA IARDEAH IREGA	 	1 1 1 1 1 1	i 	 	 	i 	 	 	0 0	0	1 0 1 0	0 1

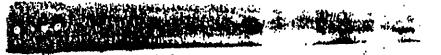


Table (4)
Treated Effluent Quality

يونيو - 1990 - JUNE - 1990

STAGE	 LOC.	TEHP	 C12	1 I PH		T.ALK	 T.HARD	Br.	C1	I	N-NO3	 ORG . N .	 P-P04		504	 T.D.S	 Na	 K	 Ca	 B	i
	 	(C)	ms/1	 	iu shos] md/]	M#/1	#4/J	ad/l] md/}	md/l	#4/l 		mg/l	P4/J	a4/1	F4\1	l/ba	I/Em	<u> </u>	!
SEC					7700	700			.70	7, 77			, 50	0.71	210	240	i '			! !	i
	IJAHRA IARDEAH	27 30	0.0	17.5 17.3	1 3150	l 320 l 285	460 310		430 475	1 36.37 1 18.83	10.43	1 24.50	1 5.40	0.69	7 B	2368 2016					j
	IREQA Failaka	31 30	0.0	17.5 17.4		135 355	i .566 i .835		1 880 13762	1 28,15 1 0.00	4.96					2976 1024	 <i></i>	! 			İ
TER				<u> </u>													-~			j	
	JAHRA	30		7.7		275	463		460	35.96	5.84		6.10		270	2669	<u> </u>				
	I ARDÉAH I REQA	32 30		17.4 17.8		1 280 1 140	1 312 1 750		1 436 1 376	1 26.26 1 29.40	l 6.19 l 5.10	1 32.45 1 30.18				12000 12790] ==		 	
		- <u></u> -	1	j	1	Ì	ļ	- -		1	1	1	j	ļ	j		Ì	Ì	l	i i	Į

STAGE		H4 	Cd Dd/1	Pb	Cr	Cu md/l	Zn ms/1	Fe ms/l	Hi Ms/l	V P4/1	TOTAL COLIFORH cfu/100ml	FAECAL COLIFORN cfu/100ml	FAECAL STREPTOCOCCI cfu/100ml	SALHO-I NELLA cfu/l	COLIPHAGE
		2.000 2.000 2.000	0.30		1 1.10	3.31	82.0	423.3	1.00	2,40	10000001 2560000001	300000 4760000	850 180000 4300 (17 140 10 230	354501 1023501 194001 103501
	IARDEAH	2.000 2.000 2.000	0.50	2.00		6.21	151.0	259.5	1.00	2.40	Ŏ	0 0	0	0 0	1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

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بسسبول رقم (۱)

MONTHLY MEAN CONCENTRATION OF THE GASES EXPRESSED AS PPM AND PPB RECORDED BY THE AIR POLUTION MONITORING STATIONS TOGETHER WITH THE MAXIMUM LEVEL AND THE PERCENTAGE DISTRIBUTION OF THE VALUES EXCEEDING THE THRESHOLD LEVEL DURING SEPTEMBER 1989

:			!			Ĺ	DCATIONS		·		
:	; ! !		MANSORIA !			RABIA.			REGA		
	G#	ASES	! MEAN	MAX !	XEX. LIHIT	MEAN	HAX !	ZEX.	MEAN !	MAX !	%EX.
: : :	TS H2S SO2 THC NCH4 CH4	IN PPB IN PPB IN PPB IN PPM IN PPM IN PPM	2. 668 0. 615 2. 039 2. 702 0. 839 1. 862	56.000; 9.000; 13.310; 11.260;	3. 1 0. 0 73. 6	14. 388; 11. 625; 3. 421; 2. 218; 0. 536; 1. 681;	929. 000 1 887. 000 1 951. 000 2 8. 410 1 6. 290 1 4. 730 1	18. 4 0. 8	1. 517! 0. 233! 1. 196! 1. 930! 0. 162! 1. 708!	18. 000: 15. 000: 9. 000: 7. 260: 5. 870: 4. 480:	0. 2 0. 0
:	03 03 003 003 003 003	IN PPB IN PPB IN PPB IN PPM IN PPM IN PPM	52. 518; 23. 061; 29. 394; 1. 054; 0. 004;	888.000; 789.000; 504.000; 13.240;	11.6 12.4 0.6	49. 379: 20. 321: 28. 039: 1. 153: 0. 003:	882.000 800.000 281.000 20.750 0.039	9.5 9.6 0.5	32. 126! 14. 585! 17. 351! 1. 111! 0. 002! 0. 176!	695. 000: 573. 000: 312. 000: 34. 370: 0. 138: 2. 300:	6.7 : 5.6 : 0.6 : 0.0 :

Source: Environment Protection Council/Environment Protection Department, Kuwait

جدول رقم(۱)

MONTHLY MEAN CONCENTRATION OF THE GASES EXPRESSED AS PPM AND PPB RECORDED BY THE AIR POLUTION MONITORING STATIONS TOGETHER WITH THE MAXIMUM LEVEL AND THE PERCENTAGE DISTRIBUTION OF THE VALUES EXCEEDING THE THRESHOLD LEVEL DURING JANUARY 1990

LOCATIONS															
:	; ! !				MANSORIA		: - ! ! -		AIBAR		: ! !		REGA		
!!!!!	G,	ASE!	5	!	MEAN	! MAX	ZEX.	: ! ! !	MEAN :	MAX !	XEX.		MEAN !	MAX ! !	XEX. LIMIT
;	TS	IN	PPB	1	2. 346	35.000		: - !	5, 316	407, 000		1	1. 587	18. 000	
	H25	IN	PPB	i	0, 355	33, 000	2. 4	ì	3. 178	396, 000	7. 4	;	0. 260	17.0001	1.0
1	502	IN	PPB	1	1. 951	3.000	0.0	ŧ	2, 105	17, 000	0. 0	ŧ	1.0091	3. 000 !	0.0
;	THC	IN	PPM	;	2. 287	9, 420		•	1.8641	7, 580	-	ł	2. 231 !	8. 7201	
i	NCH4	IN	PPM	1	0. 418	7. 7201	54. 1	ŧ	0.4111	5. 450	60. 7	ť	0. 5071	6. 8701	81. 9
:	CH4	IN	PPM	1	1.868	4, 580		1	1. 4521	4. 610		1	1. 7241	3. 480 :	
;	NOX	IN	PPB.		57. 355	756. 0001		1	53. 742!	712.000	-	:	52. 2191	678. 0001	
;	NO	IN	PPB	:	29. 683	647.0001	15. 1 -	1	27.8051	498, 000	16. 1	ł	25. 8281	636. 0001	13.6
ŧ	NO2	IN	PPB	t	27. 671	327.0001	10.4	l	25. 912:	229, 0001	6. 0	ł	26. 3491	287. 0001	7.8
i	CO	IN	PPM	ŧ	1,008	9. 800 1	0.3	ŀ	1. 155	13. 7701	0. 4	;	1.0401	31. 4901	0.5
:	03	IN	PPM	1	0. 002	0. 016	0.0	1	0. 0051	0. 0621	0.0	ŧ	0.0041	0.021;	0.0
:	NH3	IN	PPM	1		;	(ŀ	!	}	-Commit	i	0. 0541	2. 6901	10.2

مِسدول رائم (1 أ)

MONTHLY MEAN CONCENTRATION OF THE GASES EXPRESSED AS PPM AND PPB RECORDED BY THE AIR POLUTION MONITORING STATIONS TOGETHER WITH THE MAXIMUM LEVEL AND THE PERCENTAGE DISTRIBUTION OF THE VALUES EXCEEDING THE THRESHOLD LEVEL DURING JUNE 1990

!							OCÁTIONS				!
:	; 										
į	: !		! !	MANSORIA			RABIA		. ————————————————————————————————————	REGA	
:		•	! !	<u>.</u>	!	!	!	; !	!		·
!	G/	ASES	! MEAN!	MAX !	ZEX.		MAX !	XEX.		MAX !	KEX.
:		IN PPB	1 2.7651	85, 0001		! 15. 3781	932. 000		1. 6731	21. 000	!
:	H2S	IN PPB	1 1, 2511	84. 0001	5. 5	12, 4631	B63. 000 l		0, 2531	20, 0001	1.3
1	802	IN PPB	1 1.4311	12. 0001	0.0	2. 9531	142.000	1.2	1,2841	3. 0001	0. 0
1	THC	IN PPM	1 2.1161	B. 0601		2, 0811	9. 070		2, 1381	9. 410	
1	NCH4	IN PPH	1 0.3421	6, 1301	49. 9	0. 6501	4. 250	97. 1	0. 3571	7. 6901	39. 2
1	CH4	IN PPM	1 1.7721	4. 5201		1 . 1, 4311	6. 1301		1.7801	4. 6001	
i	NOX	IN PPB	1 26, 2241	460, 0001		1 28.0111	251.0001		33, 5331	540. 0001	
1	ND	IN PPB	1 5. 3321	340, 0001	3.3	7.6651	208,0001	2.8	10, 2781	445.0001	5.0
ŧ	NO5	IN PPB,	1 20. 8751	178. 0001	11.1	20. 357	120.0001	3, 3	23, 2631	242, 0001	8.3
1	CO	IN PPM	1 0. 8461	II. 910¦	0.1	0.8031	7. 320 1	0.0	0.7741	37, 0601	0. 2
ı	03	IN PPM	1 0.0131	0. 1371	0.4	0. 0101	0, 066	0.0	0.0121	0. 0531	0.0
1	CHN	IN PPM	: :			l ;	1		0. 0631	1. 5801	10.8
•			!!	!		!!	!		!		

Date		Locations	<u> </u>	Daily Tot.			
	Shuwaikh Industrial Area	Kuwait City	Jahra	Mean .	No. of Sample		
1/1/90	0.082	0.814	0.328	0.408	3		
2/1/90	0.320	0.086	4.041	1.482	3		
3/1/90	0.330	0.824	0.265	0.473	3		
4/1/90	1.099	2.209		1.654	2		
5/1/90	0.685	0.211	-	0.448	2		
6/1/90	0.022	0.127	0.024	0.058	3		
7/1/90	1.097	1.927	1.855	1.626	3		
8/1/90	1.877	1.620	2.890	2.129	3		
9/1/90	0.378	0.042	0.595	0.338	3		
10/1/90	0.434	0.265	0.022	0.240	3		
11/1/90	0.275	0.472		0.374	2		
12/1/90	0.780	0.623	•	0.702	2		
13/1/90	1.560	0.563	0.784	0.969	3		
14/1/90	0.484	0.390	0.301	0.392	3		
15/1/90	0.358	0.458	0.358	0.391	3		
16/1/90	0.448	0.597	0.474	0.506	3		
17/1/90	0.444	0.537	0.537	0.506	3		
18/1/90	0.872	1.218	-	1.045	2		
19/1/90	0.163	0.677	. •	0.42	2		
20/1/90	0.681	9.032	0.711	3.475	3		
21/1/90	0.922	9.212	0.839	3.658	3		
22/1/90	0.953	0.933	0.667	0.851	3		
23/1/90	0.796	0.259	0.344	0.466	3 .		
24/1/90	1.154	1.791	0.468	1.138	3		
25/1/90	0.866	0.902	0.279	0.682	3		
26/1/90	0.617	0.448		0.533	2		
27/1/90	0.717	0.179	•	0.448	2		
28/1/90	0.249	0.979	0.179	0.469	3		
29/1/90	0.199	0.657	0,159	0.338	3		
0/1/90	0.320	0.486	0.105	0.304	3		
1/1/90	0.553	0.701	0.398	0.551			
onthly Mean	0.637	1.266	0.723	0.889	85		
S.d.+	0.424	2.165	0.960	1.437			

Source: Environment Protection Council/Environment Protection Department, Kuwait

جـدول رقم (6 - 1)

Distribution of Settled Daily Dust JUNE (1990) (grams/square meter/day)

		Locations	:	Daily	Total
Date	Shuwaikh Industrial Area	Kuwait City	Al-Jahra	Mean	No. of Sample
1/ 6/90	0.478	0.458		0.468	2
2/ 6/90	0.826	0.756	0.687	0.756	3
3/ 6/90	3.613	3.065	8.877	5.185	. 3
4/ 6/90	5.245	4.723	18.650	9.539	3
5/ 6/90	3.394	3.658	13.057	6.703	3
6/ 6/90	20.232	20.740	60.150	33.707	3 .
7/ 6/90	25.527	34.131		29.829	2
8/ 6/90	0.587	0.736		0.662	2
9/ 6/90		0.677	1.035	0.843	3
10/ 6/90	2.189	1.270	3.115	2.191	3
11/ 6/90	0.627	0.577	1.334	0.846	3
12/ 6/90	0.916	0.846	1.234	0.999	3
13/ 6/90	0.557	0.468	1.015	0.680	3.
14/ 6/90	4.498	2.816		3.657	2
15/ 6/90	1.065	0.806		0.936	2
16/ 6/90	1.334	1.373	1.483	1.397	. 3
17/ 6/90	1.509	1.015	2.185	1.570	3
18/ 6/90	0.876	0.587	1.980	1.148	3 3
19/ 6/90	2.787	2.249	1.821	2.286	
20/.6/90	2.528	1.742	6.071	3.447	3
21/ 6/90	6.747	5.792		6.270	2
22/ 6/90	10.251	12.749		11.500	2
23/ 6/90	31.349	47.829	98.499	59.226	. 3
24/ 6/90	2.757	2.249	5.892	3.633	3
25/ 6/90	0.796	0.617	1.921	1.111	3
26/ 6/90	0.587	0.518	0.969	0.691	3
27/ 6/90	0.806	0.717	1.188	0.762	3
28/ 6/90	5.304	4.429		4.867	, 2
29/ 6/90	6.081	7.583		6.832	2
30/ 6/90	0.916	0.766		0.841	2
31/ 6/90					. -
Mean	4.840	5.531	11.558	6.779	80
S.D.+	7.583	10.691	24.444	14.648	

Concentration of Suspended Particulate Matter in daily samplesJanuary..1990....

(micrograms per cubic meter)

Date		Location	,	·	Daily	Total Samples
<i></i>	Shuwa ikh	Ruwait City	Shamieh	Jahra		
1	-	<u>-</u>	-	<u>.</u>		
2	_	_		_		
3	208.24	267.93	<u>-</u> ·		238.09	2
4	-	•	292.13	280.60	286.37	2
5	-	258.78	•	_	258.78	1
6	-	•	139.02	166.79	152.91	2
7	185.01	329.79	•		257.4	2
8	-	-	336.77	528.94	432.86	2
9	133.42.	118.69	-	-	126.06	2
10	-		89.71	150.47	120.09	2
11	334.02	150.54		-	242.28	2
12	-	_	121.12	193.57	157.35	2
13	-	135.27	-		135.27	1
14	_	-	70.45	63.01	66.73	2
15	92.22	106.46	-	-	99.34	2
16	-	-	64.18	65.68	64.93	2
17	-	135.27	-	-	135.27	1
18	-	-	113.69	304,65	209.17	2
19	159.69	107.07	-	-	133.38	2
2U	-	-	139.40	135.00	137.2	2
21	-	261.97	-	-	261.97	1
22	-	_	146.33	177.70	162.02	2
23	257.15	238.69	-	-	247.92	2
24	-	_	144.79	190.09	167.44	2
25	174.17	262.62		-	218.39	_ 2
26	_	- 1	78.15	144.21	111.18	2
27	110.56	82.71		-	96.64	2
28	-	_	49.93	38.81	44.37	2
29	116.43	175.58	-	. •	146.01	2
30	_		79.14	59.72	69.43	2
31	_	-	_	_	_	
Monthly Mean	177.09	187.96	133.20	178.52	168.58	52
S.d.+	74.23	79.09	83.70	128.06	94.98	

Source: Environment Protection Council/Environment Protection Department, Kuwait

Concentration of Suspended Particulate Matter in daily samples June (1990) (micrograms/cubic meter)

Date		Loca	tions			
Date	Shuwaikh	Kuwait City	Shamiah	Al-Jahra	Daily Mean	Total Samples
1/ 6/90						_
2/ 6/90						-
3/ 6/90			616.9	1089.1	853.0	2
4/ 6/90	903.1	710.3			806.7	. 2
5/ 6/90			606.9	753.3	680.1	2
6/ 6/90		1355.2			1355.2	1
7/ 6/90			2228.3	1780.6	2004.5	2
8/ 6/90	328.0	235.2			281.6	2
9/ 6/90			229.1	456.1	342.6	2
10/ 6/90	323.9	302.2		·	313.1	2
11/ 6/90			235.4	297.6	266.5	2
12/ 6/90	382.7	226.9			304.8	2
13/ 6/90			214.0	318.3	266.2	2 ·
14/ 6/90	447.4	387.6			417.5	2
15/ 6/90			304.9	374.6	339.8	2
16/ 6/90	552.5	390.3			471.4	2
17/ 6/90			288.0	365.3	326.7	2
18/ 6/90						-
19/ 6/90			345.9	356.7	351.3	2
20/ 6/90	492.0	349.7			420.9	2
21/ 6/90			796.8	730.8	763.8	2
22/ 6/90	1375.4	1266.9			1321.2	2
23/ 6/90			1443.5	1853.3	1648.4	2
24/ 6/90	887.7	767.2			827.5	2
25/ 6/90			261.4	360.5	310.9	2
26/ 6/90	408.9	310.9			359.9	2
27/ 6/90						-
28/ 6/90						-
29/ 6/90			1042.9		1042.9	. 1
30/ 6/90	432.9	353.8			393.4	2
Mean	594.0	554.7	662.6	728.0	636.3	48
S.D.+	327.8	391.7	600.7	560.9	478.6	

جدول رقم (7 - ب)

Size Distribution of Suspended Particulater MatterJanuary 1990......

		Shuwa	ikh (n	- 1)	Kuwa	itCity	(n=3)	Sham	ieh (n	- 3)
Particle Size	Size Range (Micron)	Mean Conc. (ug/m ³		_	Conc	X in . Size Range m ³)	Freq.	Come.	X in Size Range 3)	Cumul. Freq.
	0.1-1.1	34.2	17.7	17.7	57.8	23.2	23.2	33.8	26.0	26.0
	1.1-2.0	10.4	5.3	23.0	12.0	4.8	28.0	8.2	6.3	32.3
Respirable	2.0-3.3	13.1	6.8	29.8	15.4	6-2	34.2	11.5	8.8	41.1
	3 .3-7 .0	42.0	21.7	51.5	43.3	17.4	51.6	23.5	18.0	59.1
Non- respirab	> 7.0 le .	39.7	48.5	100.0	120.6	48.4	100.0	53.3	40.9	100.0
Total	-	193.4	100.0	•	249.1	100.0	-	130.2	100.0	_

Source: Environment Protection Council/Environment Protection Department, Kuwait

جـدول رقم (7 - ب)

Size Distribution of Suspended Particulate Matter June (1990)

		Shuw	aikh (1	n=2)	kuwai	t City	(n=3)	Shar	miah (1	n=3)
Particle Size	Size Range (micron)	Mean Conc. ug/m3	% in Size Range	Cumul Freq.	Mean Conc. ug/m3		Cumul Freq.			Cumul Freq.
R E S	0.1-1.1	282.7	30.3	30.3	793.9	50.6	50.6	273.6	31.82	31.8
P I R	1.1-2.0	57.8	6.2	36.5	75.6	4.8	55.4	43.0	05, 00	36.8
A B L	2.0-3.3	107.0	11.4	47.9	126.7	8.1	63.5	97.4	11.33	48.2
E	3.3-7.0	162.1	17.4	65.3 :	158.8	10.1	73.6	129.3	15.04	63.2
Non Re- spirable	> 7.0	323.9	34.7	100.0	413.7	26.4	100.0	316.5	36.81	100.0
To	tal	933.5	100.0		1568.7	100.0		859.8	100.0	

REPORTABLE COMMUNICABLE DISEASES KUWAIT 1988 - 1991

Amebic Dysentry Enteropathic Escherchia coli Notified Diarrhea Lead Poisoning Upper Respiratory Infection Leprosy Exanthem Subitum Cutaneous Leismaniasis (imported) Mycoplasma pneumonia Erysipelas Staphylococcal Carrier |Giardiasis shigellosis Shigella Carrier Aseptic Meningitis Encephalitis Mononucleosis Infectious. Scarlet Fever Herpes Zoster Meningococcal Meningitis (not specified) Meningococcal Meningigits (Group A) Meningococcal meningitis (Group B) Neisseria meningitidis carrier (not Group A) Neisseria meningitidis carrier (Group A) Septic Meningitis Rocky Mountain Spotted Fever Brucellosis Anthrax Toxoplasmosis Relapsing Fever (imported) Hepatitis (not specified) Food Poisoning Malaria (imported) Filariasis (imported) Endemic Typhus Chickenpox Rabies (imported) Viral Hepatitis A Viral Hepatitis B Viral Hepatitis non-A, non-B .Tetanus Neonatorum Poliomyelitis Measles Rubella-Mumps Salmonella Carrier DLiphtheria Diphtheria Carrier Whooping Cough Tetanus.

Paratyphoid (A) Carrier Paratyphoid (B) Fever Paratyphoid (B) Carrier Paratyphoid (C) Fever Salmonella Enteritis Cholera Non 0-1 Vibrio cholera Typhoid Fever Typhoid Carrier Paratyphoid (A) Fever

REPORTED COMMUNICABLE DISEASES

KUWAIT - 1988

Di	Jan	Feb	Mar	Ann	May	Jun	Jul	Aug	Sep	0ct	Nov	Dec	Total
Diseases	Jan	reb	Mar	Apr	may	Jun	Jui	Rug	seb	UCL	NOV	Dec	TOCAL
s. typhi carrier	1	1	0	0	0	0	0	0	1	0	0	0	3
Typhoid Fever	4	7	9	9	16	12	24	38	43	31 .	7	7	207
Non 0-1 V. cholerae	0	0	0	0	5	3	7	21	9	1	0	0	46
Cholera (imported)	0	0	0.	0	0	0	0	0	1	1	0	0	2
Paratyphoi d (A) Fever	2	0	2	1	2	4	2.	7	7	3	1	2	33
Paratyphoi d (A) Carrier	0	0	0	1	0	0	1	0	2	0	0	O	4
Paratyphoi d (B) Fever	1	0	0	2	0	1	1	1	2	0	0	0	8
Paratyphoi, d (B) Carrier	0	0	O	2	2	2	1	2	0	0	2	1	12
Paratyphoi d (C) Fever	1	0	1	0	0	0	0	0	0	0	0	o	2
Salmonella Enteritis	24	22	38	54	57	68	46	59	74	70	45	39	596

•													
Salmonella Carrier	59	48	69	86	95	117	66	152	192	193	135	86	1,298
Shigellosi s	32	13	17	24	10	21	20	34	25	40	55	33	324
Amebic Dysentary	0	1	4	0	0	0	0	2	0	2	0	1	10
Food Poisoning	10	32	16	3	210	26	35	106	63	8	7	4	520
(A) Viral Hepatitis	11	144	173	25	29	31	408	109	251	308	124	93	1,706
(B) Viral Hepatitis	29	24	24	19	25	16	28	31	44	28	4	32	304
(Non A Non B) Viral Hepatitis	1	5	5	8	1	2	3	0	3	11	0	2	41
Non Specified Viral Hepatitis	39	27	35	33	29	17	24	23	41	647	71	45	435
Tetanus	0	0	1	0	o	0	0	0	0	0	0	0	1
Tetanus Neonatorum	0	0	0	0	0	1	0	0	0	0	0	0	1
Whooping Cough	7	17	25	19	47	27	10	78	3	0	0	1	163
Measles	8	3	8	18	13	1	3	2	4	5	3	2	70
Rubella	20	39	65	79	48	43	17	20	33	34	23	32	453
Mumps	60	78	105	84	48	35	16	21	33	37	61	76	654
Chickenpox	711	547	640	711	558	431	255	183	159	218	296	330	5,069

					,								
Endemic Typhus	0	0	1	1	0	1	0	0	0	0	0	0	3
Malaria (Imported)	38	31	41	71	67	111	111	142	215	183	131	88	1,229
Filariasis (Imported)	0	0	1	0	0	1	1	0	0	1	1	4	9
Brucellosi s	20	20	56	70	50	39	36	32	23	23	18	7	395
Meningococ cal (A) Meningitis	4	0	0	3	0 .	3	1	0	0	0	1	2	14
Meningococ cal (B) Meningitis	1	0	0) 1 	0	0	0	0	1	0	0	0	3
Meningococ cal (A) Carrier	0	5	0	0	0	0	0	0	0	0	0	0 .	5
N. meningitid is Carrier not Grp A	0	23	0	3	0	0	0	0	0	0	0	o	26
Septic Meningitis	12	10	10	0	4	6	4	13	10	9	11	12	110
Aseptic Meningitis	4	9	5	3	4	3	2	6	8	6	13	7	70
Encephalit is	0	1	1	0	0	0	0	1	1	0	1	0	5
Infectious Mononucleo sis	0	1	2	3	0	1	1	3	3	3	1	0	18

Table 8

Scarlet Fever	8	1	3	6	4	2	1	0	1	5	3	5	39
Herpes Zoster	6	6	5	5	4	5	3	7	3	7	6	7	64
Erysipelis	0	0	0	1	0	0	0	0	0	0	0	0	1
Upper Respirator Y Infection	15	25	56	20	31	25	18	62	56	85	35	74	502
Leprosy	0	3	0	1	2	0	2	1	0	1	2	1	13
Staphyloco ccal Carrier	0	22	1	0	4	0	0	2	8	o	0	o	37
Exanthum subitum	2	1	0	3	1	0	1	0	2	0	1	0	11
Cutaneous Leishmania sis	1	0,	3	0	1	0	0	0	0	0	0	0	5
Giardiasis	14	24	38	22	10	36	9	8	16	28	14	12	231
Notified Diarrhea	165	138	188	308	230	259	308	842	498	363	206	268	3,773
Lead Poisoning	1	1	0	0	0	0	0	0 ,	0	0	0	0	2

Table 9

REPORTED COMMUNICABLE DISEASES

KUWAIT - 1989

Diseases	Jan	Feb	Mar	i.pr	May	Jun	Jul	Aug	Sep	0ct	Nov	Dec	Total
S. typhi carrier	0	0	2	4	1	1	2	0	0	1	6	0	17
Typhoid Fever	8	11	19	16	13	10	41	20	33	22	15	15	223
Non 0-1 V. cholerae	0	2	0	0	0	0	6	40	268	196	56	6	573
Cholera	0	0	0	0	0	0	0	15	78	34	5	4	136
Paratyphoi d (A) Fever	0	0	1	1	4	3	2	1	7	5	5	0	29
Paratyphoi d (A) Carrier	-	-	-	-	-	_	-	-	-	-	-	-	-
Paratyphoi d (B) Fever	0	0	0	1	2	2	3	2	1	0	0	0	11
Paratyphoi d (B) Carrier	0	0	0	0	2	0	0	1	0	1	0	0	4
Paratyphoi d (C) Fever	0	0	o	0	0	0	o	0	0	0	1	0	1
Salmonella Enteritis	33	20	39	41	43	41	30	72	54	42	44	38	497

Salmonella Carrier	76	56	82	107	120	122	114	174	192	203	166	110	1,522
Shigellosi s	11	7	9	30	31	27	25	19	47	40	27	38	311
Shigella Carrier	0	0	0	1	0	0	0	0	1	0	0	1	3
Amebic Dysentary	0	0	0	3	0	0	0	1	5	2	1	1.	13
Food Poisoning	18	5	10	602	9	34	36	70	12	15	8	10	829
(A) Viral Hepatitis	89	101	39	59	36	47	54	96	222	295	129	142	1,309
(B) Viral Hepatitis	20	17	31	19	24	21	17	43	23	59	23	15	312
(Non A Non B) Viral Hepatitis	0	2	2	1	1	0	1	7	3	14	6	4	41
Non Specified Viral Hepatitis	49	27	33	38	36	31	36	33	19	9	29	28	367
Tetanus	0	0	0	0	0	0	0	0	0	0	1	0	1
Tetanus Neonatorum	0	0	0	O	0	0	0	0	0	0	0	1	1
Whooping Cough	1	0	1	2	2	0	2	0.	0	1	1	1	73
Measles	4	16	12	19	10	5	4	1	1	0	0	1	11
Rubella	30	49	158	288	222	75	32	33	18	41	31	21	998

Table 9

T			[T			Γ	T	Γ		
Mumps	53	84	127	136	90	75	67	17	22	30	24	30	755
Chickenpox	375	365	458	501	495	334	217	197	143	182	244	254	3,752
Endemic Typhus	0	0	0	0	1	0	1	0	1	0	0	1	4
Malaria (Imported)	68	57	62	79	115	163	142	139	122	130	83	67	1,227
Filariasis (Imported)	2	0	0	4	7	8	7	3	3	4	8	5	61
Brucellosi s	18	28	32	32	31	42	21	18	11	14	10	7	264
Meningococ, cal (A) Meningitis	2	1	1	0	1	0	0	1	2	0	0	0	8
Meningococ cal (B) Meningitis	0	1	1	1	0	0 .	0	0	0	1	o	0	4
Meningococ cal (C) Meningitis	0	0	1	0	0	0	0	0	0	o	0	0	1
N. meningitid is Type 135W	3	1	2	1	0	1	2	0	1	1	0	0	12
N. meningitid is 135 Carrier	0	0	0	0	0	0	0	0	0	1	0	0	1

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Meningococ cal Meningitis Not specified	0	1	0		1	0	0	0	0	0	0	0	2
Septic Meningitis	14	14	14	15	13	11.	11	5	5	10	16	23	151
Aseptic Meningitis	9	8	13	13	12	13	3	7	9	7	17	27	138
Encephalit is	0	0	0	1	0	2	1	0	0	1	1	0	6
Infectious Mononucleo sis	0	2	3	2	4	1	ı	3	1	0	0	2	19
Scarlet Fever	1	3	14	14	8	4	3	3	1	7	9	6	73
Herpes Zoster	4	_	_	1	_	-	-	-		-	-	-	_
Erysipelis	1	-	-	-	_	-	_	_	-	 	_		_
Upper Respirator Y Infection	•	***	•	-	-	_	_	-	-	-	-	-	-
Leprosy	1	2	2	1	2	2	1	1	0	1	1	2 .	16
Staphyloco ccal Carrier	10	0	0	23	0	0	0	2	0	0	2	10	37
Exanthum subitum	0	0	0	2	0	0	0	1	0	O	2	10	15

Table 9

Cutaneous Leishmania sis	0	0	0	0	o	0	0	0	0	0	0	4	4
Giardiasis	24	74	82	54	55	41	16	20	77	85	27	28	583
Notified Diarrhea	145	236	206	223	272	255	276	377	789	389	327	236	3,729
Lead Poisoning	0	0	0	0	1	0	0	0	0	0	0	0	1
Strept Throat	67	30	47	54	44	39	60	50	69	104	51	34	649
Herpex Simplex	0	1	0	0	0	0	0	0	0	0	0	6	7

Table 10

REPORTED COMMUNICABLE DISEASES.

KUWAIT - 1990

Diseases	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug - Dec	Total
S. typhi carrier	0	1	4	0	0 .	- ,		0	5
Typhoid Fever	3	9	8	8	16			-	44
Non 0-1 V. cholerae	-	_	-	-	-	-	-		-
Cholera (imported)	-	_	-	-	_	-	-	_	-
Paratyphoid (A) Fever	1	3	0	1	1	-	-	0	6
Paratyphoid (A) Carrier	-	-	_	-	-	-	-	-	-
Paratyphoid (B) Fever	0	3	0	1	0	-	-	o	4
Paratyphoid (B) Carrier	0	0	1	2	0	-	-	0	3
Paratyphoid (C) Fever	0	0	0	0	0	-	_	0	0
Salmonella Enteritis	29	16	36	46	53	-	-	2	182
Salmonella Carrier	74	76	106	138	148	-	_	0	542
Shigellosis	16	20	25	21	20] -	_	0	102

Shigella Carrier	0	0	0	0	1.	-	-	0	1
Amebic Dysentary	0	0	2	0	0	_	-	1	3
Food Poisoning	5	4	6	21	46	-	-	0	82
(A) Viral Hepatitis	231	166	248	106	327	-	-	-	1,078
(B) Viral Hepatitis	35	20	27	28	15	-	_		125
(Non A Non B) Viral Hepatitis	7	3	4 .	2	1	-	-	-	17
Non Specified Viral Hepatitis	36	45	33	34	36	_	-	130	314
Tetanus	0	0	0	1	1			0	2
Tetanus Neonatorum	0	0	0	0	0	-	-	0	0
Whooping Cough	25	0	2	0	0	-	-	0 .	27
Measles	6	9	13	16	12	_		-	66
Rubella	31	46	101	76	122			1	377
Mumps	56	91	105	99	189			1	541
Chickenpox	289	284	3! 4	401	751	-	_	3	2,079
Endemic Typhus	0	0	0	1	0		_	0	1

Malaria (Imported)	49	51	59	83	94	T-	<u> </u>	2	338
Filariasis (Imported)	1	1	1	1	13	-	-	0	17
Brucellosis	10	12	22	40	60			0	148
Meningococcal (A) Meningitis	2	0	0	0	0 .	-	-	0	2
Meningococcal (B) Meningitis	2	1	1	2	1	-	-	0	7
Meningococcal (C) Meningitis	0	1	0	1	0	-	-	0	2
Meningococcal W135 Meningitis	1	0	0	2	1	-	-	0	4
Meningococcal Meningitis Not Specified	0	0	1	0	0	-	-	0	1
Meningococcal (A) Carrier	0	0	0	0	0	-	-	0	0
Meningococcal (B) Carrier	4	0	0	0	0	-	-	0	4
Meningococcal (C) Carrier	1	0	0	0	0	, -	-	0	1
N. meningitidis W135 Carrier	1	0	0	0	0	-	-	0	1

				,					
Meningococcal Carrier Not specified	17	0	0	0	0	_	-	0	17
Septic Meningitis	17	15	11	10	10	-	-	3	66
Aseptic Meningitis	11	5	10	15	15	-	-	1	57
Encephalitis	1.	1	1	0	1	<u> </u>		0	4
Infectious Mononucleosis	1	0	0	1	0	-	-	0	2
Scarlet Fever	11	1	11	11	15			0	49
Herpes Zoster	4	3	0	0	0	_		0	7
Erysipelis	-	•	-	-	-	-	_	-	-
Upper Respiratory Infection	63	39	46	27	41	-	-	_	216
Leprosy	1	1	3	0	3_	-		0	8
Staphylococca l Carrier	1	52	0	,O	4	-	-	0	10
Exanthum subitum	1	0	0	0	0	-	-	0	2
Cutaneous Leishmaniasis	2	0	0	0	0	- .	-	0	2
Giardiasis	11	19	17	17_	17	-		1	82
Notified Diarrhea	158	220	180	238	372	-	-	39	1,207
Lead Poisoning	0	0	0	0	0	÷	-	0	0

HIV	0	0	0_	0	0	<u> </u>		1	1
Sore Throat	0	0	0	0	0 '	-	_	1	1
Fever for Investigation	0	0	0_	0	0	-	_	1	1
Animal Bites	0	0	0	0	0		-	1	1.

SCHEDULE OF IMMUNIZATION IN KUWAIT FOR CHILDREN UP TO FIVE YEARS OF AGE

Age	Immunization	Location
Pregnant Women last trimester)	Tetanus Toxoid	PHC, Hospitals, MCH
2nd day	OPV (Type I) HBV (1st dose)	PHC, Hospitals
3rd month	OPV (Type I) HBV (2nd dose) DPT (1st dose)	PHC
4th month	OPV (Types I,II,III) DPT (2nd dose)	PHC
5th month	OPV (Types I,II,III) DPT (3rd dose)	PHC
6th month	OPV (Types I,II,III) HBV (3rd dose)	PHC
12 months	Measles vaccine	PHC
18 months	OPV (Types I,II,III) DPT (booster dose)	PHC .
2-4 years	Mumps, rubella	PHC
2.5 years	OPV (Types I, II, III)	PHC
3.5 years	OPV (Types I,II,III) DPT (booster dose)	PHC
3-6 years	BCG	SMV, BCG Centers
4.5 to 5 years	OPV (Types I,II,III)	PHC

PHC = Preventive Health Center

MCH = Maternal and Child Health Center SMV = School Mass Vaccination Survey

Vaccination	Number	1909	1900	1987	1906	1985	1984	1983	1982	1981	1980	1979	1970	1977
OTP	1st Dos 2nd Dos 3rd Dos Booster	60294 61746 64009 105296	50265 50438 59879 94134	60993 62049 93214 97836	63506 61139 62670 966 34	65392 61881 62727 95121	63157 59309 60757 90903	56520 53645 55132 75199	59896 57700 59330 76360	58406 56479 55544 60089	56669 52769 52530 58088	52233 46219 46954 47067	67241 54793 56003 61159	68263 65567 73818 42941
Polio	1st Dos 2nd Dos 3rd Dos 4th Dos Booster	60422 61943 64207 60899 184055	58902 58665 59962 63601 167600	61901 62786 63555 73053 189042	64432 61701 63018 73808 188224	67555 69766 63422 74007 208502	65906 60501 61626 68073 191463	59691 55146 55949 59940 179965	64404 60530 62028 67609 199554	65099 62439 66072 72357 185958	69699 63776 67254 69243 170635	46079 50981	09536 66512 06307 9043 199398	91029 97563 108086 89983
Measles		53434	50205	59911	63555	66841	70469	61172	54346	36528	32 099	31155	56790	30085
Tetanus 	1st Dos 2nd Dos 3rd Dos Booster	44247 17179 19716 92973	40804 17994 11495 90 8 2	30665 19562 11000 10329	29444 16858 16237 7302	31263 24179 12924 3599	56105 21555 7407 1900	96003 14694 7197 2969	47123 22147 7001 1622	39002 22572 297 4988	58545 22960 4326 1241	41589 22502 5362 1022	50529 22949 4750 9745	30104 16505 3598 242

					_									Table
	Number	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
4.07						F000	4.50	40.0				5450	5056	4000.
OPT	1st Dos	5661	5022	5763	4.361	5038	4459	4510	4885	4752	5098	5159	5006 5303	60294
	2nd Dos	5678 5758	4916	6066 627 4	5266 5500	5235 5690	4886 5200	4461 4567	4740 4611	4630 4847	5221. 5394	5254 5448	5393 5517	61746 64088
	3rd Dos Booster	9196	5186 7801	10082	97 17	8716	5200 0485	7004	7137	7994	9142	9740		104006
•	buoster	21.20	1001	10002	0, 1,	tar #O	0103	7007	1131	6337	2172	2770	10072	107000
								ı	1					
	1st Dos	5686	5027	5763	4879	5041	4473	4510	4884	4760	5104	5176	5119	60422
	2nd Dos	569A	4933	6080	5279	5247	4893	4450	4743	4630	5208	5339	5443	61943
Polio	3rd Dos	5765	5205	6275	5500	5691	5289	45 86	4604	4043	5406	5475	5560	64207
	4th Dos	6311	5544	6599	5052	6116	5640	5137	5003	5257	5750	5740	5946	68899
	Booster	16291	14243	18099	15571	15116	14273	11558	12743	1.3488	15006	18194	18603	104055
m. 1.1														
Polio (NB)		3023	3054	3009	2742	2710	2766	2921	2677	3073	3751	3740	3019	36501
		4760	7000	E220	4004	4267	2625	2001	2704	5001	4001	C221	45.4.4	
Measles		4760	3066	5930	4094	4267	3635	3601	9784	5201	4831	5231	4814	59494
OT .		190	160	286	146	120	109	101	105	257	717	422	212	71.74E.74
(1)		1 (0)	100	200	170	120	102	101	14171	2,37	212	433	217	2952
MR		3020	2970	4230	3956	4020	3520	3306	97 09	4249	4542	4035	460,0	47293
		W-176.4	2.7.0	142.50	3200	1020	2000	وادادو	J(11.1	72 ()	1372	4055	40 11,10,0	77233
Meningococcal	A+B	20154	21000	22210	17795	25156	46723	24427	19105	24680	22030	24434	21224	289458
•		,	- * *							_ ,	22,500	2		20.7100
Yellow Fever		30	61	13	74	107	52	31	41	203	38	26	25	709
Rabies 16		38	35	36	40	17	32	35	37	32	35	34	39	410
Gamma Globuli	n	604	505	556	491	440	509	454	905	699	829	741	700	7412
T-1.1 .1:		0.3				-								
Tetabulin		83	60	91	66	69	83	62	101	89	75	57	29	864
Danking L C	•										_			
Pertussis I G						4					2	4		16
Tetanus	1st Dos	3934	4007	0405	2652	4205	4000	3487	4652	4400	2000	าธาก	1000	
I E L GI IU S	2nd Dos	2045	1329	2762	1471	959	944	1276	872	4490 1537	3029 944	35 36	1882	44247
	3rd Dos	950	867	1475	1162	1355	1611	1138	1440	1332	185	1110 1901	2055 392	17193
	Booster	2923	3117	3245	3462	3901	3455	2774	3004	2037	1963	740	955	13716
	1,0051	8.0 m / San - Al	J. 1.	444 JQ	JIGE	3.701	3133	2111	CHAIR	2.13.17	1,003	770	.34,34,4	92973
Typhoid	1st Dos	1,179	1245	1710	470	1474	1732	1122	1925	1543	1695	1289	1491	16719
· Silver re- and	2nd Dos	วันสกั	986	1771	511	629	874	971	1707	1730	1209	1274	1559	13005
	Dooster	31,15	1050	1162	375	1069	1190	1020	1696	1420	1924	1454	1662	14449
											I 13-14.		B 7 11.16	
Cholera		4906	4462	5367	2947	6503	8985	- 5040	44'161	5921	6042	57 95	6134	6 5 90n
			•											C.G.:
Rabies		771	294	298	305)	316	322	380	3.14	272	297	300	324	3733
11 111 5														- -
Hepatitis D		501	97	124	27	127	END.	39	26.	60	101	50	0.3	1021
Rubelila									•	_		_		
MODELLA		1.	11	3		2	6	3	. a	Ţi	.3	35	109	194
Manger / S												f 11 A -		
()							. (1			ĭ	Sitte		. 5000

						.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	ii kaaaii		109 11	-3111.112.17				Tat	;
	Number	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Hav.	Dec.	Total	
(IPT	1st Dos 2nd Dos	4981 5047	4447 4263	5105 5109	3884 4191	4922 5005	4055 4420		1116 1174	1127 997	1509 1449	1661 1490	1351 1171	94152 94426	
	3rd Dos Booster	5026 8475	4290 7181	5144 8685	4313 6142	552 5 92 89	45 19 7690		1191 1361	1003 1607 ,	1661 20 4 5	1532 2134	1054 1406	35750 56015	
	1st Dos 2nd Dos	5017 5060	4480 4282	5124 5198	9894 4198	4939 5139	4066 4420		1121 1175	1126 1004	1514 1150	1661 1495	1951 1121	94293 34242	
Polio Vaccine	9rd Dos 4th Dos Booster	5042 5647 16200	42/38 4561 13651	5139 5905 14946	4200 4205 10160	5595 5574 10314	4523 4699 12517		1191 1177 2052	1006 - 811 2420	1929 1100 3556	1462 1317 4329	1054 1073 3008	34771 35469 93241	
Polio (New Bor		4027	3681	41 32	4027	4910	3902		27	949	936	1059	371	26021	
Measiles		4230	3943	4559	3503	5067	3772		801	742 .	1064	1194	1100	29975	
B.T. Vaccine		250	164	152	201	217	105		26	14	θ	19	2	1292	
M.R. Vaccine		4204	3562	4252	2863	4593	3496		861	727	1010	1959	1003	27994	
Meningococcal	A+B	19317	16960	21564	14498	34981	88184		1001	1027	1906	1101		199947	
Yellow Fever		50	43	63	17	90	61							332	
Rabies I G	٠				16	16	33	:			3			60	
Gamma Globulin	•	1404	1107	1005	1169	2199	1760		44	307	49	80	400	9635	
Tetabulin		56	64	65	36	64	62		1	3	1	26		378	
Pertussis I G					5	10	3							18	
Tetanus	1st Dos 2nd Dos	6416 1483	5706 1109	6549 2585	4522 1069	5673 1120	4483 650		66 1	71 19	25 14	3 9 6	16 2	90640 9057	
•	3rd Dos Booster	992 794	511 511	266 1494	76 984	36 1320	332 748			10 4	5	1	•	1629 5066	
lyphaid	1st Dos	1502	1296	1691	1096	1830	1496		63	71 60	49	15	5	9194	
	2nd Dos Booster	1200 1796	1022 1690	1219 1680	1298 640	1237 2308	1924 1740		10 10	60 31	32	Э	4	7400 9893	
Cholera	•	5600	4907	4889	1904	626 4	0235		45	36	15	297		31834	
Rabies		920	242	302	292	434	310		15	31	34	54	49	2090	
'Hepatitis B	Peds Adult	3567 003	9695 1969	4121 1270	6251 1013			•				21 8	130 19	17785 5155	
Rubella		21	. 11	5	2	4	9		103		147	30	92	0 424	
Munps		901		965	В	6		: .	•			1		201	

The Politic Health Kausel

REPORTED COMMUNICABLE DISEASES KUWAIT JANUARY - MARCH 9, 1991

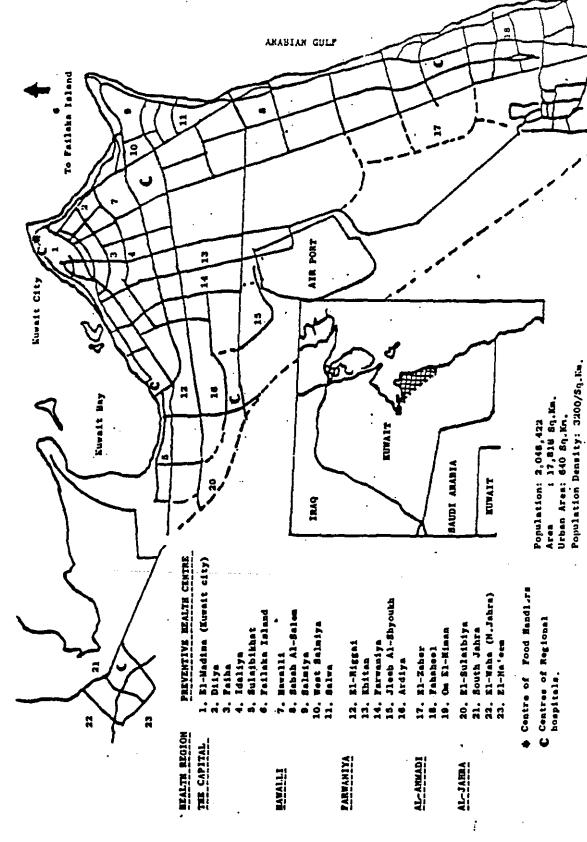
Diseases	January	February	March	Total
Hepatitis A	144	9	22	175
Hepatitis B	0	0	1	1
Mumps	1	1	0	2
Meningitis	0	1	0	1
Dog Bites	1	0	0	1
Diarrhea	0	0_	5	5
Fever	0	0	1	1

HEPATITIS A
KUWAIT BY YEAR 1988 - MARCH 9, 1991

YR	J	F	М	A	н	J	Ţ	λ	s	0	N	D	TO T
88	11	14 4	17 3	25	29	31	40 8	10 9	25 1	30 8	12 4	93	17 06
89	89	10 1	39	59	36	47	54	96	22 2	29 5	12 9	14	13 09
90	23 1	16 6	24 8	10 6	32 7	-	-			13 0			12 08
91	14	9	22										

HEPATITIS B KUWAIT BY YEAR 1988 - MARCH 9, 1991

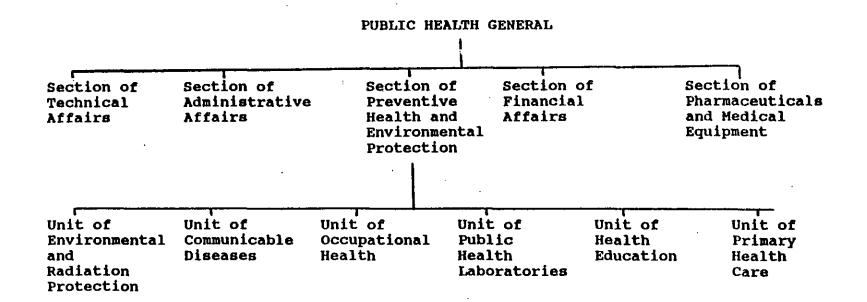
YR	J	F	М	A	М	J	J	A	s	0 -	И	D	TO T
88	29	24	24	19	25	16	28	31	44	28	4	32	30 4
89	20	17	31	19	24	21	12	43	23	59	23	. 15	31 2
90	35	30	27	28	15	-	-	0	0 .	0	0	0	12 5
91	0	0	1										



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FIGURE 2

ORGANIZATION OF PUBLIC HEALTH DURING THE IRAQI OCCUPATION, AUGUST 1990 - JANUARY 1991



ORGANIZATION OF KUWAIT MINISTRY OF PUBLIC HEALTH AS OF MARCH 16, 1991

Minister of Public Health (Dr. Abul Wahab AL-Fozan)

Undersecretary of The Ministry of Public Health (Vacant)

Assistant Secretary for Public Health Affairs (Dr. Ali AL-Saif)

Department of Environmental Health

Director: Mr.

Ibrahim Hadi Assistant: Dr.

Mohammed Yousif

Department of Public Health Director: Dr.

