

Marine Industry Collegium Opportunity Brief

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FIELD SCREENING FOR
ENVIRONMENTAL POLLUTANTS:
DEFINING USER INSTRUMENTATION NEEDS

October 26-27, 1992
Cambridge, Massachusetts

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MIT Sea Grant College Program



Massachusetts Institute
of Technology
Cambridge, Massachusetts
02139

**The MIT/Marine Industry Collegium
Opportunity Brief #61**

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INTRODUCTION

The number of contaminated sites, both here in the United States and overseas, continues to rise with each passing year. Costs to characterize and remediate these sites are also rising. And stricter regulations are being promulgated requiring greater specificity and accuracy, in both the assessment