Rashed AL-Owaish

Department of Health Education Director: Dr. Yousif

AL-Moumen

Department of International Health

Director: Dr. Abul Latif AL-Zaid

ORGANIZATION OF THE DEPARTMENT OF PUBLIC HEALTH

Department of Public Health

Epidemiology 1		Environmenta		Nutrition Unit	•
Protection Division Chief: Dr. Yousif Bagen	Health Laboratories Chief: Mr. Yagoob AL-Motaweh	Health Division Chief: Dr. Rached AL-Owaish	Medicine Division Chief: Dr. Jaffar Dawood Assistant Dr. Adnan AL-Garabaly	Health Division Chief: Dr. Abul Latif AL-Zaid	Insect Control Division Chief: Dr. Mohammed Balbah
Radiation	Public	Port	Preventive	International	Rodent and

Chief: Dr. Abdul Amir

Chief: Dr. Tareq AL-Dowesan Chief: Dr. Zamzam AL-Kalidar

FIGURE 5

HEALTH DISTRICTS AND DISTRICT DIRECTORS

DISTRICT

Capital (Amiri District)

AL-Ahmadi District

Hawalli District

Farwaniya District

AL-Jahra District

AL-Sabah Region for Specialized Services

DISTRICT DIRECTOR

Dr. Ahmamed AL-Aiaf

Dr. Abdulla Hamadi

Dr. Abdul-Razak AL-Bahar

Dr. Suliman AL-Fallah

Dr. Rashid AL-Roshood

Dr. Salah AL-Ategi

FIGURE 6

HOSPITALS AND HOSPITAL DIRECTORS BY DISTRICT

DISTRICT	HOSPITAL		DIRECTOR
Capital (Amiri)	Amiri Hospital	Dr.	Ahdy AL-Ghanim
AL-Ahmadi	Adaan Hospital	Dr.	Adnan AL-Edan
Hawalli	Mubarek Hospital	Dr.	Yousef AL-Nasif
Farwaniya	Farwania Hospital	Dr.	Ali AL-Fowderi
AL-Jahra	Jahra Hospital	Dr.	Abdul Raoof AL-Jahari
AL-Sabah	Allergy Center Audiology Center Burns and Plastic Surgery Center Cancer Control Center Chest Hospital Gynecology-Maternity Hospital Infectious Disease Hospital Islamic Medicine Center Neurosurgery Center Ophthalmology Hospital Orthopedic Hospital Pediatric Hospital Physiotherapy Center Psychiatric Hospital Transplantation Center	ter	Salah AL-Ategi

Water Team Accomplishments

- 1. Accompanied Army Engineers to assess damage to the Schwaiyk Desalination Water Treatment Plane.
- 2. Met with Mr. Nasser, Deputy of the Ministry of Electricity and Water, and Dr. Fatima AL-Awad, Director of the Water Resource Development Centre. A plan was established to test all of the existing reservoirs which provide water to Kuwait City and surrounding communities. The water would be tested for lewesite, mustard, cyanide, nerve agent, and arsenic. Samples were collected at the following reservoirs:

Mutla Low, Mutla High, West Finatas, Doha, Subhan

One positive lewesite sample came from Mutla High. It was thought to be an error in sampling and was retested the following day and found to be negative.

3. The Navy and Army Water Team visited the water testing laboratory at the Water Resources Development Centre (WRDC). The staff of the WRDC was taught how to use the M-272 water chemical test kit and the Millipore Filter Water Bacteriological Field Test Kit. Seven (7) M-272 kits, one (1) Field Bacti kit from the Navy team, and one (1) Field Bacti kit from the Army, along with the bulk of the Navy Millipore Water Testing supplies were transferred to the Director, WRDC, for use in conducting water analysis. Humanitarian efforts by the Navy Water Team were concluded at this point.

Assessment

Given the equipment and training provided the WRDC, adequate water testing may be accomplished until such time as the WRDC is 1. Supplied and returns to normal operation.

Vector Control Report of 5 March 1991

- 1. LTC Lambrinos, LCDR Schultz, LT Lluberas, Cpt Leonard, and several vector control technicians met with Osama Omar EL-Ruby (head of Rodent Control) and Dr. Ibrahim Hadi, Director of the Environment Protection Department, Ministry of Public Health. The meeting took place at the Pest Control Garage main office in the Industrial Area near AL-Mina and the 4th ring road.
- 2. Mr. EL-Ruby described their limited work during the occupation as mainly supporting five hospitals in rodent and cockroach control. Most of their vehicles and nearly all of their pesticides were stolen. He described how all of their pesticide mixing equipment was carefully removed and flown to Iraq.
- 3. A tour of the facility was then conducted. Areas such as record keeping, which were of no use to the trespassers, was badly trashed. The pesticide storage garage was empty with the exception of a small amount of rat bait. Several vehicles were present but had their tires removed or were damaged in some way. They had six truck-mounted ultra-low volume machines.
- 4. They reported that on 9 March about 116-120 previous employees would be returning to work. Most of these people had 15 years experience in pest control. By that date, Mr. EL-Ruby said they should have completed their assessment on how much equipment and supplies were available for their use.
- 5. We discussed with them the amounts and kinds of pesticides and equipment we brought and was available for them to use. The pesticides would be enough for a 14-day supply for their teams until additional pesticides could be purchased. Most of the equipment in our inventory is similar to that which they used before the invasion, so only refresher training would be needed.
- 6. Mr. EL-Ruby said that there were no immediate vector control problems that needed spraying by our team. He mentioned that they had a 3-month plan for resuming operations.

Entomology Team Accomplishments

- 1. Visited hospitals and interviewed doctors on prevalence of vector-borne diseases. No vector-borne diseases were reported in Kuwait during the occupation and they gave no indication that any would be a likely problem.
- 2. Acquired body bags and delivered them to several hospitals in which morgue storage facilities had been exceeded.
- 3. Provided vector control in morgues for flies, and at the U.S. Embassy and airport for mosquitos.
- 4. Visited pesticide distributors in Damman; got availability and price information. Developed a suggested list of pesticides with amounts that the contractor should purchase to restock the Kuwait Pesticide Garage.
- 5. Performed assessment of the Pest Control Garage. Reviewed their activities for the past 7 months. Of special note was removal of their pesticide mixing equipment which was flown to Iraq. Also noted was the nearly complete removal of their pesticide supplies and vehicles used for spraying.
- 6. Assisted the Ministry of Health in an overall assessment of the pest and vector situation. Overall conclusion is that although there are minor local fly and mosquito problems, the city is in very good shape.
- 7. An extensive amount of pesticides, pesticide spraying equipment, and general laboratory equipment has been transferred from our team to the Kuwait Pest Control Garage.

<u>Assessment</u>

Mr. Osama EL-Ruby, head of the rodent control division, reported that on 9 March about 120 previous employees would be returning to work. These are experiences pest control workers averaging about Since during the occupation most of the 15 years on the job. pesticides and equipment were stolen, we felt that the greatest help we could provide was to transfer our pest control supplies and equipment to them. We discussed pest control priorities and agreed that there should be fly control in areas where garbage had been Mosquito, roach, and rodent control would be previously piled. responded to on the basis of public complaint. Sanitation was stressed as the key to returning things back to normal. We feel confident that the pest control garage, with their experienced workers and the addition of our pesticides and equipment, will quickly return to the effective service that it previously provided.

Epidemiology Team Accomplishments

- Hospitals were visited and needs were assessed.
- 2. Arrangements were coordinated for the delivery of water to the hospitals. In some cases, supplies of bottled water were delivered to the outlying hospitals such as the Infectious Disease Hospital which had a small in-patient population (five persons).
- 3. Meetings were held at the Ministry of Public Health and their disease surveillance program was discussed.,
- 4. Delivery of some supplies requested by the hospitals was accomplished.
- 5. Epidemiology Team members participated in other activities of the 352nd Civil Affairs Command, such as the identification of sites where animal herds were without water, assessment of displaced civilians returning from Iraq, and evaluation of problem areas, such as refuse disposal.

Assessment

The overall health of the population of Kuwait City was good as a result of optimal health care during the period preceding the occupation. The relatively short duration of the occupation and the ground war was a factor in the minimal degradation of the health and nutritional status of the population. The cool season of the year, which limited the opportunity for vector breeding, helped to minimize the potential for vector-borne disease. Although the ability to conduct surveillance had been degraded during recent months due to severe limitations on communication and transportation, the basic reporting mechanisms were still intact. The efforts to keep up with immunization and basic public health services were impressive.

It is apparent that as soon as the basic services of electricity, water, and communication are restored, that mechanisms are in place for resuming health care and public health service at a high level. The Ministry officials and physicians are among the most highly training professionals in the world. Probably one of the more difficult challenges will be to obtain adequate numbers of service personnel who can restore systems, orderliness, and cleanliness to the hospitals, clinics, and other public institutions.

15 MARCH, 1991

RESULTS OF INFECTIOUS DISEASE SURVEILLANCE IN KUWAIT CITY, 5 MARCH - 15 MARCH, 1991 CONDUCTED JOINTLY BY MUBARAK HOSPITAL LABORATORY (DR KAMAL ELHAG AND DR AWAD EL-MEKKI) AND NAVY FORWARD LABORATORY

BACKGROUND:

DURING THE PERIOD OF 5 MARCH - 15 MARCH, 1991 MUBARAK HOSPITAL LABORATORY (DR KAMAL ELHAG AND DR AWAD EL-MEKKI) IN COLLABORATION WITH THE NAVY FORWARD LABORATORY CONDUCTED INFECTIOUS DISEASE SURVEILLANCE IN MAJOR, KUWAIT CITY HOSPITALS TO DETERMINE THE POST-WAR ETIOLOGY AND INCIDENCE OF ACUTE DIARRHEA AND HEPATITIS.

METHODS:

DIARRHEAL STOOL SPECIMENS AND SERA FROM PATIENTS WITH SYMPTOMS OF ACUTE HEPATITIS WERE COLLECTED DAILY FROM ALAMIRI HOSPITAL, SABAH HOSPITAL, PEDIATRIC HOSPITAL, THE INFECTIOUS DISEASES HOSPITAL AND MUBARAK HOSPITAL (SOME DIARRHEAL STOOL SPECIMENS WERE FROM KUWAITI DETAINEES HELD IN IRAQ). DIARRHEAU STOOL SPECIMENS WERE CULTURED FOR SHIGELLA SP., SALMONELLA SP., CAMPYLOBACTER SP., AND VIBRIO CHOLERAE 01. LT PRODUCING ENTEROTOXIGENIC E. COLI WERE IDENTIFIED USING A DNA PROBE. DIARRHEAL STOOLS WERE ALSO EXAMINED FOR PATHOGENIC PARASITES. SERA FROM PATIENTS WITH CLINICAL SYMPTOMS OF ACUTE HEPATITIS WERE TESTED FOR THE PRESENCE OF IGM ANTIBODY TO HEPATITIS A VIRUS AND IGM ANTIBODY TO HEPATITIS B VIRUS CORE ANTIGEN.

RESULTS:

A TOTAL OF 49 DIARRHEAL STOOL SPECIMENS WERE COLLECTED. THERE WERE 13 SHIGELLA SP., 8 CAMPYLOBACTER SP., 2 SALMONELLA SP., AND 7 VIBRIO CHOLERAE 01 OGAWA ISOLATES. THE SPECIES OF THE SHIGELLA ISOLATES ARE SHOWN IN TABLE 1.

OF THE 7 PATIENTS WITH VIBRIO CHOLERAE 01, OGAWA ISOLATED FROM THEIR STOOL, 4 PATIENTS HAD LEUCOCYTES IN THEIR STOOL. CAMPYLOBACTER SP. AND SHIGELLA DYSENTERIAE WERE ISOLATED FROM TWO OF THE PATIENTS WITH LEUCOCYTES IN THEIR STOOLS. THESE PATIENTS WERE LIKELY VIBRIO CHOLERAE 01, OGAWA CARRIERS. OF THE REMAINING

3 PATIENTS, 1 PATIENT HAD 100,000,000 VIBRIO CHOLERAE 01, OGAWA ORGANISMS PER ML OF STOOL AND WAS LIKELY A CASE OF CHOLERA DIARRHEA. THERE WAS NO EVIDENCE OF PATHOGENIC PARASITES. THESE RESULTS ARE SUMMARIZED IN TABLE 1.

NINE SERA WERE OBTAINED FROM PATIENTS WITH CLINICAL SYMPTOMS OF ACUTE HEPATITIS. OF THESE SERA, 8 WERE POSITIVE FOR IGM ANTIBODY TO HEPATITIS A VIRUS AND 1 PATIENT HAD NON A, NON B HEPATITIS. THESE RESULTS ARE SUMMARIZED IN TABLE 1.

FIGURE 1 COMPARES NUMBERS OF ENTERIC ISOLATES BY SPECIES BETWEEN MARCH, 1990 AND 5 MARCH - 15 MARCH, 1991. THERE IS AN APPARENT INCREASE IN THE NUMBER OF ENTERIC PATHOGEN ISOLATES WHICH IS NOT OF EPIDEMIC PROPORTIONS AND WOULD BE EXPECTED DUE TO CURRENT CONDITIONS IN KUWAIT CITY.

TABLE 2 SHOWS THE ANTIBIOTIC SENSITIVITY PROFILE OF BACTERIAL ISOLATES FROM DIARRHEAL STOOLS. SHIGELLA GROUP A ISOLATES WERE SENSITIVE TO ALL ANTIBIOTICS TESTED IN VITRO. THE SHIGELLA GROUP B ISOLATES WERE ALL RESISTANT TO AMPICILLIN AND 8 OF 9 ISOLATES WERE RESISTANT TO CHLORAMPHENICOL, DOXYCYCLINE AND SULFATRIMETHOPRIM. ALL SHIGELLA GROUP B ISOLATES WERE SENSITIVE TO THE QUINOLONE, NORFLOXACIN. THE 7, VIBRIO CHOLERAE 01, OGAWA ISOLATES WERE SENSITIVE TO ALL ANTIBIOTICS TESTED. ALL BACTERIAL PATHOGENS ISOLATED FROM DIARRHEAL STOOLS WERE SENSITIVE IN VITRO TO THE QUINOLONE ANTIBIOTIC, NORFLOXACIN.

SPECIAL NOTE !!!

EXTREME CARE SHOULD BE TAKEN IN THE INTFPRETATION OF THE ISOLATION OF VIBRIO CHOLERAE 01, OGAWA FROM STOOLS. IT IS LIKELY THAT 4 OF THE 7 PATIENTS FROM WHICH WIBRIO CHOLERAE 01 WAS ISOLATED WERE CARRIERS SINCE THEY HAD LEUCOCYTES IN THEIR STOOL AND ANOTHER ENTERIC PATHOGEN CAUSING INVASIVE DIARRHEA WAS ISOLATED. IN AT LEAST ONE OF THE PATIENTS WHERE A HIGH NUMBER OF VIBRIO CHOLERAE 01, OGAWA (100,000,000 ORGANISMS PER ML OF STOOL CONSISTANT WITH CHOLERA DIARRHEA) ORGANISMS WAS ISOLATED IT WAS LIKELY THAT THIS ORGANISM WAS THE CAUSE OF THE RESULTANT DIARRHEA. THE ISOLATION OF VIBRIO CHOLERAE 01, OGAWA DOES NOT SIGNIFY AN EPIDEMIC OR THE START OF AN EPIDEMIC HOWEVER, CONTINUED SURVEILLANCE IS IMPORTANT.

DR KAMAL ELHAG

LCDR JAMES BURANS

LT SCOTT THORNTON

DR AWAD EL-MEKKI

RESULTS OF DISEASE SURVEILLANCE IN KUWAIT CITY HOSPITALS, 5 MARCH - 15 MARCH, 1991

NUMBER OF DIARRHEAL STOOL SPECIMENS COLLECTED - 49

SPECIES	# OF ISOLATES
SHIGELLA GR A	2
SHIGELLA GR B	10
SHIGELLA GR C	0
SHIGELLA GR D	1
CAMPYLOBACTER SP.	6
SALMONELLA SP.	2
VIBRIO CHOLERAE 01, OGAWA	7

NUMBER OF SERA COLLECTED FOR HEPATITIS SEROLOGIES - 9

SEROLOGICAL	YASBA	# POSITIVE
HEPATITIS A	IgM ·	8
HEPATITIS B	CORE IgM:	0

* 1 SERUM PROBABLE NON A, NON B HEPATITIS

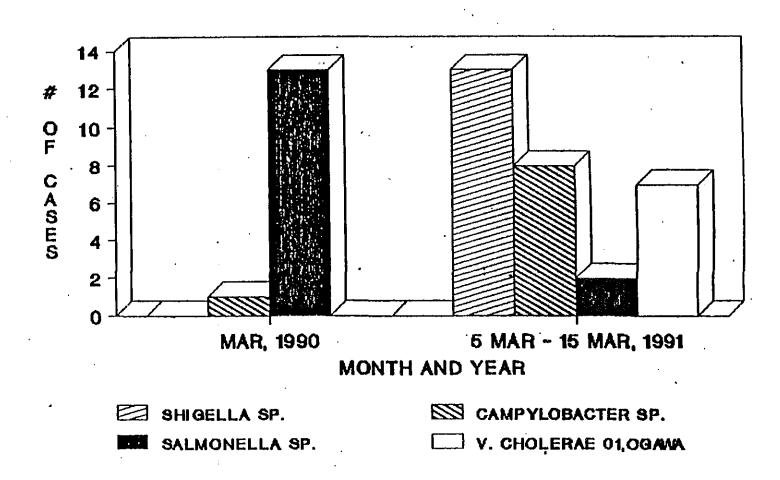
MUBARAK HOSPITAL LAB AND NAVY FORWARD LAB

ANTIBIOTIC RESISTANCE PROFILES OF ENTERIC PATHOGENS FROM KUWAIT CITY 5-15 MAR, 1991

	# OF			ANTIBIO	ric	
ISOLATE	ISOLATES	NOR	С	AM	DOX	SXT
SHIGELLA GROUP A	2	0	0	0	0	o
SHIGELLA GROUP B	9	0	8	9	8	8
SHIGELLA GROUP D	1	0	0	0	1	0
CAMPYLO- BACTER SP.	6	0	· · o	1 '	0	5
SALMONELLA SP.	2	. 0	O	0	2	۰.0
V. CHOLERA O1, OGAWA	E 7	0	0	0	0	0
			:			

NOR-NORFLOXACIN, C-CHLORAMPHENICOL, AM-AMPICILLIN DOX-DOXYCYCLINE, SXT-SULFATRIMETHOPRIM

RESULTS OF DIARRHEAL STOOL CULTURE AT MUBARAK HOSPITAL



15 MARCH, 1991

MEMO

FROM: NAVY FORWARD LABORATORY

SUBJECT: DAILY REPORT

ENCL: PROTOCOL FOR IDENTIFICATION OF V. CHOLERAE O1 CARRIERS

- 1. 1 DIARRHEAL STOOL SPECIMEN FOR CULTURE AND NO SERA FOR HEPATITIS SEROLOGIES WERE RECEIVED.
- 2. THERE IS NO EPIDEMIC INFECTIOUS DISEASE IN KUWAIT CITY AT THE CURRENT TIME.
- 3. THE NAVY FORWARD LABORATORY TEAM HAS DRAFTED A PROTOCOL WITH DR KAMAL ALHAG, DIRECTOR LABORATORY SERVICES, MUBARAK HOSPITAL FOR THE IDENTIFICATION OF VIBRIO CHOLERAE 01 CARRIERS TO SIMPLIFY LABORATORY WORKUP AT MUBARAK HOSPITAL (ENCL 1). MEDIA AND REAGENTS FOR PROCESSING 400 SPECIMENS HAVE BEEN PROVIDED AND PREPARED.
- 4. THE NAVY FORWARD LABORATORY TEAM WILL DEPART KUWAIT CITY ON SUNDAY, 17 MARCH, 1991 TO AL JUBAIL, SAUDIA ARABIA.
- 5. A FINAL REPORT OF THE JOINT INFECTIOUS DISEASE SURVEILLANCE CONDUCTED BY THE NAVY FORWARD LABORATORY AND MUBARAK HOSPITAL LABORATORY HAS LEEN PREPARED. THIS REPORT HAS BEEN PROVIDED TO DR KAMAL ELHAG, DIRECTOR OF LABORATORY SERVICES, MUBARAK HOSPITAL, DR ALKHANDARI, EPIDEMIOLOGIST, KUWAITI TASK FORCE, DR BASHIR, DIRECTOR OF LABORATORY SERVICES, KUWAIT MINISTRY OF HEALTH, CAPT JOHN ANDREWS, USPHS, KUWAITI TASK FORCE AND LTC MCNAUGHER.
- 6. IF A SITUATION DEVELOPES THE NAVY FORWARD LABORATORY CAN BE CONTACTED IN AL JUBAIL, SAUDIA ARABIA, THROUGH 24 MARCH, 1991 AT:

AL JUBAIL COMMERCIAL TEL # 341-0912

AFTER THIS TIME INFECTIOUS DISEASE LABORATORY SUPPORT CAN BE OBTAINED THROUGH CONTACTING:

CAPT MICHAEL KILPATRICK, MC, USN COMMANDING OFFICER NAVAL MEDICAL RESEARCH UNIT No. 3 CAIRO, EGYPT

COMMERCIAL TEL # 00202-284-1375 TELEX 23035 NAMRU UN

OR CABLE THROUGH US EMBASSY TO US EMBASSY, CAIRO

LCDR JAMES BURANS

LT SCOTT THORNTON

PROCEDURE FOR THE IDENTIFICATION OF VIBRIO CHOLERAE 01 CARRIERS

STOOL SPECIMEN OR RECTAL SWAB INNOCULATE ALKALINE PEPTONE WATER, PH 8.5

INCUBATE 6 HR, 37 C

SUBCULTURE ON TCBS AGAR -

INCUBATE 16 - 18 HR, 37

SUBCULTURE SUCROSE POSITIVE COLONIES ON GRIDDED TSA

INCUBATE 3 - 4 HR, 37 C

PERFORM OXIDASE TEST ON EACH EACH_COLONY

OXIDASE POSITIVE COLONY SEROTYPE WITH VIBRIO CHOLERAE 01 POLYVALENT TYPING SERA

Ministry of Public Health Kuwait-Arabian Gulf World Health Organization





EMERGENCY HEALTH PLAN OF ACTION APRIL-JUNE 1991

KUWAIT

Working document

EXECUTIVE SUMMARY

HEALTH

The health care system in Kuwait had until August 1991 achieved levels of quality and coverage which compared favourably with those of most industrialized countries.

The invasion and subsequent occupation of the country affected it severely in at least two ways. Firstly, it caused the departure of large numbers of health professionals, in particular those who represented the very heart of the health care structure - nurses and other allied health personnel. Their numbers shrunk to about 20% of their initial levels, creating major difficulties in appropriately managing curative and preventive services.

Secondly, it disabled the provision of quality medical investigations and care by crippling the electro-medical equipment, key elements of which were removed, damaged or rendered unusable by the lack of maintenance and repairs.

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By the end of the occupation period; only urgent medical and surgical care could be provided by a nucleus of remaining staff who had to rely largely on their clinical skills to diagnose and treat patients, deprived as they were of the solid biomedical and X-ray supports they once had. Generally, health care facilities did not suffer major structural damage but certain facilities, among them the kidney and gastroenterology centres and the Institute of Islamic Medicine, were subjected to complete internal destruction.

The Primary Health Care network, which used to rely on 72 polyclinics in the country, had only ll of them operating at the time of the visit of the mission. The challenges facing the health structure in providing medical and public health services were compounded by mounting environmental hazards related to air. water and sea pollution and, most critically, the widespread presence of explosives and land mines.

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An emergency response plan was elaborated in March 1991, jointly by the Ministry of Public Health and the World Health Organization team. The plan, which covers a period of 3 months from April to June 1991, aims at providing essential health services to the population presently in the country and preparing for the return to Kuwait of displaced nationals.

The following ten programme areas have been identified which require immediate action:

Health Care Infrastructure
Surveillance
Environment Health
Disease Prevention and Control
Psychological Trauma
Essential Drugs
Diagnostic Facilities and Blood Bank
Health Information and Education
Emergency Medical Services
Management and Coordination

During the three month emergency response and rehabilitation period, steps will be taken to formulate a medium term health development plan, as based on policies concerning such issues as the provision of health care and immigration which are under review.

In addition to resources made available by Kuwait, funds are required to begin operations without delays at a time when the national administrative structure does not yet enable these resources to permeate the entire system.

The present plan proposes a set of short term objectives, targets and activities which will require technical support from WHO, other UN agencies, multilateral, bilateral or private groups.

The budget figure of US\$ 4 100 000 covers the cost of this technical expertise and of some urgently required supplies and equipment.

EMERGENCY RESPONSE AND REHABILITATION IN THE HEALTH SECTOR

With a crude death rate at 2.4/1000, an infant mortality rate at 16.3/1000 live births, and a life expectancy at birth of 71.2 years and 75.5. years for males and females, respectively, Kuwait had until August 1990 achieved one of the highest health standards in the world. As communicable diseases and other main contributors to childhood morbidity and mortality were brought under control, the national health, services had gradually expanded their scope by creating diagnostic and treatment facilities for noncommunicable diseases which required a constantly increasing level of technical sophistication and amount of resources. This was reflected by the number and the quality of fired health facilities, the efficiency of the emergency medical care and the creation of centres specializing in such areas as oncology, nephrology, organ transplant, open-heart surgery and neonatology. The 6 regional and 9 specialized hospitals, the 72 health centres and several medico-social institutions in the country were providing medical, surgical, dental care and rehabilitation services to the entire population, free of charge. Private health facilities were completing this extensive network. Over 9900 nurses (of which 90% were foreign workers) and more than 3200 physicians (of which 80% were foreigners) were providing these services, with a ratio of physicians and nurses to population which compared favourably with most industrial countries in the world. A large proportion of highly trained manpower is no longer in the country.

It is against this background that the invasion of Kuwait took place. Its immediate effects were the departure from the country of thousands of foreign health workers, followed by the destruction or the removal by the occupying forces of large amounts of equipment and supplies, particularly in hi-tech fields.

At the time of this WHO emergency response and rehabilitation mission. Kuwait was faced with acute difficulties inherent to its prior dependency on expatriate health personnel - a majority of whom had by now left the country, and with challenges created by an adverse environment. Health hazards

generated by the pollution of the air, the scarcity of water and the large amount of explosives scattered in and around populated areas were facing a population unprepared for a lifestyle closer to survival than to the secure environment it had known over the past decade. Of the six regional hospitals, one is closed due to shortage of nursing personnel, the non-availability of electricity and water. The others operate at reduced capacity, in the range of 10-20% for most of them. The Mubara; Alkabeer Teaching Hospital which has saved most of its equipment but lost more than 60% of its staff has enroled volunteers and is currently functioning(at 48% of its total bed capacity. Only 3 of the 5 operating theatres are used, and only for emergencies, as water is scarce and the maintenance of equipment has been lacking for months. Only one of the six intensive care units is functioning at present. Elsewhere, the damage caused to the infrastructure, the removal of equipment, the reduction in labour force and the lack of electricity and water have severely affected the provision of care. The Centre for Organ Transplant which had a large kidney-dialysis capability has come to a complete stop and will take months and large resources to rehabilitate. The Cancer Centre has had to refer as many patients as it could to foreign countries, suspended surgical activities due to the lack of water and electricity and reduced drastically its provision of chemotherapy as the number of specialists in this field fall from 10 before August 1990 to only one today. The gastroenterology center, highly sophisticated diagnostic and treatment centre adjacent to the Al-Amiri hospital is closed and a large proportion of its initial equipment is damaged or missing.

Of the 72 pre-existing health centres, eleven are functioning with reduced staff, the others are closed. The ambulance services saw their pool of vehicles reduced from 170 to less than 40, newly supplied multi-purpose vans.

The number of dental chairs in the country fell from 350 to 180 at present and the number of dental surgeons from 350 to 110.

In spite of these major difficulties, the existing medical, surgical and dental facilities are coping with the most urgent needs of a population which is temporarily reduced in size, and which has at the moment a lesser demand for health care as a result of competing priorities in the restoration of normal livelihood. In the area of public health, immunization activities continued, albeit at a lower level than required, over the last 7 months. Power failures have however affected the cold chain for the storage of vaccines. Fresh stocks are needed, some of which were supplied together with basic cold chain elements shortly by UNICEF after the liberation of Kuwait. Vector control activities had been maintained for years at a high level of efficiency. They led for example to the dramatic reduction of the rodent population and the absence or low prevalence of certain vector borne diseases (malaria included) which are otherwise present in the region. The access of the population to safe (piped) water supply, sanitation and solid waste disposal was close to 100%, creating a favourable environment. unprecedented situation created by the burning of oil wells, or the uncontrolled spilling of oil over large areas is a matter of grave concern although preliminary analyses are reported to have shown low levels of acid forming gases in the smog emanating from these fires. The short and long term effects of this pollution call for complementary monitoring systems, some aimed at the measurement of environmental parameters, others at the trend of selected diseases, signs or symptoms. The air and water monitoring stations are not yet operating due to lack of electricity or the loss of equipment. The vast amount of live ammunition scattered throughout the country and the large number of mines in populated areas have resulted in a high number of injuries, particularly among children and adolescents. Reportedly, there are two or more such injuries from this cause every day. The pollution by mines is a particular concern at present but also in the context of the expected return of a large part of the population, mostly unprepared for this risk. Finally, it has been suggested by a UNICEF child psychologists that the violence, stress and anxiety generated by the war have cause childhood trauma and loss which will require both short and long term rehabilitation programmes. Against the background, the Ministry of Public Health and a WHO team elaborated a plan of action for an emergency response period covering

three months. During this period, the situation would be reassessed and further plans formulated. The plan can be highlighted as follows:

1. Health Care Infrastructure

While electrical and water supply are being restored gradually, there is an urgent need to verify, repair and put back into operations the electromedical equipment which has not been maintained or used for an extended period of time. The deficit in health personnel has to be made up for, particularly in the nursing area where it has been estimated that 680 nurses are now required to enable the health care system to meet the need of the population currently present in Kuwait.

Surveillance

The health impact of prevailing environmental hazards need to be monitored immediately and continuously. This applies to air pollution related health issues, water borne, food borne and vector borne diseases and those eligible for immunization. Towards this aim, surveillance sentinel sites should be chosen and a simplified, interim surveillance system designed which should produce information on trends of such diseases or syndromes such as fever, acute diarrhoea, respiratory or allergic manifestations.

Environmental Health

The restoration of environmental control systems for the protection of community health is a pricrity task in Kuwait. Activity areas should encompass the

monitoring of environmental health impacts, as proposed above, emergency centrol measures and community education and information. Equipment and supplies including chemicals, are required to assess environmental quality and provide bases for centrol measures and community information. As a prerequisite to equipment operation electric generators must be acquired urgently. Control measures are being undertaken vigorously by the Ministries of Electricity and Water, Public Works and Kuwait Municipality.

Community education and information is an important function of the Ministry of Health and the Environmental Protection Council. Emergency funds and staffing must be provided to these in order to carry out information campaigns on environmental hazards and prevention and control methods.

4. Disease Prevention and Control

The health staff and the community must be prepared to face the possible occurrence, or increase of health problems inherent to the current situation. This includes the management of cases of acute diarrhoea, respiratory syndromes, and such other manifestations of environmental health impact as allergies and mucous membrane irritation.

Other diseases requiring close monitoring are those subjected to sustained therapy: cancer, cardiovascular and renal diseases, and diabetes.

Physical injuries caused by mines, explosives burns or traffic accidents demand an enhanced first-

aid response capability, an efficient referral system and awareness campaigns.

In the area of maternal and child health, advantage should be taken of the functioning health centres and maternities to re-establish effective preper- and post-natal care services. Child growth monitoring and immunization are important elements at a time when vaccination coverage is low and when nutritional disorders may occur.

5. Psychological Trauma

A special programme needs to be established to address and deal with post-war trauma and the consequences of mental stress in the population, with special emphasis on children, repatriated POWs and people who were subjected to atrocities. A special programme for children will be undertaken in cooperation with UNICEF.

6. Essential Drugs

Large amounts of drugs have been received by Kuwait from various sources. The storage and distribution of these drugs was, before the war, monitored by a sophisticated computer system which is currently inoperative. Some of the drugs, reagents or baby-food received are near or beyond expiration date, thus requiring a careful inventory and verification of the shipments which are not always announced. Additional manpower is needed in this area to inventory, stock and distribute medical supplies in a coordinated fashion.

7. Diagnostic Facilities and Blood Bank

In this high-tech area, repair and maintenance skills are lacking. Many sophisticated diagnostic facilities such as X-ray and NMR are non-functional due to lack of maintenance and spare parts. There is an urgent need to establish a coordinating mechanism to undertake these tasks.

Certain diagnostic reagents are lacking which should be supplied on an emergency basis.

The equipment of the Blood Bank has been little affected and most are functional as services are being provided continously. There is however a shortage of diagnostic supplies.

8. Health Information and Education

There is on the part of the general population and professional groups, a high demand for information on the potential health impact of the current environmental health hazards. Education and information communication should be channelled through means currently available: radio, printed medias and taking the opportunity of community gatherings at the Mosques. Some activities have been described earlier in this regard. There is a general need to improve the circulation of valid information to overcome rumours and fears with positive and factual messages.

9. Emergency Medical Services

Of the intensive care units which existed in the country before the occupation only one remains in

operation. Personnel should be brought in or redeployed to ensure that these essential services are provided. The ambulance and mobile emergency medical unit system needs to be re-created with an entire fleet of vehicles, effective tele-communication system and trained personnel.

10. Management and Coordination

The country now requires a wide variety of skills to rehabilitate and reconstruct its health infrastructure. The need for tighter management and closer coordination is acute. The secondment of staff on a multilateral or bilateral basis to the Ministry of Public Health and the creation of coordinating committees are needed urgenuly.

KUWAIT APRIL - JUNE, 1991 HEALTH EMERGENCY 0 ج

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EMERGENCY HEALTH PLAN OF ACTION APRIL - JUNE 1991

ESTIMATED BUDGET REQUIREMENTS

(All figures in US Dollars)

1.	Health Care Infrastructure		220	000
2.	Surveillance		60	000
3.	Environment Health	1	350	000
4.	Disease Prevention and Control		240	000
5.	Psychological Trauma		300	000
6.	Essential Drugs		200	000
7.	Diagnostic Facilities and Blood Bank		570	000
8.	Health Information and Education		200	000
9.	Emergency Medical Services		840	000*
10.	Management and Coordination		120	000
	TOTAL	4	100	000

^{*}This represents only a fraction of the cost of restoring ambulance services. Donations in kind will be sought.

EMERGENCY HEALTH PLAN OF ACTION

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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
1. To rehabilitate the health care infrastructure so as to cope with urgent needs within next 3 months	access to adequate medical, surgical, dental and rehabilitation care to meet		- Provide 2 consultants to help coordinate assessment, repair and maintenance of electro- medical equipment	WHO	April	Consultants in place
	their urgent needs.	- Assess current availability and needs for for personnel particularly nurses and medical technicians and establish projections	- Human resources assessment and projections to be made	MOPH WHO	May	Human Resources Projection Plan available
		- Regroup available personnel and complement by volunteers and bring in additional staff on emergency basis	- Reach agreement among hospital directors on immediate needs, redeployment and recruitment	MOPH WHO	(in progess)	Reduced number of beds / facilities functioning. Urgent needs in Personnel met

OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
OBJECTIVE	;	- Design and automate health information system and patients records to optimize personnel use and increase system effectiveness	- Determine	Ministry of Public Health/ WHO	June	Project proposal formulated
,		- Assess availability of equipment and supplies to operate health facilities	- Inventory to be made by each institution, compiled by Hinistry of Public Health	Ministry of Public Health	In progress	Inventory list available
		- Procure essential supplies that may be lacking	- List of needed essential supplies to be made by central medical store	Ministry of Public Health/ CMS		
			- Procurement and distribution	Ministry of Public Health/ WHO/UNICEF	In progress	Missing essential supplies available

OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
	- Improve efficency of hospitals and Health facilities by June.	- Support MOPH decentralized activities through regional Health	- Monitor regional Health Department activities	WIIO	May June	Weekly meetings meetings of Regional Directors held
	o une.	Departments	- Assign an STC in Hospital		May	Consultants assigned
		- Support individual hospitals	Adminstration - Determine long term needs in Hospital Management		June	Needs identified and listed
			- Estimate cost for 3 months - Identify sources of funds	MOPH WHO UN Agencies Bilateral Agencies	May	. Budget formulated . Resources allocated
		- Formulate to a budget and allocate resources	- Allocate resources - Establish criteria	MOPH/ WHO	April May	Criteria established
	- Operate fully 50% of polyclinics and MCH	- Develop criteria for ratios facility/	- Identify needs - Develop staffing structure - Develop job descriptions - Identify	MOPH/ WHO	April May	Staffing short term projections and structure
	centres in 3 months time	population and manpower/ facility - Redeploy Polyclinic	sources of personnel - Bring in additional staff	MOPH/ Bilateral Agencies	April June	Staff recruited
		staff & secure additional manpower	- Conduct in-service retraining	Contractors	May June	In service training conducted

OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
2. To restore the surveil- lance of selected diseases and conditions	By the end of three months: a basic surveillance system for selected conditions will have been established	- Establish and maintain a daily recording and reporting of selected conditions used as indicators of diseases related to environmental hazards - Acute Diarrhoea - Respiratory ailments - Skin/Mucous membranes	- Design form - Record information - Collect data daily - Provide data to MOPH for continuous monitoring	MOPH/WHO/US Sentinel hospitals US US	April (in action)	Data collected and reported to MOPH daily
	The pre- existing surveillance system will be re-introduced as staff and data processing become available	- Restore a surveillance system for diarrhoeal diseases and other water/food borne diseases - Vector borne diseases - Diseases elligible for immunization - Overall morbidity and mortality	- Identify sites for information recording and reporting (Health facilities and laboratories) - Train/retrain surveillance personnel - Provide with periodic reports to MOPH - Exploit these reports for public information and action	·	May	System designed First report reaching MOPH

OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
	;	- Correlate environmental health data with health information	- Formalize coordinating mechanism between Environmental Protection Council and Directorate of Public Health to correlate data	морн	April	- Committee created - Meetings held - Conclusions formulated
3. To undertake and expand monitoring and prevention measures related to environmental hazards.	AIR: By the end of April, air quality monitoring stations (3 fixed) will have been put back into operations		- Provide generators to monitoring stations and supply reagents	Moph/EPC Who/UNEP	April	- Monitor reports submitted to MOPH
	By the end of April a scale of warning signals and corresponding cautionary statements will have been established		- Recruit consultants to assist in establishing scale and developping statements	MOPH/EPC WHO/UNEP	A pril	- Scale end

OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
		- Design and undertake monitoring and research project(s) to assess	-Identify groups in Kuwait with monitoring and research capacity	MOPH/WHO/ UNEP	April	group (s) identifies
		possible short and long term effects of air pollution	-Identify groups internationally with such capacity	WHO/UNEP	May	group (s) identified
	WATER:	- Provide informaton to public on findings and preventative measures	-Establish a coordinating mechanism (See No.& below)	MOPH/WHO UNEP	Нау	Mechanism developed
	By the end of May, safe piped water supply will have been restored and monitored continuously	- Rehabilitation and reconstruction of water supply system	Covered by prvis under Ministry of Waters' sup	Electricity and	,	

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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
		- Monitoring of water safety - Public Information	- Provide chemicals and reagents (see No. 8 below)	WHO	April	- Supplies provided - Monitoring done
	SEWAGE:	- Restore waste-water system - Monitor marine	Covered by pri	vate contractor	Apri1	
	SOLID WASTES	pollution - Clear garbage	EPC and UNEP	istry of Public Wo	orks April	- Sewage system in operation
	DISPOSAL.	from the city Re-establish a solid waste disposal system	Under the resp	ality and covered	April	- solid water disposal in operation
	MINES/EXPLOSIVES	- Appeal to international solidarity to enhance demining operatings	_	MOPH other Ministries WHO	April - June	- Appeal launched

OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
OBJECTIVE 4. To prevent and control selected diseases	Diarrhoeal Diseases: By mid-April, health staff and facilities will be prepared to respond to the possible spread of diarrhoeal diseases	- Staff will be alerted to the rise of spread of	- Disseminate guidelines in case management - Plan a referral system - Verify the availability of ORS, ensure availability of transport medium (Cary Blair) for	- MOPH/ Department of Public Health - MOPH/ Dept. of Public Health - Central Medical	CHRONO Now Now	INDICATOR - Guidelines available in all facilities - ORS available in all facilities Transport Mediuim avail. at all levels Diagnosis
	Diseases elligible for immunization By end April & continuously		stool samples at all facilities - Verify/ensure capability of at least one laboratory to diagnose Shigellas and v. cholera - Public information of prevention/ treatment (see No. 8)	Hospital Public Health Laboratory and Mobarak Hospital		Capability in place

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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
	Diseases elligible for immunization By end April & continuously the	- Continue and reinforce immunization activities through	• Restore the cold chain as electiricty returns	Moph/ Unicef/who	APRIL	Effective cold chain in operation
•	immunization coverage of children and pregnant women will be above	polyclinics and private facilities according to national immunization	- Use cold boxes for the transport and short storage of vaccines	UNICEF	DONE IN MARCH	Cold Boxes available
		strategies .	- discard old stock of vaccines and replenish by fresh ones	UNICEF	DONE IN MARCH	Fresh vaccine available
	Air Pollution Hazards		- Reestablish immunization recording and reporting systems	МОРН	MAY	- Records available - Reports submitted
	- By end- April Respiratory and allergic	- Provide treatment to o respiratory	- Formulate guidelines	MCPH/ Internists	APRIL	Guidelines formulated
	manifestations attributable to air pollution will be		- Disseminate these guidelines to all facilities	МОРН	MAY	Guidelines distributed
	attended to according to set guidelines		- Provide recommend drugs to facilities	Central Medical Store	MAY	Drugs available
			- Provide STG for seminar on air permution	WHO	APRIL	Seminar conducted

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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
	Maternal and Child Health Operate 50% of MCH centres as well as child by June	- Provide Maternal and Child Health (MCH) Services and strengthen Primary Health Care	- Provide standby genera- tor to MCH centres with no electricity - Install water tank on roof of MCH centres and bring drinking water to 50% health centres - Supply distilled water and reagents to peripheral laboratories	bilateral Agencies, Civil Administration	April April	Percentage of Health Centre with adequate water/power supplies
	Non-communica- ble diseases Ensure sustained therapies to chronically ill populations	- Provide drugs to specific cases	- Order and supply drugs for Diabetes, Hypertension and Cancer - Supply skin ointments, Family planning pills and disposables	Central medical store, WHO	April	Percentage of treatment prescriptions filled Percentage of treatment prescriptions filled

OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
5. To create and sustain services for adults and children suffering from violence-	By June; psychological diagnostic and support services will be provided to adults and	- Assess needs and develop a plan of action	- Assess needs in qualitative and quantitative terms among children (Psychologists)	Moph/unicef/who	April	Status report available
related psychological traumas	children suffering from psychological traumas related to violence and incarceration (POWs)	- .	- Establish diagnostic, counselling and therapy services for children and for adults	морн/wно морн/wно	May June	Services operating Services operating
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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
6. To ensure availability of essential drugs to meet current needs	- By the end of the 3 months the needs in essential drugs will have been met	- Rehabilitate the stock management system and coordinate supply to	- Restore software and assign computer technicians to Central Medical Store	MOPH/Central Medical Store (CMS)	April (ongoing)	Computer based management system in operation
	continuously	health facilities	- Sort out present stocks of drugs	CMS	April (ongoing)	
			- Distribute to facilities	CMS	April (ongoing)	Drugs available on request at health facilit.
	will have been made available treatment of disbetes, cancer, cardio-vascular diseases, other chronic	continuous availability of	distribute of specialized	CMS	April	Specialized drugs available
		available in country - Order drugs not present in stock	cms/who	April	Specialized drugs available	
	- By the end of June, plans will have been made for the rehabilitation of the drug quality control laboratory	diseases - Convene a task force to propose plan for rehabili- tation	- Convene Task Force - Elaborate proposal	Drug quality control laboratory staff	June	Task Force established Proposal elaborated
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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
7. To meet current needs in laboratory diagnosis, other electromedical equipment and blood supply	By the end of three months immediate needs in laboratory diagnosis and blood supply will have been met	Formulate plan and gradually undertake rehabilitation and reconstruction of PHC and relocate different exfaculty of medicine laboratories		MOPH/WHO (MOPH labora- tory staff)	May	Inventory completed
		laboratories	Formulate plan of action for restoring laboratory services to health facilities	морн/wно	June	Plan formulated
			Provide specific support to operating laboratories to meet the immediate demand	MOPH/WHO Bilateral agencies	April (ongoing)	Critical needs

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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
	;	: :	- Ensure maintenance and repair through firm representatives with WHO's coordination (2 consultants)	морн/чно	Мау	Two WHO consultants in coordinating position
,		restore needs to restore self.	- Procure spare parts, reagents and supplies		Hay	Procurement effected
,			- Identify and procure new equipment	морн	June	List prepared
	By the end of June restore self- sufficiency		- Expand donor recruitment to meet demar.d	MOPH/Military	June	Donors recruited
<i>;</i>	in blood supply		- Procure small supply of blood to restore reserve		Hay	Procurement effected
			- Procure diagnostic reagents for HIV and Hepatitis tests	морн/wно	April	Procurement effected
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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
8. To provide health and other professional groups, children and the population at large, with information on prevailing health huzards	By the end of April, factual messages will have been disseminated on air, water, sea and mine/explosives pollution	- Strengthen the roles and functions of health education/ information/ communication committees through regular meetings	- Conduct periodic meetings - Produce reports and messages - Develop action plan	MOPH, WHO, UNEP	April	Regular meeting held
and means of prevention and treatment		- Reestablish a department for health information education and communication	- Identify/ assign personnel - Reestablish audio-visual capability	морн, чно	Нау	Health Information/ Education/ Communication operational
	·	- Produce factual messages and disseminate them through medias and alternate channels (social and religious groups)	- Disseminate messages	MOPH, WHO, UNEP	April .	Messages periodically released
		- Evaluate levels of aware ness of health staff, other relevant staff on prevailing	- Conduct assessment	MOPH, WHO, UNEP	Мау	100% health and other personnel aware of message contents
		health hazards - Evaluate level of popula tion awareness of message contents	- Conduct assessment	MOPH, WHO, UNEP	Hay	80% of population aware of message contents

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OBJECTIVE	TARGET	APPROACHES	ACTIVITIES	RESPONSIBLE	CHRONO	INDICATOR
9. To provide emergency medical	By the end of May, the emergency	- Inventory ambulance and MCU's needs	- Conduct inventory and formulate needs	морн	Мау	Inventory conducted
services to the population present in Kuwait	medical services will have been rehabilitated to meet the	- Assess staff training or retraining needs	projections - Identify personnal and skills needs and undertake	МОРН	June	Training plan formulated
	current population needs and, by June, the needs of twice this	- Restore short wave communica- tion system	retraining - Procure and assign equipment	морн	May	Equipment provided
	population	- Redeploy/ recruit staff needed in intensive care units	- Redeploy or recruit ICU staff as a matter of urgency to operate 1 ICU by April, 3 by May, 4 by June	морн	April (in progress)	4 ICUs operating by June
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PLAN OF ACTION FOR PROTECTING PUBLIC HEALTH

Prepared by

THE KUWAIT WORKING PARTY

convened by

United States Public Health Service

Department of Health and Human Services

May 31, 1991

Frank E. Young (Coordinator)
Deputy Assistant Secretary
for Health\Science and Environment
Telephone: 202-245-6811

Dr. Frank E. Young Coordinator, Kuwait Working Party Assistant Secretary for Health\Science and Environment DHHS

Dr. John S. Andrews, Jr. Head, Kuwait Working Party ATSDR, USPHS

Mr. James A. Rifenburg

Executive Officer, Kuwait Working Party
CDC, USPHS

CDR Kenneth St. Andre', OASH, DOD

Dr. Kenneth Bernard, OD, OIH

Ms. Kathy Bishop, CEPPO, EPA

Dr. Terri Damstra, NIEHS, NIH

Mr. James Douglas, Jr., NMFS, NOAA

Mr. Martin Erlichman, OD, AHCPR

Mrs. Lynne Fairobent, OD, DOE

Dr. Ellery Gray, OASH, USPHS

Dr. Richard Greenfield, OD, NSF

Dr. Ronald Hart, NCTR, FDA

Mr. Bruce Hicks, ARL, NOAA

Dr. Wendy Kaye, DHS, ATSDR

Dr. Henry Kissman, NLM, NIH

Dr. Rice Leach, OD, OSG

Mr. James Lyda, OIA, FDA

Dr. Thomas Margrave, ORD, CIA

Dr. Susan Mather, VACO, DVA

Dr. Maurice Mixson, APHIS, USDA

Dr. George Mullholland, NIST, DOC

Dr. Susan Perlin, OHR, EPA

Dr. John Robinson, NOAA, DOC

Dr. Paul Seligman, NIOSH, CDC

Dr. Debra Silverman, NCI, NIH

Dr. Terry Thomas, OEHS, DOE

Dr. Snorri Thorgeirsson, LEC, NIH

Dr. Diane Wagner, NCHS, CDC

Dr. Marleen Wekell, CFSAN, FDA

Dr. Peter West, OES, DOS

Dr. Mary White, CEHIC, CDC

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I. Executive Summary

During the 1991 war to liberate Kuwait, several events occurred that damaged the environment and created concern about the occurrence of adverse human health effects. These events included the spilling of oil from an oil pipeline into the Persian Gulf, setting approximately 530 of Kuwait's 1,000 oil wells on fire, and creating pools of oil in the desert. The Policy Coordinating Committee, convened by the Department of State, delegated to the U.S. Environmental Protection Agency (EPA) responsibility for developing a plan to address the health and environmental consequences of the oil well fires in Kuwait. The EPA, at the request of the Department of State, sent teams to Kuwait to assess the environmental impact from the oil spills and from the oil well fires. The U.S. Interagency Air Assessment Team (USIAAT), made up of personnel from the EPA, the National Oceanic and Atmospheric Administration, and the U.S. Public Health Service (PHS) drafted a proposed program in three broad areas: Air Monitoring, Development of a Forecast Capability, and Human Health Surveillance and Risk The EPA asked the PHS to assist it with developing a list of the human health surveillance and risk assessment issues, strategies, and approaches that should be used to address the concern about possible adverse health effects associated with the oil pools and the oil well fires in Kuwait.

Therefore, at the request of EPA and the Department of Health and . Human Services' (DHHS) Committee to Coordinate Environmental Health and Related Programs (CCEHRP), the Kuwait Working Party (KWP) met to identify public health issues, strategies, and approaches, related to the oil pools and oil well fires burning in Kuwait in KWP, which consists of participants from PHS agencies and 1991. other governmental agencies, developed a plan of action. This plan of action encompasses the range of issues, strategies, and approaches that should be addressed to explore the potential acute and chronic risks from the oil pools and the oil well fires in multiple This document considers Kuwait. exposures to environmental media including air, water, food and seafood, and soil. This plan of action will be provided to the Interagency Team chaired by the EPA for incorporation into its overall plan of action related to the oil pools and oil well fires in Kuwait.

The issues, strategies, and approaches can be divided into specific areas of action for individual U.S. agencies, foreign countries (Kuwait or other), or international organizations (World Health Organization).

The six priority public health issues defined by the KWP include:

- 1) Are there acute or chronic health hazards from the oil pools and oil well fires in Kuwait?
- Who is exposed to the oil pools and oil well fires in Kuwait?
- 3) What is the nature and extent of the exposure?
- 4) What public health infrastructure should be developed so that possible adverse health effects associated with exposure to the oil pools or the oil well fires can be identified and evaluated?
- 5) What risk management and disease prevention policies need to be set up for persons exposed (already or in the future) to the oil pools and oil well fires?
- 6) What new knowledge about the possible adverse health effects associated with exposure to the oil pools and oil well fires needs to be obtained?

As a follow-up action, the public health issues, strategies, and approaches identified in this plan of action need to be subjected to more detailed analysis and prioritized into "plans of action." To carry out plans of action (whether by PHS or other U.S. governmental agencies, agencies from Kuwait or another country, or international agencies), resources need to be identified so that specific public health activities can be undertaken.

II. Background

During the war to liberate Kuwait, an oil pipeline was opened, spilling millions of gallons of crude oil into the Persian Gulf and creating an oil slick many miles in length. During the final days of the war, approximately 530 oil wells in Kuwait were set on fire. Other wells that were not set on fire were damaged by explosives and were found to be creating pools of oil in the desert. An estimated six million barrels of oil are being burned each day. Oil well fire fighters responsible for putting out the fires and capping the wells estimate that it will take them 1-2 years to put out all of the fires and to cap all of the wells. Never have so many oil wells been burning for so long. These burning and uncapped wells have created concern among the world community as to the damage being done to the environment (air, water, food, and soil) and the resulting potential adverse health effects.

The U.S. Environmental Protection Agency (EPA), the coordinating agency, and the Coast Guard, sent teams to investigate the oil that had been spilled into the Persian Gulf from the oil pipeline. The EPA also sent two other teams to collect information on the constituents of the oil pools and the oil well fires. They have also carried out air sampling in populated areas. At the request of EPA a PHS medical epidemiologist accompanied one of their air monitoring teams to the Persian Gulf to provide medical interpretations to the monitoring data.

At the request of the Department of State, the EPA's U.S. Interagency Air Assessment Team (USIAAT) made up of personnel from the EPA, the National Oceanic and Atmospheric Administration, and the Department of Health and Human Services (U.S. Public Health Service or PHS) prepared a draft proposed program in three broad areas: Air Monitoring, Development of a Forecast Capability, and Human Health Surveillance and Risk Assessment. The EPA requested that the PHS develop a list of strategies and approaches that should be used to answer the important human health surveillance and risk assessment questions.

The Plan of Action to Protect Public Health encompass all of the issues, strategies, and approaches that should be addressed without regard to what agency or agencies, national, foreign, or international, will develop action plans and carry out specific activities. All of the listed issues, strategies, and approaches can be divided up into specific actions, parts of which can be carried out by individual agencies.

This plan of action was written from a generic viewpoint. Although American citizens living or working in or traveling to Kuwait, U.S. military personnel, and U.S. citizens working for contractors in Kuwait, are of prime responsibility of the PHS, other U.S. agencies, foreign nations (Kuwait or other), or international agencies (World Health Organization) may find this document useful.

At the request of the EPA and the DHHS Committee to Coordinate Environmental Health and Related Programs (CCEHRP), the Kuwait Working Party (KWP) met to identify public health issues, strategies, and approaches, related to the oil pools and oil well fires burning in Kuwait in 1991. The Kuwait Working Party (KWP) consists of participants from various PHS and other governmental agencies.

While in the Arabian Gulf the PHS medical epidemiologist who was assisting the interagency air assessment team collaborated with the Kuwait Ministry of Public Health to develop a health plan for protecting individuals from the hazards associated with exposure to the burning oil wells in Kuwait. The Kuwaiti plan is consistant with the plan of action developed by the KWP. Key provisions of the Kuwait plan are: 1. The initiation of a health alert system to warn the population when potentially dangerous concentrations of air pollutants are reached, 2. Provide medical information and advice to physicians regarding environmental health concerns, Provide general information and advice to the public regarding environmental health concerns, 4. The collection and comparison of recent mortality data with the same months in 1990, 5. The initiation of an emergency room surveillance system to monitor respiratory diseases, 6. The design and implementation of a longitudinal study of asthmatic patients registered at the Kuwait Center for Allergic Diseases, 7. The design and implementation of a cohort study of presumably highly exposed population, and 8. Implementation of the Human Exposure Asssessment Locations (HEAL) Program.

III. Kuwait Working Party

A. PURPOSE

The purpose of the KWP is

To develop a plan of action that encompasses the range of public health issues, strategies, and approaches that should be addressed to identify and prevent acute and chronic adverse health effects associated with all routes of exposure to spilled oil and oil well fires in Kuwait. This plan of action should make it possible in the future to look back to 1991 and see that the priority health issues associated with oil spills and the oil well fires were identified.

B. OBJECTIVES

The specific objectives of the KWP are

To prepare jointly with all interested federal agencies, a plan of action that describes the public health issues, strategies, and approaches that should be addressed to identify and prevent or mitigate potential acute and chronic adverse health effects associated with exposure to oil pools and oil well fires in Kuwait.

To identify issues, strategies, and approaches that should be used by federal agencies so that they can coordinate their efforts in identifying and preventing or mitigating potential acute and chronic adverse health effects associated with exposure to spilled oil and oil well fires in Kuwait.

To develop jointly with other federal agencies, a list of issues, strategies, and approaches that will support the "human health surveillance and risk assessment" part of the Proposed Program of the Interagency Team chaired by the EPA.

To share this plan of action with United States legislators, Kuwait, other countries, and the World Health Organization, so that priorities can be determined, action plans developed, and resources obtained to carry out specific activities to prevent potential acute and chronic adverse health effects.

C. INTERRELATIONSHIP OF FEDERAL AGENCIES

Many PHS offices and agencies (Agency for Toxic Substances and Disease Registry, Centers for Disease Control, Food and Drug Administration, Indian Health Service, National Institutes of Health, Office of International Health, and Office of the Surgeon General), and other federal agencies (Department of Agriculture, Department of Defense, Department of Energy,

Department of Commerce, Department of State, and EPA) are concerned about the potential public health issues associated with the oil pools and oil well fires in Kuwait. However, there are also personnel from Kuwait, other nations, international organizations who are also concerned about the potential public health effects of the oil pools and the oil well fires. These potential effects include exposure from inhalation, skin contact, and ingestion of food (such as seafood and crops) that may be contaminated with oil products. For example, the World Health Organization has had a team in Kuwait assessing the public health needs. A United Nations Environmental Team is scheduled to travel to Kuwait to assess the environmental situation.

This plan of action has attempted to address the priority public health issues from the perspective of the United States agencies participating in the KWP. A list of background documents is attached.

IV. Assessment In Kuwait

A. ENVIRONMENTAL ASSESSMENT IN KUWAIT

The EPA's U.S. Interagency Air Assessment Team (USIAAT) 1. collected measurements of H2S, SO2, oxygen, and total particulate at 13 locations in Kuwait and Saudi Arabia during March 1991. The highest readings were taken in the smoke plumes in the oil fields. The highest levels were: total suspended particulates - 5.4 mg/m3, volatile organic compounds (VOCs) -2.5 parts per million (ppm) adjacent to large pools of oil, H_2S - 42 parts per billion (ppb), and $SO_2 - 2$ ppm (The SO_2 reading may be high because a different SO2 monitor with a detection limit of 0.1 ppm did not indicate any SO2 and field personnel did not detect any sulfur odors at any of the The only elevated level observed in locations.). populated areas was for particulates, with a reading of 480 ug/m in Dhahran, Saudi Arabia which was thought to be due to a combination of smoke from the fires and sand. Baseline particulate levels due to blowing sand in Saudi Arabia and Kuwait usually range from 200 - 3,000 ug/m³.

The results from this monitoring indicate that particulates are the primary acute potential health threat. The results did not indicate an acute health threat from SO_2 and H_2S . However, a change in conditions (such as the extinguishing of an oil well fire without capping) could cause an acute threat near the wells to occur. An inversion or touchdown of the plume in populated areas could result in an acute health threat.

These results were obtained with limited equipment, irregularly placed monitors that were not positioned near the plumes, and with the use of short averaging times. These results should be considered to be preliminary and must require a more detailed evaluation.

2. Gases and particulate byproducts associated with the burning oil wells were identified. Air samples from 10 locations were measured for: volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs, i.e., naphthalene, benzo[a]pyrene), heavy metals, SO₂, and inorganic acids (i.e., sulfuric, nitric). Some samples were collected for H₂S, formaldehyde, CO, and total nuisance dust. 3. Although a number of samples were taken from a variety of locations, the monitoring was done at a small number of locations, over a relatively short period (one month), in a relatively cool month (March), for a limited number of compounds. Respiratory particulates less than 10 microns (PM₁₀) were not measured. Mercury and lead, thought to be present in some of the oil wells were not measured. Other substances not measured include uranium, ozone, elemental carbon, benzene, other metals, In addition, the constituents of oil nitropyrenes. droplets were not characterized.

B. POSSIBLE HEALTH EFFECTS IN PERSONS EXPOSED TO OIL WELL FIRES

- 1. The oil fields are located away from Kuwait City where most of the Kuwait population lives. The direction traveled by the plumes is variable and dependent on the local meteorological conditions. Based on National Oceanic and Atmospheric Administration models and on personal observations (Dr. John Andrews), on most days, Kuwait City is not noticeably affected by the oil well plumes. Continuous exposure to the oil well fire plumes in Kuwait City for a period greater than forty-eight hours occurs infrequently. Any risk assessment that is carried out must take into consideration the number of persons in the path of the plumes for various local meteorological conditions and the duration of exposure.
- 2. The main health effects predicted to occur from exposure to the oil well fires depend on the assumptions that are made regarding the constituents of the plumes.
- 3. Persons with asthma or preexisting pulmonary disease (chronic bronchitis, chronic obstructive pulmonary disease), and possibly infants, children, and elderly adults would be at risk of exacerbation of their conditions due to exposure to the oil well fires. It is not known if chronic exposure to oil well fires will be associated with an increased incidence or prevalence of pulmonary disease.

C. HUMAN HEALTH SURVEILLANCE

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1. Information obtained from two Kuwaiti physicians and one asthmatic by Dr. John Andrews, indicated that asthmatics were reporting acute asthma attacks when the plumes from the oil well fires were present. One physician reported to Dr. John Andrews that three of his patients with chronic lung disease had died on one of the days when the plumes from the oil well fires were severe. Visits to

seven hospitals by Drs. Andrews and Seligman and reports of visits to all hospitals in Kuwait by the U.S. Army Disaster Area Survey Teams indicated that there were no report of large numbers of persons becoming ill on days when the plumes from the oil well fires were severe. Neither were there reports from Kuwaiti physicians of adverse health effects in infants, children, or the elderly. The absence of reports does not necessarily mean that such effects were not occurring, only that they had not been observed by the physicians and hospital personnel interviewed.

2. The main symptoms experienced by Drs. Andrews and Seligman and by U.S. Army personnel when plumes from the oil well were present were burning eyes (mild to moderate), increased postnasal discharge (mild to moderate), increased cough (mild), throat irritation (mild to moderate), and an acrid smell to the air (mild to moderate). Estimates of the prevalence of these or other symptoms among U.S. Army and U.S. Marine personnel may be available from the Department of Defense.

D. INFRASTRUCTURE IN KUWAIT

- 1. The public health infrastructure, including the disease reporting system, public health laboratory, environmental laboratory, continued to operate in limited fashion from the beginning of the Iraqi occupation (August 2, 1990) until January 15, 1991. Beginning with the start of the war of liberation (January 17, 1991), public health functions essentially ceased. Through late March 1991, telephones were not working and transportation was difficult. By late April, telephones and transportation were available. Despite these terrible conditions the Kuwaiti medical community has done an excellent job.
- During the Iraqi occupation, safe water continued to be available through the municipal distribution system. Water quality continued to be checked (The Iraqis were extremely concerned about the possibility of waterborne disease in their troops.). Only during the ground war (February 22 26), and in the initial liberation period (February 27 late March), after the desalination plants had been made inoperable by explosives, did people have to rely on water stored in cisterns or on rooftops.
- 3. During the Iraqi occupation, most people who stayed in Kuwait had adequate supplies of food, including grain, rice, and staples; fresh milk from cows; and fruits and vegetables from Iraq and Jordan. Only during the ground war (February 22 26) and during the initial period of liberation (February 27 late March) were fresh milk,

fruits, and vegetables unavailable or in limited supply. As of late April, fruits, vegetables, and milk were available, although some Palestinians and third country nationals without financial resources, may not be able to purchase adequate amounts of these foods.

- 4. A number of U.S. Army Civil Affairs personnel, U.S. Army Corps of Engineers, and private contractors have been in Kuwait since early March assisting with restoring the infrastructure in Kuwait. By late April, electricity is available, a chlorinated municipal water system is operational (93-97% of water comes from desalination plants and the rest is supplied from wells), sewage treatment is functioning, garbage trucks and waste disposal sites are operational, and hospitals and clinics are functioning. Ministry of Public Health personnel have been meeting in their offices since March 8.
- 5. Despite the availability of senior Kuwaiti Ministry of Public Health personnel, a number of the workers are no longer in Kuwait. Many were Iraqi, Jordanian, or Palestinian. There will be a need to identify new personnel and train them to carry out the various public health activities.
- 6. It is estimated that 450,000 people are now living in Kuwait. Prior to the Iraqi occupation, the Kuwait population was approximately 2.1 million, 600,000 (28%) of whom were Kuwaiti. The government of Kuwait has stated its intention to have Kuwait's population grow to approximately 1 million. Various Government of Kuwait ministries (including the Ministry of Public Health) are planning to downsize. This will involve decreasing the number of hospitals and clinics.
- 7. The disease reporting system in Kuwait was not functional as of late March. However, visits to all hospitals by U.S. Army Disaster Survey Team personnel and to seven hospitals by Drs. Andrews and Seligman, found no evidence of any widespread epidemics. Although several physicians believed that they were seeing increased numbers of persons with hepatitis A, a review of hepatitis surveillance records by Dr. Andrews from 1988 through March 9, 1991, did not verify that there was an increase. Also several Kuwaitis returning after being detained in Iraq were found to have <u>Vibrio</u> cholerae in their stools. Several children with diarrhea were admitted to the hospital, there was no evidence of an epidemic of gastrointestinal disease.

V. Risk Assessment and Risk Management

In this document, risk assessment and risk management are used as described in the report "Risk Assessment and Risk Management of Toxic Substances" (A Report to the Secretary, Department of Health and Human Services [DHHS], from the Executive Committee DHHS Committee to Coordinate Environmental and Related Programs [CCERP], April 1985). The material below is quoted from this document.

Risk - The probability of an adverse health effect as a result of exposure to a hazardous substance(s).

Risk Assessment - The use of available information to evaluate and estimate exposure to a substance(s) and its consequent adverse health effects. Risk assessment consists of one or more of the following four elements:

- Hazard Identification The qualitative evaluation of the adverse health effects of a substance(s) in animals or in humans....Hazard identification is largely a judgmental process that requires the expert knowledge and experience of scientists from a variety of disciplines in interpreting the best identification available information....Hazard relies primarily on results generated from clinical epidemiologic studies and from unimal types toxicologic experiments. Other information that may, when available, contribute to the hazard identification process include: shortterm in-vivo and in-vitro test results; comparative metabolism and kinetic information; and when available data on the physiologic, pharmacologic, biochemical, chemical, and physical properties of the chemical of interest.
- Exposure Assessment The evaluation of the types 0 (routes and media), magnitudes, time, and duration of actual or anticipated exposures and of doses, when known; and, when appropriate, the number of persons who are likely to be exposed.... Exposure assessment deals primarily with estimating the types, magnitudes, and durations of actual or exposures to hazardous anticipated agents....Exposure assessment is typically based on monitoring studies that involve direct measurement of exposures, mathematical modeling, and the study microcosms of mini-environments, or combination of these approaches.

- process of 0 Assessment The Dose-response estimating the relation between the dose of a substance(s) and the incidence of an adverse health effect....Dose-response Assessment is concerned and with the evaluation guantitative characterization of the relationship or association between the level of exposure to the agent under study and the toxicologic response or responses that are elicited by such exposure, particularly as applies to humans. The techniques most frequently used in this quantification process are safety-factor approach, margin-of-safety procedure, and mathematical modeling.
- Risk Characterization The process of estimating 0 the probable incidence of an adverse health effect to humans under various conditions of exposure, including a description of the uncertainties involved....Risk Characterization, the final step risk-assessment process, involves multidisciplinary evaluation of all relevant data on hazard identification, exposure assessment, dose-response, and species extrapolation to reach an overall determination of the health risk posed by anticipated or known exposures to a given agent. Because of differences in human susceptibility and exposure corditions, some consideration should be given, when possible, to the identification of high-risk subgroups in the general population at this phase in the process.

Risk Management - The process of integrating risk-assessment results with engineering data and social, economic, and political concerns, then weighing alternatives to select the most appropriate public health action, ranging from public education to interdiction, that will lead to reduction or elimination of the identified risk.

VI. Assumptions

A number of assumptions were made by the KWP based on information available to KWP participants, information available from the news media, or information reported from federal agencies who have had personnel in Kuwait. Assumptions are being listed below to document that these issues were considered.

- A. This document assumes that basic medical services (clinics and hospitals) are functioning, and that electricity, water supply, garbage collection, and vector control programs are functioning in Kuwait.
- B. The priority public health issues, strategies, and approaches identified in this plan of action are designed to explore acute and chronic adverse health effects due to spilled oil and oil well fires in Kuwait. However, some of these strategies and approaches are equally applicable to other areas of public health.
- C. The priority public health issues apply to a variety of persons exposed to spilled oil and oil well fires including fire fighters, oil well workers, persons living or working in Kuwait, and tourists.
- D. As additional information is obtained, the situation in Kuwait should be reassessed. With the availability of additional data, priority issues, strategies, and approaches can be reevaluated.
- E. This plan of action is a technical document. It is written to be an encompassing document that describes the issues, strategies, and approaches that should be explored from a technical viewpoint.

VII. Public Health Issues

A. IS THERE A HEALTH HAZARD FROM THE OIL POOLS AND OIL WELL FIRES IN KUWAIT? (Hazard Identification)

It is essential to identify whether or not there are current hazards associated with oil pools and oil well fires. However, there is not much information on the constituents of these oil pools and oil well fires. Measurements for H₂S and some polyaromatic hydrocarbons (PAHs) have been positive near wells. However, there are a variety of additional contaminants that may be present in the oil or the oil well fires. Specifically, KWP personnel suggest that sampling in populated areas be carried out for the following substances: benzene, elemental carbon, ozone, nitropyrenes, lead, arsenic, total respiratory particulates, uranium, other metals, and mercury. After the levels of these substances are known, then other decisions can be made on the frequency that the oil, oil well plumes, air, food, water, or soil should be retested.

As different oil well fields (and even different oil wells) may have different amounts of one or more of these substances, individual wells as well as plumes need to be sampled enough times so that environmental personnel believe they have a reliable estimate of the total emissions of smoke particulate and chemical species from the fires to which people (and their food, water, crops and livestock) may be exposed. In addition, as the oil well fires are extinguished and the oil wells capped, the pollutants released into the atmosphere will decrease.

Strategies and approaches should include

- 1. Measuring contaminants listed above in environmental media and generating population specific data.
 - a. Carrying out a chemical characterization of particulates and oil droplets and comparing the substances found against standards such as EPA Reference Doses.
 - b. Determining the size fractionation of particles in plumes from the oil well fires.
 - c. Measuring contaminants in oil, in plumes of oil well fires, and at ground level in populated areas, areas where animals graze, and in areas where food is produced, processed, stored, or sold.

- d. Measuring the levels of respiratory pollutants including total suspended particulates, respirable particulates, dust, pollen, hydrocarbons, SO₂, and O₃, and acid aerosols.
- e. Identifying contaminants in well water and water coming from desalination plants.
- f. Identifying contaminants in soil in populated areas, in areas predicted to have high cumulative soil contaminants from plume models, and in areas where children spend a great deal of time (school).
- 2. Measuring contaminants in food and water
 - a. Identifying and measuring contaminants in food and milk produced or stored in the open.
 - b. Identifying and measuring contaminants in the food supply of grazing animals and chickens.
 - c. Identifying and measuring contaminants in seafood.
 - d. Identifying contaminants in drinking water and reservoirs.

3. <u>In vivo</u> and <u>in vitro</u> tests

- a. Carrying out <u>in vivo</u> studies in animals or in animal models for human disease by analyzing animals grazing in affected areas.
- b. Carrying out <u>in vitro</u> immunogenicity, mutagenicity, and cytogenetic studies with substances produced by the oil well fires or on specimens collected from exposed persons.
- B. WHO IS EXPOSED TO THE OIL POOLS AND OIL WELL FIRES IN KUWAIT? (Exposure Assessment)

The extent of exposure to the oil pools and the plumes of oil well fires depends on the local meteorological conditions which are extremely dynamic and which vary from hour to hour. If information was available to identify where the plume was located at specific times of the day, this would assist greatly in determining who is exposed. Analysis of plume migration, therefore, will be a critical factor in establishing who was exposed.

An important issue related to the oil pools and oil fires in Kuwait is to determine who has been exposed. It is important to identify areas where persons were likely to be exposed and to identify the nature and probable level of exposure in those areas. In several situations, substances thought to be safe were later found to be hazardous. Also, in the past, even when the presence of a hazardous substances could be documented, without information on who had been exposed, the association or lack of association of adverse health effects with a substance could not be studied easily.

In Kuwait, the exposure of a variety of individuals to oil pools and oil well fires needs to be determined (Kuwaitis, third country nationals, Palestinians, oil well fire fighters, oil well workers, other persons living or working in Kuwait, and persons transiently exposed).

If specific hazardous substances are identified in the oil or oil well plumes, and risk assessments show that people are exposed to enough of one or more of these substances to be associated with acute or chronic adverse health effects, then it is even more important to identify potentially exposed persons.

Strategies and approaches should include

1. Population Information

- a. Determining the number of persons living or working in each area of Kuwait by age and sex (using a geocoding system if possible) so that amount of exposure based on oil well plume measurements or oil well plume modelling can be determined.
- b. Identify representative populations or subpopulations who may have had differing exposures to the oil pools or the oil well fires.

2. Highly exposed individuals

- a. Identifying potentially highly exposed individuals to oil pools or oil well fires.
- b. Setting up a registry of the most highly exposed persons (e.g., oil fire fighters, military, persons working close to the oil fires).
- c. Tracking the more highly exposed persons so they can be given information on health effects (adverse or not adverse) in the future or so that additional information on adverse health effects can be obtained from these persons.

- d. Obtaining baseline information on more highly exposed persons, including biological monitoring of exposure (blood and urine), monitoring of different microenvironments, such as homes, work places, and outdoor areas, personal monitoring, and the use of questionnaires.
- e. Determination of the most reliable biological markers for establishment of the extent of exposure.
- C. WHAT IS THE NATURE AND EXTENT OF EXPOSURE? (Dose-Response Assessment)

The dose-response assessment human data as well as animal and in vitro studies is a critical aspect of risk assessment. Namely, the amount of exposure via various routes must be quantified so that acute and chronic risk can be estimated.

Strategies and approaches should include

- 1. Obtaining information on the relationship of forest fire (western United States and other countries) or urban air pollution (Mexico City, Lima, Los Angeles) to the air pollutants in Kuwait including known health effects from these sources of pollution. Health data from smaller oil fires will be particularly relevant.
- 2. Reviewing information on the relationship of forest fire and urban air pollution to acute and chronic adverse health effects.
- 3. Identifying by time, place, duration of exposure, level of exposure, various groups of individuals including oil well fire fighters, oil well workers, military personnel, and citizens.
- 4. Using plume measurements and plume modelling to estimate individual exposure to oil pools and the oil well fires.
- D. WHAT PUBLIC HEALTH INFRASTRUCTURE NEEDS TO BE DEVELOPED SO THAT POSSIBLE ADVERSE HEALTH EFFECTS ASSOCIATED WITH EXPOSURE TO THE OIL POOLS OR THE OIL WELL FIRES CAN BE IDENTIFIED AND EVALUATED? (Risk Characterization)

The ability to identify acute or chronic adverse health effects is necessary to determine if unexpected adverse effects are occurring or if predicted adverse health effects did not occur. An active and well functioning infrastructure is necessary to assure that vital information is collected.

Strategies and approaches to strengthen the infrastructure should include

1. Surveys

Surveys of the general health status of subpopulations living or working in Kuwait are needed so that information will be available on the existing adverse health conditions.

2. Surveillance

- a. Reinstating a communicable disease surveillance system in Kuwait.
- b. Reinstating public health programs such as well-baby clinics, immunizations, health education, and injury control.
- c. Reinstating vital statistics recording to include births, deaths, and fetal loss beyond 28 weeks.
- d. Beginning surveillance for respiratory and chronic diseases including chronic obstructive pulmonary disease, and asthma.
- e. Beginning registries of birth defects, fetal loss (beyond 28 weeks), and cancer.

3. Standard Methods and Quality Assurance

- a. Instituting the use of standard definitions of diseases (World Health Organization standards) and standardized forms.
- b. Instituting a quality assurance/quality control program in the public health laboratory, environmental health laboratory, hospital laboratories, and clinical laboratories.

4. Data Analysis

- a. Beginning computerization of Kuwait's surveillance systems and registries.
- b. Developing the capability to quickly collect, collate, analyze, and distribute data from the various surveillance and registry systems.

5. Personnel

a. Obtaining the services of trained personnel to carry out pathological examinations on tissues.

- b. Developing an expertise in environmental epidemiology and toxicology.
- C. Training staff so that they can carry out case investigations and epidemiologic investigations.
- d. Obtaining the equipment and training environmental laboratory personnel to be able to identify substances associated with the plumes from oil well fires.

6. Risk Characterization

The presence of an active and well functioning infrastructure will give rise to disease-specific incidence and incidence rate information. With this information, the numbers and types of acute and chronic adverse health effects that are predicted based on the hazardous substances identified and the amounts of exposure can be compared to the actual amount of disease. Of particular importance will be the modeling of the plume and the verification of the models to establish actual exposure.

E. WHAT RISK MANAGEMENT AND DISEASE PREVENTION POLICIES NEED TO BE SET UP FOR PERSONS EXPOSED (ALREADY OR IN THE FUTURE) TO THE OIL POOLS AND OIL WELL FIRES?

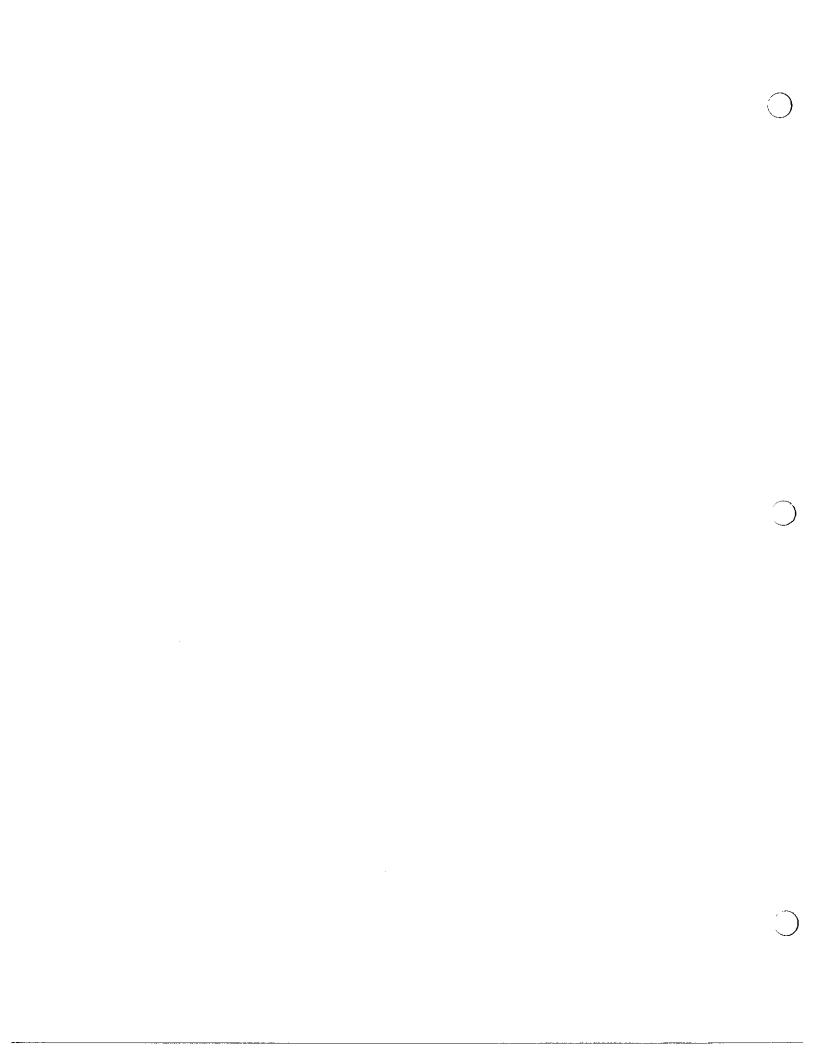
Once risks have been characterized, decisions have to be made about how the risks, if any, will be reduced and the adverse health effects, if any, will be prevented.

Strategies and approaches should include

- 1. For persons with long-term exposures to spilled oil and oil well fire plumes.
 - a. Identifying populations at high risk of having adverse health effects if exposed to plumes from oil well fires.
 - b. Encouraging Kuwait and other countries to do risk management for their citizens working or traveling to Kuwait.

- c. Encouraging Kuwait to test soil for contaminants In areas of new housing, in areas where animals graze, crops are grown, and where children spend time.
- d. Having the ability to predict when air quality will deteriorate and to provide sufficient notice that persons at risk of acute or chronic adverse health effects can go to protected buildings or areas of the country until the air quality improves.
- e. Identifying buildings or areas of the country where persons at risk of adverse health effects due to exposure to plumes from oil well fires can go until the air quality improves.
- 2. For persons with short-term exposures to spilled oil and oil well fire plumes.
 - a. Preparing travel advisories for persons going to Kuwait.
 - b. Coordinating United States risk management policy with the National Response Team
 - c. Developing methods to disseminate information and provide health education and training for travelers to Kuwait on such topics as environmental hazards and injury prevention.
 - d. Prescreening persons going to Kuwait and identifying those with preexisting conditions that might be exacerbated by travelling to Kuwait while the oil well fires are burning.
- F. WHAT NEW KNOWLEDGE ABOUT THE POSSIBLE ADVERSE HEALTH EFFECTS ASSOCIATED WITH EXPOSURE TO THE OIL POOLS AND OIL WELL FIRES NEEDS TO BE OBTAINED?

The KWP realize that much human suffering has been associated with the oil well fires in Kuwait. Some strategies and approaches listed in this document will provide information that is of importance to persons who have already been exposed to oil or to substances produced by the oil well fires. Other strategies and approaches will provide information that may be of little or no importance to already exposed persons, but may provide much needed information to help persons who may be exposed in the future to oil well fires, other airborne pollutants, or future environmental disasters.



The following is an announcement released by the Public Health Service on June 10, 1991.

Emergency Room Surveillance -- Kuwait City

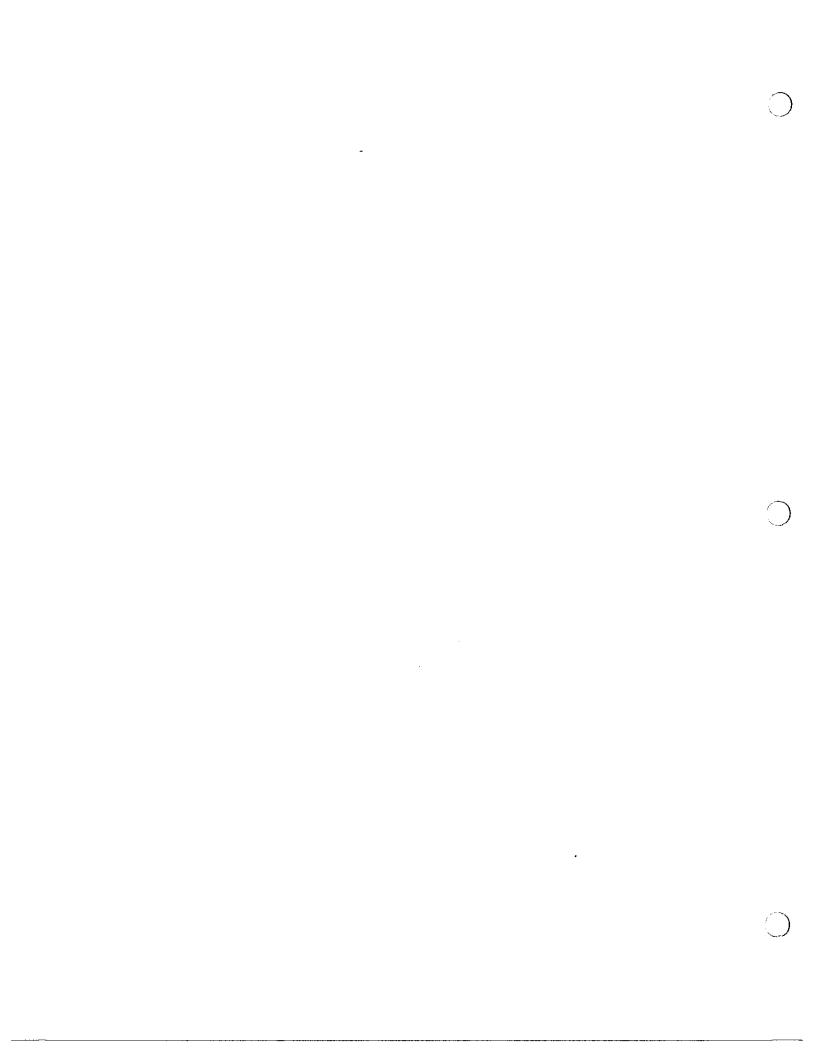
This is a summary of the results of emergency room surveillance conducted at two hospitals in Kuwait City from January 1st to April 30th, 1991. During that period, a total of 6,127 visits were recorded. There were 2,373 visits in the period before the oil fires were started (January 1 - February 22) and 3,754 visits in the period afterwards (February 23 - April 30). Since the population of Kuwait was not stable during this period, it is impossible to compute the rates of various diseases treated in the hospital emergency roms before and after the ignition of the oil fires. However, the proportion of total visits for the selected illnesses before and after the fires can be compared. The data are shown below:

CONDITIONS	Jan 1-Feb 22	Feb 23-Apr 30	
	(n = 2,373)	(n = 3,754)	
Upper/Lower Respiratory	29.2%	19.0%	
Gastrointestinal Illness	19.6	23.2	
Muscular Pain	12.3	9.9	
Asthma	7.4	7.0	
Urinary Tract Infection	5.5	4.4	
Skin Diseases	5.1	1.7	
Headaches and Migraine	4.8	4.6	
Hypertension	4.1	8.3	
Heart Disease	2.8	5.2	
Diabetes	1.2	3.7	
Urticaria/Angioedema	.9	2.0	
Psychiatric Conditions	.5	1.6	
Hypotension/Dizziness	.08	1.1	
Drug Allergy	.04	.1	
Chronic Bronchitis	.04	.5	
Other Illnesses	6.0	7.0	

It is notable that visits to the emergency room for gastrointestional illnesses, heart diseases, psychiatric illnesses and chronic bronchitis increased during the period after the oil fires were ignited

These data suggest that there was no documented increase in the proportion of persons seeking care in hospital emergency rooms for upper and lower respiratory illnesses and asthma as a result of exposure to the oil fires.

Further data collection underway at additional hospitals and polyclinics will provide a more comprehensive picture of the current situation.



HARVARD SCHOOL OF PUBLIC HEALTH KUWAIT AIR SAMPLING SURVEY

- April 24 to May 11, 1991 -

In Conjunction With:

The Kuwait Ministry of Health: The Environmental Protection Department and the Environmental Protection Council

In Association With:

The World Health Organization - The World Meteorological Organization, Dr. David Mage, Project Director

Harvard University School of Public Health Department of Environmental Health

Dr. John D. Spengler

Professor of Environmental Health

Dr. Yukio Yanagisawa

Assistant Prof. of Environmental Health

Thomas Dumyahn

Research Engineer

David Gilmour

Field and Research Assistant

Xiaowei Yan

Research Assistant

Collaborators:

MIT ---

Dr. Ilhan Olmez

DRI ---

Dr. Judith Chow

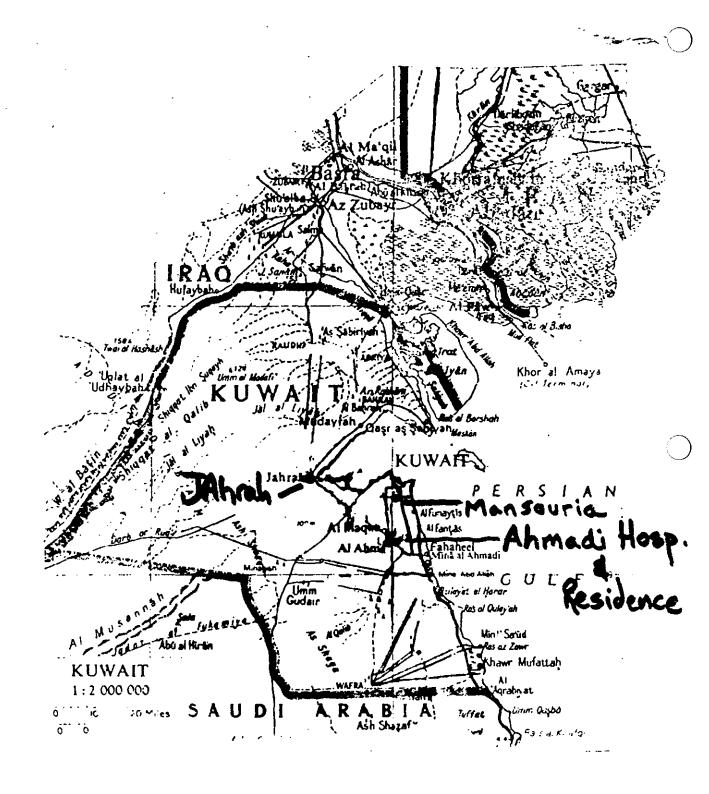
LBL ---

Dr. Joan Daisey

Bell ---

Dr. Charles Weschler





HSPH KUWAIT

HARVARD'S KUWAIT AIR SAMPLING SURVEY PARTICULATE SAMPLES - ANALYSIS AGENDA

<u>PARAMETER</u> <u>ANALYSIS</u> 1.) Combined Samples for Bulk / PM3.5 Animal Bio Assays -Dr. J. Brain, HSPH 2.) Combined Samples for Cell Mutagenicity -Dr. H. Liber, HSPH 3.) Polcyclic Aromatic Hydrocarbon Analysis -Dr. Joan Daisey, Lawrence Berkeley Labs 1.) Mass Concentrations at HSPH PM 10 2.) Elemental Analysis: INAA -Dr. I. Olmez, MIT Nuclear Reactor Laboratory 1.) Elemental Carbon Analysis & "Quartz Filter" Black Carbon 2.) Graphic Carbon Analysis -Dr. J. Chow. **Desert Research Institute** Univ. of Nevada, Reno **Particle Acidity** 1.) PH Analysis at HSPH 2.) Ion Chromatography Analysis Particle Sulfate at HSPH



HARVARD'S KUWAIT AIR SAMPLING SURVEY - Spring 1991 -

SAMPLE INVENTORY

AMBIENT PARAMETER	INSTRUMENT
Respirable Bulk Mass (3.5 microns and below)	Harvard Modified Anderson Bulk Sampler with Cyclone Separator
PM10	Harvard Impactor with Black Box (4LPM Pump); Mounted Pre-Weighed Filters
Particulate Carbon	Harvard Impactor with Mounted Quartz Fiber Filters
PM2.5 Acidity No Acidity	Harvard Impactor with 2.5 Micron Nozzles and Mounted Teflon PH Filters
Nitrogen Dioxide 20 - 30 ppb	Yanagisawa Passive NO ₂ Badge
Carbon Monoxide 10 pp m	Yanagisawa CO Passive Diffusion Tube
Volatile Organic Compounds	3M Passive Vapor VOC Badges
Hydrogen Sulfide	DuPont Passive H ₂ S Badges



ANALYSIS APPROACH

Statistical Correlations

Enrichment

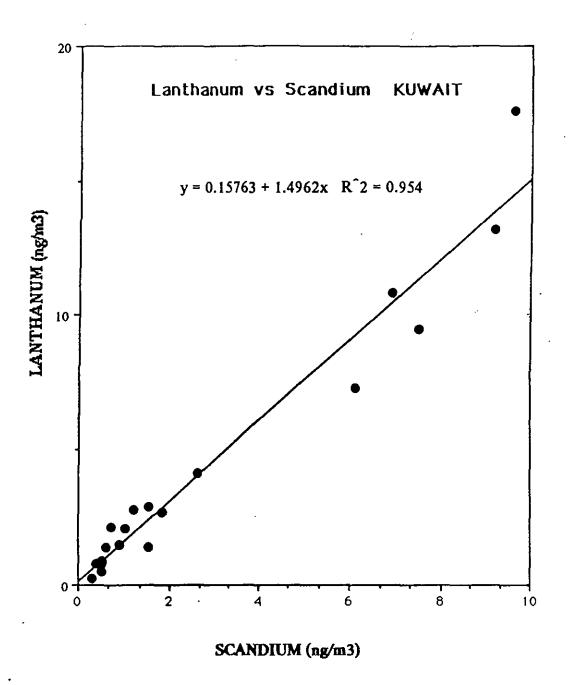
(Element / Sc) sample (Element / Sc) crustal

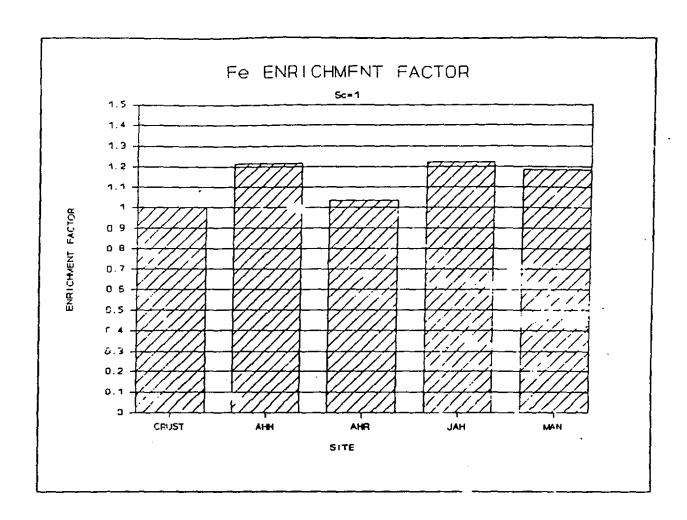
Factor Analysis

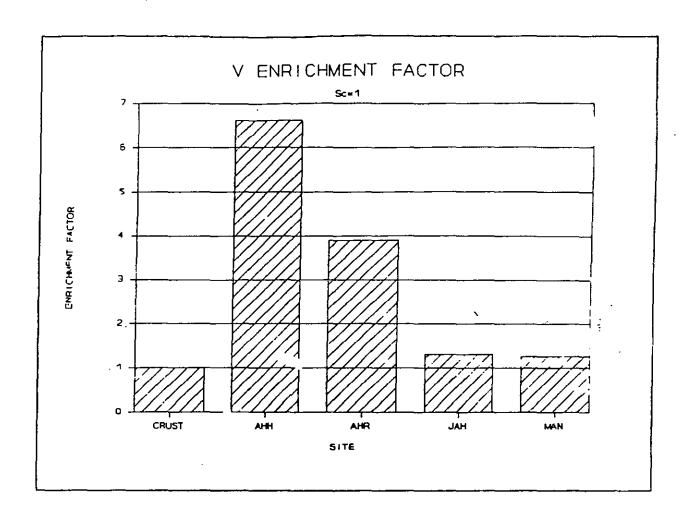
Regression Analysis

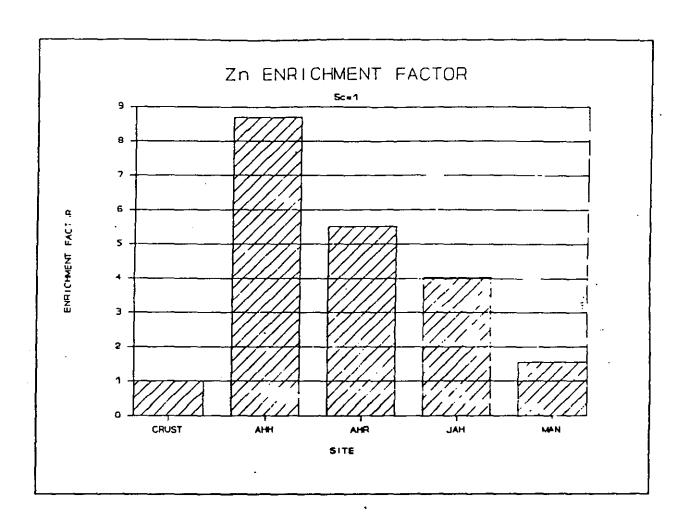
 $mass = x + \beta_1 X_1 + \beta_2 X_2$











ENRICHMENT ANALYSIS

Oil Related*

Na

Al

Cl

Fe

V

La

Zn

Sm

Th

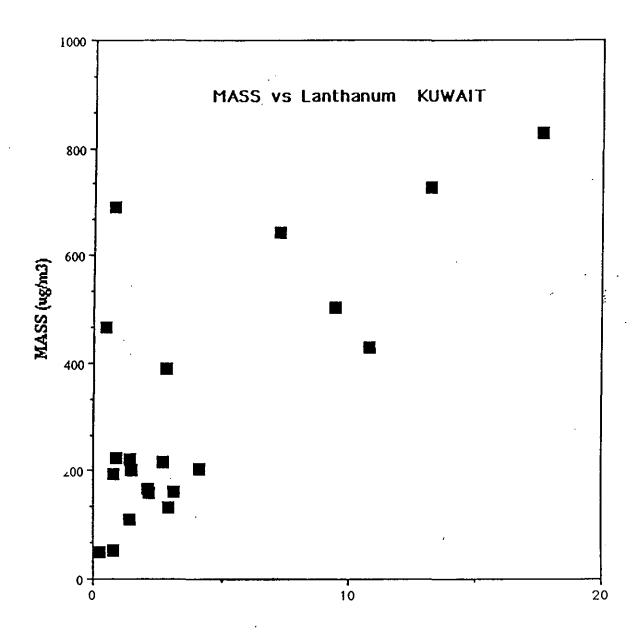
Sc

Br

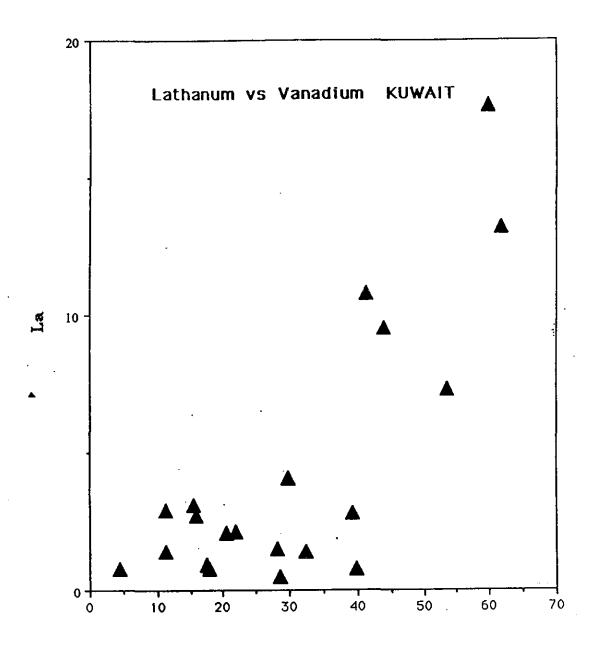
Sb

HSPH WWAIT

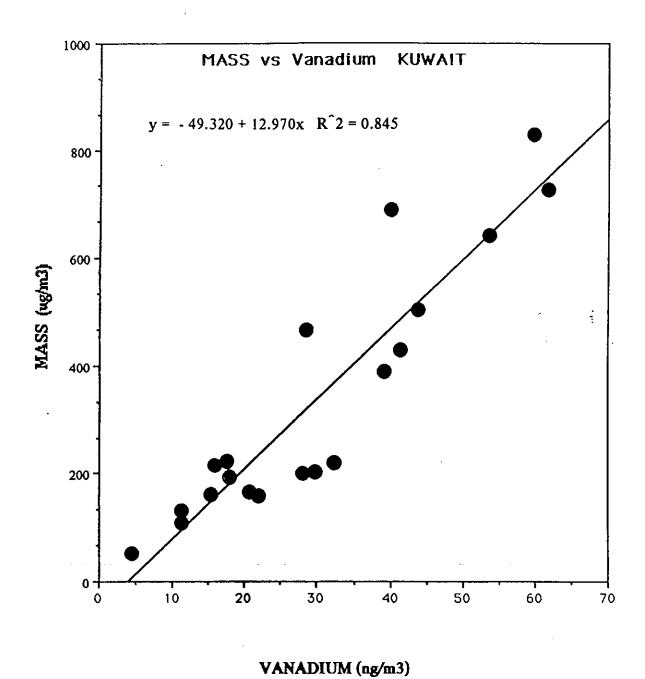
^{*} High Impact Day

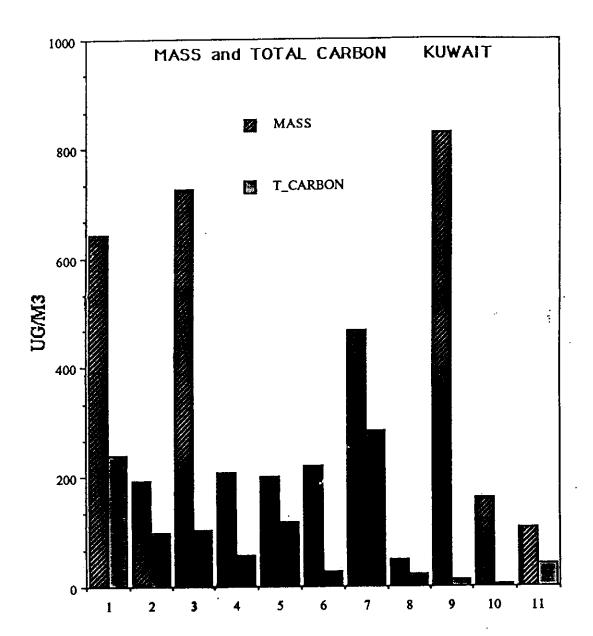


LANTHANUM (ng/m3)

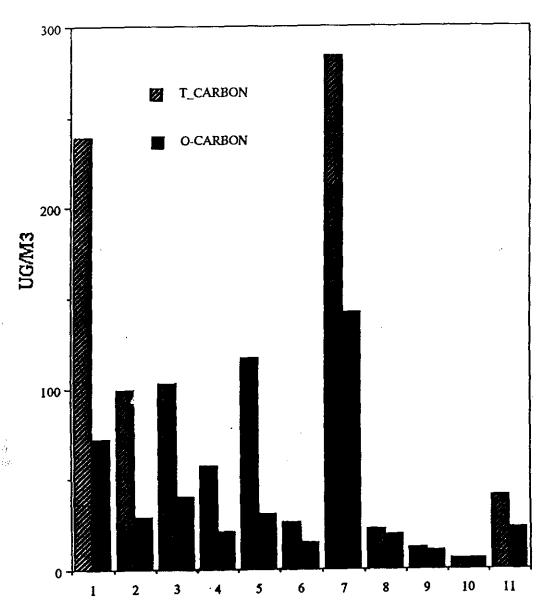


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TOTAL and ORGANIC CARBON KUWAIT



CARBON ANALYSIS

Total Carbon 15 - 450 µg/m³

Organic Carbon 10 - 315 µg/m³

Elemental Carbon 0 - 170 µg/m³

% Organic in Carbon 30% - 90%

%OC in Total Mass 1% - 60%

PM10 CONCENTHATIONS

Range 50 - 830 μg/m³

Mean 328 μg/m³

SD 239

·····The Kuwait Oil Fires

Presentation Abstracts & Speaker Biographies

Conference Arranged By:
Harvard University School of Public Health
Center for Middle Eastern Studies

Jointly Sponsored By:
The Arab Fund for Economic and Social Development
The United Nations Development Programme

Cosponsored By:
The World Health Organization
The World Meteorological Organization
The United Nations Environment Programme
The International Maritime Organization

12-14 August 1991
American Academy of Arts and Sciences
Cambridge, Massachusetts

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PRESENTATION ABSTRACTS

EFFECTS OF THE GULF WAR ON THE ENVIRONMENTAL GEOLOGY OF THE REGION

Farouk El-Baz Center for Remote Sensing Boston University

Preparations for and conducting the Gulf War resulted in much damage to the environment of the region. Foremost among the irreparable damage are changes to the terrain due to the digging of trenches, building walls of soil, and otherwise disturbing the desert pavement in and around Kuwait. The disruption of the usually one-grain thick layer of pebbles on the desert floor exposes soil to wind action. Furthermore, changing the contours of the normally flat land increases resistance to the wind, and thereby, increases the potential of particle transport until the land is peneplained. This condition will increase the frequency and the ferocity of dust storms in the region (Fig. 1). It will also result in the formation of new sand dunes; sand drifts were observed along roads in northern Kuwait.

The second effect on the geology of the region is that of the oil spill in the Gulf water. Hundreds of miles of the western coastline of the Gulf are already covered by oil. Petroleum "mats" have settled on coral reefs and in other ways have reduced the Gulf water productivity.

The third effect is related to the damage caused by oil well fires in terms of air pollution as well as the potential damage to the petroleum reservoirs. Photographs from the Landsat Thematic Mapper and the NOAA 10 and 11 spacecraft illustrate evidence for the damage to the environment and can help in monitoring environmental change in the future.

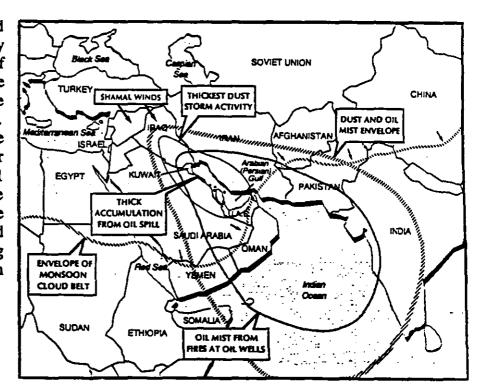


Figure 1. Schematic illustration of potential regional effects of damage to the environment due to recent Gulf War.

SESSION ONE:

Measurements of Air Pollution from the Fires

KUWAITI WELL FIRE INVESTIGATION -- MONITORING AND MODELLING

Dr. Abdallah E. Dabbagh King Fahd University of Petroleum and Minerals

Digitally processed National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) and Landsat Thematic Mapping (TM) data have been successfully used to monitor the Kuwaiti oil fires. Based on the processed information of satellite imagery, the number of burning oil wells and their locations in different oil-fields were identified. Knowing the productivity index of wells, an estimate was made on the amount of oil and associated gases on daily basis.

The total suspended particulates (TSP) using high volume samplers and inhalable particulates using PM-10 samplers were collected at various locations in the Eastern Province of Saudi Arabia. These filters were analyzed for toxic metal concentration and oil hydrocarbons including some carcinogenic organic compounds.

Air particulate samples using PM-10 samplers, collected from Dhahran and Khafji, were analyzed for polycyclic aromatic hydrocarbons (PAHs) and aliphatic hydrocarbon compounds. The concentration levels of PAHs compounds found in Dhahran and Khafji were not significantly high and compare favorably with levels found in urban areas in some parts of the world. However, the concentration of aliphatic hydrocarbons, which are not known to be toxic, were about several times higher than PAHs concentrations in most of the samples analyzed.

Air particulate samples were also analyzed to determine concentrations of aluminum, barium, cadmium, chromium, cobalt, copper, iron, magnesium, molybdenum, manganese, nickel, lead, strontium, vanadium and zinc in the filtrates were determined. Chloride, sulfate and nitrate were also determined.

Real time measurements of various pollutants in the ambient air were carried out in Dhahran, Abqaiq, Rahimah, Jubail, and Tanajib. No significant impact of the burning of oil wells in these areas has been observed. However, the inhalable particulate concentrations have been found to be relatively high.

A number of available air pollution modelling packages were reviewed. RAM Model (a multiple-point and area-source algorithm) within Users' Network for Applied Modeling (UNAMAP) is used to assess the impact of burning of oil wells in the Kuwaiti oil-fields within 100 km radius. For regional transport modeling, ARL-ATAD model is used, to study the behavior of the plume, its movement, decay of the pollutants with time, dispersion, and deposition with the distance and time.

The U.S. Interagency Air Assessment Team in collaboration with the Meteorology and Environmental Protection Administration (MEPA) and Research Institute of the King Fahd University and Petroleum and Minerals (KFUPM/RI) has developed a plan entitled Gulf Regional Air Monitoring Program (GRAMP). A part of the above plan, specially the

IMPACT OF KUWAITI OIL FIRES AND OTHER WAR ACTIVITIES ON INORGANIC ATMOSPHERIC POLLUTION IN SAUDI ARABIA

Muhammed Sadiq King Fahd University of Petroleum and Minerals

Multitude of environmental problems has been associated with the Kuwaiti oil fires and other war activities. The Research Institute of King Fahd University of Petroleum and Minerals (KFUPM/RI), in cooperation with the Meteorology and Environment Protection Administration, initiated a research program to assess atmospheric pollution from these events. This presentation will discuss data obtained on inorganic atmospheric pollution as a part of this program.

Air particulates, both TSP (from March 1) and PM10 (from early May), were collected using standard Hi-Vol samplers. The collected samples were extracted with aqua regia and the digests were analyzed for aluminum, arsenic, barium, cadmium, calcium, cobalt, chromium, copper, iron, manganese, magnesium, molybdenum, potassium, lead, nickel, sodium, strontium, vanadium, titanium and zinc. Water soluble concentrations of sulfate, nitrate and chloride were also determined in the selected samples. The analytical data were statistically analyzed to evaluate the impact of Kuwaiti fires on the concentrations of the above parameters.

Soil samples were collected from Hafr Al-Batin area and digested in concentrated nitric acid. Concentrations of the above metals were determined in the digestates using an ICAP. It was found that concentrations of aluminum, cadmium. cobalt, chromium, molybdenum, titanium, nickel and vanadium in the top soil were dependent on the distance from Saudi/Kuwaiti border. These preliminary data suggest that Kuwaiti oil fires and other war activities were responsible for the elevated metal concentrations in the top soils. Distribution of copper and zinc did no follow a similar trend.

Over one hundred scalp hair samples were collected from five cities in Saudi Arabia to obtain first approximation of metal contamination in humans. The samples were thoroughly washed, wet digested and analyzed for about 20 metals. The analytical results were used for inter-city comparison. The data of this investigation were compared with the published information from other countries.

REVIEW OF THE SURVEY BY JAPANESE TEAM

Toshiichi Okita Obirin University

From 28 April to 5 May, 1991, a Japanese team has made measurements related with oil fires at nine sites in Kuwait as shown in Table 1.

Table 1. Pollutants measured at different sites

NO ₂	NO _x , NO ₂	Particu- lates	BaP
000	000	O •	00
· 0	Q		0
000	000		0
U	O	•	
00	00		
	. 000 00	0000	NO ₂ NO _x , NO ₂ lates O O O O O O O O O O O

e: Components of particulates such as SO_4^2 , Cl^2 , NO_3^2 , total and elemental carbons, V, Cd, and Pb were determined.

Table 2. Maximum concentrations of SO2, NO2 and NO2

118

Gases	Conen. (ppb)	Site	Sampling Unit
SO ₂	23	Ahmadi residential area	PbO ₂ candle Aerosol gas sampling unit
NO _x NO ₂	54 33	Internat'l Hotel NW side	Ogawa sampler Filter badge

Derived from the sulfation rate (mgSO4/100 cm2 day) by multiplying 0.034 according to the Report of Japanese Environment Agency in 1973

The maximum concentrations of SO₂, NO₂ and NO₂ shown in Table 2 were rather low. The concentrations of particulates and their components in residential area of Ahmadi are shown in Table 3.

The mobile laboratory was equipped for automatic measurement of ozone, sulfur dioxide, nitrogen oxides, and carbon monoxide.

- Sampler for black smokes
- Samplings on active charcoal of hydrocarbons analyzed
- Sequential particles, sampler on cellulose acetate filter for measurement of metals (1 hour each sample 1.5 m³/h)
- One sampling cartridge of tenax and glass fiber filter to measure PAH in both gaseous and particulate phases

An automatic data logger stored each fine minute average data from each automatic sensor.

Black smokes and sequential particles samplers take automatic one hour sampling.

The other sampling were made during various times of 4 hours to 14 hours.

The measurements were made both far enough from the burning wells (where a majority of people is living in the city or the suburbs) and close to the fires (underwind) or inside the oil fields.

The main results are following:

- the carbon monoxide and nitrogen oxides levels were always very low and less than in an urban site.
- the sulfur dioxide and black smokes levels were generally medium but with unfavorable weather conditions, very high levels were observed: (2991 μg/m³ SO₂ on 5 mn, 2030 μg/m³ BS on 1 hour). These levels were observed close to the field as well as the city.

The ozone levels were "normal" taking into account the latitude and amount of sunshine.

The heavy paraffinics hydrocarbons levels were relatively high, particularly close to the fields: (decane 58.6 µg/m³ on 8 hours).

The light paraffinic hydrocarbons and the aromatics showed relatively low levels (toluene max $46 \mu g/m^3$ on 7 hours -'benzene: $11.9 \mu g/m^3$ - octane: $51.6 \mu g/m^3$).

The polycycliques aromatics hydrocarbons (PAH) levels are largely variable depending on the site and on the specific PAH.

High levels are observed for fluoranthene 110 ng/m³, benzo-a-pyrene 30 ng/m³, indeno (123cd) pyrene 49 ng/m³, but generally the levels were lower than the maximum observed in Paris.

THE GULF REGIONAL AIR MONITORING PLAN (GRAMP)

Andrew E. Bond
Atmospheric Research and Exposure Assessment Laboratory
U.S. Environmental Protection Agency

Timothy R. Gerrity
Health Effects Research Laboratory
U.S. Environmental Protection Agency

The U.S. Interagency Air Assessment Team (USIAAT) developed a 5-phase plan to assess the impact of the oil fires in Kuwait on the gulf region. This plan was jointly developed by the USIAAT, Saudi Meteorology and Environmental Protection Administration (Saudi MEPA), and the Saudi Arabian Oil Company (Saudi ARAMCO) during March and April 1991. The plan includes several objectives: an early warning health advisory system, the capability to track the air pollution emanating from Kuwait, the capability to collect airborne samples for toxicity testing, and the capability to generate a database for model validation. The presentation will focus on the USIAAT recommendations, to the governments of Saudi Arabia, Kuwait, and Bahrain concerning the expansion of their existing air monitoring capability. These recommendations were made to enable these governments to collect a comprehensive database necessary in assessing the long term health risks attributed to fires in Kuwait, on the population centers throughout the region.

WHO/UNEP GEMS/HEAL STUDY OF EXPOSURES TO PARTICLES IN KUWAIT

Lance Wallace and Mel Kollander U.S. Environmental Protection Agency

David Mage
World Health Organization

WHO/UNEP, together with the Kuwait Environmental Protection Department (KEPD) of the Kuwait Ministry of Health, is sponsoring a study of personal exposure to inhalable particles (PM-10) and fine particles (PM-2.5) in Kuwait. The study is designed to estimate the frequency distribution of personal exposures to PM-10, and indoor-outdoor concentration of PH-10 and PM-2.5, for all nonsmoking Kuwait citizens above the age of 10, between October 1991 and January, 1992. Additional measurements will be made of vanadium (as a marker of the oil fire contribution to exposure), nicotine (as a marker of cigarette carcinogenic effects).

SESSION TWO:

Predictions of Air Pollution Concentrations

PRE-WAR ASSESSMENT OF THE IMPACTS OF THE USE OF OIL AS A WEAPON IN KUWAIT

B. D. Zak Sandia National Laboratories

During the closing days of November 1990, Sandia National Laboratories was asked by the Department of Energy to assess the probable impacts of the potential use of oil as a weapon by Iraqi forces in Kuwait. A draft report was needed in a little over three weeks. Impacts on the Kuwaiti oil reservoirs, the health of exposed populations, the optical properties of the atmosphere, global climate, and terrestrial and marine ecology were to be assessed. The request was made of D. Engi, who responded by assembling the multidisciplinary team including H. W. Church, M. W. Edenburn, W. Einfeld, D. Engi, S. A. Felicetti, T. H. Fletcher, G. S. Heffelfinger, K. D. Marx, J. T. McCord, P. W. Moore, D. A. Northrop, L. D. Potter, J. R. Waggoner, and N. R. Warpinski. This paper focuses only upon the atmospheric impacts.

With regard to oil well destruction and ignition, a set of four scenarios was developed to span the range of potential impacts. The scenarios differed in number of wells blown and fraction ignited, covering the range from 100 to 900 blown, and 20 to 80% of the blown wells ignited. In each scenario, the wells presumed blown and ignited were assigned to the three major oil fields (Southeast, West North) into which the existing wells had been grouped.

Using available data, petroleum engineers on the team then estimated flow rates and gas-to-oil ratios for average blown wells in each field. For the presumed average blown well, the two phase flow was modeled, and oil droplet size distributions estimated. Modeling indicated that for the average wells, the output would be a fine oil mist under 15 microns in diameter. Combustion modeling then confirmed that for these conditions, each well would effectively be a blowtorch, with little or no rainout of burning oil drops. Available data on soot, sulfur dioxide, and carbon monoxide emission factors were then used to calculate source strengths for downwind dispersion modeling, but with an allowance made for a small fraction of the oil burning in pools to account for non-ideal venting.

In the interest of time, the burning oil fields were modeled as line sources with no lateral dispersion and no wind shear, but separately for day and night, and using actual climatological wind data from Kuwait City. The results indicated that, except for sensitive populations, the prompt health effects would be modest. Assuming smoke optical properties similar to other carbonaceous seets, impacts on visibility and available light could be very significant during daylight hours at ground level and aloft for a 100 km or more downwind. Regional, but not global climatic effects were expected.

A similar approach was taken for presumed fires associated with oil storage facilities and the system of trenches to be filled with oil and ignited. Downwind of the trenches, extreme conditions were anticipated. However, seepage modeling had identified probably difficulty for the Iraqis in filling the trenches and keeping them full from available pipelines.

defined bounds of the smoke dispersion. While measurements, data reductions, and analysis will continue for some time, early results are significant. Nuclear winter was a poor analog for Kuwaiti fires; crude oil smoke is not as absorbing as previously estimated, nor did self-lofting dominate the cloud dynamics. The smoke readily interacts with moisture and scavenging rates are greater. Analysis of cloud dynamics self-lofting, and definition of cloud properties and environmental damage using multispectral satellite imagery will lead to new models and assessments of smoke physics, nuclear winter, the long-range transport of pollutants, and the impacts of prolonged exposure to persistent smoke fallout.

THE EFFECT OF MIXING HEIGHT AND WIND SPEED ON THE DISPERSION OF AIR POLLUTION IN KUWAIT

Dr. Dhari N. Al-Ajmi
Kuwait Institute for Scientific Research

The mixing height and wind speed are two important meteorological parameters that affect the dispersion of air pollution. The product of the mixing height and the transport wind speed gives the ventilation factor, which is inversely proportional to the relative pollutant concentration. In this paper, the morning and afternoon mixing height data at Kuwait International Airport have been analyzed. Hourly wind speeds were evaluated. Finally, the relationships between the mixing height, wind speed and dispersion of pollution were discussed.

SHORT-RANGE AND REGIONAL TRANSPORT MODELING OF POLLUTANTS FROM KUWAITI OIL FIELDS

Tahir Husain
King Faud University of Petroleum and Minerals

The following two types of models were selected to estimate the concentration of the pollutants and to track the smoke plume due to burning of wells in Kuwaiti oil fields:

- 1. RAM Model within Users' Network for Applied Modeling (UNAMAP) to assess the impact of burning of oil wells in the Kuwaiti oil-fields within a radius of 100-150 km from the source.
- 2. Air Resources Laboratory, Air Transport and Dispersion Model (ARL-ATAD) to determine the movement of smoke from the Kuwaiti oil fields and regional impact.

SOME RESULTS OF ARAC'S EFFORTS TO ESTIMATE THE AIR POLLUTION IMPACTS OF THE FIRES

Thomas J. Sullivan, Ph.D. Lawrence Livermore National Laboratory

The Atmospheric Release Advisory Capability (ARAC) was originally conceived and developed at Lawrence Livermore National Laboratory as a nuclear accident emergency response service. It's purpose is to provide near real-time dose assessment calculations for accident response decision makers. Based on operationally robust three-dimensional atmospheric transport and dispersion models, extensive geophysical databases, real-time meteorological data acquisitions and a highly experienced staff, ARAC responds to U.S. events in the 30-90 minutes time frame. The present ARAC service is supported by a combination of DOE and DoD funding

Beginning with the Chernobyl accident, DOE has on several occasions requested that ARAC calculate the transport and dispersion of pollutants for accidents outside the U.S. and for non-nuclear material. One of the latest such requests was for support of the U.S. aircraft research flight programs measuring the pollutants from the Kuwait oil field fires (5/14-6/15 and 7/29-8/20) and the WMO request for assistance to the region's environmental and meteorological services. Since 14 May ARAC has been calculating the continuous smoke plume dispersion throughout a 3200 km region, using meteorological data sources from the U.S. Air Force Global Weather Central. These calculations have been directed toward optical depth estimates based on the integrated vertical (carbon soot) pollutant impact on visible light. ARAC has also reconstructed the long range pollutant transport on a hemispheric scale, again using AFGWC meteorological data, which depict the most probable far field dispersion and deposition patterns, albeit without washout or particle growth effects. These dispersion patterns provide insight as to where international scientific organizations should perform detailed measurements and analyses.

WMO ACTIVITIES FOR MONITORING AND ASSESSING THE ATMOSPHERIC EFFECTS OF THE KUWAIT OIL FIRES

Rumen D. Bojkov
World Meteorological Organization

Within the United Nations system of Specialized Agencies the World Meteorological Organization (WMO) has the responsibility of providing authoritative information and advice on the global atmosphere and, because of this, WMO was asked in the joint UN response to the UN Inter-Agency Action Plan to take the lead in the evaluation of atmospheric pollution resulting from the Kuwait oil fires.

none appeared at levels that would suggest a significant health effect. These data in combination with the informal health surveillance lead to the conclusion that short-term health effects, especially in a relatively healthy population, would not be significant. But, that longer term health consequences would not be predictable until better characterization of the emissions had been done. This presentation will focus on several issues including the rationale behind the methodologies employed by the Team and the reasoning behind the preliminary conclusions. Additionally, the roles that monitoring and modeling will play in risk assessment for health effects in the region will be discussed in the context of the National Academy of Sciences risk assessment paradigm.

This is an abstract of a proposed presentation and does not necessarily represent EPA policy

SESSION THREE:

Risk Assessment and Epidemiology

MORTALITY RISKS FROM SO₂ AND PARTICLES: INSIGHTS FROM THE LONDON FOGS

George D. Thurston, Sc.D.

Kazuhiko Ito, Ph.D.

Institute of Environmental Medicine, New York University Medical Center

Air pollution epidemiology has been able to clearly demonstrate instances were increases in mortality and/or morbidity were associated with elevated concentrations of pollution. Probably the most studied case is that of the 5-9 December, 1952 London, England episode during which the city center levels of daily air pollution reached 1340 ppb (3830 μ g/m³) sulfur dioxide (SO₂) and 4460 μ g/m³ of British Smoke (BS), and there was an estimated total of 4000 "excess" deaths over a two week period. Other wintertime episodes occurred in following years, especially 4-7 December, 1962 when peak daily center city levels reached 3834 μ g/m³ SO₂, 3144 μ g/m³ BS, 347 μ g/m³ particulate acidity (reported as H₂SO₄), and some 340 "excess" deaths reportedly occurred. The 1962 data supports the assumption that elevated acid aerosols were also present in 1952.

Quantitative statistical analyses have now been conducted on London's daily wintertime mortality/pollution records (compiled since 1958). We have completed a time-series analysis of these London data during the period when daily acid aerosol records were kept (1965-72). Long-wave trends (e.g., seasonal cycles and influenza epidemics) as well as autocorrelations were first removed from the data, providing robust statistical regression estimates of short-term pollution-mortality associations. The central London pollution during these periods were fairly stable from year to year and less extreme than the past periods (maximum wintertime $SO_2 = 1076$ $\mu g/m^3$, BS=336 $\mu g/m^3$, H₂SO₄=30 $\mu g/m^3$). Although the effects of the individual pollutants could not be separated, the two-day "mean effect" was found to be significant and to range from 7-9 deaths/day in Greater London (depending upon pollutant employed), after controlling for meteorological influences. Normalizing these results with respect to pollution level and population size yields the following coefficient estimates: $0.004(\pm 0.001)$, $0.015(\pm 0.003)$, and $0.150(\pm 0.047)$ in (deaths/day)/(μ g/m³)/million persons for SO₂, BS, and H₂SO₄, respectively. Converting the BS coefficient to total carbon (TC), based upon a past London calibration (i.e., TC=0.41xBS), yields a $0.037(\pm 0.008)$ normalized coefficient estimate for TC. Comparable analyses of London summer data gave results not statistically different from these. Care must be taken in applying these estimates at other locations (e.g., where the population age distribution or poliution mix differ substantially from London's).

- (2) Repeated high concentration of SO₂ reaching to 1.0 ppm at maximum was observed.
- (3) The meteorological conditions such as the direction and velocity of wind, had a great contribution on where and to what extent the pollution occurred.

According to the monitoring results by our mission between April 30 and May 8, SO₂ concentration was generally at a low level in Kuwait City and other monitoring points; 0.0025-0.0279 ppm (TEA passive sampler). During that period, relatively high pollution reaching 0.35 ppm (detector tube) was recorded only once, when black smokes covered over the city. Therefore, as far as SO₂ pollution was concerned, it might not be possible to think that serious acute effect such as the increase of asthma or bronchitis would occur, based on our experiences in Yokkaichi. It seems, however, the meteorological conditions have an important role in the observed level of pollution in residential areas of Kuwait. It seems important to know how frequent that sort of smoke pollution will occur, in order to assess the risk of this pollution problem properly.

SESSION FOUR:

Ecological Impacts

BURNING OF OIL WELLS IN KUWAIT - NEED FOR PERSPECTIVE

Dr. Fatima Abdali Kuwait Institute for Scientific Research

The Kuwait action plan (KAP) region is undergoing the world's most extraordinary environmental crisis. More than 600 oil well storage tanks and refineries are currently producing an enormous amount of smoke and other pollutants each day.

Most of the conclusions reached by international teams in Kuwait have been considered suggestive rather than definitive because of the limitation in data collection from limited sites.

The scenario should be oriented to correlate the quantitative characterization of the smoke source with risk assessment. This could be approached by focussing on the feasibility of the sampling sites, types of samples, chemical analysis and environmental and concentration distribution. This scenario should be framed under an Environmental Health Impact Assessment (EHIA) Program, which is directed toward the prediction and identification of the changes in the environmental parameters as a result of any assault, such as the oil well blowouts in Kuwait.

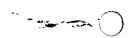
We must not adopt action programs with too little planning, and long-term implications of today's action must always be considered. We are not only concerned with ourselves and today's problem but at the same time, we are carrying out a responsibility to future generations.

ASSESSMENT OF THE IMPACT OF THE CRISIS ON GROUND-WATER POLLUTION FROM MASSIVE SPILLAGE OF OIL FROM DAMAGED WELLS

Dr. Adnan Akbar Kuwait Institute for Scientific Research

This article presents the future prospects of the ground water in Kuwait, in light of the tremendous and shumane damage of the Kuwaiti oil wells caused by the defeated Iraqi army. Of special and shumediate concern are the Kuwait Group and Dammam Aquifers which are considered to be the main source of fresh and brackish ground water in Kuwait. These two aquifers are believed to be hydraulically connected and therefore, the effect on one of them will certainly be reflected on the other. Taking this into consideration, the possibility of contaminating these ground water sources is great - either through direct seepage from ponds of leaked oil, or from the "Acid Rain" generated from the emitted pollutants of the burning oil wells.

AIRBORNE PETROLEUM CONTAMINATION OF COASTAL FISHERIES' FOOD-WEB



Anitra Thorhaug, Ph.D. Florida International University

Andrew Oerke Greater Caribbean Energy and Environment Foundation

The Kuwait oil fires present the world's largest-scale petroleum airborne contamination event. Food chains leading to man (i.e. groundwater, soil, agriculture, livestock and fisheries) may become contaminated with hazardous metals, organic compounds and acids. Fish provide 80% of the protein nutrition for the coastal Iranians. The number of people fishing, selling fish or dependent on fish probably number more than 350,000 with those directly employed by the fishing industry numbering 55,000 (40,000, Iran; 10,000, Saudi Arabia; 2,200, Qatar; 3,000, U.A.E.). It is well-known that fishing was an important historical natural resource in the area, prior to petroleum. Sport-diving and fishing of several types (shoreline and small craft) are popular.

The major fisheries products throughout the Gulf are shrimp snapper, grouper, emperor fish, lobster, crabs, queen fish, needle fish, clams and oysters. The food web has yet to be described for these species with tagging or other tracer techniques. However, clear evidence of <u>Peneus</u> food webs from other similar ocean basin shows early stages migrating into the very shallow seagrass beds where a detrital food web, based on seagrass, is their major food source; adults migrate to spawning grounds. Seagrasses have been shown by <u>Thorhaug & Schroeder (1982)</u> to incorporate metals, either through sediment or water, and to accumulate these, thus becoming an accumulation factor of some of the more toxic contaminants of the food web leading to man.

The nearshore waters and estuaries, particularly in northern Iran, are fisheries nurseries and many of them as well as fishing grounds are close to the fires. The fall-out into large bodies of water from air contaminants has the potential to be a considerable source of pollution. In the U.S.A.'s Great Lakes, more pollutants enter the water from airborne sources than from waterborne sources. If the fallout follows concentric circles around the source and is linear, then a large area of the northern Gulf will receive heavy inputs of contaminants from burning fires. If logarithmic fallout patterns occur, this would be intensified.

The nearshore tenthically driven fisheries products include snapper, grouper, clams, oysters, scallops and endangered species of turtles and dugongs. There are also offshore fisheries, some of which have adult stages which feed in coral reefs. There are open-ocean species whose entire life-cycle is spent in the sea -- i.e., tuna. Phytoplankton, which does become contaminated, is the primary producer here.

The marine ecosystems of the Gulf are fragile because of high salinities, being relic at the upper edge of the subtropics and highly restricted in numbers of species. The waters already have 47 times more petroleum than average sea water. It must be understood that the food webs

SESSION FIVE:

What Can Be Done? What Can Be Learned?

THE POTENTIAL ROLE OF ENVIRONMENTAL IMPACT ASSESSMENT (EIA) IN MINIMIZING THE ADVERSE IMPACTS OF THE BURNING OIL FIELDS IN KUWAIT

Dr. Ali Mohammad Khuraibet Kuwait Institute for Scientific Research

This paper will mainly focus on the approach of the application of Environmental Impact Assessment in terms of the Formulation of a Base Line Study and impact identification, prediction and assessment.

UN INTER-AGENCY PLAN OF ACTION ADDRESSING THE ENVIRONMENTAL CONSEQUENCES OF THE ARMED CONFLICT OVER KUWAIT

Dr. Makram A. Gerges
United Nations Environment Programme

The UN Inter-agency Plan of Action for the ROPME region, developed by UNEP in cooperation with ROPME, the Regional Organization for the Protection of the Marine Environment of the Kuwait Regional Convention of 1978, was adopted at the Second UN Inter-agency Consultation (Geneva, 14 March 1991).

The Plan of Action is now being implemented by a number of UN and non-UN agencies and organizations under the overall co-ordination of UNEP. Its focus is on four separate but interlinked areas: the coastal and marine environment, the atmosphere, inland terrestrial areas and hazardous wastes. It consists of three distinct phases: the survey phase, the assessment phase and the action plan design phase. Every effort is being made to build on data and information already generated by teams operating in the area, and on initiatives and actions being undertaken by various agencies, organizations and institutions working in the region.

An essential element of the Plan of Action is the establishment of a multi-disciplinary data-base which will contain the data and information collected in the surveys, as well as data from other sources required for the impact assessment.

This presentation reports on the progress achieved so far in the collective UN effort to deal with the environmental consequences of the armed conflict in the region, and describes UNEP's approach to the future development of the plan of action for the mitigation, rehabilitation and protection of the above four environmental areas.

SPEAKER BIOGRAPHIES

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Mahdi Abdal, Ph.D. and Dhari Al-Ajmi, Ph.D. Kuwait Institute for Scientific Research

Drs. Abdal and Al-Ajmi have done work in various types of soil in Wisconsin and Tennessee, USA and in Kuwait, focussing mostly on the physical characteristics and soil conservation. They have also managed different projects and tasks related to vegetable production, halophyte, wheat and forges in the avid zone.

Fatima K. Abdali, Ph.D. Kuwait Institute for Scientific Research

Dr. Fatima K. Abdali received a Ph.D. in Environmental Health Sciences (majoring in Environmental Chemistry and minoring in Ecological Toxicology & Chemical Oceanography) from the University of Michigan, Ann Arbor in 1990. Dr. Abdali is currently working as an Associate Research Scientist in the Environmental and Earth Sciences Division at the Kuwait Institute for Scientific Research in the Marine Pollution group.

Adnan Akbar, Ph.D. Kuwait Institute for Scientific Research

Dr. Adnan Akbar is a Research Associate, Water Resources Division/Hydrology, KISR.

Dhari Al-Ajmi, Ph.D. Kuwait Institute for Scientific Research

Dr. Dhari Al-Ajmi has experience in meteorological studies, including the development and utilization of mathematical models to determine dispersion patterns of air pollutants emitted from industrial sources. Dr. Al-Ajmi directed all air pollution and atmospheric studies in the Environmental and Earth Sciences Division in KISR and led several research projects in air pollution modelling, environmental impact assessment, and dispersion of heavy gases.

Jasem Al-Besharah, Ph.D. Kuwait Institute for Scientific Research

Dr. Jasem Al-Besharah is the Director of the Petroleum Division at KISR.

Rumen D. Bojkov, Ph.D. World Meteorological Organization

Dr. Bojkov has a B.S. in physics from the University of Sofia and a M.Sc. in meteorology and geophysics. He also holds a Ph.D. in physics and mathematics from the University of Moscow and a D.Sc. in atmospheric physics from the University of Rostock.

He began his career as a synoptician in the Bulgarian Meteorological Service (1955-59) and was an assistant and associate professor at the University of Sofia (1960-64). He has held research fellowships in the Canadian Meteorological Service (1960-61, 1965-66) and at the National Center for Atmospheric Research (1966-68). From 1968 to 1969 he was professor of stratospheric physics at the State University of New York at Albany, has served with the World Meteorological Organization as an expert in Egypt on upper-atmosphere research (1969-70) and from 1970 to 1984 was Chief, Atmospheric Sciences Division at the Secretariat in Geneva. From 1984 to 1988 he held the position chief scientist at the Atmospheric Environment Service, Canada and since 1988 has been Chief, Environment Division in the Secretariat of the World Meteorological Organization. In 1988 he was elected secretary of the International Ozone Commission. He is a fellow of the AMS.

Dr. Bojkov has published more than 70 papers on atmospheric circulation and ozone problems, a university text book (1966) and has also initiated and edited dozens of WMO meeting reports, many of which are widely known in the world community of atmospheric sciences.

Andrew E. Bond U.S. Environmental Protection Agency

Serves as a chemist on the staff of the Field Measurements and Monitoring Branch, Human Exposure and Field Research Division, of the Atmospheric Research and Exposure Assessment Laboratory, Office of Research and Development, located in Research Triangle Park, North Carolina. Responsible for planning field air pollution monitoring studies, designing and/or modifying air pollution sampling systems, and developing quality assurance techniques for use in the measurement and calibration of a variety of air sampling equipment. A member of the initial eight-member US Interagency Air Assessment Team which visited the Gulf region during March and April 1991, and contributed to the development of the Gulf Regional Air Monitoring Plan (GRAMP).

Abdallah E. Dabbagh, Ph.D. King Fahd University of Petroleum & Minerals

Dr. Dabbagh obtained his B.Sc. in Geology, 1968, from the American University of Beirut. His Ph.D. in Geology was obtained in 1975 from the University of North Carolina. He is now an Associate Professor at King Fahd University of Petroleum and Minerals (KFUPM).

exacerbations, the health effects of air pollution and the use of biologic markers of exposure in epidemiologic studies.

John S. Evans, Sc.D. Harvard University

Dr. Evans is an associate professor of environmental science and director of the program in environmental health and public policy at Harvard University. He received a B.S.E. in industrial engineering from the University of Michigan, a M.S. in water resources management from the University of Michigan, and a S.M. and Sc.D. in environmental health sciences from Harvard University. Since 1980, he has been involved in efforts to improve the models used to assess the health consequences of nuclear power plant accidents. His other research interests include analysis of the propagation of error in environmental measurements and models, validation of expert scientific judgement, and application of the decision analytic paradigm for assessing the value of information in support of environmental research and control decisions.

Dr. Evans is a member of the American Association for the Advancement of Science, the Society for Risk Analysis, the American Academy of Industrial Hygiene, and Sigma Xi. He serves on the editorial board of <u>Risk Analysis</u>, is past president of the New England Chapter of the Society for Risk Analysis, and was chairman of the Committee on Risk Assessment and Management of the Air Pollution Control Association.

Nabil M. Fayad, Ph.D. King Fahd University of Petroleum and Minerals

Dr. Nabil M. Fayad is a research scientist at the Water Resources and Environment Division at the Research Institute of King Fahd University of Petroleum and Minerals. He has a Ph.D. Degree in analytical chemistry in 1979 from Loughborough University of Technology, UK where he had previously obtained his MS degree. His research interests have centered around the investigation of oil pollution, and organic pollutants in the water, marine and air environment.

Makram Gerges, Ph.D. United Nations Environment Programme

Dr. Makram Gerges, a Senior Programme Officer at the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP) in Nairobi since 1986, got his M.Sc. in physical oceanography at the Massachusetts Institute of Technology in 1966 and then went on to take a Ph.D. at Moscow State University. Previously, Dr. Gerges worked as field expert and project manager for UNESCO and a long-term consultant to both

Jerome L. Heffter, Ph.D. NOAA - Air Resources Lab

Forecasted radioactive fallout from Pacific and Nevada nuclear tests during the 60's to the mid-70's. Researched on long-range transport and dispersion of boundary layer pollutants from the early 70's to the present with emphasis on long-range tracer experiments for model verification, and emergency response modeling procedures for forecasting pollutant and volcanic ash long-range transport and dispersion.

Tahir Husain, Ph.D. King Fahd University of Petroleum and Minerals

Dr. Tahir Husain is a Research Engineer-I in the Division of Water Resources and Environment at the Research Institute, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. He joined the Research Institute in 1979, since then he has been in conducting research in water resources and environmental disciplines. Dr. Husain has also been associated on a part-time basis with the Department of Civil Engineering in graduate teaching and supervision of MS and Ph.D. theses.

Dr. Husain earned his Ph.D. in Civil Engineering from University of British Columbia, Canada in 1979; M.Eng. in Systems Engineering and Management from Asian Institute of Technology, Bangkok, Thailand in 1972, and B.S. in Civil Engineering from Aligarh Muslim University in India in 1969. In 1975, he also completed UNESCO sponsored Postgraduate Certificate Course in Water Resources Management at Water Resources Research Institute (VITUKI) in Budapest, Hungary.

In 1986, Dr. Husain was honored with "Distinguished Researcher" award in recognition of his outstanding performance as the best researcher. In June 1990, the university again honored him with "Distinguished Research Project Leadership" award in recognition of his services as the best project manager at the Research Institute.

Ali Mohammad Khuraibet, Ph.D. Kuwait Institute for Scientific Research

Dr. Ali Mohammad Khuraibet received a B.S.C. in zoology from Kuwait University, and went on the receive his M.S.C. and Ph.D. in Environmental Impact Assessment from Aberdeen University, Scotland. Dr. Khuraibet is an Associate Researcher at the Kuwait Institute for Scientific Research and has been listed as an environmental expert with the United Nations Development Program (UNDP) since 1989.

Prof. Toshiichi Okita Obirin University



1948: Graduated from Department of Physics, Tohoku University

1948: Assistant, Department of Geophysics, Tohoku University

1952: Assistant Professor, Hokkaido Gakugei University

1961: Head, Laboratory of Industrial Health, National Institute of Public Health

1973: Head, Department of Community Environmental Sciences, National Institute of Public Health

1977: Professor, Department of Sanitary Engineering, Hokkaido University

1983: Director, Division of Atmospheric Environment, National Institute for Environmental Studies

1988: Professor, School of International Studies, Obirin University

Muhammad Sadiq, Ph.D. King Fahd University of Petroleum and Minerals

Dr. Sadiq obtained his Ph.D. in Soil Chemistry from Colorado State University in 1977. After graduation, he joined USEPA at Ada, Oklahoma to investigate the movement of sewage-borne metals through soil profiles. He joined the Research Institute of King Fahd University of Petroleum and Minerals in 1979. Since that time, he has been evaluating metal pollution both in the terrestrial and marine environments of Saudi Arabia. Recently, he has been involved in the assessment of metal contamination of air, soil, humans and marine ecosystem from the Gulf War activities. His research interests are metal chemistry, bioaccumulation and toxicity in the terrestrial and marine environments.

Richard D. Small, Ph.D. Pacific Sierra Research Corporation

Richard D. Small holds a Ph.D. degree in Aeronautical Engineering (1971) from Rutgers University. He is currently Director of Thermal Sciences and Co-chairman of the Environmental Monitoring and Assessment Program at Pacific-Sierra Research Corporation in Los Angeles, CA. His research interests include fire and smoke physics, dust processes, geography, atmospheric physics, fluid mechanics, and aerodynamics. Dr. Small has written and spoken on environmental impacts of Kuwaiti fires and published extensively on fire effects, smoke

in Meteorology from the University of Oklahoma (1970), and a Ph.D. in Atmospheric Sciences from the University of California/Davis in 1982.

Anitra Thorhaug, Ph.D. Florida International University

Anitra Thorhaug, Ph.D., C.E.P., Research Professor, Sponsored Program, Florida International University, has received a medal from UNEP for her coastal pollution works in 1981. In 1985, she became one of UNEP's Global 500. For 30 years, she has studied shallow nearshore subtropical and tropical pollution in all regions of the tropics. As an FAO Consultant in 1985-86, in Southeast Asia, she examined fisheries rehabilitation potential. Recently she has studied oil spill and clean up methods in tropical seas. She has worked in the middle east since 1969. Trace metal cycling pollution effects on critical tropical matrix organisms are the subject of a series of her experiments.

George D. Thurston, Ph.D. New York University

Dr. Thurston is an Assistant Professor at the New York University Medical Center's Institute of Environmental Medicine. He received his doctorate in Environmental Health Sciences from the Harvard School of Public Health in 1983, and his Bachelor of Sciences degree in Environmental Engineering from Brown University in 1974.

Dr. Thurston's research into the human health effects of ambient air pollution has ranged from field studies of the effects of ambient ozone and acid aerosols on the lung function and health of asthmatic children at summer camps to large-scale epidemiologic studies of cross-sectional associations between particulate matter and U.S. mortality rates. At present, he is the Principal Investigator of a five year NIEHS study of the effects of ambient acidic aerosols on New York State daily hospital admissions for respiratory causes. Prior to joining NYU, Dr. Thurston was a Research Fellow at Harvard's Kennedy School of Government.

Lance A. Wallite, Ph.D.
U.S. Environmental Protection Agency

Dr. Wallace received his Ph.D. in physics from the City University of New York, following undergraduate work at Caltech and the University of Washington. Since 1977, he has been an environmental scientist at the U.S. Environmental Protection Agency in Washington, DC. His main interest at EPA has been in developing instruments to measure personal exposure and body burden (particularly exhaled breath) for a wide range of environmental pollutants. He conceived and implemented the Total Exposure Assessment Methodology (TEAM) Study, for which he

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ENVIRONMENT AGENCY

1-2-2, KASUMIGASEKI CHIYODA-KU, TOKYO 100 JAPAN

TEL 81-3(3581)3351 FAX 81-3(3580)7173

October 22,1991

Dr. Peter C.Hill

United States Department of Commerce National Oceanic and Atmospheric Administration

Dear Dr. Peter C.Hill

I am a technical officer that have been to the Harvard School of Public Health with Dr. Okita of Obirin University. And I heard that you are collecting data and information about Kuwait Oil Fires.

So, I send our mission's papers and copys which Dr. Okita used for OHP at the conference. The latter is twelve pages(not twenty pages), and used on August 12.

Yours sincerely

Hirotaka TACHIKAWA

Unit Chief of Environment Quality Standards

Planning Division

Air Quality Bureau

Environment Agency

Air Pollution from the Kuwait Oil Fires

August, 1991

Japanese Official Mission

on

the Environmental and Health Effects of the Oil Fires

1. Purpose of Survey

In view of the current situation in Kuwait, where the environmental and health effects of the oil fires there are of great concern, the intent of this survey was to measure air pollution at various sites and to collect related information so as to assist the government of Kuwait in its investigation of countermeasures.

Duration of Survey

April 25 - May 10, 1991 (Entered Kuwait on April 28, and left on May 6)

3. Measurement of Air Pollution

Air pollution was measured by using simplified measuring tools. The items measured and measuring points were as follows. Preliminary measurement of air pollution was performed on April 30. Full-scale measurement was started on May 1, and ended on May 5.

Table 1. Items measured at each measuring point

Measuring point\ltem measured	SO ₂	NO _x , NO ₂	Dust	BaP	co	H ₂ S
l. Ahamadi Hospital	0	0	0	٥.	0	0
2. Residence in Ahamadi	0	0	*	0	0	0
3. Rigga Hospital	0	0			0	
4. Environment preservation dept.	0	0		0	0	
5. Mansouriya Hospital	0	0			0	
6. Northwest side of hotel	0	0		0	0	
7. Southeast side of hotel	0	0	*	0	0	
8. Jahra Hospital	0	0			0	0
9. Northern area of Jahra	0	0			0	

At the points marked with * in the dust column, carbon compounds, anions and heavy metals were also measured.

The measurements revealed that the concentrations of sulfur dioxide and nitrogen dioxide detected by this survey were at levels lower than the environment quality standards of Japan even at their highest values. However, because the measurements were conducted for a short period of time and at a limited number of points, it would be premature to judge that the entire area of Kuwait is at levels free from trouble.

It can be seen from these measurements that the concentration of particle matter is at a considerably high level. The concentration itself is not so high as compared with the concentration level before the war. However, when the constituents of the dust were investigated, it was found that several specimens had concentrations of elementary carbon, which appeared to be soot, exceeding $0.1~\text{mg/m}^3$ (the environment quality standard corresponding to the daily average value for suspended particle matter in Japan). Thus, it is surmised that the crude oil is burning imperfectly. It is known that many of the carbon compounds generated from burning of oil have particle sizes of about $0.5~\mu\text{m}$, which easily deposit in the lungs. Therefore, the effects from elementary carbon have to be watched in the future.

It was also observed that the concentration of benz (a) pyrene at Ahamadi was slightly higher than that in major cities in Japan.

Chloride ions and sulfate ions also had high concentrations. If they exist in the form of chloride mist or sulfate mist, their effect on life is of concern. Therefore, it will be necessary to find out in what form they exist.

The concentration of nitrate ions is lower than in Tokyo, while all heavy metals are at less than the lower limits of their detectable values.

Table 2. Measurement results for sulfur dioxide and the like

	Haximum yalue	Point (measuring and sampling method)	[ps	ality standard om] oan)	
	[ppm]		Daily average	Hourly value	
	0.0279	Residential area in Ahamadi (Lead dioxide method)	0.00		
S0 ₂	0.0233	Residential area in Ahamadi (Aerosol sampling unit)	0.04	0.1	
NO _×	0.054	Northwest side of International Hotel 4th floor (Aerosol sampling unit)	-	-	
NO ₂	0.033	Southeast side of International Hotel 5th floor (Filter badge)	0.04 - 0.06	-	

Table 3. Measurement results for particle matter (at Ahamadi Hospital and residential area in Ahamadi)

Item		Maximum value	Average value	Geometric mean value	Remarks
Total suspender particle	otal suspended (AS)		0.539 mg/m ³	0.448 mg/m ³	Environment quality standard in Japan covers particle matter of 10 µm or less:
Particle matter particle size or or less		0.952 mg/m ³	0.5t4 mg/m ³	0.4′ 4/4 ,mg/m³	Daily average: 0.10 mg/m ³ Hourly value: 0.20 mg/m ³
Total carbon	(AS)	0.536 mg/m³		_	
Elementary car	rbon (AS)	0.445 mg/m ³		-	
Benz(a)	(AS)	25.5 ng/m³	6.3 ng/m ³	1.2 ng/m³	Tokyo in 1989 Maximum: 15.2 ng/m ³
pyrene	(PP)	6.6 ng/m³	2.2 ng/m³	1.2 ng/m³	Average: 2.7 ng/m ³
Chloride ion	(AS)	60.1 µ g/m ³	12.3 µ g/m³	6.5 µ g/m³	Tokyo Maximum: 6.2 in 1981 Average: 3.0 μ g/m³
Sulfate ion .	(AS)	58.2 µ g/m³	16.0 µ g/m³	12.2 µ g/m³	Tokyo Maximum: 16.1 in 1989 Average: 6.8 μ g/m³

Note Symbols in () in the item column, which means measuring and sampling method as belows

AS: Aerosol sampling unit

PD: Personal dust sampling set PP: Personal PAH sampling set

Situation regarding Damage to Health

According to an analysis of data on emergency outpatients in the three months from January through March, 1991, which was provided by the Health Department, there were 877 and 374 (70.1% : 29.1%) emergency outpatients with asthma, allergic diseases

and respiratory diseases before and after the oil fire started on a full scale on February 26. The durations before and after the oil fire were 56 days and 34 days (62.2%: 37.8%), respectively. Thus, it cannot be said that damage to health has increased due to the air pollution from the oil fires.

An investigation of the status of patients at hospitals near the Ahamadi area where the oil wells are burning revealed that the number of patients has not increased significantly as yet after the oil fire.

However, even if there are some effects from air pollution, it may take some time before they are noticed. Therefore, even if the number of patients has not increased as yet, this does not guarantee that the number will not increase in the future. Continuous observation will be required.

Table 4. Comparison of number of emergency outpatients before and after oil fires

Disease	Asthme and allergic	Respiratory	Digestive	Others	Total
Before oil fire	75	299	268	610	1,252 (34.5%)
After oil fire	182	695	465	1,031	2,373 (65.5%)
Subtotal	257 (7.1%)	994 (27.4%)	733 (20.2%)	1,641 (45.3%)	3,625 (100.0%)

5. Suggestions for Future Measures

Based on a comprehensive assessment of the results of the survey, it is strongly recommended that the following measures be put into effect, mainly by the Government of Kuwait.

(1) Realization of an air pollution monitoring system

It is necessary to ascertain the form of the sulfate ions and the concentrations of volatile organic compounds such as aldehyde and ketone. In addition, a continuous measurement network should be built for fine particle matter and sulfur dioxide, and for sulfate ions, if

necessary, and an emergency forecasting system should be instituted based on this network.

Since observations were made at times when the sky was covered with smoke, a wind direction/velocity observation network must be built to study the causes of such conditions.

(2) Implementation of measures against indoor air pollution

Measures to be considered include mounting hoods on ventilation fans at hospitals or households, installing filters, and, if necessary, installing air purification devices with active carbon.

(3) Conducting health surveys of residents

Because the delayed effects of soot or other compounds in the air are a matter of concern in areas near the burning oil wells, it will be necessary to provide a tracing system for observing the progress of the situation for a long period of time, which could include a) preparation of records on hospital outpatients, or b) health surveys of residents near the burning oil wells.

Attachment Table 1. Weather conditions during survey

			-	-	
Heasuring point	Heasuring time	Weather	Temperature (*C)	Wind direction	Wind velocity (m/s)
Southeast side of International Hotel	Apr. 29 15:17	Clear, but covered with smoke	34.0	South- southeast	2.7
Northwest side of International Hotel	Apr. 29 16:30	Clear, but covered with smoke	34.6	Northwest	4.7
	Apr. 29 17:20	Clear, but covered with smoke	34.0		
	Apr. 29 22:00	Clear, but covered with smoke	30.0		
Southeast side of International Hotel	Apr. 30 18:30	Clear, but covered with smoke	30.6		
	Apr. 30 18:45	Clear, but covered with smoke	30.2	}	
	Hay 1 7:00	Clear, but covered with smoke	29.6		
Environment preservation dept.	Hay 1 8:40	Clear, but covered with smoke	29.2	Northwest	1.2
Mensouriye Hospital	May 1 9:15	Clear, but covered with smoke	3.38	Horthwest	1.8
Rigge Hospital	Hay 1 10:18	Clear, but covered with smoke	31.0	Korthwest	1.2
Residence in Ahamadi area	Hay 1 12:45	Clear, but covered with smoke	32.7	Karthwest	0.8
	, Pay 1 13:20	Clear, but covered with smoke	32.4	Northwest	8.0
Ahemadi Hospital	May 1 13:25	Clear, but covered with smoke	32.4	Northwest	0.6
Jahra Hospital	Hay 2 9:45	Covered with smoke (the sun being visible)	27.8	Korthwest	3.3
Northern area of Jahra	Hay 2 11:30	Clear, but covered with smoke	28.4	Korthwest	4.1
	Hay 3 12:00	Clear, but covered with smoke	32.4	Northwest,	- 6.0
	May 3 13:00	Clear, but covered with smoke	32.0	Horthwest	4.5
	Hey 3 14:30	Clear, but covered with smoke	32.0	Northwest	5.3
	May 3 16:15	Clear, but covered with smake	32.0	Northwest	4.8
	Fay 4 9:30	Clear, but covered with smoke	28.8	Horthwest	4.5
	Kay 4 10:00	Clear, but covered with smoke		Korthwest	4.4
	May 4 10:30	Clear, but covered with smoke :	29.2	West	2.7
Residence in Ahamadi area	Hey 4 11:00	Clear, but covered with spoke	30.9	West	2.9
JESTOCHEC III WHEMEST SIES	Hay 4 11:30	Clear, but covered with smoke	31.4	Korthwest	5.3
	Fay 4 12:00	Clear, but covered with spoke	32.2	West	4,2
	May 4 12:30	Clear, but covered with smoke	32.8	West-northwest	3.3
	May 4 13:00	Clear, but covered with smake	1	Northwest	3.1
	May 4 13:30	Clear, but covered with smoke	1	West	1.8
_	May 4 14:00	Clear, but covered with smoke		Northwest	5.1
-	May 4 15:49	Clear, but covered with smoke	34.6	West	4.1
	Hay 5 12:30	Clear, but covered with smoke	38.6	Northwest	4.2

(Reference)

Measuring point	Measuring point Heasuring time Weather		Temperature (°C)	Wind direction	Wind velocity (⊏/s)
Ohahran (in running vehicle)	Apr. 28 7:30	Clear, but with effect of sout	23.6		5.2
220 km to Khafji (in running vehicle)	Apr. 28 8:30	Clear, but with effect of soot	27.6		
150 km to Khafji (in running vehicle)	Apr. 28 9:35	Clear, but covered with smoke	29.5	Hortheast	
60 km to Khafji (in running vehicle)	Apr. 28 10:30	Clear, but covered with smoke	28.4		
At Arabian Oil in Khafji, 100 km to inland sea	Apr. 28 11:24	Clear, but covered with smoke	27.4		
At Arabian Oil in Khafji, 100 km to inland sea	Apr. 28 14:00	Clear, but covered with smoke	28.0	Substantially no wind	

Attachment Table 2. Sulfur dioxide (SO₂) measurement results

Sampling point	Sampling time	Measurement	Measurement results [ppm]
Ahamadi Hospital	5/ 1 12:45-5/ 5 10:00	TE	0.0214
	5/ 1 11:27-5/ 5 9:18	TE	0.0062
	5/ 1 11:20-5/ 5 9:35	Pb	0.0279
	5/ 2 9:59-10:34	2A	0.0233
	5/ 2 10:59-12:01	AS	0.0204
	5/ 2 12:14-13:43	2A	0.0182
	5/ 2 13:57-15:35	AS	0.0150
Residence in Ahamadi area	5/ 3 9:58-11:48	AS	0.0046
Residence in Analizof area	5/ 3 12:21-14:13	AS	0.0060
	5/ 3 14:30-15:45	AS	0.0052
,	5/ 3 15:00-5/ 4 9:20	. ZA	0.0046
	5/ 4 9:50-12:03	AS	0.0084
	5/ 4 12:30-14:00	AS	0.0061
	5/ 4 14:11-15:41	AS	0.0042
	5/ 4 15:55-5/ 5 9:18	AS	0.0025
Rigga Hospital	5/ 1 10:15-5/ 5 10:55	TE	0.0027
Environment reservation dept.	5/ 1 8:25-5/ 5 8:10	TE	0.0014
Mansouriya Hospital	5/ 1 9:25-5/5 11:50	TE	0.0005
Horthwest side of International Hotel	4/29 18:20-5/ 1 7:35	TE	0.0005
not timest side of litternational note!	5/ 1 7:35-5/ 5 7:15	TE	0.0026
	4/29 17:50-5/ 1 6:55	TE	<0.0003
Southeast side of International Hotel	4/30 15:45-21:45	ZA	0.0005
	5/ 1 7:05-5/ 5 6:30	TE	0.0110
Jahra Hospital	5/ 2 9:35-5/ 5 14:33	TE	0.0012
Northern area of Jahra	5/ 2 11:25-5/ 5 14:55	TE	0.0004

Note: The method of converting measurements by the lead dioxide method (marked with Pb in the measurement column) to ppm yields unfavorable accuracy. However, because the Report by the Environment Agency 1973 suggested multiplying by an average coefficient of 0.032 - 0.036, 0.034 was used here.

Attachment Table 3. Nitrogen oxide (NO_x) measurement results

Sampling point		Sampling ti	ne	Measurement	Measurement results [ppm]
Ahamadi Hospital	5/ 1	12:45-5/ 5	10:00	TE	0.044
Residence in Ahamadi area	5/ 1	11:27-5/ 5	9:18	TE	0.003
Rigga Hospital	5/ 1	10:15-5/ 5	10:55	ΤE	0.008
Environment preservation dept.	5/ 1	8:25-5/ 5	8:10	TE	0.030
Mansouriya Hospital	5/ 1	9:25-5/ 5	11:50	TE	0.041
Northwest side of International Hotel	4/29	18:20-5/ 1	7:35	TE	0.054
	5/ 1	7:35-5/ 5	7:15	TE	0.023
Southeast side of International Hotel	4/29	17:50-5/ 1	6:55	TE	0.040
,	5/ 1	7:05-5/ 5	6:30	TE	0.024
Jahra Hospital	5/ 2	9:35-5/ 5	14:33	TE	0.008
Northern area of Jahra	5/ 2	11:25-5/ 5	14:55	TE	0.008

Attachment Table 4. Nitrogen dioxide (NO_2) measurement result

Sampling point		Sampling tim	e	Measurement	Measurement results [ppm]
Ahamadi Hospital	5/ 1	12:45-5/ 3	16:25	FB	0.014
	5/ 3	16:25-5/ 5	10:00	FB	0.010
Residence in Ahamadi area	5/ 1	11:27-5/ 2	10:00	FB	0.019
	5/ 4	10:45-5/ 5	9:34	FB	0.003
Rigga Hospital	5/ 1	10:15-5/ 5	11:50	FB	0.022
Environment preservation dept.	5/ 1	8:35-5/ 5	8:25	FB	0.014
Mansouriya Hospital	5/ 1	8:57-5/ 1	21:27	FB	0.024
	5/ 1	8:57-5/ 2	10:07	FB	0.017
	5/ 1	8:57-5/ 5	13:30	FB	0.012
,	5/ 1	9:27-5/ 5	12:30	FB	0.015
Northwest side of International Hotel	5/ 2	7:25-5/ 3	7:30	FB	0.003
•	5/ 3	7:10-5/ 4	7:25	FB	0.002
	5/ 4	7:13-5/ 5	7:00	FB	0.002
Southeast side of International Hotel	4/30	19:24-5/ 1	7:10	FB	0.002
	5/ 1	7:10-5/ 2	7:10	FB	0.033
	5/ 2	7:10-5/ 3	7:10	FB	0.004
•	5/ 3	7:30-5/ 4	7:13	FB	0.001
	5/ 4	7:25-5/ 5	6:30	FB	0.003
Jahra Hospital	5/ 2	9:35-5/ 5	14:38	FB	0.006
Northern area of Jahra	5/ 2	11:28-5/ 5	14:54	FB	0.001

(Reference)

	Sampling point		Sampling tim	e	Measurement	Measurement results [ppm]
Individual	Central area in Ahamadi	5/ 2	10:07-5/ 3	10:30	FB	0.012
exposure	Hetropolitan area in	5/ 1	10:00-5/ 1	21:00	FB	0.034
	Kuwait	5/ 1	10:00-5/ 1	21:00	FB	0.034
		5/ 2	9:00-5/ 2	22:00	FB	0.018
		5/ 2	9:15-5/ 2	19:20	FB	0.014
		5/ 2	9:15-5/ 3	7:10	FB	0.003
		5/4	7:30-5/ 5	6:40	FB	0.010
Inside (Int	ernational Hotel)	5/ 3	7:18-5/ 4	7:36	FB	0.002
Bahrain	· · · · · · · · · · · · · · · · · · ·	5/ 6	19:15-5/ 9	7:55	F6	0.020

Attachment Table 5. Particle matter measurement results

									_			
Heasurement point	Measuring time	Heasure-	Dust	BaP	T-C	1-0	CI	SO ₄	ИО ³	V	Cd	Pd
neasurement point	, neasoning cine	ment	[mg/m ³]	[µg/m ³]	[μց	/m³]		[μg/m³]			[µg/m³]	
Residence in Ahamadi area	5/ 1 12:07-5/ 2 9: 5/ 2 9:59-10:34 5/ 2 10:59-12:01 5/ 2 12:14-13:43 5/ 2 13:57-15:35 5/ 3 9:58-11:48 5/ 3 12:21-14:13 5/ 3 14:30-15:45 5/ 3 16:00-5/ 4 9: 5/ 4 9:50-12:03 5/ 4 12:30-14:00 5/ 4 15:55-5/ 5 9:	AS AS AS AS AS AS AS AS AS	1.014 0.800 0.387 0.309 0.875 0.883 0.463 0.637 0.339 0.739 0.250 0.211	0.02550 0.01120 0.00929 0.01230 0.01010 0.00135 <0.00002 0.00600 0.00057 0.00500 <0.00003 <0.00003	536.2 394.0 163.9 97.9 151.5 51.8 <43.0 <68.0 51.2 130.0 <72.0 24.8	445.3 311.0 140.5 73.4 92.6 <42.0 <43.0 <68.0 44.7 <97.0 <72.0 <72.0 16.4	20.3 60.1 21.6 13.8 16.3 3.3 2.4 3.6 2.9 6.5 6.4 1.5	25.3 58.2 9.7 10.0 20.3 15.4 12.4 15.2 9.9 17.0 6.2 5.1 3.1	3.5 <11 <6 <4 4.7 <3 <4 0.6 <6 <4 <4 0.2	< 5 <11 < 7 < 4 < 5 < 3 < 4 <0.5 < 4 < 0.5 < 4 < 0.5	<pre>0.6 <1.4 <0.8 <0.6 <0.3 <0.3 <0.5 <0.6 <0.6 <0.7 <0.8 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6</pre>	< 6 <14 < 8 < 6 < 3 < 3 < 5 < 1 < 8 < 6 < 3 < 3 < 5 < 1 < 8 < 6 < 3 < 5 < 8 < 6 < 7 < 8 < 6 < 7 < 8 < 7 < 8 < 8 < 8 < 8 < 8 < 8 < 8 < 8 < 8 < 8
Southeast side of International Notel	4/30 15:45-21:45	۸S	1.000	<0.00010	<342.0	<342.0	7.0	33.7	<21	<20	<2.5	<25
Ahamadi Hospital	5/ 3 16:38-5/ 5 9:	56 PP	<u> </u>	0.00253	-		-					
Residence in Ahamadi area	5/ 1 12:00-5/ 2 10: 5/ 2 9:44-5/ 3 15: 5/ 3 10:30-5/ 4 9: 5/ 3 15:58-5/ 5 9:	15 PP 35 PP		0.00657 0.00103 0.00074 0.00041	7 7 1 3	- - -	-	1 1 1 1	- - -	- - -	- - -	- - -
Environment preservation dept.	5/ 1 8:30-5/ 2 8: 5/ 3 8:00-5/ 4 8: 5/ 4 8:08-5/ 5 8:	00 PP	- - -	0.00083 0.00008 0.00005	-	-	- - -		- - -	- - -	- -	-
Northwest side of International Notel	5/ 1 7:40-15:50 5/ 1 16:10-5/ 2 7: 5/ 2 7:00-5/ 3 7: 5/ 3 7:25-5/ 4 7: 5/ 4 7:10-5/ 5 7:	25 PP 05 PP	- - - -	0.00018 0.00096 0.00032 0.00009 0.00005		-	11111	11111	1 1 1	- :	- - - -	- - - -
Southeast side of International Note:	4/29 15:00-4/30 18: 4/30 18:45-5/ 1 7: 5/ 1 7:15-5/ 2 7: 5/ 2 7:21-5/ 3 7: 5/ 3 7:05-5/ 4 7: 5/ 4 7:27-5/ 5 G:	00 PP 15 PP 05 PP 22 PP	-	0.00009 0.00069 0.00011 0.00030 0.00005 0.00004	1 1 1 1	1 1 1 1	11111	11111	11111	1 1 1 1	- - - -	- - - - -
Ahamadi Hospital	5/ 1 9:31-11:07 5/ 1 13:30-13:40	09 01	0.151 0.420		-	-	1 1	-	-	-	-	-

- 10 -

T-C 8aP 1-C CI SO. 1103 ٧ Cd Ρđ Measure-Dust Heasuring time [mg/m³] ment [jtg/m³] [jtg/m³] $[\mu g/m^3]$ $[\mu g/m^3]$ Residence in Ahamadi area 5/ 1 12:11-12:21 PD 0.190 5/ 1 12:31-12:41 5/ 1 12:36-13:34 5/ 1 14:03-14:25 PI) 0.740 PD 0.300 PD 0.636 5/ 1 14:10-15:43 0.409 PD 5/ 2 9:41-10:03 5/ 2 10:08-11:09 5/ 2 12:03-12:13 PD 0.952 PD 0.576 PD) 0.669 5/ 2 12:20-12:31 PD 0.706 5/ 2 12:45-12:55 PD 0.750 5/ 2 12:57-13:10 5/ 2 13:49-13:59 PD 0.280 PD 0.382 5/ 2 14:12-14:22 PD 0.418 5/ 2 15:08-15:18 PD 0.946 5/ 2 15:20-15:31 PD 0.756

0.346

0.133

0.000

PD

PD

PD

;

5/ 4 10:30-12:10

5/ 4 12:15-15:52

Southeast side of International Hotel 4/29 10:25-11:25

(Reference)

Sampling point	Sampling time	Measurement	Dust [mg/m³]	BaP [µg/m³]	
Khafji-burning oil well side- metropolitan area in Kuwait	4/28 14:00-4/29 15:00	PP	-	0.00007	
On the premises of Arabian Oil in Khafji	4/28 12:03-13:42	PP	-	<0.00009	
On the premises of Arabian Oil in Khafji	4/28 14:48-12:05	PO	0.035	-	
230 km to Khafji (in running vehicle)	4/28 8:13- 8:28	PD	0.573	-	
On the road from Khafji to Dhahran (in running vehicle)	4/28 7:39- 7:59	PD	0.837	-	
Inside (residence in Ahamadi area)	5/ 2 12:07-12:27	PD	0.월9	-	
	5/ 2 12:42-13:02	PD	0.282	-	
•	5/ 2 14:16-14:41	PD	0.204	-	
	5/ 2 15:13-15:33	PD	0.538	_	
	5/ 3 14:53-15:23	PD	0.058	-	

- Note 1: BaP represents benz (a) pyrene, T-C total carbon, I-C inorganic carbon.
- Note 2: With the personal dust sampling unit method, all dusts with particle sizes of 7 μm or less are eliminated but they remain in other sampling methods.

IMPACT OF OIL WELL FIRES ON AIR QUALITY IN THE URBAN AREAS OF KUWAIT

I. POLLUTION BY PARTICULATES LESS THAN 10u

Team Coordinators

Dr. Mostafa El Desouky

Dr. Mahmood Y. Abdulraheem

Members (Alphabetically):

- Ms. Abdulwahhab Sabah
- Mr. Abel, Ahmed
- Mr. Atash, Haider
- Mr. Al-Hader, Abdulrida
- Mr. Al-Kadi, Mahmood
- Mr. Moussa, Ghasan
- Mr. Al-Safar, Fuad
- Mr. Al-Shawaf, Jassim
- Ms. Al-Subageha Wafa

Environment Protection Department
Ministry of Public Health
Kuwait

August 1991

IMPACT OF OIL WELL FIRES ON AIR QUALITY IN THE URBAN AREAS OF KUWAIT

I. POLLUTION BY PARTICULATES LESS THAN 10u

INTRODUCTION

Particulates in air constitutes a wellknown health hazard. The association of the particulates with the SO₂ as the principal pollutant is well documented (WHO, 1990). Kuwait had always suffered of high particulate loads (El Desouky et al, 1985). However a large proportion of the particulates are derived from the soil.

The relation of the particulates load and the health impacts was discussed by the WHO working group on Assessment of Risks to health from Smog Episodes. The level of 24 hour average concentration of 200 ug/m^3 particulates is believed to be associated with small, transient decrements in lung function (FVC, FEV₁) in children and adults, which may last for 2-4 weeks.

The magnitude of the effect is in the order of 2-4% of the group mean and is classified moderate. When the concentration is 250 ug/m³ (black smoke), the health effect would be increase in respiratory morbidity among susceptible adults (chronic bronchitis) and possibly children. The overall effects are moderate. Increase in mortality among elderly and chronically ill people are associated with levels of 500 ug/m³ and the effect is classified as severe (WHO, 1990).

The US EPA uses slightly different criteria. The national air quality standard is taken as 150 ug/m^3 TSP. The alert level is 350 ug/m^3 . At this level mild aggravation of symptoms is experienced by susceptible persons. Irritation symptoms are reported in the healthy population. Persons with existing heart or respiratory ailments are advised to reduce physical exertion and outdoor activity. The warning level is 420 ug/m^3 . This is

associated with significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population. At this level, elderly and persons with existing heart or lung disease should stay indoors and reduce physical activity.

The level of 600 ug/m³ is classified as being_associated with significant harm. At this level, premature death of ill and elderly is seen and healthy people experience adverse symptoms that affect their normal activity. All persons should remain indoors, keeping windows and doors closed and minimize physical exertion. Starting from 1987, the PM-10 reference method, given in the Code of Federal Regulations (40 CFR 50, Appendix J), replaced the total suspended particulate (TSP) standard to focus concern and control from the larger particulates to the more health-threatening, respirable particulates.

In Kuwait, a large volume of information is available as a result of the data collected about the dust. Information about dust fall were collected from 12 sites. TSP samples were collected since 1980 from 4 sites covering the urban areas. The data have been reported to GEMS since 1980. The geographic distribution shows that the commercial residential area had relatively higher particulates load (699.5 ug/m^3) . However, the correlation between the values reported in the different sites was quite high. It ranged between (r = .875 and .966).

Monthly variability was quite evident with very high loads in June (1191.6 ug/m^3). The minimum was seen in December (318.6 ug/m^3). Friday the weekend had slightly lower mean (574.3 ug/m^3). Weather conditions had a marked impact on the particulates load. The mean with the dust storms (1852.0 ug/m^3) was much higher than that with rising sand (868 ug/m^3), dust in suspension (638 ug/m^3) or dust haze (397 ug/m^3).

The particle sizes, taken by Andersen head, from different

sites showed seasonal variability similar to that seen for the TSP. This was also seen with the weather phenomena. The clear weather had 141.9 ug/m^3 of 7 microns or over and 87.2 ug/m^3 of <1.1 micron (61.5%). With dust storms, the corresponding values were 910.2 and 698.0 ug/m³ (76.7%).

Starting from 1989, The high volume TSP was replaced by PM10 smaplers. The samplers were used to investigate the particulate loads resulting from the quarries operation and the contribution of offroad vehicles to the particulate loads. They were installed on jeeps and provided with mobile generators to provide the needed power. In Kuwait, the health significance of the particulates and its chemical composition is expected to be quite different from the types seen in Europe, USA, Japan or other industrialised countries (Bennett et al, 1985).

The programme was interrupted on the 2nd of August 1990 when Iraq invaded Kuwait. Two of the 3 PM10 samples were taken away together with the jeeps and the generators. The programme was restarted by the end of April 1991. However we went back to the TSP. The samplers were installed at the general hospitals where power was available. The sites were different from what was used before. The samples were analysed for trace metals and organics at the EPD lab. Some of the samples were sent to the USA & UK for quality control.

Several teams visited Kuwait in the last few months and took air samples in an attempt to assess the pollution problem resulting from the well fires. The US EPA took samples from 2 urban sites, namely the US Embassy and Um Al Heiman. At the Embassy, the levels were 10 and 55 ug/m³. At the other site, 320 ug/m³ was reported. The other sites were mostly in the oil fields. Though a number samples were taken at Ahmadi Hospital, the levels were variable and ranged from 120 to 935 ug/m³. A group from Harvard School of Public Health and another from Japan took samples, but they were purely interested in toxicity testing rather than assessment of the total particulate load.

MATERIAL & METHODS

The study is designed to examine the distribution of the respirable particulates in the area to the east and north of the Burgan oilfield. The original design included a point to the south east at Al Zoor and another point in the immediate vicinity of the field but no suitable or safe site could be found at the time the investigation started. The sites used for sampling are shown in Fig. (1).

The samplers used are the portable PM10 designed by Dr. John Scheweiss of US EPA. The equipment was given to EPD as a loan by the courtesy of the US EPA as a part of the US Gulf Air Monitoring Programme covering Saudi Arabia, Kuwait, Bahrain, and Qatar. The samplers are battery operated and have a constant rate of 5 liters/min. The air is passed through pretreated, dried, and weighed Whatman Ultrapure quarts filter paper.

The sampling programme covered 10 weeks (1 May - 10 July). The samples were taken daily starting around 9 A.M. and the samplers were run for 24 hours. The samplers are provided by timers and a digital counter for the total volume of air handled by the samplers. The samplers were calibrated by the EPA before being delivered and the behaviour of each of the samplers were cross checked by running each for a fixed time (30 min.) several times and the consistency of the sampler was determined. Two samplers were also run together in the lab. This was also repeated in the field by taking particulate sa ples by rotating one of samplers among the sites.

The investigation is a part of the more extensive one which includes running three fixed Sierra PM10s, two TSP, one Andersen head and several dustfall buckets. Almost half of the samples (collected on the even days) were sent to the States for analysis of the trace metals and the organics. The results are not yet a ailable and the local capabilities which were severely crippled as a result of the Iraqi invasion is being upgraded to handle the other

other half of the filters as a quality check. The present report will be limited to the discussion of the weights at the different sites and the factors that probably influenced the results.

RESULTS:

The mean concentration of PM10 reported for the different sampling sites is shown in Table (1). Ahmadi had the highest particulate load (338.3 ugm/m^3) followed by Fahaheel (309.9 ugm/m^3). The lowest was in Salmiya (249.6 ugm/m^3). The levels seen for Farwaniya (256.8 ugm/m^3) was slightly lower than that for Andalus (273.9 ugm/m^3). It is interesting to note that apart from Ahmadi and Fahaheel the mean for the other sites was lower than the overall mean.

Table (1)

The mean concentration of the PMIO according to the location

Location	Mean	S.d.	No.
Salmiya	249.6	330.2	55
Fahaheel	309.9	257 •1	66
Ahmadi	338.3	304.3	69
Farwaniya	256.8	284 .3	66
Andalus	273 •9	354 .8	67
Total	287.4	307.3	323

The correlation between the daily particulates load at the 5 sites is shown in Table (2). The highly significant positive correlation points to the tendency of the values to change in the same direction due to the presence of a number of factors affecting the different sites in a similar way. The proximity of the sites should be considered. It is interesting to note that relatively

higher correlation was found between Fahaheel and Ahmadi (r = .929), both in the proximity of the major oil field. The relatively weak correlation between Salmiya and the other sites (.851-.890) could also be explained by the presence of the site on a promontory projecting into the Gulf relatively away from the direct impact of the plume. The correlation between the particulates load between Farwania and Andalus (.929) was also quite nigh. Both sites are to the north of the Burgan field.

Table (2)

Correlation coefficient matrix between the PM10 recorded at the various sampling sites.

	Salmia	Fahaheel	Ahma đí	Farwania	Andalus
Salmia	-	-	_	-	
Fahahee1	.851	-	-	-	-
Ahmadi	.895	.929		· -	-
Farwania	.890	.883	.924	-	-
Andalus	.895	.888	.890	.933	-

The daily mean in micrograms/ m^3 for the 5 sites is shown in Fig. (2). The data for the individual sites are found in the Appendix. The overall mean for the whole period was 287.4 ugm/ m^3 . Much higher levels were seen on 17 and 22nd May. The level was also higher than the overall mean in the period 20-25 of June and around the 9th of July.

Various factors would influence the daily fluctuations in the particulates concentration. Wind speed is probably the most important. Strong winds are likely to ventilate the plume and thus lower the concentration. It is also known that it would stir up the soil and cause the suspension of soil dust into the air. The overall mean concentration according to the wind speed is shown in Table (3). With calm wind the concentration (299.4 $\rm ugm/3$) was slightly higher than the concentration with stronger winds and this was seen up to 4 m/s. The drop was quite steady and persistent, though the difference was quite small.

Table (3)

The mean concentration of the PM10 according to the wind speed

Wind Speed (m/s)	Mea n	S.d.	No.
<2	299.4	172.9	42
2-	288.8	188.2	86
3-	278.6	440.2	107
4-	263.9	267.3	105
5+	367.1	267.7	29

With the strongest winds (5 m/s or more) the concentration was appreciably higher (307.1 ugm/3). These are the days shown as a peak on the graph Fig. (2). Sand storms are frequently seen in the summer months in Kuwait and they are known to be accompanied by heavy particulate loads (El Desouky et al, 1985). The dust storms by definition are accompanied by strong wind and diminished visibility due to the dust obstructing sunlight. Unfortunately no differentiation according to the weather phenomena is possible because the Meteorological Department is not functioning at the time being.

Table (4)

The correlation coefficient between the total particulates load (PM10) and the mean wind speed recorded at the different AQ Stations.

Total	Exc. 5m/s
.075	047
115	138
097	019
030	079
.017	036
029	089
	.075 115 097 030 .017

The correlation between the wind speed and the overall mean particulate load in the different locations is shown in Table (4). The correlation coefficient was calculated for the total samples and after excluding the days in which the wind speed was 5 m/s or higher the difference is quite clear. With the total, the overall mean gave a week negative correlation (-.029). A week negative correlation is also reported for Fahaheel (-.115), Ahmadi (-.097) and Farwania (-.030). These 3 sites are nearer to the principal oilfield on fire. An insignificant positive correlation was found in the more remote areas (Salmiya = .075 and Andalus = .017).

Excluding the cases in which the wind speed was 5 m/s or over, the picture changed slightly. The correlation was negative and this was seen for all the sites. Relatively stronger coefficient of correlation was seen with Fahaheel (-.138) and Farwania (-.079). This is quite different from what is expected and what was previously reported for the last years. The effect of the plume is influencing the picture to a great extent.

A significant negative correlation was seen between the daily particulate load and the level of the solar radiation reported at the Mansoria air pollution monitoring station (-.350**) and with the UV (-.397). This is an indication of the plume passing over the monitoring site. No solar measurements are available at Requistation which is more close to the oilfield. The correlation between the intensity of the solar radiation and UV is shown in Fig. (3-A & B). The coefficient with the solar was (-.350) and with the UV (-.397). This is much higher than the correlation between the wind speed. The significant correlation shows clearly the higher concentration of the particulates with the drop in both the UV and solar radiation due to the passing plume.

The other factor that is relevant is the wind direction. The effect will show in the geographical distribution of the particulates. The data for the wind direction is available from the measurement done by the air pollution monitoring stations at Mansoria and Reqa. The prevailing wind direction is not always similar the 2 sites due to the influence of the heat islands. The distribution of the overall concentration reported for the 5 sites according to the wind direction reported for Mansoria is shown in Fig. (4-A).

The concentration was quite low with winds blowing from the west (2.33 ugm/m^3), NW (253.7 ugm/m^3) or the east (264.7 ugm/m^3). The highest was seen with the northerly winds (650.2 ugm/m^3). This was significantly higher than the lowest 3 means. With the winds blowing from the SE, and the SW which is the direction of the Burgan oilfield, the concentrations were quite high, though they were not significantly different from the concentration recorded with the west, NW or easterly winds.

A similar picture is seen with the wind direction reported for Reqa (Fig. 4-B). Higher overall mean was seen with winds blowing from the NW (729.3 ugm/m^3). This was significantly higher than the means reported with the NW (149.3 ugm/m^3), the SW (194.3

ugm/ 3), the west (280.0 ugm/ 3) or the north (313.8 ugm/ 3). The NW winds is not likely to bring the plume in the direction of the sites. The southerly winds is the most likely candidate. The mean with this direction (633.3 ugm/ 3) was appreciably higher than that reported with any other wind direction except for the NE.

The concentration of the level at each of the sampling sites with the wind direction recorded at both the Mansoria and Reqa is shown in the Appendix.

The colour of the filter paper is quite important. The smoke coming from the well fires is likely to give the filter papers a black colour. Less heavy loads is likely to give the filter papers a grey colour. The overall mean concentration according to the colour of the filter paper is shown in Fig. (5). The colour of some of the filters was not changed appreciably and these were termed white. These had the lowest overall mean (117.9 ugm/m^3). The grey filters came next with almost double the load (257.7 ugm/m^3).

The brown filters had the highest particulate load (1388.0 ugm/m³). This was significantly higher than the mean with all the other colours. It is interesting to note that the number of filters with this colour did not exceed 8 cases. The black filters had a mean of 295.2 ugm/m³ and this was significantly higher than that for the white filters. It is interesting to note that the filters which had a light colour that could not be assigned to either grey or brown, had a higher mean (278.8 ugm/m³) compared to the grey (257.7 ugm/m³). The contribution of the soil dust is disturbing the picture very much. It was expected to find the highest loads with the black filters, followed by the grey, the light and the white. However, the colour of the sand is covering up the black tinge of the filters and causing a rather inconsistent distribution pattern.

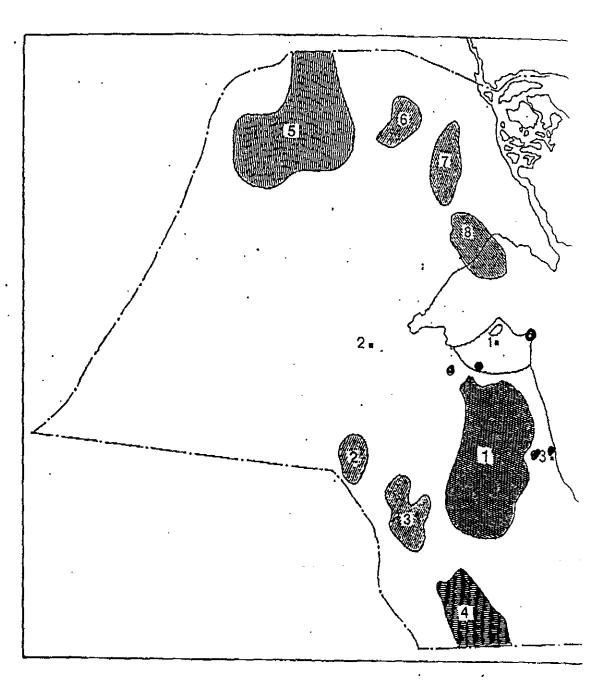
DISCUSSION:

the prevalence of sand and dust storms. The arid climate, the scorching hot summer, the extensive sand sheets, and the fresh winds are contributing factors. The anthropogenic factors as the overgrassing of sheep, offroad vehicles and quarrying for gravel and sand are disturbing the surface sand making it much more friable and prone to saltation by the wind. Added to this background is the particulates load resulting from the oil well fires.

The magnitude of the problem is not clear, and estimates of the amount of smoke varies widely, according to the quantity of oil burned and the emission rate. The rates range between 5-15 gm/kg of oil burnt. Based on the official figure of 6 m barrels, between 30-90 thousand tons of smoke is being emitted into the air daily. The impact on the level of particulates on the ground level is a matter of speculation. With the plume rising to 2-3,000 of meters, the contribution of the particulates load on the ground is likely to be much smaller than what would be expected.

The samplers used in this investigation are rather new, and have never been tested in a hostile environment and hot climate like that in the summer in Kuwait, but they behaved in a very reliable manner. The variability within the samplers and the consistency of the different samplers and their tolerance is worth mention. The reading taken by the samplers correlated well with the Fixed PM10 and more samples are being taken at the moment.

The influence of the well fire on the particulates load is quite substantial. This could be calculated from the negative correlation between the wind speed and the weight of the particulates which is very much different from what was reported in the previous years where a very strong positive correlation was reported (El Desouky et al, 1985). The positive correlation between the particulates load and the drop in the intensity of the solar radiation would further support this point. The levels reported here are within the range found out by the US EPA though they were merely source related.



Oil Field

1.Burgan 2.Manakeesh

3.Um-Qudair

4.Wafra

5.Mutreba

6.Rawdatain

7.Sabriya

8.Bahra

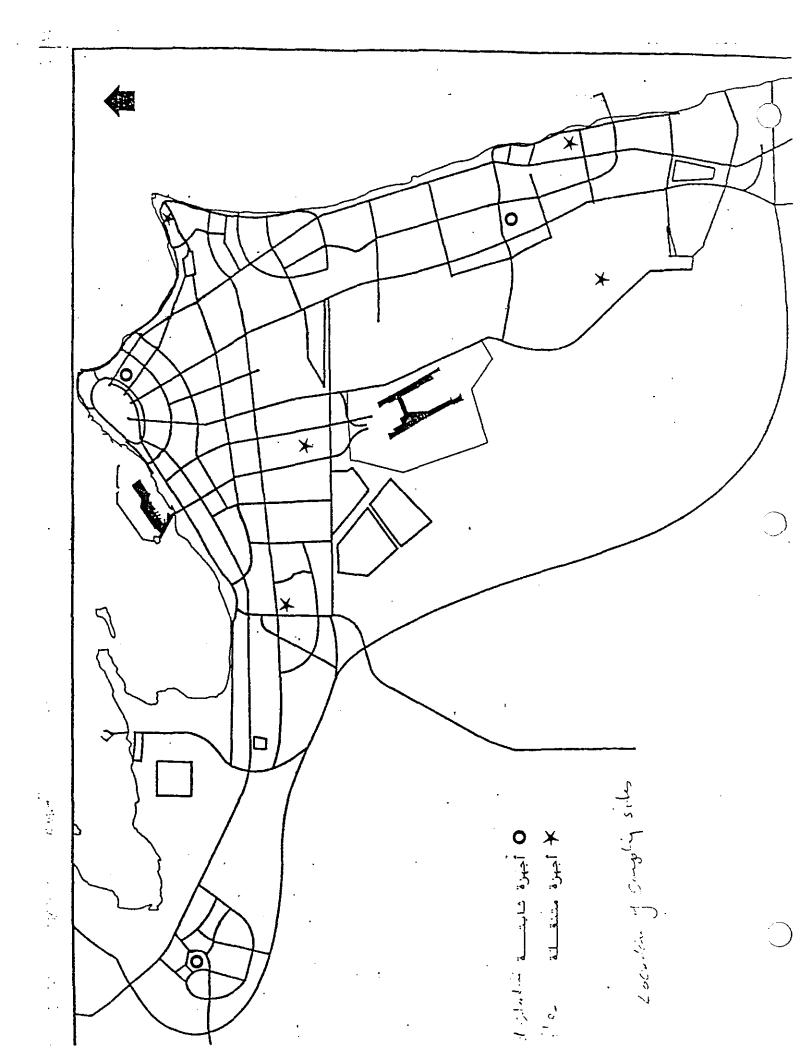
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South Control Position of the Land

2.Jah: 3.Fah:

4.Khee

Locating Sampling sights relative
Burgan field



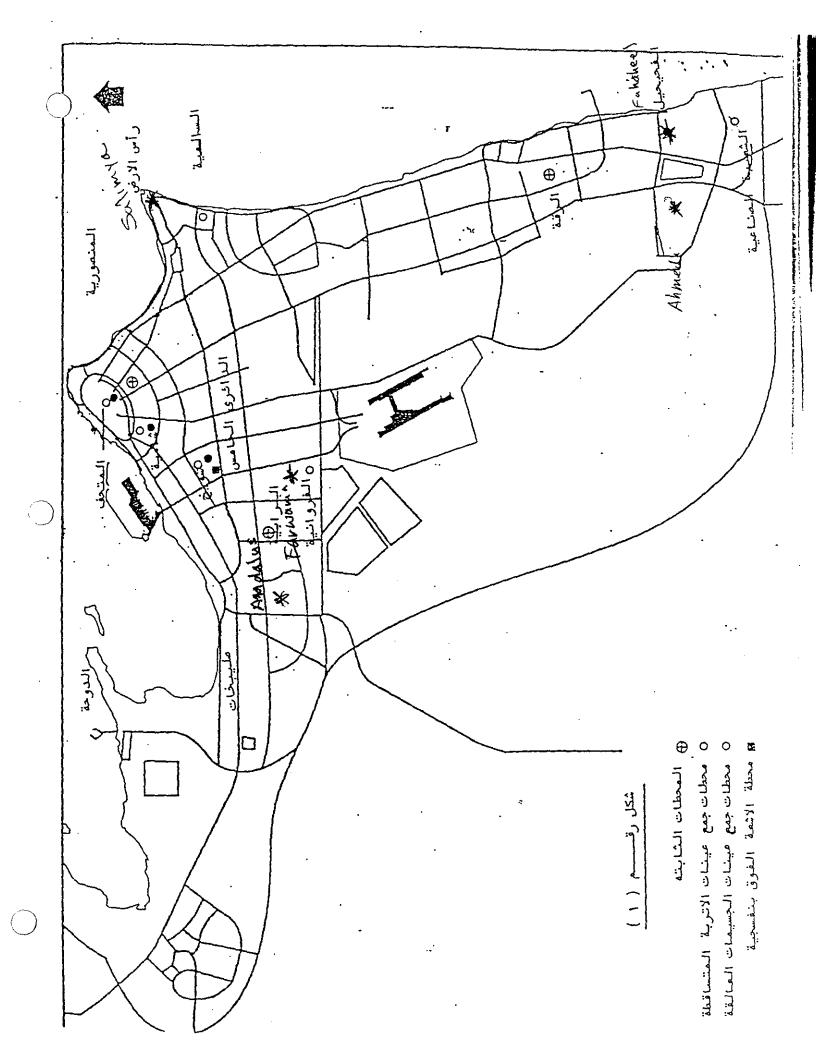
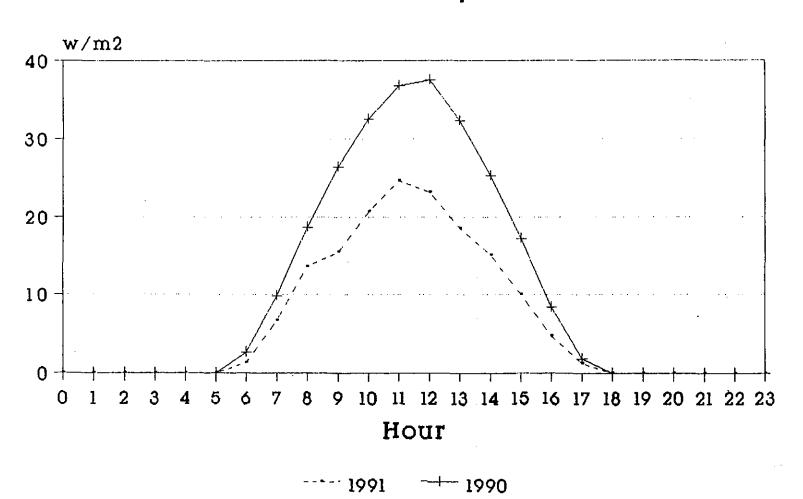
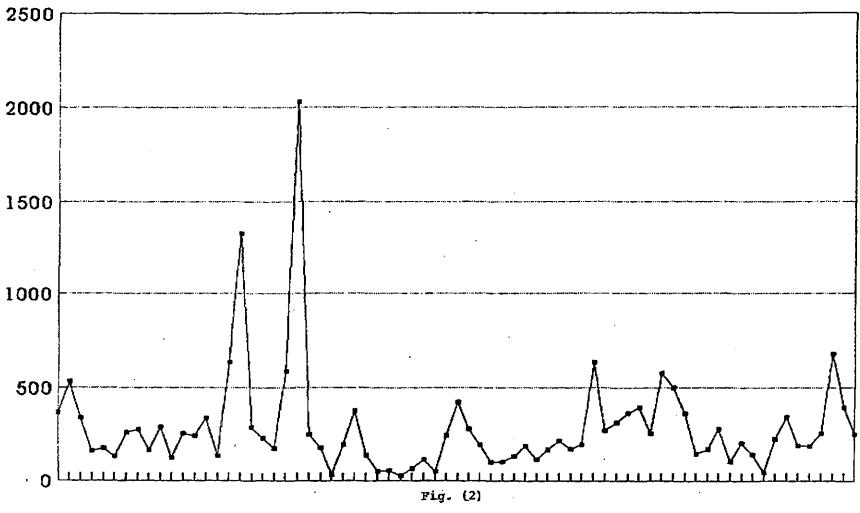


Table 1 A: Daily mean PM10 loads
May - July 1991.

Do to	May		June		July	
Da te	Mean	S.d.	Mean	S.d.	Mean	S.d.
1	367.4	259.4	67.3	47.7	144.6	82.2
2	530.4	152.1	117.0	17.1	46.8	40.5
3	340.3	0.0	52.9	38.4	227.3	36.1
4	163.7	46.7	246.5	39.3	344.9	43.3
5	176.9	119.1	•422.6	75.3	193.5	16.7
6	133.2	60.9	282.0	52.6	189.9	43.8
7	261.8	220.9	195.6	48.2	257.4	44.7
8	278.6	107.8	102.7	28.6	• 675.2	115.0
9	167.4	184.7	105.5	50.7	, 393 .6	77.0
10	292.0	74.3	135.8	39.0	254.3	45.3
11	127.3	45 .7	189.9	58.7		
12	255.9	114.3	117.9	16.5		
13	244 .1	121.4	171.5	26.5		
14	338.5	171.6	218.1	117.4		
15	136.7	15.7	174.8	50.8		
16	633.3	204.8	200.3	29.6		
17	1329.7	275.4	•631.5	344.8		
18	289.5	42.9	273.2	64.8		-
19	233.3	113.7	316.5	72.6		
20	177.0	116.6	366.4	119.7		
21	586.9	212.2	.395.3	80.5		
• 22	2029.4	291.1	257.4	0.0		
23	251.5	135.9	• 574 •8	144.6		
24	181.2	39.5	•500.1	54.3		
25	34.2	14.1	362.9	169.9		
26	196.9	148.7	148.0	16.4		
27	377.7	15.4	172.2	60.0		
28	142.1	52.1	281.9	76.7		
29	54 .0	28.1	104.1	51.3		
30	57 . 3	58.4	204.6	71.3		
31	28.0	. 26 .4				
Mean	. 390.2	430.7	243.2	168.5	272.7	173.4
No.	1	.32	1	141	!	50

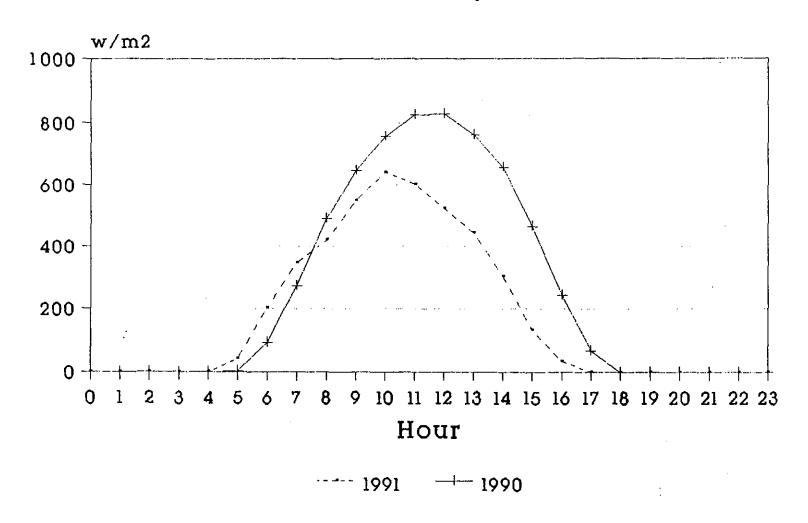
Average UV in Kuwait
Period 3 Mar to 13 Apr 1990 & 1991





The daily mean particulates less than 10 microns recorded at the 5 sites in the residential areas of Kuwait in the period May 1 to July 10, 1991.

Average Solar Radiation in Kuwait
Period 3 Mar to 13 Apr 1990 & 1991



Correlation between the measurement taken by the portable and the standard PM10 was highly significant (.949**). The levels measured by the portable are particularly lower than the fixed sampler. The ratio was 74.4%. The scatter between the mean daily values taken by the two samplers is shown in Fig. (6). Another study is in progressing measuring the levels at three sites simultaneously and better correlation will be computed.

No data about the content of the particulates will be discussed at this stage. Further investigation using the same samples have been designed. In addition to the comparison between the particulates and the Fixed AM10, the indoor out door level will be investigated in a number of houses, hospitals and schools. Another study will look into the day and night loads. A third study will use acetate filter to examine for the soot. A short study will be made in the next fall to the north and south of the Burgan oil field to try to locate the site of the impact of the plume, after the fires are extinguished to a large extent, and the plume is likely to be much lower.

Daily mean PM10 loads May - July 1991.

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Da Le	Mean	S.d.	Mean	S.d.	Mean	S.d.
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IMPACT OF OIL WELL FIRES ON AIR QUALITY IN THE URBAN AREAS OF KUWAIT

II. POLLUTION BY NOXIOUS GASES

Team Coordinators
Dr. Mostafa El Desouky
Dr. Mahmood Y. Abdulraheem

Members (Alphabetically):

- Ms. Sabah Abdulwahhab
- Mr. Ahmed Abu Ghaseba
- Ms. Lamya Al-Ansari
- Mr. Fa hiu Akroof
- Mr. Yosri Melik
- Mr. Mostafa Salem
- Ms. Fayza Thuwainy

Environment Protection Department
Ministry of Public Health
Kuwait

August 1991

IMPACT OF OIL WELL FIRES ON AIR QUALITY IN THE URBAN AREAS OF KUWAIT

II. POLLUTION BY NOXIOUS GASES

BACKGROUND:

Before the iraqi troops were forced to pull out from Kuwait, they set fire to all the oil wells, gathering centres and tank farms. The quantity of oil that would have been ignited were estimated by Small (1991) to be around 13 million barrels in the first week based on a storing capacity of 10 days. The real quantity burnt in the first week following the setting of fire is probably much lower than that estimated by Small (1991) since the Iraqis shipped some of the refined products to Iraq. Most of the crude in the Ahmadi tank farm was discharged into the sea exchanging one pollution crime with another. Some of the crude was also pumped in a trench dug along the Saudi/Kuwaiti border to deter the invasion of the allied troops.

The estimates of the quantity of crude burnt daily differed as much as the workers that made them. Small (1991) suggested 1.6 million barrels based on the quantity exported before the war. Schumann (1991) reported that estimates are very uncertain. may vary between 100 thousand to one million tons/day and that the weak convection seen from space suggest amounts less than 220 thousand barrels/day. MEPA (1991) estimates the quantity of oil burnt at 5 million barrels together with 70 million m^3 of associated gas daily from 516 oil wells. The same estimate was made by US Interagency Air Monitoring Team. Another estimate by the Research Institute, King Fahad University in Saudi Arabia, based on productivity puts the burnt crude at 2.4 million barrels and the gas at 34 million m³. Based on data collected from aircraft, UK Meteorological Office (1991) estimated the amount of crude burnt to 4.1 million barrels/day; however an error of 40% was anticipated and a range of 2.5-5.7 million barrels/day was estimated. The official figures announced by the Ministry of Oil in Kuwait in April 1991 is 6 million barrels/day.

The rate of extinguishing the fire is collecting momentum and by now the number of wells that were successfully capped is about 240. Most of the effort is directed to the Burgan field owing to its vicinity to the urban area, the large number of wells on fire an the relatively high quality of the crude extracted from the fields.

The quantity of oil is reflected on the amount of pollutants being emitted. However estimates as regards the rate of emission is not agreed upon by different workers. The percentage of the soot or smoke being generated varied between 5-15% (Schumann, 1991). Small (1991) based on laboratory finding, estimated the smoke to range from 20-98 G/Kg with an average value of 73 ± 25 G/Kg of crude, with 69% elemental carbon. Mathallad et al (1991) from measurement of smoke collected on filters and CO₂ concentration of aeroplane samples estimated the smoke to be 110 G/Kg of crude. However, this is an upper boundary.

The amount of the sulphur in the crude was also estimated to vary between 2.1-4.1% on the mean. Some of the fields, namely Wafra, Managish and Um Qader are believed to have more sulphur. The estimate of NOx also varies within an order of magnitude. Based on a temp of ignition of 3000° F, the expected quantity of NOx is much higher (30,000 tons/day) than that suggested by the UK Meteorological Office (1991) of 1,400 tons or by Browning et al (1991) (650 tons). The Research Institute, King Fahad University, based on 2.5 million barrels of crude burnt daily estimated that 20,000 tons of SO₂, 1500 tons of particulates, 250 tons of CO and 500 tons of NOx are emitted to the atmosphere daily.

The height of the plume is rather critical. Small (1991) expected the plume to rise to 1-3 Km for desert conditions from large pools of oil. From individual wells a height of 700 meter was suggested. However, small (1991) stated that higher and lower heights were probable. Other estimates vary from 1,000 to 5,000 m. Aireal surveys showed a very complex picture. The height of the

plume was different from time to time. At times a single plume was seen and at others a number of distinct plumes with clean air in between was reported (Hobbs, 1991). The effect of the heat prevailing in the summer months and the probability of lofting the plume to the stratosphere was discussed by various workers. However the observations do not give support to this hypothesis.

The public health impacts of the well fires is rather complicated. The short term impacts will depend on the level of the pollutants and the length of the exposure. The particulates resulting from the well fires mostly soot have different metallic composition than that resulting from the burning of coal. The contribution of the soot to the particulates load in Kuwait is adding to the complexity of the picture. The level of pollution will be markedly influenced by the weather conditions. The direction of the wind near the ground will determine the site of the i pact. The presence of the oilfields to north and south of the urban area, and the distance of the major fields are rather critical. The height reached by the plume plays a major role in determining the site of the impact.

The colour of the fire coming from the wells was sometimes white and this was thought to be due to the brine being mixed up with the oil jetting from the wells. However, some workers found no water vapour in the plume (Hobbs, 1991). The white colour may be resulting from the atomisation of the oil itself and not due to the water vapour.

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Of the different weather phenomena and based on the previous experience from air pollution episodes. Stagnation is probably the most critical (French, 1989). In Kuwait, the radiation ground based thermal inversion is very common (El Desouky & Abdelwahhab, 1985). The top of the layer is 180-220m from the ground. Elevated inversions are also quite common. With the first Km, the percentage of the days in which an inversion in the period of April-September as reported by NOAA (1991) varied between 30 and 40%. Between 1 and

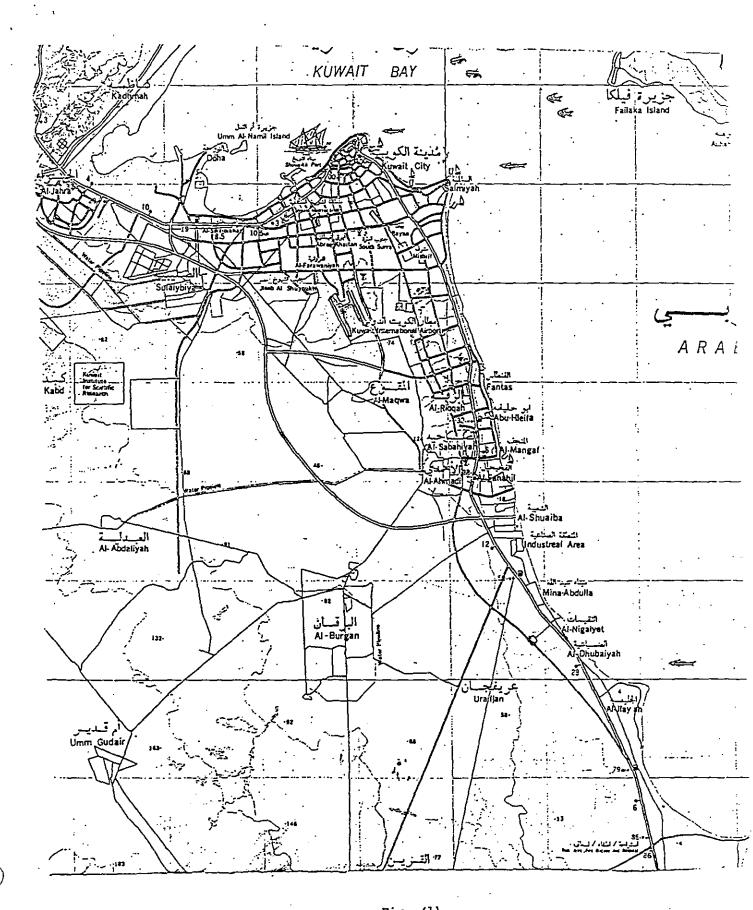


Fig. (1)

The location of the existing air quality monitoring stations and the stations that are decided to be installed next fall.

2 km, the percentage varied between 10 to 15% based on the finding in the period 1988-1990. More detailed information about the height of inversion up to 1500m reported by the Meteorology Department in Kuwait in the 5 years is shown in Table (1).

Previous observations about wind direction are not very useful. The heat islands generated by the intense burning of the oilfields is disturbing the pattern to a great extent. The wind direction at the ground level was seen to blow from the periphery of the fields towards their centres. The plumes from the individual wells were seen to rise up, turn towards the centre of the field and form a single huge plume, before rising up again (Hobbs, 1991). This has a great implication for the prediction of the level of pollution expected in the urban areas based on weather forecasting from synoptic data.

Air quality monitoring in Kuwait started since 1970. Grab samples for the gases and dust fall buckets were used at that time. Three monitoring stations were commissioned in 1985. The sites (Fig. 1) were chosen to look into the pollution by traffic, industry an power plants. Total suspended particulates were sampled and reported to the GEMS since 1980. Apart from the hydrocarbons (methane and non-methane) and the TSP, the level of the noxious gases were generally less than the AAQS adopted in Kuwait. The caregation of the industrial areas and high stacks installed in the power plants helped in the control of the air pollution. Traffic was more difficult to handle and just before the invasion by the Iraqis, the Environment Protection Council was discussing an ambitious plan to control pollution from traffic. The plan included the use of unleaded gasoline, catalytic convertors and setting a programme of inspection and maintenance of the vehicle fleet.

MATERIAL & METHODS

The present report will discuss the finding of the Air Quality Monitoring Stations at both Mansoria and Reqa. The first

represent the main urban area, the other is situated in the coastal area extending to the east of the Burgan oilfield. The stations have Horiba equipment which take samples every 5 minutes. The data are stored on cassettes that are picked up every 2-3 days and read by the mainframe at the EPD.

The parameters measured are H₂S, SO₂, Total Sulphur, NO, NO₂, NOX, CO, O₃ and methane and non-methane hydrocarbons. The monitors are calibrated automatically every 25 hours and manual checks are done every 2 weeks and whenever the monitoring is interrupted. The two stations are provided with meteorology sensors for temp, RH, wind speed and direction. The Mansoria station has in addition to the standard sensors, total solar and UV measuring devices.

Air pollution monitoring was stopped on the 2nd of August 1991. This included the AQS and the particulates. The Mansoria station was started up by the beginning of April 1991 after the power was made available. The Reqa was started almost one month later. At Reqa, the voltage was not stable and this caused many problems. The third station (Rabia) was cannabalised and used to provide spare parts to keep the other 2 stations running. With international aid, plans were put to fix the Rabia Station and install 2 more with the help from the Norwegian NILU at Jahra and Mina Al-Zoor (Fig.1). The stations are expected to be running by the middle of September.

RESULTS:

The mean and maximum level of the principal pollutants measured at both Mansoria and Requ in the period April to July 1991 is shown in Table (2). Also shown in the Table are similar parameters for the same months in 1990. The most obvious finding is the higher mean level of hydrocarbons in 1991, particularly the non-methane, in Mansoria. The mean NCH4 for 1991 in Requ was slightly higher than the corresponding figure for 1990. For the methane, the level of Mansoria was slightly higher in 1991. But the

maximum was about triple that seen for 1990. Though the means of CH4 in Reqa was comparable the maximum was much higher in 1991. This is rather interesting and is probably due to the emission of me than and non-me than from the extensive crude pools resulting from the oozing wells that were exposed and were not set on fire. The other obvious finding was the much lower mean CO in 1991 compared to last year. The mean for Mansoria (.648 ppm) was about half that for 1990. A similar picture was seen for Reqa. The maximum values however reported in 1991 for Mansoria (38.1 ppm, or Reqa (44.8 ppm) were appreciably higher. These are peak 5 minute value reported in the whole period.

The levels of SO₂ in 1991 in Mansoria (2.3 ppb) and Reqa (3 ppb) were within the detection limit of the equipment and are slightly higher than that reported for 1990 (1.8 and 1.4 ppm) for the two stations. NO was lower in 1991 in Mansoria and higher in Reqa. With NO₂ it was the other way round. NOx showed the same picture.

Hydrocarbons:

The mean and maximum CH4, NCH4 in 1991 in the four months for which the data were available is shown in Table (3). Higher values were seen for CH4 in April and May, and f r NCH4 in June and July at Mansoria. The maximum behaved in the same manner. The Mansoria generally had much higher means than the Requand this was seen for April and May. No data was available from Requant for June or July due to technical problems resulting from power failure.

Correlation between the CH4 and NCH4 in the period of the study in Mansoria was positive and significant (r = .488). With the Reqa, it was much lower. The sources of CH4 are generally considered natural. However this is not always the case and in Kuwait the geogenic contribution should be considered. The positive correlation shows that the variability of the two compounds are moving in the same direction and that the factors that are

influencing the correlation of the methane may be affecting the non-methane in the same direction.

The trend lines for the period of the study in the Mansoria Station where the data were more continuous, is shown in Fig. (2). It could be seen that there is a slight drop in the level of the CH4 and NCH4. It is interesting to note that the slope for the NCH4 (-.0156 ppm/month) was smaller than that seen for CH4 (.0335). It seems that the level of CH4 and NCH4 is coming down. The level in July is lower than that in April. The authorities are doing all they can to extinguish the fires, cap the wells and pump the crude from the pools. The drop may be due to this but the time is too short to draw any conclusion and the meteorology may be playing a more significant role.

The overall mean for both the total hydrocarbons and for NCH4 in Mansoria according to the time of the day is shown in Fig. (3 A & B). The night time is characterized by a marked drop in the anthropogenic activities and hence for the man made sources of the hydrocarbons. Before the present crisis, the major sources of NCH4 were traffic (76.2%) and industry (20%). Both are expected to drop at the night times. The highest mean CH4 was seen between 6-8 AM (2.8 ppm) and the lowest (2.6 ppm) at 3.5 AM. No significant difference was found between the means calculated for any periods (F With the total hydrocarbons, the lowest mean was seen between 3-5 AM and the highest was between 15-17 followed by the 18-20 hours. The mean for the 18-20 was significantly higher than the lowest mean (3-5). The mean for 15-17 was significantly higher. than the lowest 3 means. No significant difference was seen between the means for all the other times. A similar picture was seen for the NCH4 (Fig. 3B). The highest overall mean was seen at 15-17 hours (2.3 ppm) followed by that between 18-20 hours. Both were significantly higher than the lowest 4 means seen at 3-5, 0-2, 21-23, and 6-8. The mean for the period 15-17 hours was also significantly higher than that measured between 9-11 AM. With the methane, no significant difference was seen between any of the means

and the plot was not computed.

In Reqa, though the data was only available for April and May, the means for NCH4 and CH4 according to the time of the day is shown in Fig. (4 A & B). With NCH4 the highest mean was seen at 3-5 (.869 ppm) followed by that for 6-8 AM (.720 ppm). The lowest means were for 12-14 (.290) and 15-17 (.376 ppm). The difference between the means are tested for and the results are shown in the figure. The means for all the periods are higher than the two lowest means. The mean for the 3-5 AM was also significantly higher than almost all the other means except that for the 6-8 AM

With methane (Fig.4B), the means for 18-20 (1.719 ppm) and 3-5 AM (1.718 ppm) were slightly higher than the lowest two means seen at 12-14 and 15-17. The total hydrocarbons was similar to that seen for the NCH4, with the highest mean for 3-5 AM (2.587 ppm) and the lowest (1.897 ppm) at 12-14 hours. It could be concluded that with the exception of the level of CH4 in Mansoria, the level of hydrocarbons shows significant variability with the time of the day. Factors including the emission and dissipation of the hydrocarbons should be investigated.

The effect of wind speed and wind direction is rather critical. Data for the wind direction may not be very reliable owing to the presence of the heat islands and this has been discussed. The effect of the land and sea breeze and the representation of the wind direction measured inside an urban area should be considered. The data for both the CH4 and NCH4 for the 4 months at Mansoria are shown in Fig. (5 A & B).

With NCH₄, the mean reported for the winds blowing from the SE (3.130 ppm) was significantly higher than the means with any direction. This is the direction of the Burgan field. High mean values were also seen with SW (2.411 ppm) and S (2.380 ppm). The lowest means were seen with the northerly winds (1.208 ppm) and NE winds (1.208 ppm).

With CH4, the highest mean was found with the SE (3.364 pm) followed by the S (3.087 ppm) and SW (3.016 ppm). The lowest mean was found for the NE (2.516 ppm) and W (2.559 ppm). The mean with the SE was significantly higher than the lowest 5 means. The means in the Se and SW were significantly higher than that seen with the W and NW.

With Reqa, the mean NCH4 according to the wind direction is shown in Fig. (6A). Higher means were seen with the SW (1.137) and S (1.022 ppm). The lowest values were seen with the NE (.274 ppm) and N (.279 ppm). The two were significantly lower than the means with all the other directions. The S and SW are the directions from which the wind will be blowing from Burgan oilfield. The NE is the direction of the Gulf.

With CH4 (Fig.6B), the SW (1.923 ppm) and SE (1.773) had the highest mean values. It is interesting to note that the westerly winds had the lower means (1.163 ppm). Though the level were significantly higher with the S and SW, the difference in real values was quite small and did not exceed 0.3 ppm.

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Different wind speeds are found at different wind directions. Moreover, the dissipating effect of the fresh wind should be considered. The mean NCH4 at Mansoria according to the wind speed is shown in Fig. (7A). A higher mean was seen with winds 4-5 m/s(2.343 ppm) and 5-6 m/s (2.236 ppm). This was higher than the mean seen for the stronger or weaker winds. The lowest mean was found with less than 1 m/s winds (1.854 ppm). The level of significance between the means is shown in the Fig. (8A). With CH4 the mean with winds 2-3 m/s (2.818 ppm) or 1-2 m/s (2.687 ppm) was significantly higher than the mean seen with winds 5-6 m/s which had the lowest (2.395 ppm) (Fig. 8B).

With Requ the highest mean value of NCH4 was seen with very calm winds (1.434 ppm) followed by 1-2 m/s winds (1.285 ppm). The lowest was that seen with the winds 6 m/s (.075 ppm) or 5 m/s (.156

ppm). The expected pattern of a lower mean with stronger wind due to dissipation is seen. The means that were significantly different are shown in the Fig. (10A). The finding should be taken cautiously since the wind direction at the ground is strongly influenced by the burning oilfields. With CH4 the highest mean was seen with winds 1-2 m/s (1.893 ppm) followed by winds 2-3 m/s (1.787 ppm). Appreciably lower means were seen with winds 5-6 m/s or 6 m/s and over. The cases in which the means were significantly different are shown in Fig. (10B).

Carbon Monoxide:

The other pollutant that behaved in a distinct manner is the Carbon Monoxide (CO). The amount of the CO generated by the fires was estimated to be 250 tons daily (Research Institute, King Fahad University, 1991). The monthly mean CO at both Mansoria and Reqa in 1991 and 1990 was shown in Table (2). The appreciably lower mean CO in 1991 is clear. The principal source for CO in 1990 was traffic. The much lower traffic load in the period covered by the study is clear. Though NO counts are available for this time the absence of the morning rush hour traffic is quite noticeable.

The monthly mean and the maximum reported for the individual sites are shown in Table (4). Traffic load is building up and the effect could be seen from the rise in the mean CO for the 4 months in both Mansoria and Reqa, though a lower mean was seen for Mansoria during May (.253 ppm) compared to that found for either April (.643 ppm) or June (1.0 ppm). A more uniform rise was seen for Reqa. The high level of CO in July compared to April is quite clear and the difference was significant. The rise in the mean CO in July could be attributed to the traffic since a large number of oil well fires have been extinguished since April.

It is interesting to note that the well fires may be a significant source of CO. The incomplete combustion of the oil is quite clear from the droplets that fly around and the black smokes

seen rising from a large number of wells. It should be mentioned that generally the mean CO in the summer months particularly July is lower than that seen for the other seasons and this was reported from the previous findings in Kuwait (El Desouky et al, 1988). The trend line calculated for both Mansoria and Requipment of the 4 month period is shown in Fig. (11A & B). The rising trend could be seen.

The hourly mean values for Mansoria is shown in Fig. (12A). The highest mean was seen in the period 18-20 (1.344 ppm) followed by 21-23 (.966 ppm). The lowest mean was seen at 3-5 AM (.221 ppm). The means that differed significantly are shown in the figure.. With Reqa (Fig. 12B), a similar picture was seen. The highest mean was also at 18-20 (1.223 ppm) followed by the 21-23 (.983 ppm) and the lowest between 3-5 (.324 ppm). The means that were significantly different are shown in the figure. The virtual absence of any morning peak in the period 6-8 AM was seen for both the stations. The afternoon peak 12-14 was not conspicuous previously (El Desouky et al, 1988) and with the finding in the last 4 months it was persistently lower than the 3 hour periods before or after. The hourly mean values in the period 18-24 hours in the two stations in the 4 months were quite high. This is the time of the evening and night peak for the CO observed in Kuwait in the normal situation.

The mean CO computed from the wind direction at Mansoria and Reqa is shown in Fig. (13A & B). Significantly higher values were seen with the S (1.517 ppm) and SW (1.419 ppm). These are the directions associated with high mean values previously and were explained by the presence of a filling station and the highway network in this direction (El Desouky et al, 1988). The lowest mean was found with the NW wind (.420 ppm) and the W (.626 ppm). These are the prevailing wind directions and are known to be blowing from the Kuwait City with the high traffic load. The level of significance between the means is shown in the figure.

With Reqa (Fig.13B), the wind directions that were having

higher mean CO were the S (1.806 ppm), SE (1.097 ppm) followed by the SW (.978 ppm). The lowest means were seen with the N and NE (.431 ppm) and the NW (.433 ppm). It is interesting to note that the directions that were associated with higher CO were not those blowing from the Burgan field in the vicinity of the station. However the station is a few Km from the shore and the wind regime recorded in the last four months has not been the same as that seen in the last years.

The relation with the wind speed showed the normal picture of the high mean values with calm winds. The dissipating effects of the winds is clear. This was seen with the 2 stations (Fig. 14A & B). The difference in the wind speed with the different wind directions should be however taken into consideration.

SO2, NOx:

The sulphur dioxide is probably the most serious of the pollutants resulting from the oil well fire. The sulphur content of the Kuwaiti crude is quite high. The form in which sulphur is found in the crude is usually H2S and some organic sulphur compounds. The monitors used by the stations measure the two gases and the sum is the total sulphur. Nitrogen oxides measured by the stations are the NO, NO2 and the sum NOx. NO is generated by the heat and is later oxidised to NO2. Near the sources more NO is found being the primary compound. The NO2 is more of a health hazard than the NO. Both the SO2 and NO2 are used for the Health Alert System in Kuwait.

Unlike CO, both the SO₂ and NOx have significant sources other than the oil wells on fire. The power plants at Doha started production partially since April and more and more units are producing electricity. The Al-Zoor power plant was not destroyed and was producing the normal load though the power lines were disconnected. Both use crude oil with high sulphur content and are also producing a substantial amount of NO and NO₂. The mean SO₂, NO and NO₂ seen at the two stations in the last 4 months was summarised

in Table (5). Shown in the Table is also the finding in the period April-July 1990. H₂S was not included, the level was quite low in general. The major source before the oil well fires was the sewers and this was seen in the Rabia Station which is not functioning now. The sewage treatment plants are not working as the Iraqis destroyed them.

The hourly mean and maximum for the SO2, NO, and NO2 in the individual months is shown in Table (5). The monthly means for SO2 were quite similar with a slightly higher mean in April at Mansoria (3.0 ppb) and for May at Reqa (3.1 ppb). These are well within the limit of detection of the equipment. The maximum was also low. The means for NO and NO2 were higher for Reqa compared to Mansoria and this was seen for the 4 months. The maximum NO2 was quite high in July (771 ppb). It is interesting to note that the proportion of NO2 was higher than NO in Mansoria, whereas with Reqa a larger proportion of the NOx was in the form of NO; also the maximum NO in July exceeded the level reported at any time in Reqa or Mansoria (1108 ppb).

The trend in the four months for both the SO_2 , NO and NO_2 is shown in Fig. (15A & B). A slight insignificant positive trend could be seen. The level of either SO_2 or NO_2 is not rising in the period covered by the investigation.

The distribution of the SO₂ and NO₂ according to the hour of the day is shown in Table (6). Very little variability was seen in SO₂ in the different times of the day and this was seen for both Mansoria and Reqa. The sources of SO₂, wheather the oil well fires or the power plants, do not differ with the hour of the day. The contribution of industry to the SO₂ load is not substantial in the time being and most of the measurements are within the detectability of the equipment.

With the NO, at Mansoria high mean values were seen in the period 18-20 and 21-23 (22 ppb) and the lowest mean was seen

between 3-5 (1.3 ppb). With NO2, the highest means were also seen at 18 (24.8 ppb) and 21 hours (18.2 ppb). With Reqa, a much higher NO was seen at 18 (73.6 ppb) and 21 hours (67.7 ppb). NO2 showed a similar picture. It could be concluded that the level of both NO and NO2 was higher in the late afternoons and before midnight and this was seen for the 2 stations. The picture was similar to that seen for CO and the contribution of traffic though quite small may explain a part of the fluctuation in the mean NO and NO2. The difference in the proportion of NO and NO2 in the different hours of the day is expected and the complex interaction with ozone and the sunlight should be considered. The role of the maeterological parameters is probably much more important than the fluctuations in the source strength.

The mean SO₂ and NO_x according to the wind direction is shown in Table (7). A higher level of SO₂ was seen with winds blowing from the SE (4.2 ppb) in Mansoria and for SW (5 ppb) and S (6.1 ppb) in case of Reqa. No industrial sources of SO₂ are found in the vicinity of Mansoria. However, in April the garbage was not collected by the Municipality and some was burnt inside the residential areas. The fluctuation in the level of SO₂ was much higher in Reqa compared to that in Mansoria.

With the NO the fluctuation was appreciably higher with the Reqa. Much higher levels were seen with the NW (94.9 ppb) and w winds (76.5 ppb). With Mansoria a relatively higher means were seen with S (34.4 ppb) and SW (37 ppb) winds. With NO2 the levels at Mansoria were parallel to that of the NO. The maximum was found with the S winds (30.6 ppb) and SW (23.6 ppb). With Reqa a different picture was seen. A relatively higher levels were seen with the S (33.0 ppb) and SW (26.6 ppb). The general picture of a relatively higher NO in Reqa and higher NO2 in Mansoria was preserved except with the SE and SW winds when the NO2 was higher. It is interesting to note that to the NW of Reqa is the Burgan field. The small distance between the station and the major field on fire is likely to cause the relative high level of NOx seen.

Though no similar rise was seen for the SO2, only with the winds from the south were both the NOx and SO2 high.

The relation with the wind speed is shown in Table (8). Very little fluctuation was seen with the SO₂ and this was seen for the two station. With NO, the expected picture of the higher mean values with the calm wind and a gradual drop in the means with stronger winds was seen. This was seen with the NO₂ though the gradual drop in the means was not as steep as that seen with the NO. A much higher level of NO was seen at Requ with winds 6+ m/s (100.7 ppb). The probable explanation is the difference in the wind speed with wind direction and probably this reflects with winds coming from a direction with high pollution load.

Solar and U.V.

Total solar and UV are mesured in the Mansoria monitoring station. The effects of the plume will be detected in the drop in the intensity of the solar radiation. The effect of the plume will be independent of the height it reaches since it will obstruct the sunlight regardless of the height. It was however stronger on the days that the plume was moving in the direction of the monitoring station and with the density of the plume. The density is a matter of the wind speed which will determine its capability to disspite the plume. Fig. (16A & B) shows the intensity of solar radiation and the total UV in Watt/ m^2 at Mansoria with the wind speed. The highest mean (242.6 w/ m^2) was seen with the 4-5 m/s winds. This was significantly higher than that seen with winds 3-4, 2-3 or less than 2 m/s. The means with wind 3-4 (206.2 w/ m^2) and 2-3 m/s (183.6 w/ m^2) were also higher than that with calm winds (104.8 w/ m^2).

With the UV a similar picture was seen. The highest mean (7.8 w/m^2) was seen with the strongest wind. A much lower level (2.3 w/m^2) was seen with calm winds. The effect of the wind speed seem to be through ventilation of the plume, and the tiny oil droplets that escape being fired with the main plume. It is worth

noting that the days in which the solar and UV readings were quite low, the level of SO_2 , NO and NO_2 were not appreciably higher than the other days. The calm winds will help the plume rise and this seems to play a critical role in determining the level of the pollutants detected at the air quality monitoring stations at Mansoria and Reqa.

CONCLUSION:

The present study is preliminary in nature. There are a lot of uncertainties. The picture of air pollution problem in Kuwait is far from being clear. The level of SO₂ and NO, NO₂ is very close to what was measured before the air pollution episode to which Kuwait is passing through. The levels of CO was lower than that seen for the same period in 1990. The traffic is building up and we expect the levels to rise soon. The levels of hydrocarbons were quite high. These were high before but the pools of oil in the oilfields are probably causing that rise.

The Ministry of Oil is doing all it can to extinguish the fires and pumping the oil from the ground pools. The plume is rising to relatively great heights at the time being and this may explain the relatively low levels of sulphur and nitrogen oxides. The data are available only for 2 sites and very little information is availiable from the residential areas to the west of the country or the south. Two fixed stations are commissioned at the time being and are planned to be installed in the areas from which the information is valuable. The Norwegian NILU is helping in this respect.

A mobile lab was made available to the EPD by the courtesy of the German Government. The lab was used for the intercalibration of the existing stations. The findings are quite comparable except for 03 where the measurement by the German lab was higher. This was also reported previously from comparing the finding with the French team. The level at Al-Zoor to the south are appreciably higher than those reported in the town. The data for the Al-Zoor and Jahra which is next on the plan will be used to advise the Norwegian NILU as regards the levels expected on the sites the new stations will be installed.

We hope that the existing air pollution episode would not result in any health problem but we should be prepared and with the help and advise we are getting from the international community we are sure the problem will be solved.

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The problem of heat island is causing due concern as the prediction of the wind direction on the ground level is not possible. The NOAA was kind enough to help install and run 15 met stations all over the State covering the oil fields and urban area. The data from the met stations and the air quality monitoring stations will be used as an imput to the Health Alert System being developed at the time being.

The expection as regards the future are guarded. The wind direction changes in fall and more southerly winds are expected. More calm winds are also anticipated and this together with the rate at which the fires are being extinguished will probably expose the urban area to the north of the Burgan field to higher levels of SO₂, NOx and the other pollutants resulting from the oil well fires.

Table (1)

Mean number of cases of Inversions according to the month

Kuwait International Airport 1973-1977 Time 2300 G.M.T.

24 25			Air Layer						
Month		300m-600m	600m-900m	900m-1200m					
Jan.	22 .6	5.6	5.0	4.0	1.8				
Feb .	23.0	6.0	3.4	3.8	2.2				
Mar.	27.0	6.2	2 .4	1.8	1 .4				
Apr.	23.8	5.8	0.8	0.8	0.6				
May	26.25	7.0	1.5	0.4	0.5				
Jun.	26.4	6.0	0.4	0.2	0.2				
Jul.	27.4	2.6	0.2	0.2	0.4				
Aug.	30.0	4.6	0.2	0.4	0.6				
Sep.	28.8	6.6	8.0	-	0.2				
Oct.	27.6	8.4	1.8	1.0	0.6				
Nov.	27.0	8.2	2.8	2.0	1.2				
Dec.	24.6	10.0	5.8	3 .8	2.2				

Table (2)

The overall mean SO2, nitrogen oxides, and hydrocarbons measured at the 2 AQMS in the period April-July in 1990 and 1991.

			Mar	soria			Req	 a	
Pollu	tant		1990	199	1	199	0	199	
		Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.
so ₂	ррЪ	1 .8	52.0	2 .3	38.0	1.4	28.0	3.0	38.0
NO-	ppb	15.0	1011.0	8.2	920.0	17.6	1436.0	60.2	1108.0
NO ₂	ppm	23.8	370.0	13.4	496.0	24.2	456.0	20.5	771.0
NOx	ppb	38.8	1201.0	21.6	938.0	41.8	1470.0	80 .8	1187.0
NCH4	ppm	0.449	12.8	2.030	23.4	0.417	22.2	0.619	20.0
CH ₄	ppm	1.767	6.0	2.658	19.8	1.737	4.7	1.669	10.8
со	ppm	1.022	22.0	0.648	33.1	0.982	24.8	0.592	44.8

Table (3)

The mean and maximum Hydrocarbons (NCH4 and CH4)

measured at the 2 AQMS in the period April-July 1991.

M = A1.			Ma ns	orta	Reqa		
Month			Mea n	Max.	Mean	Max.	
April	NCH4	ppm	1.742	13.4	0.781	6.2	
	СН4	Ħ	4.596	19.4	1.845	3.8	
May	NCH4	ti	1.176	10.6	0.606	20.0	
	CH4	H	5.743	19.8	1.875	10.9	
June	NCH4	11	2.254	23.0			
	CH ₄	u	1.797	7.8	**************************************		
July	NCH ₄	11	2,226	9.0			
	СН4	11	1.729	3 . 7			

Table (4)

The mean together with the maximum Carbon Monoxide (ppm) at the 2 AQMS in the different months.

Month	Ma	nsoria	Req	a
	Mean	Max.	Mean	Max.
Apr.	.643	7 .3	.492	32.4
May	.253	7.9	.615	30.6
Jun.	1,000	33.1	.699	44.8
Jul.	.655	13.3	. 5786	27.6

Table (5)

The hourly mean and maximum of SO₂, NO, and NO₂ (ppb) at the 2 AQMS in the different months.

	Mansorta					*	Reqa					
Month	S(02	ì	40	NO	02	SO	2	NO.	0	1	102
· ·	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max .	Mean	Max.	Mea n	Max.
Apr.	3.016	38.0	8.0	341.0	12.2	490.0	1.603	22.0	39.1	1006.0	19.7	167.0
May	2.132	20.0	5.6	368.0	12.5	74.0	3.116	15.0	49.0	1094.0	21.9	186.0
Jun.	2.108	17.0	17.0	420.0	16.2	287.0	2.200	22.0	16.1	737.0	16.7	317.0
Jul.	1.945	2.0	3 .8	571.0	12.9	211.0	2.620	8.0	165.3	1108.0	24 .6	771 .0

Table (6) The mean level of SO2, NO, NO2, and NOx (ppb) measured at the 2 AQMS in the period April-July 1991.

Tr. 4		Manso	ria			Req	a	
Time	50 ₂	NO	NO ₂	NOx	so ₂	NO	NO ₂	NOx
0-	2.3	7.0	9.0	16.1	3.0	58.3	20.0	78.4
3	2.2	1.3	5.2	6.6	3.5	55.9	15.7	71.6
6-	2.1	2.9	10.5	13.4	3.0	53.7	17.0	70.7
9-	2.3	3.7	15.2	18.9	3.1	62.7	17.2	79.3
12-	2.3	2.1	10.8	12.9	2.7	54.7	13.0	68.1
15-	2.3	4.7	13.5	18.3	2.7	51.6	16.5	68.3
18-	2.5	22.2	24.8	47.0	2.8	73.6	34.9	112.7
21-	2.5	22.1	18.2	40.0	3.0	67.7	30.7	98.0

Table (7) The mean level (ppm) of SO_2 , NO, NO_2 , and NOx measured at the 2 AQMS in the period April-July 1991 according to the wind direction.

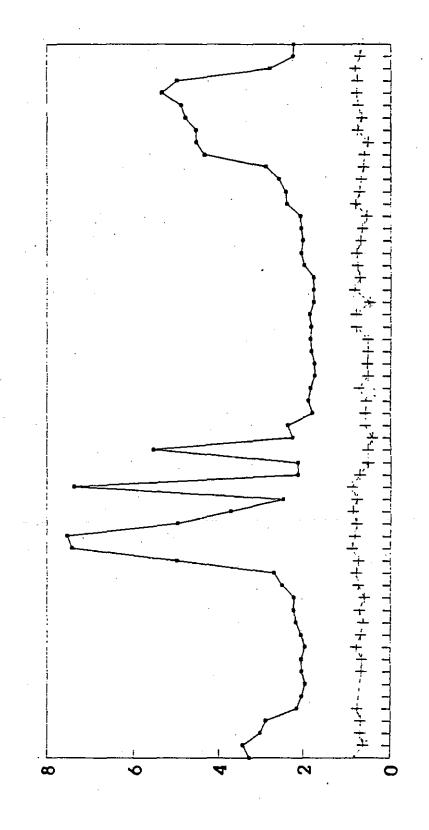
Wind Direction		Mansor	ia			Reqa		
	so ₂	NO	NO ₂	NOx	so ₂	NO	NO ₂	NOx
N	2 .0	5.3	12.2	17.4	2.7	43.1	20.0	62.9
NE	2.5	5.5	13.9	19.4	2.3	10.8	15.5	26.2
E	3.2	12.1	19.3	31.5	2.2	26.5	18.6	45.2
SE	4.2	9.6	23.2	32.8	3.9	21.3	25.6	47.1
S	3.1	34.4	30.6	65.1	6.1	47.5	33.0	80.7
· SW	2.9	37.0	23.6	60.7	5.0	20.0	26.6	46.6
W	2.0	10.0	12.2	22.2	2.6	76.5	19.5	95.9
NW .	2.0	2.0	9.8	11.8	3.3	94.9	20.4	115.7

Table (8)

The mean level (ppm) of SO2, NO, NO2, and NOx measured at the 2 AQMS in the period April-July 1991 according to the wind speed.

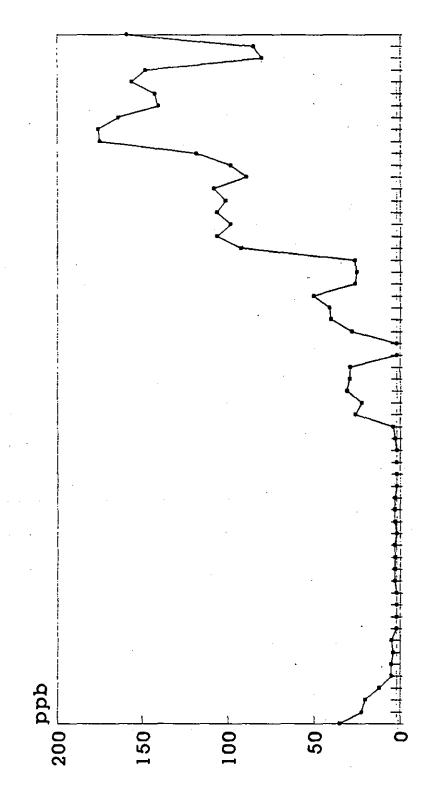
Wind '		Mansori	a	* * * * * * * * * * * * * * * * * * *		Reqa		
Speed (m/s)	so ₂	NO	NO ₂	NOx	SO ₂	NO	NO2	NOx
<1	2.5	31.8	27.9	79.7	2.0	98.6	40.0	138.1
1	2.4	14.6	19.4	34.0	2.4	45.2	31.1	76.1
2	2.3	2.9	12.1	15.0	3.4	33.9	22.9	56.8
3	2.3	1.3	9.1	10.5	3.5	48.8	18.6	67.5
4	2.2	1.3	8.8	10.1	2 .8	55.8	18.1	73.7
5	2.0	2.0	9.6	11.6	2.8	60.1	14.7	74.6
6+	2.0	2.3	10.0	12.4	3.3	100.7	16.7	118.0

THC MEASURED BY GERMAN LAB (3/8/1991 11:45 TO 4/8/1991 8:45)



Al-Zoor --- MANSORIA

SO2 MEASURED BY GERMAN LAB (3/8/1991 11:45 TO 4/8/1991 8:45)



Al-Zoor

-- MANSORIA

DARWIN SCIENTIFIC FOUNDATION

Kuwait Oil Fires and International Environment Considerations

Washington Conference

28 September 1991

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Washington DC

DARWIN SCIENTIFIC FOUNDATION

Kuwait Oil Fires and International Environment Considerations

Washington Conference

Presentation Abstracts

and

Speaker Biographies

EFFECTS OF THE GULF WAR ON THE ENVIRONMENTAL GEOLOGY OF THE REGION

Farouk El-Baz Center for Remote Sensing Boston University

Preparations for and conducting the Gulf War resulted in much damage to the environment of the region. Foremost among the irreparable damage are changes to the terrain due to the digging of trenches, building walls of soil, and otherwise disturbing the desert pavement in and around Kuwait. The disruption of the usually one-grain thick layer of pebbles on the desert floor exposes soil to wind action. Furthermore, changing the contours of the normally flat land increases resistance to the wind, and thereby, increases the potential of particle transport until the land is peneplained. This condition will increase the frequency and the ferocity of dust storms in the region (Fig. 1). It will also result in the formation of new sand dunes; sand drifts were observed along roads in northern Kuwait.

The second effect on the geology of the region is that of the oil spill in the Gulf water. Hundreds of miles of the western coastline of the Gulf are already covered by oil. Petroleum "mats" have settled on coral reefs and in other ways have reduced the Gulf water productivity.

The third effect is related to the damage caused by oil well fires in terms of air pollution as well as the potential damage to the petroleum reservoirs. Photographs from Landsat Thematic Mapper and the NOAA 10 and 11 spacecraft illustrate evidence for the damage to the environment and can help in monitoring environmental change in the future.

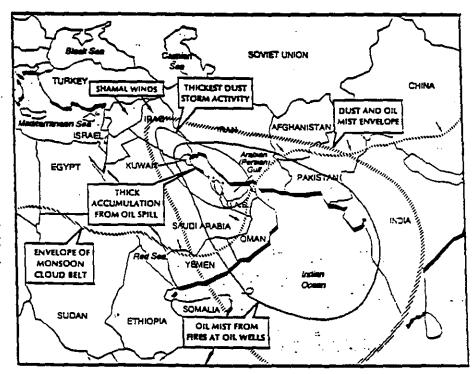


Figure 1. Schematic illustration of potential regional effects of damage to the environment due to recent Gulf War.

THE IRAQI INVASION OF KUWAIT: AN ENVIRONMENTAL CATASTROPHE

Prof. Jassim Al-Hassan Kuwait University

Kuwait, an environmentally active country, was rendered the center of the worst environmental disaster ever recorded in history through Iraqi design and execution. The Iraqis threatened to blow up the oil wells as well as other essential services, and they ended up by doing much more than that. In fact, they used the environment as a weapon of mass destruction. The invaders blew up oil installations, laid down and diverted oil pipe lines to dump oil into the Gulf, filled trenches with oil to prevent allied forces from landing, laid down mines on the coast and in the desert, and left huge amounts of ammunition everywhere in Kuwait, thus imposing an instant hazard to human life, indeed an unusual form of pollution. The Iraqi military activities in the desert led to the establishment of a huge network of trenches and bunkers in a land whose top soil is delicate and unstable, thus causing tremendous amounts of sand drifts due to the prevailing winds. The drifting sand buried large areas of trenches, bunkers, mines, ammunition dumps, and even oil lakes. The land, sea, and air pollution resulting from the Iraqi occupation imposed and will continue to impose a constant threat to the environment for many years to come. With very little chemistry done on the nature of the emitted organic and inorganic pollutants from the oil well fires or the oil lakes, it is unsafe to speculate on or minimize the effect of these organic and inorganic pollutants on human and animal health and on marine and desert ecology.

As there is a complex and unprecedented environmental situation in Kuwait, a concerted and integrated international effort involving all related fields of science is needed in order to understand the nature of the Kuwaiti environmental catastrophe and to recommend solutions to the problem.

SOME RESULTS OF ARAC'S EFFORTS TO ESTIMATE THE AIR POLLUTION IMPACTS OF THE FIRES

Thomas J. Sullivan, Ph.D. Lawrence Livermore National Laboratory

The Atmospheric Release Advisory Capability (ARAC) was originally conceived and developed at Lawrence Livermore National Laboratory as a nuclear accident emergency response service. It's purpose is to provide near real-time dose assessment calculations for accident response decision makers. Based on operationally robust three-dimensional atmospheric transport and dispersion models, extensive geophysical databases, real-time meteorological data acquisitions and a highly experienced staff, ARAC responds to U.S. events in the 30-90 minutes time frame. The present ARAC service is supported by a combination of DOE and DoD funding

Beginning with the Chernobyl accident, DOE has on several occasions requested that ARAC calculate the transport and dispersion of pollutants for accidents outside the U.S. and for non-nuclear material. One of the latest such requests was for support of the U.S. aircraft research flight programs measuring the pollutants from the Kuwait oil field fires (5/14-6/15 and 7/29-8/20) and the WMO request for assistance to the region's environmental and meteorological services. Since 14 May ARAC has been calculating the continuous smoke plume dispersion throughout a 3200 km region, using meteorological data sources from the U.S. Air Force Global Weather Central. These calculations have been directed toward optical depth estimates based on the integrated vertical (carbon soot) pollutant impact on visible light. ARAC has also reconstructed the long range pollutant transport on a hemispheric scale, again using AFGWC meteorological data, which depict the most probable far field dispersion and deposition patterns, albeit without washout or particle growth effects. These dispersion patterns provide insight as to where international scientific organizations should perform detailed measurements and analyses.

MEASUREMENTS OF AIR POLLUTION FROM THE FIRES AND THEIR IMPLICATIONS TO HEALTH

Halûk Özkaynak and John D. Spengler Harvard School of Public Health

In April a team of investigators from the Department of Environmental Health of the Harvard University School of Public Health travelled to Kuwait where they collected ambient air samples for several days in each of four locations in Kuwait (two locations in Ahmadi, Monsouria and Jahara). The field team included Thomas Dumyahn, David Gilmour (Harvard School of Public Health). Xiaowei Yan, Yukio Yanagisawa (Harvard School of Public Health), Ilhan Olmez (Massachusetts Institute of Technology), and Judith Chow (Desert Research Institute, University of Nevada) contributed to laboratory and data analyses. The purpose was to characterize the chemical and elemental composition of particulate mass as well as gases and vapors in locations representative of exposed populations. Bulk mass samples were collected using a modified HiVol with cyclone pre-separator (< 3.5 µm). These samples provided the material for animal and cell culture bioassays. Harvard impactors were adapted to collect PM_{2.5} pH samples and black carbon samples, as well as serving their primary function of obtaining PM₁₀ concentration data. Four types of passive badges were used to roughly quantify the gases and vapors present and gain a baseline understanding of the concentrations encountered.

Ambient PM_{10} concentrations over 24-hour periods ranged from 50 to 829 $\mu g/m^3$. Mass concentrations do not usually represent the signature of the oil fires alone; rather it is a combination of crustal dust re-suspended by wind and oil fire soot. PM_{10} samples were analyzed through Neutron Activation techniques to obtain a fingerprint of oil fire impacts. Black carbo analysis of quartz filters exposed on days where we have mass concentrations also enables an estimate of the plume/soot impacts.

Scandium was used as an indicator of earth crustal element. V, As, Cr, Cl, Na, Nr, and Ni appear enriched in the particle samples. Al, Fe, La, and Sm appear to be soil related. Preliminary regression analysis shows V is a significant predictor of mass concentration. The carbon is a substantial fraction of the total mass, varying between 2% and 60%. On plume impact days the contribution of carbon to mass was typically greater than 30%. The organic fraction of total carbon ranged from 25% to 90% in Ahmadi.

PM₁₉ concentrations measured in Kuwait were often found to be high due to impacts from the oil weil fires. The composition of the particle samples collected also showed organic and metal species that are of potential human health concern. Accurate estimates of acute or chronic health effects of plume impacts are not yet available. However, using historic epidemiologic data bases on air pollution and health records, it is possible to make projections of the likely morbidity and mortality effects from exposures to elevated levels of ambient particles. In particular, inferences made by utilizing mortality risk coefficients obtained from the analysis of daily mortality and pollution measurements from New York City and Los Angeles indicate that acute health risk for Kuwait and neighboring countries could be significant (e.g., excess acute mortality could reach 10% in some areas). Chronic health effects are much more difficult to estimate but could be very significant.

KUWAIT OIL BLOWOUTS AND OIL LAKES FORMATION PERSPECTIVES AND CONSEQUENCES

Dr. Jasem Al-Besharah Kuwait Institute for Scientific Research

The Kuwaiti oil well blowouts are of different characteristics and structure, depending on their locations, the formations and oil fields, the extent of destruction of the well heads, and finally, the type of crude oils and their impact on the environment. Therefore, these determinant factors helped in setting up priorities for extinguishing and controlling the 600 oil wells on fire.

This paper will concentrate on the extent of the damage that the Kuwait oil fields have been subjected to, the economical and environmental impacts and their consequences, and the priorities of the fire fighting efforts.

Special emphasis will be placed on the formation of the oil lakes in the Kuwaiti desert: their causes, behavior, impact on the environment (air and land), and the methods of oil reclamation and soil cleaning.

Douglas Dockery Harvard School of Public Health

Dr. Douglas Dockery, Associate Professor of Environmental Science and Physiology at the Harvard School of Public Health, is Principal Investigator of the Harvard Six Cities Study, a 12 year longitudinal study of the effects of sulfur oxide and particulate air pollution on the development of lung function in children and the development of respiratory disease among adults. He is also Co-Investigator of the Harvard 24 Cities Study, which is measuring the effects of acid air pollution on respiratory health of children in North America. Additionally, he is directing several studies quantifying the acute effects of air pollution episodes on respiratory symptoms and lung function of children, and on increased mortality among adults.

Internationally, Dr. Dockery is collaborating in epidemiologic studies of the effects of air pollution on respiratory health in Mexico City, Beijing, Switzerland, the Netherlands, Germany and Czechoslovakia. He is currently serving as a consultant to the European Community in developing a coordinated program in air pollution epidemiology methods, and is also organizing the efforts at the Harvard School of Public Health to evaluate the respiratory health effects of smoke from the oil fires in Kuwait.

Dr. Dockery received a BS degree in physics from the University of Maryland, an MS degree in meteorology from the Massachusetts Institute of Technology, and an MS and Doctor of Science in Environmental Health from the Harvard School of Public Health.

Farouk El-Baz, Ph.D. Boston University Center for Remote Sensing

Dr. Farouk El-Baz is director of the Center for Remote Sensing at Boston University, which he founded in 1986, that deals with applications to archaeology, geography and geology. He contributed to pioneering efforts in this field as supervisor of science planning for the Apollo missions to the moon (1967-1972); founding director of the Center for Earth and Planetary Studies of the Smithsonian Institution (1973-1982); and vice president for science and technology at Itek Optical Systems (1982-1986). He presently serves as president of the Arab Society for Desert Research.

Michael B. McElroy Harvard University

Michael B. McElroy received his elementary and graduate education from Queen's University in Belfast, Northern Ireland. After spending a postdoctoral year in the Chemistry Department at the University of Wisconsin, he was appointed staff scientist in 1963 at Kitt Peak National Observatory in Tucson, Arizona. In 1970, Professor McElroy was named Abbott Lawrence Rotch Professor of Atmospheric Sciences at Harvard University, and in 1975 was appointed Director of the Center for Earth and Planetary Physics. He is currently Chairman of the Department of Earth and Planetary Sciences at Harvard. Professor McElroy's research interests range from studies on the origin and evolution of the planets to, more recently, an emphasis on effects of human activity on the global environment of the Earth. He is a fellow of the American Academy of Arts and Sciences and the International Academy of Aeronautics. He was the recipient of the Macelwane Award of the American Geophysical Union in 1968, and the NASA Public Service Medal in 1976.

Halûk Özkaynak, Ph.D. Harvard School of Public Health

Halûk Özkaynak is a Research Associate and Lecturer at Harvard School of Public Health, Department of Environmental Health. He has over fifteen years of experience in air pollution data analysis, model development and epidemiologic investigations. His experience includes application of standard air pollution models to infer concentrations, development of state-of-the-art models of long-range transport and visibility, development of detailed indoor air quality models, environmental risk analysis, investigation of biases in air pollution epidemiological data and studies on the implications of air pollution on health. Dr. Halûk Özkaynak has worked in both the private and academic settings conducting research on technical and policy-oriented environmental problems. He has been responsible in the management of large scientific investigations involving monitoring and modeling of human exposures and performing multimedia risk assessment for environmental contaminants. He has several publications in the field of exposure and risk assessment. Dr. Halûk Özkaynak holds degrees in Mathematical Physics and Air Pollution Control.

Thomas J. Sullivan, Ph.D. Lawrence Livermore National Laboratory

Tom Sullivan is Group Leader for the Atmospheric Release Advisory Capability (ARAC). He has been with the ARAC Program since 1979 and at LLNL since 1974. Prior to his LLNL employment he was an U.S. Air Force weather officer for 11 years, providing a range of weather support services including six years of operations and development of automated support. Tom received his A.B. in Mathematics from College of the Holy Cross (1963), M.S. in Meteorology from the University of Oklahoma (1970), and a Ph.D. in Atmospheric Sciences from the University of California/Davis in 1982.

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Environment Crisis Persian Gulf 1991

International Environment and Peace Funds International Environment Strategy

Darwin Scientific Foundation

Kuwait Oil Fires

and

International Environment Considerations

Washington Conference

28 September 1991

John M. Eaton

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DARWIN SCIENTIFIC FOUNDATION

CHAIRMAN
S. Dillon Ripley
TREASURER
John Lastavica
SECRETARY
John M. Eaton

Kuwait Oil Fires and International Environment Considerations

Washington Conference

28 September 1991

The health effects of the Kuwait oil fires and international environment issues will be considered. Environment damage and dispersion of pollutants will be explained. Satellite imagery, satellite photographs and other satellite obtained data including meteorological information will be presented.

Benzene, polycyclic aromatic hydrocarbons and other potential carcinogenic and toxic compounds contained in the plume from the oil well fires and from the evaporating oil lakes will be described. Hydrophilic carbon pollutants which may be rain seeding and the effects therefrom will be explained.

Accountability and compensation for damage to the environment will be discussed. Mobilization of people to assure that similar environment damage will not occur in the future will be considered.

The Washington conference follows the conference to consider health effects of the Kuwait oil fires held from 12 to 14 August 1991 at the American Academy of Arts and Sciences, Cambridge, Massachusetts and arranged by the Harvard University School of Public Health and the Harvard Center for Middle Eastern Studies. The Cambridge Conference was jointly sponsored by the Arab Fund for Economic and Social Development and the United Nations Development Programme and co-sponsored by the World Health Organization, the World Meteorological Organization, the United Nations Environment Programme and the International Maritime Organization.

DARWIN SCIENTIFIC FOUNDATION

Kuwait Oil Fires and International Environment Considerations

Washington Conference

Agenda - Saturday, 28 September 1991

9:00		Welcome	S. Dillon Ripley John M. Eaton
		Man's Impact on the Global Environment	Prof. Michael McElroy
		Effects of the Gulf War on the Land, Air and Sea	Dr. Farouk El-Baz
		The Iraqi Occupation of Kuwait - An Environmental Catastrophe	Prof. Jassim Al-Hassan
10:15		Break	
10:30		Kuwait Oil Fires Pollution Dispersion	Dr. Thomas J. Sullivan
		Air Pollution Incidents	Dr. Douglas Dockery
12:00	•	Discussion	
12:30		Lunch Break	

DARWIN SCIENTIFIC FOUNDATION

Kuwait Oil Fires and International Environment Considerations

Washington Conference

Agend	la - Saturday, 28 September 1991	• • • • • • • • • • • • • • • • • • • •
2:00	Measurements of Air Pollution from the Fires And Their Implications to Health	Dr. Haluk Ozkaynak
•	International Environment Issues	John M. Eaton
	Kuwait Oil Blowouts and Oil Lakes: Perspectives and Consequences	Dr. Jasem Al-Besharrah
3:30	Discussion	
4:00	Conference Adjournment	

Speakers Committee

S. Dillon Ripley
Darwin Scientific Foundation, Chairman
Smithsonian Institution, Secretary Emeritus
Washington, DC

John M. Eaton Darwin Scientific Foundation, Secretary Washington, DC

Professor Jassim M. Al-Hassan Biochemistry Department Faculty of Science Kuwait University Kuwait City, Kuwait

Dr. Jasem Al-Besharrah Kuwait Institute for Scientific Research Safat, Kuwait

Dr. Douglas Dockery Associate Professor of Environmenal Science Department of Environmental Health Harvard School of Public Health Boston, MA

Professor Michael McElroy Chairman Department of Earth and Planetary Sciences Harvard University Cambridge, MA

Dr. Haluk Ozkaynak Department of Environmental Health Harvard School of Public Health Boston, MA

Dr. Thomas Sullivan Lawrence Livermore National Laboratories Livermore, CA

Conference Chairmain

Dr. Farouk El-Baz UN Development Programme Representative and Director, Center for Remote Sensing Boston University Boston, MA

International Environment and Peace Funds International Environment Strategy

Environment Crisis Persian Gulf 1991

International Environment Strategy

Basis -

- Arab contributions to world civilization
- War presents an environmental threat to world civilization
- Environment is a global concern and the ultimate deterrent of conflict
- Environment provides the catalyst for the new era

Strategy --

- Strategy for the environment and peace in the Middle East
- Strategy for a new security framework in the Middle East
 - Environment Corps and Peacekeeping force under United Nations
 - Available world-wide
 - Financed by a percentage of oil revenues
- Strategy for a world-wide peace and security framework
 - Administered by representatives from the five permanent members of the Security Council
 - Financed by a percentage of oil revenues
- Strategy for a world-wide environment preservation framework
 - Administered by representatives from the five permanent members of the Security Council
 - Financed by a percentage of oil revenues
- Strategy for international environment research and scholarship
 - Financed by a percentage of oil revenues

ENVIRONMENT CRISIS PERSIAN GULF 1991

INTERNATIONAL ENVIRONMENT AND PEACE FUNDS

immediate Goal

Perpetuate Arab contributions to civilization. Address threat to the Environment. Preserve major source of oil production. Major international environment and peace programs commence activities.

Important Arab Contributions to Civilization

- Law
- Mathematics
- Philosophy
- Medicine
- Astronomy
- Islam

Historic Models

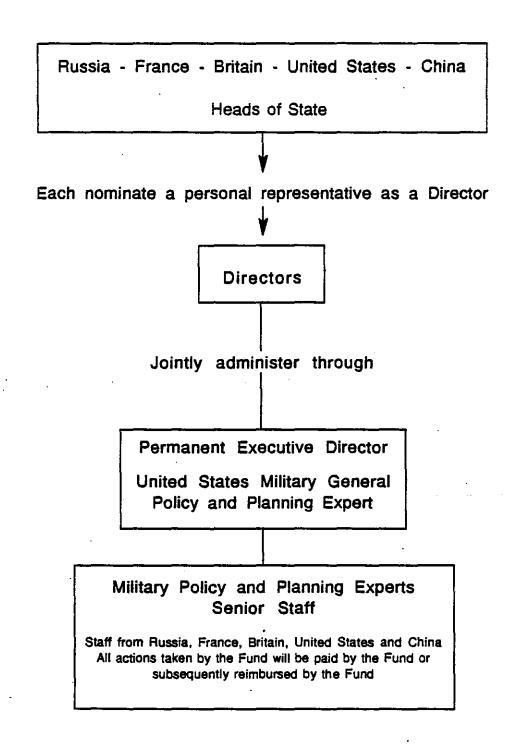
- League of Nations and United Nations in the aftermath of World War I and World War II, respectively.
- Rhodes Scholars
- Nobel Prizes

International Environment and Peace Funds

The International Environment and Peace Funds will be viewed in history as following the last war just as the United Nations is viewed as arising out of World War II.

- International Peace Fund for the maintenance of peace. The International Peace
 Fund will be administered by five personal representatives of the heads of state of
 the five permanent members of the United Nations Security Council. The
 immediate effort of the Peace Fund will be the elimination of pollution from the
 oil wells and oil lakes.
- Darwin Scholars for environmental research and education throughout the World.
- International Environment Fund for environmental preservation and elimination
 of environmental damage throughout the World. The International Environment
 Fund will be administered by five personal representatives of the heads of state of
 the five permanent members of the United Nations Security Council. The
 immediate effort of the International Environment Fund will be the
 commencement of an environment impact study and the removal of toxics from
 Kuwait.
- United Nations Environment Corps for the protection of the environment and for the maintenance of peace. United Nations Environment Corps will protect oil fields and oil production and transportation facilities of Kuwait. United Nations Environment Corps will assure that the oil under the territory of Kuwait and the revenues from such oil will belong to, and be for the account of, the government of Kuwait. United Nations Environment Corps will immediately administer all border crossings, ports and airports in Kuwait.

INTERNATIONAL PEACE FUND



INTERNATIONAL ENVIRONMENT SCHOLARSHIP

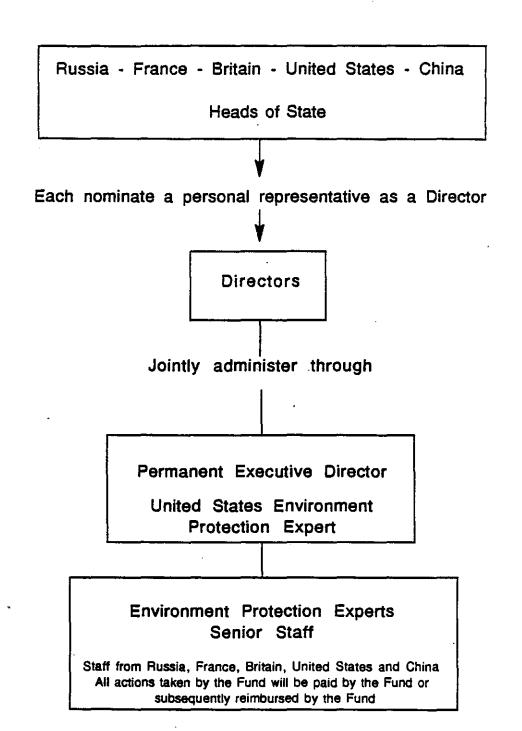
DARWIN SCHOLARS

Darwin Scholars:

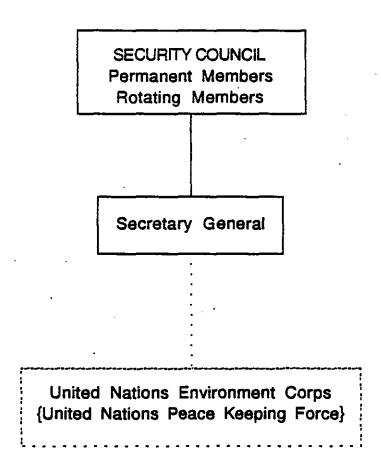
- Select Darwin Scholar recipients who will be the best and brightest scientists, professors and other scholars in the World working to preserve the environment and survival of species.
- Fund scholars, environmental programs and environmental studies throughout the World.
- Assist in developing and in funding environmental education.
- Award Darwin Prizes for outstanding environmental achievement.
- Publish environmental research reports.

Darwin Scholars immediately awards Darwin Prizes to outstanding environment scientists, professors and other scholars.

INTERNATIONAL ENVIRONMENT FUND



UNITED NATIONS



CONTRIBUTION TO WORLD CIVILIZATION

The contribution of a percentage of future oil revenues assures for future world civilization and for the environment supra-national coordination of education, research, planning and action targeting on the environment.

Education, research and planning targets natural disasters and manmade disasters including natural events and war.

In the context of oil production, the cost of the contribution to world civilization is not great.

Conceptually the contribution to world civilization and to humanity includes present funding and assignment of future revenues.

The International Peace Fund receives ten to twenty-five million dollars and a permanent assignment of five percent of oil revenues.

The Darwin Scholars receives ten to twenty-five million dollars and a permanent assignment of one percent of oil revenues.

The International Environment Fund receives ten to twenty-five million dollars and a permanent assignment of five percent of oil revenues.

The United Nations Environment Corps receives a permanent assignment of one percent of oil revenues.

Centers for Disease Control:
National Center for Environmental Health and Injury Control
National Institute for Occupational Safety and Health
and

The Agency for Toxic Substances and Disease Registry

HEALTH ADVISORY FOR KUWAIT AND SAUDI ARABIA

OCTOBER 8, 1991

BACKGROUND:

In February 1991 more than 749 oil wells were damaged or set on fire throughout Kuwait. Efforts to extinguish the fires and end the pooling of oil in the desert have now resulted in the successful capping of over 500 wells. On March 21, 1991, the Public Health Service (PHS) issued a preliminary health advisory related to the burning oil fires which addressed the potential health threats posed by the smoke, the signs and symptoms of exposures, and recommended public health measures. At the time of the preliminary health advisory, no data were available on the levels of airborne pollutants generated by the oil fires. Similarly, no information was available on the health problems being experienced by the civilian and military populations as a result of exposure to the oil fire pollutants. Several United States and international teams of environmental and health experts have visited Kuwait and Saudi Arabia to assess the changing situation. This health advisory is based on the preliminary data generated by these activities.

This update will provide:

- Results of the air monitoring data collected by the US
 Interagency Air Assessment team and other international organizations;
- Summary of the health surveillance findings for civilian and military populations in Kuwait; and
- Revision of the public health recommendations for US citizens.

SUMMARY OF AIR MONITORING DATA:

Since the fires were set in February, the plume of the fire has typically risen 10,000 to 12,000 feet, mixing with the air and then being dispersed for several thousand miles downwind over a period of several weeks. As the plume travels, the particles and gases contained within it become more widely dispersed and also more diluted. The highest concentrations of pollutants are found in the areas nearest the affected oil fields and the areas immediately downwind.

SULFUR DIOXIDE, NITROGEN DIOXIDE, CARBON MONOXIDE:

During April through July the levels of two major air

pollutants (sulfur dioxide and nitrogen dioxide) never

reached harmful levels based on the U.S. EPA air pollution

index (See Appendix). The level of CO exceeded the U.S.

alert level on rare occasions, possible due to increased traffic.

	AVERAGE MONTHLY	MAXIMUM 5-MIN	U.S.
	LEVEL PPM	LEVEL PPM	ALERT
	APRIL-JULY	APRIL-JULY	LEVEL*
Sulfur Dioxide	0.002	0.038	0.3
Nitrogen Dioxide	0.013	0.496	0.6
Carbon Monoxide	0.648	33.1	15.0

^{*}See Appendix for time periods of measurement.

PARTICULATES:

The average level of particulate matter measuring less than 10 microns, that portion of airborne particulate with the greatest health impact on the respiratory system, measured each day between May - July 10 was 308 ug/m³ and the maximum level was 2029 ug/m³. The alert level in the U.S. is 350 ug/m³. It must be remembered that Kuwait, for various reasons including frequent sand and dust storms, has an average annual level of PM₁₀ of about 700 ug/m³, the highest in the world (WHO/GEMS). The PM₁₀ levels of daily samples exceeded 500 μ g/m³ on 5 days during May, 3 days during June and 1 day in the first 10 days of July.

HYDROGEN SULFIDE:

For hydrogen sulfide, the highest measured level was 0.042 ppm by the US EPA in a grab sample in a well plume in Sabiriyan. This level is well below levels that can cause mucous membrane and conjunctival irritation (10 ppm), olfactory fatigue (100-500 ppm) or asphyxiation (500 ppm). Levels greater than 1000 ppm can cause apnea within seconds. The peak level of 0.042 ppm is well below the U.S. federal occupational standard for hydrogen sulfide of 20 ppm, the ceiling concentration for an 8-hr workday.

NICKEL AND VANADIUM:

Information about concentrations of metals in the ambient air in Kuwait has been collected by a team of French researchers who visited Kuwait from March 27 to April 4, 1991. The Laboratory of Hygiene of the city of Paris and the French Institute of Petroleum measured vanadium and nickel from 8 samples collected from different parts of the city at different times on several days. The average concentration of nickel in the 8 samples was 221 ng/m³ (values ranged from 20 ng/m³ to 600 ng/m³). The average concentration of vanadium was 32 ng/m³, (values ranged from less than 20 ng/m³ to 200 ng/m³). The Kuwait Environmental Protection Department measured nickel and vanadium using high volume samplers placed at each of three different hospitals in Kuwait City during 10 days between March 16 and April 26, 1991. The

average concentration of nickel during the 10 days was 54 ng/m^3 (values ranged from 22 to 145 ng/m^3). The average concentration of vanadium was 32 ng/m^3 (values ranged from 7 to 75 ng/m^3). To put these values into perspective, the average nickel concentrations in urban areas of Europe range from 60 to 300 ng/m^3 and the average vanadium concentrations range from 7 to 200 ng/m^3 .

BENZO (A) PYRENE:

The median level of benzo(a)pyrene measured by the French team at the English school in Kuwait city was 4.9 ng/m³. In the village of Ahmadi they measured 7.6 ng/m³. For comparison, the median level measured in Paris in the winter was about 4.6 ng/m³.

It should be stressed that measurements of air pollutants from the Kuwait oil fires are still not complete nor adequate to fully evaluate the potential long-term health effects.

SUMMARY OF HEALTH SURVEILLANCE FINDINGS:

All of the substances released by the burning oil wells can cause adverse health effects, which vary depending on the concentration and duration of exposure. These effects were summarized in the Preliminary Public Health Advisory. Surveillance in civilian

clinics and emergency rooms, and a survey conducted among U.S. Marines, indicate increases in symptoms of upper respiratory irritation. These observations are consistent with the environmental air sampling results indicating high levels of airborne particulate matter.

EVALUATION OF HEALTH EFFECTS FOLLOWING SHORT-TERM EXPOSURES: Data collection from polyclinics and hospital emergency rooms continues to improve. Preliminary analyses of emergency room surveillance conducted at two hospitals in Kuwait City from January 1 to April 30 showed that 6,127 visits had occurred, 2,373 in the period during occupation before the oil fires were started (Jan 1 - February 22) and 3,754 in the period after liberation (February 23-April 30). Notable findings included the fact that the proportion of visits by residents of Kuwait City to the emergency rooms for gastrointestinal illnesses, heart disease, psychiatric illnesses, chronic bronchitis, emphysema, and bronchiectasis increased during the period after the oil wells were ignited. On the other hand, there was no documented increase in the proportion of visits for acute upper and lower respiratory infections or asthma during the period after the oil wells were ignited.

Department of Defense surveys of Marines stationed in Saudi Arabia and Kuwait showed that Marines in Kuwait reported more frequent symptoms of upper respiratory irritation such as dry cough compared with those who served only in Saudi Arabia. Marines with a history of asthma were more likely to report wheezing in Kuwait compared with Marines in Saudi Arabia.

POSSIBLE HEALTH EFFECTS FOLLOWING PROLONGED EXPOSURES:

At the lower concentration levels of air pollution observed to date, the primary public health concerns are the cumulative effects of prolonged exposure and short term exposure during a pollution episode. Of particular concern are the potential effects of elevated levels of particulates on the respiratory system, such as a decrease in lung function or the development of chronic bronchitis.

Some of the hydrocarbons, measured at low concentrations in the smoke, have been shown to cause cancer in laboratory animals at higher levels of exposure. In addition, epidemiologic studies show that exposure of humans to high concentrations of nickel for many years can cause lung cancer. At an air nickel concentration of 1000 ng/m³ (higher ever measured in Kuwait), a conservative estimate of the lifetime cancer risk is 4 per 10,000. There is no evidence that vanadium concentrations below 1000 ng/m³ have adverse health effects.

Based on risk estimates from coke-oven emissions, about 9 per 100,000 exposed people may die from cancer of the respiratory tract as a result of spending a lifetime in ambient air containing an average of 1 ng benzo(a)pyrene per m³ mixed with all the other polycyclic aromatic hydrocarbons and related substances in coke-oven emissions.

Most epidemiologic studies of health effects following prolonged exposures are based on a lifetime of exposure to the chemical of interest. Thus, it is difficult to extrapolate those results to the current situation, in which exposure levels changes as the wind shifts direction. In addition, most, if not all of the oil fires are expected to be capped by March, 1992, 5 months from now. Thus, individuals are cautioned not to extrapolate these risk estimates to their particular exposure history.

PUBLIC HEALTH RECOMMENDATIONS FOR US CITIZENS IN KUWAIT AND SAUDI ARABIA:

These recommendations are slight modifications of the preliminary precautions to protect public health issued in March, 1991:

 All personnel stationed or working in the immediate vicinity of the burning oil wells (such as firefighters) should be medically evaluated prior to their assignment for pre-existing cardiac and pulmonary diseases and issued appropriate personal protective equipment. Sufficient training should be provided in the use of this equipment and appropriate safety precautions.

2. US Embassies should consider the initiation of a health alert system during this period of decreasing winds in Kuwait during October, November, and December 1991. During air pollution episodes persons residing in areas with high air pollution should be advised on measures they can take to reduce their exposures. These include staying indoors during air pollution episodes and keeping windows shut, and monitoring changes in their own health status. Persons at risk for experiencing health problems from air pollution, particularly asthmatics, and individuals with underlying respiratory or cardiac conditions, should be educated as to the early warning signs and symptoms of potential serious exposure such as runny nose, sore throat, watery eyes, chest pain, headache, nausea, dizziness, cough, shortness of breath, etc. Persons experiencing even minor symptoms should be instructed to seek medical attention.

- 3. Persons who smoke should be encouraged to stop smoking.

 They should be warned about the possible additive effects of exposure to cigarette smoke and air pollution.
- 4. Persons exposed to the smoke from the oil well fires should thoroughly wash exposed areas of skin each evening, to prevent excessive dermal absorption.
- 5. Medical personnel should be advised of the potential health hazards posed by the burning oil. Individuals with respiratory complaints should be carefully evaluated and clinical personnel should be educated on the appropriate medical management of acute airway obstruction.
- 6. Public health authorities should develop and effectively disseminate information to the public covering the above measures in addition to advice concerning and symptoms of potential ill-effects, and steps to follow if such symptoms appear.

ACTIONS TO FURTHER ASSESS THE SITUATION:

- 1. The medical facilities in the affected areas should be prepared to both diagnose and treat medical conditions which may occur as a result of exposure to emissions from the burning oil wells. These include adequate cardiac and respiratory monitoring equipment for patients presenting with chest pain and shortness of breath, oxygen delivery systems, chest x-ray machines, pulmonary function testing equipment, airway management equipment (etc. endotracheal tubes), and medications (eg. beta adrenergic agents).
- 2. Ambient air monitoring should continue in all major residential areas in Kuwait and Saudi Arabia. Specific pollutants to be measured should include respirable particulates, sulfur dioxides, hydrogen sulfide, nitrogen oxides, and other pollutants. Monitoring activities should be continued in those areas most likely to be affected by the smoke plume.
- 3. Surveillance systems for adverse health effects should be expanded, to better monitor the health status of persons exposed to the oil fire plumes. In addition, the availability of medical records for long-term follow-up of highly exposed persons should be assessed.

APPENDIX

The following table lists current U.S. regulations or other recommendations for environmental levels of selected air pollutants:

			AVERAGING	
POLLUTANT	STAN	DARD	TIME	SOURCE
Carbon Monoxide	9 ppm ((10 mg/m^3)	8-hour	EPA
	35 ppm (40 mg/m^3)	1-hour	
Particulate Matte	r 50 μg	/m³	1-year	EPA
(≤ 10 μm)	150 μg	$/m^3$	24-hour	
Sulfur oxides	0.03 ppm	$(80 \mu g/m^3)$	1-year	EPA
	0.14 ppm	$(365 \mu g/m^3)$	24-hour	
	0.5 ppm	$(1300 \mu g/m^3)$	3-hour	
Ozone	0.12 ppm	$(235 \mu g/m^3)$	1-hour	EPA
	-			
Hydrogen sulfide	0.15 mg/m	3	24-hour	WHO
Nitrogen Oxides	0.05 ppm	$(100 \mu g/m^3)$	Annual	EPA

August 1991

Workshop Review: Management of Data Collected in GRAMP (Gulf Region Atmospheric Measurement Program)

22-24 July 1991

Darrel Baumgardner Richard Friesen



WORLD METEOROLOGICAL
ORGANIZATION
ORGANISATION MÉTÉOROLOGIQUE
MONDIALE
CH-1211 GENÈVE 20



RESEARCH AVIATION FACILITY ATMOSPHERIC TECHNOLOGY DIVISION

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH BOULDER, COLORADO

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LIST OF ACRONYMS

ARAC The Atmospheric Release Advisory Capability

ASAP A System for Assessment of Pollution

BTAB BUFR Tabular Form BU Bahrain University

BUFR Binary Universal Form for Data Representation (WMO spec FM 92)

CBS Commission for Basic Systems

CD Compact Disk
DAT Digital Audio Tape
DCP Data Collection Platform

DDB Distributed Databases Concept

DM Data Management

DMSP Defense Meteorological Satellite Program

DNA Defense Nuclear Agency

ECMWF European Climate Modeling Weather Forecast

FGGE First GARP Global Experiment
GCOS Global Climate Observing System
GDPS Global Data Processing System

GKS Graphics Kernel System

GMEP German Ministry of Environmental Protection

GOS Global Observing System

GRAMP Gulf Region Atmospheric Measurement Program
GRIB Grid in Binary (Gridded data format--WMO spec)

GTS Global Telecommunications System

IFC IGOSS Flexible Code
ISS Integrated System Study

KFUPM King Fahd University for Petroleum and Minerals

MDD Meteorological Data Dissemination

MEPA Saudi Arabian Meteorological and Environmental Protection Agency

METEOSAT Meteorological Satellite

MTN Main Telecommunication Network

NASA National Aeronautics and Space Administration
NCAR National Center for Atmospheric Research
NIST National Institute of Standards and Technology

NMC National Meteorological Center

NOAA National Oceanic and Atmospheric Administration

NOAA/ARL NOAA/Atmospheric Research Laboratory

NOAA/AVHRR NOAA/Advanced Very High Resolution Radiometer

NOAA/NESDIS NOAA/Earth System Data Directory

RSMC Regional Specialized Meteorological Centers

RTH Regional Telecommunications Hubs

SPOT Système Probatoire pour l'Observation de la Terre

USAEHA US Army Environmental Health Agency
WGDM Working Group on Data Management
WMO World Meteorological Organization

WWW World Weather Watch

PREFACE

The demolition and subsequent burning of the Kuwait oil fires was a senseless act of destruction that has threatened public health, damaged the environment, and may possibly cause short or longer term changes in regional and global climate. Many nations responded to this disaster by offering aid and by rushing teams into the affected area to make measurements that would assess the impact of the fires.

The following report summarizes a workshop that was held July 24-26, 1991 at the National Center for Atmospheric Research (NCAR) to discuss a plan to gather all the atmospheric measurements that are being made in the Gulf region and make them available for general dissemination. This workshop was initiated by the World Meteorological Organization and co-sponsored by the National Oceanic and Atmospheric Organization.

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ACKNOWLEDGEMENTS

The idea for the workshop was originally discussed in early June but the actual planning effort did not get started in earnest until the end of that month. The fact that the workshop was conducted and well attended can be attributed to the hard work and fast action of a number of people. John Robinson of NOAA deserves special thanks, not only for obtaining financial backing to help underwrite the expenses of the workshop, but also for his relentless enthusiasm and support. Danny Foster of the WMO contacted all the potential participants. Larry Radke, manager of the NCAR Research Aviation Facility and the co-principal investigator of the NCAR effort in the Gulf, provided the necessary resources from the RAF to accomplish this workshop in what might be record time. We would particularly like to thank all the participants who managed to break away from thier already overloaded schedules to attend this workshop and provide their valuable input. Finally, we would like to offer special thanks to Barbara Knowles who made the majority of the meeting room arrangements, took notes, arranged for refreshments, typed the workshop report and managed to keep a big smile on her face the whole time.

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PART I--INTRODUCTION

A large-scale, international effort has been initiated by the World Meteorological Organization to assess the atmospheric effects caused by the man-made pollution that is introduced by the burning of more than 500 oil wells in the Kuwait oil fields. The WMO called a meeting of experts to discuss how to assess the effects and to coordinate an international response for the atmospheric part of the environmental emergency in the gulf.¹ This meeting identified a large number of agencies that had been or would soon be participating in measurement programs in the Arabian Gulf region and focused on the critical environmental issues that needed to be addressed by these measurement programs. All of these programs are being coordinated by the WMO whose responsibility is to ensure that adequate measurements are made and that these measurements are integrated and disseminated to international research organizations in a systematic and timely fashion.

This latter task requires gathering the many measurements from multiple platforms, cataloguing the attributes of each of the data sets, archiving and then disseminating this information. The need for this operation is stated in section 6.5 of the draft report. However, the methodology and mechanisms for accomplishing this task are omitted. A number of factors are involved with establishing a data archive and this task should not be undertaken without careful consideration and utilization of input from the agencies that were involved in the measurement programs. The World Meteorological Organization (WMO), seeing the need to solicit this input, asked the National Center for Atmospheric Research (NCAR, Boulder, Colorado) to organize a workshop that would focus on the salient aspects involved with starting the data archiving process. This workshop was held at the NCAR facilities on July 22-24, 1991.

The urgency of the problem and need to initiate an archiving process as soon as possible made it difficult to obtain representatives from all agencies who had participated in the Gulf Regional Air Monitoring Program (GRAMP) since there was only about a three week period between notification and start of the workshop. Nevertheless, over 45 attendees from more than 20 agencies and five countries participated in the workshop (Appendix C lists all the participants).

The remainder of this document summarizes the workshop proceedings (the agenda may be found in Appendix A).

Draft Report of the WMO Meeting of Experts on the Atmospheric Part of the Joint U.N. Response to the Kuwait Oil Fields, Geneva, 27-30 April 1991.

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PART II--OVERVIEW AND CONTEXT OF WORKSHOP

There were several objectives to be met by the workshop.

- To identify as many data sources as possible that could be assembled into an archived data set which will assist the scientific community in assessing the impact of the Kuwait oil well fires.
- To identify measurements that are still needed and things that should be done to present data sets for future analysis.
- To make recommendations with regard to how the data should be documented, archived, accessed, and disseminated to achieve maximum accessibility and portability.

Identification of Data Sources

During the course of the workshop, representatives from a number of agencies summarized the types of measurements that their groups have been making in the Gulf region. The measurements are generally grouped in four categories: ground-based, airborne, satellite, and computer models.

Ground-based Measurements

Representatives from the King Fahd University for Petroleum and Minerals (KFUPM, Dhahran, Saudi Arabia)², National Oceanic and Atmospheric Administration (NOAA), Defense Nuclear Agency (DNA)³, Environmental Protection Agency (EPA), the National Institute of Standards and Technology (NIST) and the United States Army Environmental Health Agency (USAEHA) presented overviews of their measurement programs. These are summarized as follows:

² KFUPM is one of several facilities that make up the Saudi Arabian Meteorological and Environmental Protection Agency (MEPA).

The representative from this group also discussed measurements made by the University of Bahrain who collaborated with the DNA on radiation measurements.

- MEPA Atmospheric measurements of PM-10⁴, SO₂, O₃, CO, H₂S, Polycyclic Aromatic Hydrocarbon (PAH) analysis, inorganic acids, volatile organic hydrocarbons (VOC) and heavy metals. Soil samples were analyzed for nickel and vanadium. Solar radiation measurements are also being taken at KFUPM.
- NOAA 16 meteorological towers in Kuwait are telemetering 15 minute averages of temperature, humidity, horizontal winds, and solar radiation into Kuwait City.
- EPA Measurements of SO₂, Polycyclic Aromatic Hydrocarbon (PAH) analysis, inorganic acids, volatile organics and Heavy metals. Single measurements were made at 10 different locations from March 13 March 20.
- DNA In Collaboration with Bahrain University (BU), direct, diffuse, and spectral radiation data were taken in Bahrain with DNA and BU radiometers. The university of Bahrain has also been making spectral measurements since 1986 that can serve as useful pre-fire background data.
- NIST Has made measurements of flame height on five oil wells, heat flux and release rate on one well, and analysis of particulate mass and PAHs from an oil pool fire.
- USAEHA Soil sample analysis for metals.

In addition to the ground-based measurement programs presented at this workshop, several other agencies were identified either as having made measurements or planning to. Those that were mentioned were groups from Saudi Arabia (Royal Commission, ARAMCO, MODA/MSD), Kuwait, Bahrain (Environmental Protection Committee), France (Air Parif), Germany (Ministry for Environment), Norway (Institute for Air Research), and Japan. The specifics of these measurement programs were not available for further discussion but the archiving process will need to encompass these data sets if they become available.

⁴ PM-10 is the particle mass of all particles less than 10 μ m diameter. This is a technique whereby particles are deposited on a filter after particles larger than 10 μ m have been removed from the air.

Airborne Measurements

The airborne measurements were discussed by the representatives of the German Ministry of Environmental Protection (GMEP) and the National Center for Atmospheric Research (NCAR). The measurements made by these organizations are as follows:

NCAR - Temperature, pressure, humidity, horizontal and vertical winds, turbulence Particle size distributions (0.05 - 600 μm diameter)
Cloud condensation nuclei, condensation nuclei
Cloud droplet composition
Soot mass
O₃, CO, NO_x, SO₂, H₂S, OCS, CS2, Methane, Total Sulfur, Speciated and Continuous Peroxides, Formaldehyde, Total Hydrocarbons
Short Wave, IR, and UV radiation, Surface temperature
Single particle albedo
Lidar - 0.5 μm, 1.06μm, 10.6μm
Dropsondes - vertical profiles of winds, temperature, and humidity
A total of 15 flights and 100 flight hours were flown covering the time period from May 19 - June 4, 1991.

GMEP - Temperature, pressure, humidity, horizontal winds
 Particle size distributions (0.1 - 50 μm diameter)
 Soot mass
 O₃, NO_x, SO₂, VOC, PAH, Anions, Cations, metals
 UV radiation
 A total of 29 flights were flown from the period May 20 - June 6, 1991.

In addition to these airborne measurement programs, other airborne measurement projects were identified. The British Meteorological Service operated an aircraft and flew 55 hours during seven flights from March 22 to April 2, 1991. The University of Washington aircraft flew during the same period as the NCAR aircraft in a cooperative experiment and its instrumentation was fundamentally the same as NCAR's. The Department of Energy has made airborne measurements during the months of July and August and NASA had plans to fly a helicopter near the plumes to make better estimates of emission factors. There has also been discussions of sending the NOAA P-3 to the Gulf in the October-November time period of 1991.

Satellite Measurements

A number of satellites cover the Gulf region and this data can be obtained from several different sources.

- Meteosat 4 and 5 (Geo-Stationary)
- NOAA 9, 10 and 11 (two passes/day, each satellite)
- Defense Meteorological Satellite Program (DMSP) F8, F9, F10 (two passes /day, each satellite)
- Landsat
- SPOT

Surface and Upper Air Stations

The WMO World Weather Watch has 180 surface observing stations and about 40 upper air stations in the countries concerned. The data from those stations that report are archived daily at NCAR.

Modeling Efforts

Numerous modeling efforts are presently going on around the world, many of which were identified at the WMO meeting of experts. Three of these models were discussed at the workshop.

- Lawrence Livermore National Laboratory The Atmospheric Release Advisory Capability (ARAC) is used to model optical density and provides near-real-time assessments of concentration, dose, and deposition of particulate as a function of time and location.
- NOAA/ARL The ARL (Atmospheric Research Laboratory) runs three models for emergency response smoke plume dispersion forecasts. These models are used for concentration and trajectory forecasts.
- Royal Netherlands Meteorological Institute "Puff model" provides isopleths of vertically integrated soot concentration and dispersion forecast in 24, 48, and 72 hour time intervals.

Data Analysis Requirements

One of the primary reasons for archiving large data sets is to provide an easily accessible, centralized database to facilitate extensive analysis. The database will be used to address four major issues:

- What is the composition and amount of gaseous and particulate by-products being produced by the burning oil wells?
- What is the magnitude of the exposure to toxic substances in the Gulf region in relation to human health risks?
- What are the expected effects in areas more remote from the source with regard to additional air pollution and deposition?
- Are there any global effects to be expected and what would be the magnitude and duration?

The analysis of the measurements fall into categories of diagnostic and prognostic. In the first case diagnostic analysis is used:

- To assess the immediate regional impact on public health and the environment.
- To characterize the regional emission rates of smoke particles and trace gases.
- To measure radiative properties of the smoke particles and the radiative effects of the plumes with attention to how radiation affects the altitudes of the plumes and the stability of the atmosphere.
- To measure characteristics of the smoke particles, i.e., size, shape, composition, and optical properties.
- To evaluate the degree to which smoke particles are scavenged in clouds, their subsequent effects on composition and radiative properties of clouds.
- To measure how the properties of the plume change with time.

The prognostic use of the data will be:

• To help in developing emergency response systems to warn the populace of health risks.

- To provide measurements that will aid in better parameterization of turbulent diffusion fields, particulate size distributions, and chemical reaction rates.
- To provide data on smaller scale than available from Radiosonde Observations to initialize dispersion models.
- To validate and help adjust medium, long-range, and global climate models.

Data Archival Objectives

The primary objectives to be met when archiving data from the atmospheric measurements made in the vicinity of the Kuwait oil fires are as follows:

- To catalogue and document as many atmosphere related measurements as possible that are of relevance to assessing the impact of the fire;
- To assemble as many of these data sets as possible;
- To store these data sets on high density medium that can be easily accessed;
- To maintain these data sets and update them as necessary;
- To provide utility software to allow easy access and perusal, and retrieval of these data sets.

These five objectives formed the focus of the remainder of presentations and discussions the final two days of the workshop.

Cataloguing and Documenting Measurements

The large quantity and variety of measurements that have been and are being made in the region of the oil fires makes it imperative that a major effort is made to compile comprehensive documentation on these data sets. At the minimum the following information must be included:

- What atmospheric constituents were being measured?
- What sensors were being used to make the measurements?
- What are the ranges, resolutions, sample rates and accuracies of the instruments?

- Where and when were the measurements made?
- Who is the primary contact to whom questions about the dataset should be directed?

Some data cataloging efforts are already underway, one instigated by UNEP and one by the U.S. Public Health Service. The UNEP effort is being developed by the Delft Corporation (The Netherlands) to be delivered to ROPME (Saudi Arabia). This system is called "A System for Assessment of Pollution" (ASAP) and is a PC-based database system that will contain as much information as possible about the measurements efforts taking place in the Gulf region. Information about this system can be obtained by contacting Dr. H.J. Van Zuylen (see Appendix B).

The Public Health Service has developed a database of published literature that pertains to the health effects of the Kuwait oil well fires. This database is presently on-line and can be accessed by computer dial-up. More information on this service may be obtained from Dr. John Andrews (see Appendix B).

Gerald Barton (NOAA/NESDIS) described the NOAA Earth System Data Directory that is a referral service for national environmental data. He suggested that this directory might be a possible place to put the Kuwait data catalogue information once it is assembled.

Assembling and Accessing Data Sets

Assembling the data sets requires full cooperation of each of the participating agencies. All of the organizations that attended the WMO meeting of experts agreed to participate in the sharing of data. To expedite the archiving process, these data sets will need to be available on commonly available magnetic media (e.g., magnetic tape, CDs, floppy discs) and in a easily readable format (i.e., ASCII, packed integer, etc.). It is critical that each data point is labeled in some manner with the sensor type (e.g., SO₂), time (local or UTC) and location (preferably latitude, longitude and, where applicable, altitude). This labeling method will allow rapid retrieval for subsequent analysis.

Storing Data Sets

The amount of information to be stored in a central archive is enormous. The actual magnitude is difficult to assess at this time; however, it is clear that sufficient space must be planned carefully at the archival center. In addition, since the data must be disseminated on an easily accessible medium, a high density media must also be identified.

A number of agencies routinely archive large data sets that are accessed frequently by large numbers of users. Technology is presently available for storing data in terrabyte quantities. Likewise, recent technology has been developed to store large quantities of data on relatively small devices such as compact optical discs or 8 mm video cartridges. These are but a few of the possibilities that must explored before embarking on a project of this magnitude. Discussions during the workshop concerning long-term storage of magnetic media, especially newer technology such as DATs and Exabytes, emphasized the need to use multiple storage techniques.

Disseminating, Maintaining and Updating Data Sets

The data taken during the Kuwait oil fires is unique in its breadth and scope. The number of agencies and individuals who will seek access to this data set cannot be fully determined at this time, but is quite likely to be large. This data set is also likely to be accessed over a longer period of time and will continue to evolve as the fires are extinguished or as some of the measurements are modified to account for sensor recalibration or other corrections, and as more baseline measurements become available.

A suggestion was made at the meeting of experts that the center for data archival should be located in either Kuwait or Saudi Arabia. Local impacts of the oil fires will most affect these two countries and it is reasonable that a data dissemination center be located in one of these two nations. Experience has shown, however, that a strategy should be explored in which multiple centers are established to be used as dissemination centers. International communications and computing equipment continues to improve in both speed and reliability. However, there will always be a finite chance that a power or equipment failure will temporarily disable an archive center's ability to function, oftentimes at inopportune moments when data is most needed. Locating centers in the Middle East, Europe, and the US would ensure that the flow of data remain uninterrupted and that a catastrophic failure will not jeopardize an irreplaceable data set.

Establishing three data centers does not mean three archiving centers if, by definition, an archiving center is the one that generates the initial cataloguing and formatting of data sets. The strategy is to maintain a constant line of communication between centers so that any updates or modifications be implemented in the auxiliary centers once they have been certified by the central archiving facility.

The actual dissemination of the data can be accomplished in two ways. One way is to put the complete data set on a portable media such as magnetic tape or optical disc and mail it to the user who reads the data on his own system. An alternative way, to be used with much smaller, selected data sets, is for the user to communicate over the electronic network with one of the data centers and to request the specific information from the centralized mass

storage center. This is a technique routinely used at a number of agencies at this time. A representative from NCAR discussed the present electronic network that spans the world. This network continues to expand in size and speed. Branches already stretch into the Middle East, although the coverage is not yet as extensive as found in the United States and Europe.

Some of the measurement systems provide a relatively simple set of data that is easily manipulated and analyzed. However, other measurement platforms such as aircraft can produce a complex set of measurements that is much more difficult to manipulate and interpret. As an example, there are more than 500 possible raw and derived variables available from measurements made by the NCAR Electra alone. Rapid display and manipulation of these data, coordinated with other data such as upper air and satellite measurements will require sophisticated analysis tools if useful information is to be extracted in a minimum amount of time. Some such analysis tools were demonstrated at the workshop that allow easy display of complex data sets from aircraft and for integrating measurements from multiple platforms such as satellite and ground-based measurements.

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PART III--RECOMMENDATIONS

The workshop concluded with a summary session in which a number of recommendations were made concerning the handling of data from the Kuwait oil fires. The workshop has recommended (without assigning specific priorities) that:

- NCAR should be the international archive center for regional datasets which are related to the Kuwaiti oil fires. In fulfilling this function, NCAR should:
 - Identify, collect and store the relevant datasets.
 - Manage the archive.
 - Facilitate access to the datasets.
 - Compile, maintain, and publish an inventory of the data sets.
 - Maintain a set of appropriate software tools for accessing and viewing the datasets.
 - Further develop archival perusal and display tools.
 - Make these software tools available upon request.
- The datasets should be generally available without restrictions except for necessary nominal charges covering handling and shipping of data storage media.
- NCAR should provide special assistance to Gulf Region countries to meet their requirements for accessing the data.
- NCAR should consider appropriate data formats for long-term archiving with a view
 to supporting efficient access to the data, taking into account the needs of the major
 disciplines of evaluating groups such as public health agencies, modelers, emergency
 response teams, etc.
- Relevant archived data should be made available to health agencies as soon as possible.
- An assessment should be made as soon as possible of current measurements to determine what additional measurements should be made and what on-going measurements should be continued.

- An electronic Bulletin board needs to be established for providing archive information to interested users.
- An advisory group should be formed to review the archival process.
- An Internet link to Gulf region should be established.
- WMO should take active role in publicizing Kuwait measurement activities.
- A WMO Gulf coordinator should publish quarterly situation reports.
- Encourage the Public Health Service to continue archiving health-related literature.
- Need of data focal points in the Gulf Region countries with active collaboration by scientists in the archival process.
- There should be a follow-up meeting later this year.

A number of additional measurement and analysis efforts were recommended:

- A climatological summary of the Gulf region should be made available as soon as possible. A Gulf region meteorologist should take a lead role in this effort.
- The Air Force Defense Meteorological Satellite Program (DMSP) local ground-receiving station should remain in operation in Gulf area throughout the duration of the project (5th Weather Wing from Langley AFB, VA).
- Better source term characterization is critically needed.
- Modeling must be continued but with more realistic physics, and measurements must be used to validate these models.
- Data from any classified satellite, airborne, or ground-based measurements pertinent to the problem should be made available as soon as possible.
- Continued archival of Meteosat and NOAA AVHRR data is needed until at least the end of the fires.

- Continued acquisition of higher resolution satellite data by landsat and SPOT is encouraged.
- Encourage NASA to continue hand-held camera photography of Kuwait oil fire plumes during space shuttle missions until oil well fires are extinguished.

PART IV--APPENDICES

APPENDIX A--Agenda

Agenda
A Workshop on the Management and Analysis of Data Relating to the Kuwait Oil Fires
July 22 - 24, 1991
Boulder, Colorado

Workshop Registration

Opening Comments--WMO Representative

Workshop Objectives--WMO/NCAR

Review of Available Data Sets--WMO

MEPA, Saudi Arabia KFUPM, Saudi Arabia EPC, Bahrain NOAA

NOAA EPA <u>Airborne</u>

United Kingdom

NCAR

U. Washington

Germany

<u>Other</u>

Climatological

Satellite

WMO Procedures & Formats for Data Exchange--WMO

WWW Structures & Capabilities for Data Management--WMO

Data Analysis Issues - Who will use the data archive?--WMO

Integrating and Analyzing Multiple Data Sets--Darrel Baumgardner, NCAR/RAF

Introduction to McIDAS--Tom Yoksas, UNIDATA, NCAR

Aircraft Data Analysis, Introduction to WINDS--Gary Horton/Darrel Baumgardner, NCAR/RAF

Integrating and Analyzing Multiple Data Sets--Paul Herzegh, NCAR/RDP

Archiving and Storing Massive Data Sets-Dennis Joseph, Scientific Computing Division, NCAR

Electronic Communications and teleneting--Joe Choy, Scientific Computing Division, NCAR

Common Data Formats--Russ Rew, UNIDATA, NCAR

Requirements for Data Base Services—WMO

Tour of NCAR Computing and Archival facilities

Requirements for Data Base Services-Continued--WMO

Review and Summary-WMO/NCAR

End of Workshop

APPENDIX B--List of Attendees

Angela Addario RDA/LOGICON 2100 Washington Boulevard Arlington, VA 22204 703-486-3500 FAX: 703-920-4710

Dr. Abdulaziz Al Saif MODA/MSD Post Office Box 7897 Riyadh 11159 Saudia Arabia 011-96-61-4777714 FAX: 011-96-61-4784057

Dr. Ibrahim Alam KFUPM/RI Post Office Box 812 Dhahran, Saudi Arabia 011-96-63-8603233 FAX: 011-96-63-8603661

Dr. John Andrews ATSDR 1600 Clifton Road, NE, E-28 Atlanta, GA 30333 404-639-0705 FAX: 404-639-0744 Dr. Lutz Bannehr NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1084 FAX: 303-497-1092

Daniel Barry AGPO 14th and Constitution, HCHB, Rm 6224 Washington, DC 20230 202-377-5483 FAX: 202-377-0714

Gerald S. Barton NOAA/NESDIS 1825 Connecticut Avenue, NW Washington, DC 20235 202-606-4548 FAX: 202-606-4586

Dr. Darrel Baumgardner NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1054 FAX: 303-497-1092 Dr. Joe Boatman NOAA/ARL 325 Broadway Mail Code R/E/ARX1 Boulder, CO 80303 303-497-6270

FAX: 303-497-6546

Dr. Stephan Borrmann NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1030 FAX: 303-497-1092

Nelson Bryner
NIST
Building & Fire Research Lab
Room B 258, Building 224
Gaithersburg, MD 20899
301-975-6868
FAX: 301-975-4052

Kim Buttleman NOAA-NESDIS World Weather Building, Room 510 5200 Auth Road Camp Springs, MD 20746 301-763-8142 FAX: 301-763-8131

David Carlson RDA 2100 Washington Boulevard Arlington, VA 72204 703-486-3500 FAX: 703-920-4710 CMDR Francesca Cava NOAA US DOC/NOAA Room 5128 14th and Constitution, NW Washington, DC 20230 202-377-3436 FAX: 202-408-9674

Joe Choy NCAR/SCD Post Office Box 3000 Boulder, CO 80307 303-497-1222 FAX: 303-497-1137

Dr. John Cockayne SAIC Post Office Box 1303, M/S I-9-1 McLean, VA 22102 703-821-4512 FAX: 703-356-8408

Jonathan Corbet NCAR/RDP Post Office Box 3000 Boulder, CO 80307 303-497-8793 FAX: 303-497-8770

Chris DeRosa PHS/ATSDR 1600 Clifton Road, E-28 Atlanta, GA 30333 404-639-0705 FAX: 404-639-0744 Charles Henry NOAA/LSU 42 Atkinson Hall Baton Rouge, LA 70803 504-388-8521 FAX: 504-388-4286

Dr. Jürgen Herrmann UMWELT-DATA Stresemann Strasse 17 D-6240 Uoenigstein ITS GERMANY 011-0-6174-3046 FAX: 011-0-6174-24164

Dr. Paul Herzegh NCAR/RDP Post Office Box 3000 Boulder, CO 80307 303-497-8801 FAX: 303-497-8770

LT Brian Higgins
USAEHA
Air Pollution Engineering Division
ATTN HSHB-ME-A
APG, MD 21010-5442
301-671-3500or2510
FAX: 301-671-3656

Gary Horton NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1051 FAX: 303-497-1092 Dennis Joseph NCAR/SCD Post Office Box 3000 Boulder, CO 80307 303-497-1216 FAX: 303-497-1137

Dr. Dave Johnson NCAR/Remote Sensing Post Office Box 3000 Boulder, CO 80307 303-497-2040 FAX: 303-497-2044

Barbara Knowles NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1020 FAX: 303-497-1092

Dr. Don Lenschow NCAR Post Office Box 3000 Boulder, CO 80307 303-497-8903 FAX: 303-497-8181

Sanjay Limaye
University of Wisconsin
Space Science and Engineering
1225 West Dayton Street
Madison, WI 53706
608-262-9541
FAX: 608-262-5974

Dr. Winston Luke NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1018 FAX: 303-497-1092

Dr. Thomas Mace EPA OIRM-IO (PM-211) 401 M Street, SW Washington, DC 20460 202-260-5710 FAX: 202-465-6156

1LT David Martin USAEHA Attention HS HB-ME-A APG, MD 21010 301-671-3500or2510 FAX: 301-671-3656

Valerie May National Geographic 1145 17th Street, NW Washington, DC 20021 202-775-6518 FAX: 202-828-6695

Jeff McQueen NOAA/ARL 1325 East-West Highway (SSMC II) Silver Spring, MO 20910 301-427-7295 FAX: 301-427-8119 Dr. Muhammad Owais DNA 6801 Telegraph Road Alexandria, VA 22310 703-325-2407 FAX: 703-325-2951

Dr. Janusz Pudykiewicz AES 2121 Trans-Canada Highway Dorval, Quebec, CANADA 514-421-4744 FAX: 514-421-2106

Dr. Larry Radke NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1032 FAX: 303-497-1092

Russ Rew NCAR/UNIDATA Post Office Box 3000 Boulder, CO 80307 303-497-8645 FAX: 303-497-8633

John Robinson
NOAA

14th and Constitution Avenue, NW, Room
6224 Loom 1617m

Washington, DC 20230
202-377-5483

FAX: 202-377-0714

Dieter Schiessl WMO Geneva 41 Guiseppe Motta 011-41-22-7308241 FAX: 011-41-22-7342326

Richard Schillawski NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1074 FAX: 303-497-1092

Tom Sullivan LLNL L-262 Post Office Box 808 Livermore, CA 94551 415-422-1838 FAX: 415-422-5924

Cindy Twohy NCAR/RAF Post Office Box 3000 Boulder, CO 80307 303-497-1017 FAX: 303-497-1092

Dr. H.J. Van Zuylen
Delft Hydraulics
Post Office Box 177
2600 mh delft
The Netherlands
011-31-15-569353
FAX: 011-31-15-619674

Dr. Thomas Voigt Umweltbundesamt 1000 Berlin 33 Bismarcuplatz1 011-49-30-89032582 FAX: 011-49-30-89032285

Dr. Richard Williams, Jr. U.S. Geological Survey. 914 National Center Reston, VA 22092 703-648-6388 FAX: 703-648-4227

Doug Yoon RDA 6053 West Century Boulevard Los Angeles, CA 90045 213-645-1122 FAX: 213-645-2553

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APPENDIX C--WWW Involvement in Emergency Response to Kuwaiti Oil Fires

The introduction presented by Dieter Schiessl of the WMO at the onset of the workshop.

Reestablishing and Strengthening of the WWW Structures

The WWW operational component consists of the observing network, the telecommunication system, and the data processing facilities, and as an integrating and kind of overhead component, data management. It happens that I am the officer responsible for the WWW data management component. In this capacity, I have been asked to participate on behalf of WMO.

These major components of the WWW are represented in all the member countries in different degrees of sophistication and different degrees of completeness. The facilities in Kuwait have been nearly completely destroyed during the Gulf conflict. It is our major task and our major effort at the moment to assist Kuwait and other countries in the Middle East Region to reconstruct their weather services and improve their facilities to the extent necessary to ensure that the data and products required can be generated, exchanged, or transported to the centers in areas in need. We have noted that the meteorological staff is back to about 70 percent and is well-qualified. The upper-air station in the Kuwait airport will soon receive new Vaisala radiosonde equipment. I am here to report to you that the purchasing and contracting framework have been completed, and we are now only waiting delivery of the system. The existing wind finding radar has been repaired. This allows regular wind soundings at 06 and 18 UTC. Full radiosonde ascents (Pressure, Temperature, Humidity, Wind) will be made daily at 00 and 12 UTC.

Somewhere later in the workshop, I will present to you the latest numbers on monitoring contained we executed last week so you can where we stand in terms of surface observations and upper air observations covering all the countries of interest in the Middle East Region.

Surface observations at regular synoptic hours and, if required, more frequently are needed as input for the local assessment of the pollution situation and as input to forecast models. WMO's plan is to reestablish the five Synop stations of the Regional Basic Synoptic Network. This is considered to be the permanent routine observing system which is supplemented by 15 automatic meteorological stations established already by NOAA.

As a matter of highest priority, the Global Telecommunications System (GTS) link between the Kuwait National Meteorological Center and the Regional Telecommunication Hub (RTH) Jeddah is being established. We have been informed as of the middle of July that a low speed circuit (100 baud) connection between Jeddah to the PTT center in Kuwait has recently been established, and the next step will be to connect the NMC at the Kuwait Airport to the PTT center. An upgrade of the link between kuwait and RTH Jeddah to medium speed, telephone type is necessary to enable the timely transmission of data and products required in Kuwait through the GTS. As an additional measure, WMO installed at the end of July a Data Collection Platform (DCP) at Kuwait Airport which allows the relay of radiosonde data (TEMP and PILOT) as well as surface observations directly through METEOSAT for injection into the GTS.

Now, what I'm saying has been drafted and written around Monday last week, so it's about a week old. As far as I know, these devices I am referring to have been shipped, but they are not through custom clearance.

The reception of satellite data, in particular imagery is of considerable importance. The WMO plan therefore includes the establishment of APT/WEFAX receiving station. In addition, it is planned to establish a ground receiving station for the Meteorological Data Dissemination (MDD) system operated by METEOSAT which will allow direct reception of a broad selection of meteorological products urgently needed in Kuwait, including among others those from the ECMWF, from the World Area Forecast Centre in London (to serve aviation), and from other Global Data Processing System (GDPS) centers in Europe. Those centers took responsibility within the WWW scheme to provide products of a regional or super regional basis, or in some cases, on a global basis.

Apart from the situation in Kuwait, similar attention is being given to improve the operational WWW components in neighboring countries in the down wind area. The improvements of the observing network in Iran, Iraq, and Afghanistan appears to be most urgent. However, our monitoring results indicate that for various reasons, only a small percentage of reports from these stations are routinely available from some countries on the GTS. In particular the implementation of a radiosonde station in the Northwest Iran is a matter of priority. WMO is also making all efforts to improve the timely exchange of all available observational data.

Data Management Concept

The WWW structures (Global Observing System [GOS], GDPS, and GTS) have been offered to support the management of atmospheric data generated by various groups in the Gulf region. The Regional Specialized Meteorological Center (RSMC) Jeddah has indicated that it is ready to act as a data center. This workshop in Boulder, Colorado, is expected to develop a concept for the management of air monitoring data from the Gulf collected under

the Gulf Air Monitoring Program (GRAMP). WMO will involve all concerned countries and scientific groups to reach agreement on data formats, exchange policy, management and archiving procedures, availability of data sets, etc.

The WMO Members and scientific groups concerned have requested that use should be made of proven methodology (such as NCAR data management systems) and existing WMO formats, procedures and structures, where possible to meet the requirements for data and products within and outside the Gulf Region. This may include the use of GDPS centers to provide specialized analysis and forecast products as well as data base services. It will also involve the use of the GTS for the real-time and nonreal-time exchange of data where required and appropriate.

Emergency Response

Several institutes are ready to provide analysis and forecast products to Kuwait, if required on a routine bases to support an appropriate emergency response system. WMO is taking steps to coordinate and organize such support. Although relatively high resolution meteorological (mesoscale) products are available from major GDPS centers, it is not guaranteed that these are always meaningful due to the general lack of data from the region. The products from major centers will therefore have to be interpreted by experienced forecasters before applied on a national scale and used as an input for air quality assessments and forecasts. WMO proposes that this capability be established as a warning center in Kuwait combining the expertise of a meteorologist, an air quality, and a health expert to cooperate routinely in providing analyses and regular advice to decision makers in the countries.

This briefly summarizes the position of WMO in the view of two major tasks we are trying to pursue and which I would like to convey to the workshop as objectives from the point of view of WMO, which is to provide recommendations for the establishment of an Emergency Response Scheme to give the countries in the region a mechanism at hand to warn their population and their economists in appropriate fashions. The second objective is to arrange for a consolidated, consistent, and common data storage and archiving for those centers for either producing or collecting data or who take responsibility in producing dedicated products for the region.

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APPENDIX D--The WWW Data Management Concept of WMO

Dieter Schiessl World Meteorological Organization Geneva, Switzerland

Background

The World Weather Watch (WWW)--the basic program of WMO--is twenty-five years old. From the start, this program consisted of three components, namely the Global Observing System (GOS), the Global Data Processing System (GDPS) and the Global Telecommunication System (GTS). After the first GARP Global Experiment (FGGE) had revealed a number of serious deficiencies, the WMO Congress initiated in 1979 the WWW Integrated System Study (ISS). As a result of this study, the perception of the three component structure was replaced by a concept of an integrated WWW system, whereby appropriate data-management functions should effectuate the integration. The WWW Data Management Concept was introduced through the WMO Second Long-term Plan (1988-1997) and the WMO Congress (Cg-X 1987) noted its importance as the integrating element in the WWW system and urged its rapid implementation.

Problems and Opportunities

The volume of data produced and exchanged globally within the WWW system nearly doubles every five years. This in mainly caused by:

- 1. Progressing introduction of surface-based, automated, remote-sensing systems (Radar, Sodar, Lidar, etc.);
- 2. Increasing use of automated *in-situ* observing systems (AMDAR, ASDAR, drifting buoys, etc.);
- 3. Growing volume of satellite data;
- 4. Expanding data volumes generated by numerical meteorological productions.

The total amount of data is expected to exceed, in many cases, the requirements of individual Members. The widely uncontrolled injection of information sets into the GTS will lead to overloading of many telecommunication links and of national data bases and will hinder the Members' efficient access to those sets of information needed for their daily operations.

The present data exchange system (GTS) shows deficiencies, since it still carries, in many parts, the basic features of a conventional Teletype system (i.e., store and forward of character-based data via many nodes) and is, therefore, no longer capable to render the services needed to cope with growing requirements within a reasonable financial and technical framework. It is necessary to look for appropriate means in terms of Data Management to carry the present data exchange system forward through a transitional phase to a system fully developed for the requirements of the next decade.

But side-by-side with these problems, new opportunities have emerged. Cost-efficient technologies for data processing and telecommunications favor the coordinated design and implementation of automated systems and also facilitate the cooperation of Members within the WWW system at different levels of sophistication. An array of Regional Specialized Meteorological Centers (RSMC) with geographical and activity specialization in concert with the three WMCs and a number of advanced Regional Telecommunications Hubs (RTH) provide an ideal starting point for better coordinated and improved data exchange among each other and with presently 160 National Meteorological Centers worldwide.

The rapidly growing appreciation of and adherence to international standards for telecommunications and data processing technology in the meteorological community, mainly for computer graphics, software management and telecommunication are major assets which open new and promising prospects for the WWW system.

WMO fully recognized these new opportunities for its vast data handling requirements and responded by introducing the Data Management (DM) Concept as an element of WWW.

Data Management Concept

Purpose and Scope

Data Management is the component within the WWW system which provides those support functions needed for the orderly overall management of meteorological data and products of the WWW system, the most economical use of the resources of the WWW system components, the monitoring data and product availability and quality, the identification of operational deficiencies and the initiation of remedial activities. It will be realized by implementing DM functions and services in the networks and facilities of GOS, GTS, and

GDPS and in the interfaces between them. In order to enable each member to participate at a level commensurate with its abilities and requirements, it is necessary to allow for suitable interfaces, flexible developed and developing countries. Particularly in the area of data processing and telecommunications, DM will define and design proper procedures and interfaces which will allow Members to obtain the coherent and appropriate sets of data and products required. Hence, the main long-term objectives of DM concept are defined as follows.

- 1. To fully integrate WWW operations and monitoring activities including methods to correct deficiencies in the WWW System;
- 2. To establish common procedures for management and handling of data and products within the WWW System in order to meet effectively and efficiently Members' individual requirements;
- 3. To coordinate and support DM issues for the participation of Members in the technologically advancing WWW System.

Organization

The Commission for Basic Systems (CBS-IX 1988) established the Working Group on Data Management (WGDM) to deal with concept and implementation of DM. This group should coordinate with the Working Groups on the GTS, GOS, and GDPS in DM matters as appropriate. The Working Group on Data Management is assisted by the Sub-groups on Data representation and on Codes. As to the technical expertise, the working group relies on expert meetings, workshops, and consultants. This organizational framework is supplemented on the global level by Implementation Coordination Meetings on the DM on the Main Telecommunications Network (MTN), and on the regional level by the Regional Implementation Coordination Meetings on DM and Regional WWW Implementation Coordination Working Groups.

Current Activities

Although the DM concept is just beginning to evolve in the long history of WWW, CBS has already embarked on a number of prominent issues:

Distributed Databases Concept (DDBs)

The DDB concept envisages a number of databases, each owned and operated by a center, containing a number of data sets of observational data and products of the WWW system primarily for use in real time or near real time. In entirety, each data set provides all currently available data of a particular type or of a defined scope, e.g., all TEMP data, all satellite soundings at a defined resolution. Each database is intended to relate to a specific sub-set of WWW data, by data type, period of retention, and geographic area. Database centers are distributed in relation to geographic or other requirements recognizing the constraints imposed by telecommunication facilities.

Data from the DDB will be in principle available by routine arrangements. This mechanism will be supplemented by ad hoc request/reply and special arrangements, whereby the assignment of specific responsibilities above national level to individual data centers will be by international agreement through CBS and its working groups.

- 1. Routine arrangements handle data for exchange on a regular basis on the GTS;
- 2. Ad hoc requests will occur on an occasional basis and are temporary by nature;
- 3. Special arrangements handle data which are normally not made available over the GTS, but are exchanged by-lateral agreements such as experimental data or data-related to research projects.

Planning of the data center network should ensure that each set or subset of data provided at a data center to meet the needs of a particular service domain should be available at another center and that in event of failure arrangements are made for supply of required data to/from that domain from/to alternate centers and for the rapid re-establishment of database contents on recovery of the center which has suffered failure.

The logical organization for the DDBs is illustrated Figure 1. Designation of centers with primary and alternate responsibilities must be governed by availability of appropriate telecommunication services. Principally, these will be provided by the improved GTS as illustrated by the scheme in Figure 2. The use of other facilities, e.g., public data networks, for back-up and special purpose access must also be expected. Adequate measures to protect from unauthorized access must be provided.

Complementary to subsets of data of different types, e.g., those provided by different types of observing systems, the DDBs should include added information to original observational data, e.g., quality control information provided by GOS and GDPS services. Such

information should be made available as required. Data should also be provided selectively to meet routine or specific requirements, the smallest addressable data entity within the DDB being governed by the ability to represent such data within a single element of a WMO code form, e.g., one BUFR item, one GRIB representation.

The DDB concept is envisaged to extend to data-related to status information on availability and quality of data, including products, to climatological and oceanographic data, and to data in archives.

Procedures for Monitoring of the Status of WWW System

The objectives of the monitoring activities are to improve the performance of the WWW on a national, regional and global level through identifying deficiencies and initiating corrective actions as quickly as possible. Efficient monitoring requires close cooperation between all centers concerned, as well as with the WMO Secretariat. To this end, WMO has developed plans which detail procedures and responsibilities for monitoring activities for data availability in real time and non-real time and for data quality.

Real-Time Monitoring Activities

Real-time monitoring contains activities carried out quickly enough to allow remedial action to be taken in time to be of value in day-to-day meteorological work. This requires swift exchange of information between centers concerned, e.g.:

- 1. Bulletins not received by the time specified;
- 2. Observations not received, or which are incorrect;
- 3. Inadequacies in receipt of processed information.

Non-Real-Time Monitoring Activities

Non-real-time monitoring activities are carried out over a specific time period at an agreed frequency, for instance once per year. Types of data to be monitored include observations such as TEMP, SYNOP, PILOT, AMDAR, CLIMAT, BATHY, TESAC which are marked for global exchange. WWW centers are invited to participate and provide their findings to the WMO Secretariat. The WMO Secretariat coordinates these activities and produces a summary of statistics and evaluates, as far as possible, the deficiencies.

Non-Real-Time Data Quality Monitoring

The monitoring of the quality of observational data is based on so-called "lead centers." For each type of observation, a lead center will be nominated which a view to taking a leading role in the coordination between participating centers of all monitoring aspects, including common methods and criteria to be used for compiling statistics. Such centers continuously carry out the monitoring activities and compile and distribute reports every six months. For monitoring on global level, the following centers act as lead centers:

- 1. Upper-air observations--ECMWF Reading;
- 2. Marine weather observations-RSMC Bracknell;
- 3. Satellite and aircraft observations-WMC Washington.

The plan for the monitoring the quality of surface observations is to seek lead centers on regional level for carrying out this task. Presently, RSMC Tokyo for Region II and WMC Melbourne for Region V have begun to monitor on regional level. Coordination to find other lead centers is ongoing in the remaining regions.

Coordination of Exchange of Software

Technical and procedural innovations have forced many Member countries, and in particular the developing ones among them, to look for computer support for handling improving their operations. Although, the computer industry offers higher hardware performance at lower cost, the actual benefit expected from the use of computers can only be attained through complex computer programs which are difficult to obtain, especially in developing countries. Meanwhile, progressing standardization made many basic meteorological functions that need to be performed at the various centers, similar or almost identical and programs for these functions are available in many centers. A free exchange will help others in obtaining software modules, design ideas, or development methodologies without "re-inventing the wheel" many times over and without big financial investment. In view of this, WMO has started to collect information on meteorological applications software which is offered and/or requested by Member countries for exchange, and published a catalogue on such data in early 1991. The main objectives of this activity are to:

- 1. Encourage and support the free exchange of application software among the WMO Members;
- 2. Provide an overview of applications software offered and requested by WMO Members.

Promotion of Suitable Standards

It is the view of CBS that the entire sector of software development and maintenance, including efforts to prot software between various hardware platforms could become much more cost-efficient if appropriate standards would be consequently applied. Although, CBS has not yet published firm recommendations it encouraged WMO Members to follow guidelines, such as:

- 1. The general use of UNIX;
- 2. The use of GKS in graphical applications;
- 3. The modular architecture of meteorological computer system with well-defined interfaces;
- 4. The separation of the telecommunications component from the applications component;
- 5. The preference of WMO binary formats, wherever this is possible.

Work is underway to look at graphical interfaces best suitable for a meteorological operational environment.

Data and Product Representation

Binary Formatting Systems

The use of bit-oriented formatting systems FM 92 GRIB and FM 94 BUFR is rapidly progressing in the meteorological community and their range of data representation is steadily expanding. Ten centers are presently capable of exchanging binary data, and this number will double in the near future.

It is the policy of CBS to further develop and promote the binary formats and, at the same time, maintain and improve the WMO character-oriented codes where this is necessary.

For instance, recent improvements of GRIB included:

1. Identification of high precision and mixed precision pressure and sigma layers;

- 2. Accommodation of vertical coordinate parameters and quasi-regular grids;
- 3. Revision of the definition of the Mercator grid revised to allow for more precision in the grid length specification;
- 4. Definition of a space view or "perspective" map projection, with satellite needs in mind;
- 5. Representation of a matrix of values at each grid point with the freedom to specify the coordinates of the matrix; second order packing can now be done either on a row-by-row basis or by selecting various points in the data to start, or restart, the second order packing. The latter is a variant of "run-length encoding."

BUFR was recently expanded to include:

- 1. Many new descriptors for aviation, radar, surface observations, radiation, satellites, ship reports, wind profilers, etc.
- 2. A set of new descriptors to describe information about quality control, replaced values, retained values, the original values, statistics of the measurements, etc; it will now become possible to handle quality control information in BUFR.
- 3. A feature which allows splitting of large binary data entities into smaller ones, thus facilitating more convenient handling of such data sets at GDPS centers and also allowing transmission of binary data sets that would otherwise exceed the maximum size of a message on the GTS.

WMO Character Codes

WMO maintains a spectrum of 45 character codes which are needed to represent observational data and products stemming from meteorological, climatological, aeronautical, and oceanographic sources. These codes are published in the WMO Manual on Codes Vol I and Vol II (WMO-No. 306) and kept up-to-date by the Sub-group on Codes.

Given the co-existence of both data representation standards and the adherence to the principle that one and the same should not be exchanged on a given link on the GTS in both formats, it is obvious that some kink of interface is needed between both representation forms. Standardized techniques are being sought for the transformation between bit-oriented and character-oriented formate, e.g., to:

- 1. Facilitate the human legibility (visualization) of binary coded data;
- 2. Allow for exchange on those parts of the GTS where centers are not automated or where telecommunication capabilities are insufficient;
- 3. Overcome the inflexibility inherent to character codes.

At present, two proposals are being discussed, namely the IGOSS Flexible Code (IFC) and the BUFR Tabular Form (BTAB). This is done with a view towards developing a flexible character code which are best described as character codes analog to BUFR in that they share many of the advantages of BUFR, but can be transmitted on low-speed communication lines.

Extension of DM Principles to Other WMO Programs

Other WMO programs (e.g., World Climate Program, and in particular the Global Climate Observing System (GCOS), the Global Atmospheric Water, Hydrology and Water Resources Program, the Environmental Program, etc.) will progressively take advantage of the basic services of the WWW systems in order to establish efficient and consistent data handling procedures across the programs. There are, for instance, growing requirements for the use of climatological data in near real time. Such requirements lead to requests from other WMO programs for a timelier, more reliable exchange of growing data volumes. There is a need to include oceanographic data, radioactive radiation data, volcanic activity data, satellite data archives, etc., in the WWW data handling. In this respect, consultations and cooperation are being sought with the relevant WMO technical commissions with other intergovernmental and international organizations.

Summary

The integration of the core elements of the WWW system is seen as an essential prerequisite for an efficient operation and should enable the WWW system to cope with the rapid evolution of meteorological requirements and techniques and should ensure that proper WWW data and products subsets are available to Members in a timely and convenient fashion. k The WWW Data Management concept is expected to bring about this important level of integration. The various data-management functions will be introduced progressively over a period of years and all aspects and experiences gained will be closely monitored.

References

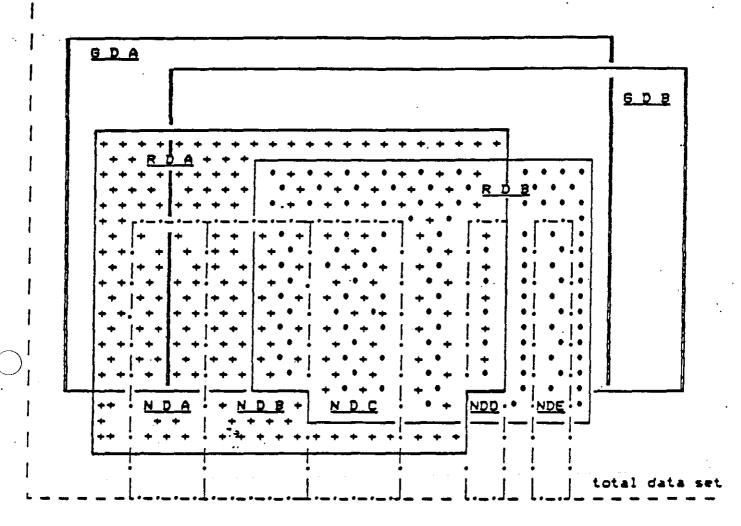
Cg-X 1987: Tenth WMO Congress, Geneva, 4-18 May 1987, Abridged Final Report with Resolutions; WMO-No. 681.

SLTP 1987: The World Weather Watch Programme 1988-1997, Second Long-Term Plan, Part II, Vol. 1; WMO-No. 691.

CBS-IX 1988: Commission for Basic Systems, Abridged Final Report of the Ninth Session, Geneva, 25 Jan - 5 Feb 1988; WMO-NO. 699.

[Figure 1]--Domains for one data set

total data set



N = National Domain: Includes all national data and the subsets received from other

national, regional, and global data centers

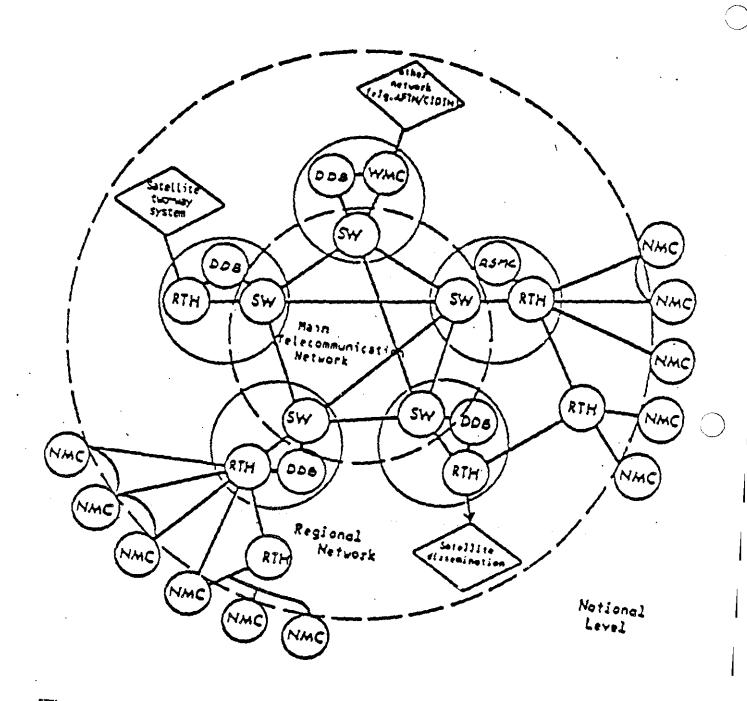
R = Regional Domain: Includes data collected from national domains and required sets

or subsets from other regional centers and from global centers

G = Global Domain: Includes all required data from global and regional exchange

Note: Required data are those data needed by centers routinely served plus data needed to provide alternate (backup) service in emergency.

Structure of GTS



[Figure 2]--Switching Node (included in fuctions of RTHs on the MTN)

Status of Kuwait Data Archive Project

One month after the official approval of the archive project, the status is as follows:

Equipment

- The workstation and software for processing and archiving AVHRR, METEOSAT, and DMSP images has been ordered and is expected to arrive within two weeks.
- The workstation for the catalog database has been installed into the network and is now accessible by outside users with network connections.

Personnel

• We have closed the advertising for the Associate scientist, programmer, and applications programmer. Interviewing of potential candidates is underway and offers are expected to be made within two weeks.

Data Catalog

- We have decided to implement the EMPRESS software package as the database for meta-data describing the data sets available in the archive. This software was selected since it is presently being used at NCAR to archive other massive data sets and because of its extreme flexibility. With this software we are offering the following services to users of Gulf region data:
 - Perusal of all available information on data sets including searches by geographical location, time period, type of measurement, type of measurement platform, type of sensor, etc.
 - Selection of archived data filtered by any of the above combination of parameters; e.g. the user could request all SO₂ measurements for the time period May 1-15, in the area bounded from 25°-26° latitude, 48°-49° longitude. Depending upon quantity, the data will be sent to the user on a medium of his choice, i.e. electronic mail, ½ tape, etc.
 - The data will be sent to the user in an easily read format and every data point will have associated with it a time and geographical location.

Data Archive

- The NCAR aircraft data is presently being reviewed for quality control and final trend removal is being implemented. These data should start being ready for public use by November 1.
- Lidar processing algorithms are presently being written and the first data sets should be ready by mid-November.
- The Dropsonde data is in final processing stage and will be in the central archive by November 1.
- Satellite data processing will begin once the equipment and software arrives and processed images will start becoming available approximately a month following.
- A catalog of all images available from LandSat has been obtained and will soon be on the data cataloging system.
- A letter requesting data will be sent this week to all organizations who are presently known to have participated in measurement programs in the Gulf. Hopefully there will be a positive response. The known sources of data at this point are:

Ground-Based Measurements

- Meteorological and Environmental Protection Agency (Saudi Arabia)
- Environmental Protection Agency (Bahrain)
- Environmental Protection Agency (United States)
- National Oceanic and Atmospheric Administration (United States)
- National Institute for Standards and Technology (United States)
- German Ministry for Environment

Airborne Measurements

- United Kingdom Meteorological Office
- National Center for Atmospheric Research (United States)
- University of Washington (United States)
- German Ministry for Environment
- National Aeronautics and Space Administration (United States)
- Department of Energy (United States)

Satellite Measurements

- Meteosat 4 and 5 (Europe)
- NOAA 10 and 11 (United States)
- DMSP
- LANDSAT (United States)
- SPOT

Surface and Upper Air Stations

• The WMO World Weather Watch has 180 surface observing stations and about 40 upper air stations in the countries concerned.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH P.O. Box 3000 • Boulder, Colorado 80307-3000

Telephone: (303) 497-1000 • Telex: 989764

October 14, 1991

In the aftermath of the Gulf War and the burning of the Kuwait Oil Wells there was a large scale, international effort to assess the impact on human health, ecology and local and global climate. The World Meteorological Organization convened an emergency response meeting of experts in April of this year to discuss how best to respond to this disaster and to muster the cooperation of all participating agencies in an organized measurement program that would cover as many aspects of the problem as possible. The participants agreed that there would need to be a method by which all the data sets could be archived in a centralized location for easy access and distribution.

The National Center for Atmospheric Research has taken on the task of creating an archive of all atmosphere related data sets at the request of the WMO and with the support of the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the National Science Foundation, the Defense Nuclear Agency, and the Department of Energy. We are in the early stages of developing this system but have in place enough of the structure that we are now ready to begin cataloguing and archiving those data sets that are complete and ready to be placed in the archive.

Access to the data will be through a commercial database that can be accessed either via the electronic network or over a telephone modern. This database will contain enough information about each of the data sets to allow the user to determine if the measurements in the archive would be of interest to his or her studies. Once a particular set of time periods, geographical locations, and parameters are selected, the data can be received on magnetic tape or compact disk or over the electronic network.

The purpose of this letter is to solicit information about the measurements that you or your organization were involved in making in the Gulf Region. We have attached a questionnaire to be completed that will be used to document these data in the centralized database. This is also the first step in helping us to obtain your data and to write the appropriate software that will allow user access to all the data. The scope of the archive is being limited to digitally formatted data on magnetic media. However, information about the availability of other data sources can be entered into the database catalogue.

We are also ready to begin receiving the actual data in the final archivable format. If the data processing has not been completed at this time and the data are not available a small sample data subset would be helpful as long as it is in the final format. When you are able to send data to be put in the archive please make sure that you have retained the original or a verified copy at your organization and notify the Kuwait Data Archive (KuDA) office by electronic mail, telephone, or FAX that the data have been sent. You will also need to include specific information on the structure and format (i.e. informational header, word size, record size, etc.) to assist us in writing the access software for reading the data from the media.

We realize the level of effort that this request will require from you and your colleagues and appreciate your cooperation. Please contact us if you have any questions about the questionnaire or any other aspect of our request.

We may be contacted at:

KuDA Archive Office

(303) 497-1029

(303) 497-1092 (fax)

Electronic Mail

(Internet)

kuda@spock.atd.ucar.edu

(OMNET)

NCAR.RAF

Send data to Kuwait Data Archive

c/o Research Aviation Facility

10800 West 120

Broomfield, Co 80021

Sincerely,

Darrel Baumgardner

Richard Friesen

KuDA Project Managers

DB/RF/bak

Enclosure

Kuwait Data Archive (KuDA) Questionnaire

Agency			_		
Research Pla	atform(s)	· •			•
Data Format	(e.g. ASC	:II)			•
Data Structi	ire on Med	lia		<u> </u>	
Media Type	(e.g ½ Mag	netic tape)			
Anticipated	Date of A	vailability of D	ata		-
Measurement	Periods a	nd Locations			
(Please	e use addi	tional pages as	needed)	•	
Date Time	Period Bou	ındaries (N,S Lat	:.;E,W Long	J.; Altit	ude)
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Ancillary or related data													
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Primary Address									ation	·	<u>.</u>		

Kuwait Data Archive (KuDA)Questionnaire SAMPLE

Agency Natio	onal Center for Atmospheric	Research		
Research Pla	atform(s) <u>Aircraft</u>			
Data Format	(e.g. ASCII) Scaled Intege	er		
Data Structu	re on Media <u>1 second bloc</u>	ks of 60 parameters		
Media Type	(e.g ½ Magnetic tape) <u>Exab</u> y	rte		
Anticipated	Date of Availability of Dat	a November 1, 1991		
Measurement	Periods and Locations			
(Please	e use additional pages as ne	eeded)		
Date Tim	ne Period Boundaries (N,S	Lat.; E, W Long.; Altitude)		
6/19/91 063	35 - 1132UCT 25.2°-29.5° ; 4	8.0° - 50.4° ; 1000-5500 m		
6/21/91 085	52 - 1347UCT 25.1°-28.1° ; 4	8.8° - 53.0° ; 900 -3650 m		
		-		
Sensor Desci	ription			
	e use additional pages as ne			
Parameter	Sensor Description	Measurement Range		
туре	(Mfg., technique)	and Estimated Accuracy		
<u>Temperature</u>	Rosemount, Platinum Wire	-60°C to +40°C, ±0.5		
Pressure	Rosemount, Diaphram	0 to 1000 mb, ±.3 mb		
Dew Point	EG&G. Chilled Mirror	-40°C to 40°C, ±0.5°C		
				
				

Ancillary or related data
Lidar, 0.5, 1.06, 10.6 µm wavelength
Filter Samples
Dropsondes
Summary of data quality and any significant problems encountered.
Generally of very high quality. Any data quality problems are
included with documentation. Time periods where instrumenation
was inoperable or measurements may be questionable are signified
with the value -9999 in the data.

Primary Contact Person for Further Information <u>Darrel Baumgardner</u> Address, telephone #, Fax #, E-mail, Etc.

NCAR/RAF Box 3000 Boulder, Colorado 80307

Tel# (303) 497-1054 1092 (fax)

E-mail (Internet) darrel@spock.atd.ucar.edu

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Status of Kuwait Data Archive Project

One month after the official approval of the archive project, the status is as follows:

Equipment

- The workstation and software for processing and archiving AVHRR, METEOSAT, and DMSP images has been ordered and is expected to arrive within two weeks.
- The workstation for the catalog database has been installed into the network and is now accessible by outside users with network connections.

Personnel

• We have closed the advertising for the Associate scientist, programmer, and applications programmer. Interviewing of potential candidates is underway and offers are expected to be made within two weeks.

Data Catalog

- We have decided to implement the EMPRESS software package as the database for meta-data describing the data sets available in the archive. This software was selected since it is presently being used at NCAR to archive other massive data sets and because of its extreme flexibility. With this software we are offering the following services to users of Gulf region data:
 - Perusal of all available information on data sets including searches by geographical location, time period, type of measurement, type of measurement platform, type of sensor, etc.
 - Selection of archived data filtered by any of the above combination of parameters; e.g. the user could request all SO₂ measurements for the time period May 1-15, in the area bounded from 25°-26° latitude, 48°-49° longitude. Depending upon quantity, the data will be sent to the user on a medium of his choice, i.e. electronic mail, ½ tape, etc.
 - The data will be sent to the user in an easily read format and every data point will have associated with it a time and geographical location.

Data Archive

- The NCAR aircraft data is presently being reviewed for quality control and final trend removal is being implemented. These data should start being ready for public use by November 1.
- Lidar processing algorithms are presently being written and the first data sets should be ready by mid-November.
- The Dropsonde data is in final processing stage and will be in the central archive by November 1.
- Satellite data processing will begin once the equipment and software arrives and processed images will start becoming available approximately a month following.
- A catalog of all images available from LandSat has been obtained and will soon be on the data cataloging system.
- A letter requesting data will be sent this week to all organizations who are presently known to have participated in measurement programs in the Gulf. Hopefully there will be a positive response. The known sources of data at this point are:

Ground-Based Measurements

- Meteorological and Environmental Protection Agency (Saudi Arabia)
- Environmental Protection Agency (Bahrain)
- Environmental Protection Agency (United States)
- National Oceanic and Atmospheric Administration (United States)
- National Institute for Standards and Technology (United States)
- German Ministry for Environment

Airborne Measurements

- United Kingdom Meteorological Office
- National Center for Atmospheric Research (United States)
- University of Washington (United States)
- German Ministry for Environment
- National Aeronautics and Space Administration (United States)
- Department of Energy (United States)

Satellite Measurements

- Meteosat 4 and 5 (Europe)
- NOAA 10 and 11 (United States)
- DMSP
- LANDSAT (United States)
- SPOT

Surface and Upper Air Stations

• The WMO World Weather Watch has 180 surface observing stations and about 40 upper air stations in the countries concerned.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH P.O. Box 3000 • Boulder, Colorado 80307-3000

Telephone: (303) 497-1000 • Telex: 989764

October 14, 1991

In the aftermath of the Gulf War and the burning of the Kuwait Oil Wells there was a large scale, international effort to assess the impact on human health, ecology and local and global climate. The World Meteorological Organization convened an emergency response meeting of experts in April of this year to discuss how best to respond to this disaster and to muster the cooperation of all participating agencies in an organized measurement program that would cover as many aspects of the problem as possible. The participants agreed that there would need to be a method by which all the data sets could be archived in a centralized location for easy access and distribution.

The National Center for Atmospheric Research has taken on the task of creating an archive of all atmosphere related data sets at the request of the WMO and with the support of the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the National Science Foundation, the Defense Nuclear Agency, and the Department of Energy. We are in the early stages of developing this system but have in place enough of the structure that we are now ready to begin cataloguing and archiving those data sets that are complete and ready to be placed in the archive.

Access to the data will be through a commercial database that can be accessed either via the electronic network or over a telephone modem. This database will contain enough information about each of the data sets to allow the user to determine if the measurements in the archive would be of interest to his or her studies. Once a particular set of time periods, geographical locations, and parameters are selected, the data can be received on magnetic tape or compact disk or over the electronic network.

The purpose of this letter is to solicit information about the measurements that you or your organization were involved in making in the Gulf Region. We have attached a questionnaire to be completed that will be used to document these data in the centralized database. This is also the first step in helping us to obtain your data and to write the appropriate software that will allow user access to all the data. The scope of the archive is being limited to digitally formatted data on magnetic media. However, information about the availability of other data sources can be entered into the database catalogue.

We are also ready to begin receiving the actual data in the final archivable format. If the data processing has not been completed at this time and the data are not available a small sample data subset would be helpful as long as it is in the final format. When you are able to send data to be put in the archive please make sure that you have retained the original or a verified copy at your organization and notify the Kuwait Data Archive (KuDA) office by electronic mail, telephone, or FAX that the data have been sent. You will also need to include specific information on the structure and format (i.e. informational header, word size, record size, etc.) to assist us in writing the access software for reading the data from the media.

We realize the level of effort that this request will require from you and your colleagues and appreciate your cooperation. Please contact us if you have any questions about the questionnaire or any other aspect of our request.

We may be contacted at:

KuDA Archive Office

(303) 497-1029

(303) 497-1092 (fax)

Electronic Mail

(Internet)

kuda@spock.atd.ucar.edu

(OMNET)

NCAR.RAF

Send data to Kuwait Data Archive

c/o Research Aviation Facility

10800 West 120

Broomfield, Co 80021

Sincerely,

Darrel Baumgardner

Richard Friesen

KuDA Project Managers

DB/RF/bak

Enclosure

Kuwait Data Archive (KuDA) Questionnaire

Agency									
Research Platform(s)									
Data Format (e.g. ASCII)									
Data Structure on Media									
Media Type (e.g \ Magnetic tape)									
Anticipated Date of Availability of Data									
Measurement Periods and Locations									
(Please use additional pages as needed)									
Date Time Period Boundaries (N,S Lat.; E, W Long.; Altitude)									
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Sensor Description									
(Please use additional pages as needed)									
Parameter Sensor Manufacturer Technique Range Accur	acy								
Measured Type									
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Ancillary or related data									
									
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Summary	of	data	qualit	y and	l any	signii	ficant	problems	encountered.
									
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INFORMATION SOURCES

INTERNATIONAL COOPERATION

- 1. "Report of the WMO Meetings of Experts on the Atmospheric Part of the Joint UN Response to the Kuwait Oilfield Fires." Contact: Danny Foster, World Meteorological Organization, 41 Avenue Giuseppe Motta, P.O. Box 2300, 1211 Geneva 2, Switzerland. Phone: 41 222 730-8259.
- 2. Gulf Regional Air Monitoring Plan (GRAMP)." Contact: Andrew E. Bond, Atmospheric Research and Exposure Assessment Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Phone: 919 629-4329.
- 3. Kuwait Oil Fires: Interagency Interim Report." Contact: Gulf Task Force, Environmental Protection Agency, 401 M Street, SW, Washington DC 20460.
- 4. "UN Interagency Action Plan on the Kuwait Oil Fires." Contact: Gulf Program Office, Office of the Chief Scientist, National Oceanic and Atmospheric Administration, Herbert C. Hoover Bldg, 14th and Constitution, N.W., Washington D.C., 20230. Phone: 202 377-5483, Fax: 202 377-9714.
- 5. "Statement by Miss Margaret J. Anstee, Director-General, United Nations Office at Vienna, and Personal Representative of the Secretary-General to Coordinate United Nations Efforts to Counter the Impact of the Burning Oil Wells and Other Environmental Consequences of the Gulf Conflict in Kuwait and in the Region." Contact: Gulf Program Office, Office of the Chief Scientist, National Oceanic and Atmospheric Administration, Herbert C. Hoover Bldg, 14th and Constitution, N.W., Washington D.C., 20230. Phone: 202 377-5483, Fax: 202 377-9714.

OVERVIEWS, ASSESSMENTS

6. "Preliminary Scientific Report - Kuwait Oil Fires," [NCAR and University of Washington flight team debriefing in Bahrain]. Contact: Gulf Program Office, Office of the Chief Scientist, National Oceanic and Atmospheric Administration, Herbert C. Hoover Bldg, 14th and Constitution, N.W., Washington D.C., 20230. Phone: 202 377-5483, Fax: 202 377-9714.

- 7. "An Updated Briefing on the Kuwaiti Oil Fire Smoke Experiment (KOFSE)." Contact: Lawrence F. Radke, NCAR Research Aviation Facility, Boulder, Colorado 80307-3000. Phone: 303 497-1030, Fax: 303 497-1092 or contact: Peter V. Hobbs, Atmospheric Sciences Department, AK-40, University of Washington, Seattle, Washington, 98195. Phone: 206 543-6027, Fax: 206 543-0308, Omnet: P. Hobbs.
- 8. "Statement by Dr. Abdulrahman A. Al Awadi, Chairman of Emergency Committee, Environment Protection Council (EPC), of Kuwait, to the Second Committee, United Nations General Assembly, 20 November 1991." Contact: Gulf Program Office, Office of the Chief Scientist, National Oceanic and Atmospheric Administration, Herbert C. Hoover Bldg, 14th and Constitution, N.W., Washington D.C., 20230. Phone: 202 377-5483, Fax: 202 377-9714.

KUWAIT OIL FIRE STATUS

- 9. "Kuwait Oil Well Fires Updated." Contact: Joseph R. Riva. Jr., Congressional Research Service, Science Policy Research Division, The Library of Congress, Washington DC 20540. Phone: 202 707 7040.
- 10: "Kuwait Oil Fire Extinguishing Chronology." Contact: Gulf Program Office, Office of the Chief Scientist, National Oceanic and Atmospheric Administration, Herbert C. Hoover Bldg, 14th and Constitution, N.W., Washington D.C., 20230. Phone: 202 377-5483, Fax: 202 377-9714.

AIRCRAFT MONITORING DATA AND INFORMATION

Meteorological Office Mission

- 11. "Summary of the GULFEX Flights, 23rd 31st March 1991." Contact: M.A. Gibbs, Meteorological Research Flight, Royal Aerospace Establishment, Farnborough, Hants GU14 6TD, United Kingdom, May 1991.
- "Observations in March 1991 of the Oil Smoke Plume from Kuwait by the UK Meteorological Office C-130 Aircraft: Preliminary Report." Contact: G.J. Jenkins, Head, Meteorological Research Flight, Royal Aerospace Establishment, Meteorological Office, Farnborough, GU14 6TD, United Kingdom, June 1991.
- 13. "Airborne Observations of the Physical and Chemical Characteristics of the Kuwait Oil Smoke Plume," Contact: D.W. Johnson, Meteorological

Research Flight, Royal Aerospace Establishment, Meteorological Office, Farnborough, GU14 6TD, United Kingdom.

National Center for Atmospheric Research (NCAR) Mission

- 14. "Aircraft Research Instrumentation, Electra N308D," [also includes raw data from flight legs]. Contact: Lawrence F. Radke, NCAR Research Aviation Facility, Boulder, Colorado 80307-3000. Phone: 303 497-1030, Fax: 303 497-1092.
- 15. "NCAR Scientists Release Preliminary Results from Kuwait Oil Fires Study." Contact: Joan Vandiver Frisch, NCAR, P.O. Box 300, Boulder, Colorado 80307-3000.
- 16. Abstracts of papers submitted to the American Geophysical Union for presentation at the December 1991 meeting in San Francisco, California and at the January 1992 Ocean Sciences meeting in New Orleans, Louisiana. Contact authors at addresses listed in abstracts.

University of Washington Mission

- 17. "Carbon Budget Data," Contact: Peter V. Hobbs, Atmospheric Sciences Department, AK-40, University of Washington, Seattle, Washington, 98195. Phone: 206 543-6027, Fax: 206 543-0308, Omnet: P.Hobbs.
- 18. "Canister Samples (Partial Results)." Contact: Peter V. Hobbs, Atmospheric Sciences Department, AK-40, University of Washington, Seattle, Washington, 98195. Phone: 206 543-6027, Fax: 206 543-0308, Omnet: P.Hobbs.
- 19. "Summary of 'Grab Bag' Chemical Samples Obtained by University of Washington in the Kuwait Oil Fire Study (16 May 12 June 1991)," Contact: Peter V. Hobbs, Atmospheric Sciences Department, AK-40, University of Washington, Seattle, Washington, 98195. Phone: 206 543-6027, Fax: 206 543-0308, Omnet: P.Hobbs.
- 20. "Kuwait Filter Data," Contact: Peter V. Hobbs, Atmospheric Sciences Department, AK-40, University of Washington, Seattle, Washington, 98195. Phone: 206 543-6027, Fax: 206 543-0308, Omnet: P.Hobbs.
- 21. Abstracts of papers submitted by members of the University of Washington team to the American Geophysical Union for its December 1991. Contact authors at addresses listed in abstracts.

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Department of Energy Mission

22. "Bahrain Debriefing of DOE Monitoring Team, August 20, 1991."
Contact: Gulf Program Office, Office of the Chief Scientist, National
Oceanic and Atmospheric Administration, Herbert C. Hoover Bldg,
14th and Constitution, N.W., Washington D.C., 20230. Phone: 202 3775483, Fax: 202 377-9714.

NASA/EPA Helicopter Mission

- 23. "Overview of the EPA/NASA In Plume and Ground Level Measurements Made in Kuwait July 28 to August 8, 1991." Contact: Robert K. Stevens and Joseph P. Pinto, Atmospheric Research and Exposure Assessment Laboratory, Environmental Protection Agency, Research Triangle Park, North Carolina, 27711. Phone: 919 541-3155, Fax: 919 541-6690.
- 24. "Kuwait Oil Fires: Helicopter Operations." Wesley R. Cofer III, NASA-Langley Research Center, Hampton, Virginia.
- Kuwait Oil Fires: NASA/EPA Near-Field Helicopter Source Characterizations." Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Studies Branch/ASD, Hampton, Virginia 23665-5225.
- 26. Kuwait Helicopter Operations: Kuwait Oil Fires." Wesley R. Cofer III, NASA-Langley Research Center, Atmospheric Studies Branch/ASD, Hampton, Virginia 23665-5225. ***Date?

SURFACE MONITORING DATA AND INFORMATION

- A. Measurement Campaign of the Regional Mobile Laboratory for Measurement of Air Quality in Kuwait, 27 March to 4 April 1991, Final Report. Contact: Philippe Lameloise, Director, AIRPARIF, 10, rue Crillon, 75004 Paris, France. Phone: 44 59 47 64, Fax: 44 59 47 00.
- B. "Analysis of Smoke Samples From Oil Well Fires in Kuwait." Contact: George W. Mulholland, National Institute of Standards and Testing [NIST], Gaithersburg, Maryland 20899. Phone: 301 975-6897, Fax 301 975-4052.
- C. "Air Quality Monitoring in Kuwait: First NII.U Mission, 5-12 June 1991." Contact: B. Sivertsen, Norsk Institut for Luftforskning, Postboks 64, N-2001 Lillestrom, Norway.

D. "Air Quality Measurements at Nordmedunit, Umm Qasr, Iraq."

Contact: B. Sivertsen, Norsk Institut for Luftforskning, Postboks 64, N-2001 Lillestrom, Norway...

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- E. "Ambient Air Monitoring Data: Dammam, Saudi Arabia," (Draft). [Data for April, May 1991]. Contact: David Olsen, Meteorology and Environmental Protection Administration [MEPA], Jeddah, Saudi Arabia. Phone: 966 2 651-2312.
- F. "Khafji," addendum to "Ambient Air Monitoring Data: Dammam," (Draft). [Data for 07 to 11 September 1991]. Contact: David Olsen, Meteorology and Environmental Protection Administration [MEPA], Jeddah, Saudi Arabia. Phone: 966 2 651-2312.
- G. "Ambient Air Monitoring Data: Kuwait," (Draft). [Data for April, May 1991]. Contact: David Olsen, Meteorology and Environmental Protection Administration, Jeddah, Saudi Arabia. Phone: 966 2 651-2312.

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- H. "Draft Report on Kuwait PAH Analysis." Contact: Charles B. Henry, Jr., Institute for Environmental Studies, Louisiana State University, Baton Rouge, Louisiana 70803. Phone: 504 388-8521, Fax: 504 388-4286.
- I. "Rainfall Samples Hydrocarbon Analyses: Analytical Data Reporting Forms," Wayne C. Curry, Surface Water Department, Ministry of Water Resources, Sultanate of Oman; Ruwi, Oman, 9 November 1991.

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HEALTH ASSESSMENTS

- J. "Assessment of Effects on Human Health from Kuwaiti Oil Field Fires." Contact: Dennis Engi, Sandia National Laboratories, Albuquerque, New Mexico.
- K. "Status Report of Public Health in Kuwait as of March 21, 1991." Contact: John S. Andrews, Jr., M.D., Associate Administrator for Science, Agency for Toxic Substances and Disease Registry, United States Public Health Service, 1600 Clifton Road N.E., Mailstop E28, Atlanta, Georgia 30333.
- L. "Emergency Health Plan of Action, Kuwait," (Working Document).
 Contact: Ministry of Public Health, PO Box 24395, Safat 13104, Kuwait.
 Phone: 965 245-6833, Fax: 965-242-1991.
- M. "Plan of Action for Protecting Public Health." Contact: Frank E. Young, Deputy Assistant Secretary for Health/Science and Environment,

Department of Health and Human Services, Room 701H, Hubert H. Humphrey Building, 200 Independence Avenue S.W., Washington, D.C. 20201. Phone: 202 245-6811, Fax: 202 245-7360.

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- "Emergency Room Surveillance-Kuwait City. "Contact: Gulf Program Office, Office of the Chief Scientist, National Oceanic and Atmospheric Administration, Herbert C. Hoover Bldg, 14th and Constitution, N.W., Washington D.C., 20230. Phone: 202 377-5483, Fax: 202 377-9714.
- O. "Harvard School of Public Health: Kuwait Air Sampling Survey, April 24 to May 11, 1991," Contact: John Dr. Spengler, Department of Environmental Health, Harvard University School of Public Health, 779 Huntington Ave, Boston, Massachusetts 02115. Phone: 617 432-1720.
- P. "The Kuwait Oil Fires: Presentation Abstracts and Speaker Biographies," [Harvard Conference materials]. Contact: John Evans, Harvard University School of Public Health, 779 Huntington Ave., Boston, Massachusetts 02115. Phone: 617 432-1720, Fax: 617 432-1226.
- Q. "Air Pollution from the Kuwait Oil Fires: Report of the Official Mission on the Environmental and Health Effects of the Oil Fires." Contact: Hirotaka Tachikawa, Chief, Environment Quality Standards, Air Quality Bureau, Environment Agency, 1-2-2 Kasumigaseki, Chiyoda-Ku, Tokyo, 100 Japan. Phone: 81-3(3581)3351, Fax: 81-3(3580)7173.
- R. "Impact of Oil Well Fires on Air Quality in the Urban Areas of Kuwait, Part I: Pollution by Particulates Less Than 10 Microns, and Part II: Pollution by Noxious Gases," Moustafa El Desouky and Mahmood Y. Abdulraheem, Environment Protection Department, Ministry of Public Health, PO Box 24395, Safat 13104, Kuwait. Phone: 965 245-6833, Fax: 965-242-1991. August 1991.
- S. "Kuwait Oil Fires and International Environment Considerations," [Darwin Conference materials], Darwin Scientific Foundation, Washington, DC, September 1991.
- T. "Health Advisory for Kuwait and Saudi Arabia." Contact: Ruth Etzel, Centers for Disease Control, 1600 Clifton Road, N.E., Atlanta, Georgia 30333. Phone: 404 488-4682, Fax 404 488-4900.

DATA MANAGEMENT

U. "Workshop Review: Management of Data Collected in GRAMP (Gulf Region Atmospheric Measurement Program)." Contact: Darrel Baumgardner, NCAR Research Aviation Facility, Boulder, Colorado 80307-3000. Phone: 303 497-1029, Fax 303 497-1092.

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V. "Status of Kuwait Data Archive Project,," Contact: Darrel Baumgardner, NCAR Research Aviation Facility, Boulder, Colorado 80307-3000. Phone: 303 497-1029, Fax 303 497-1092.

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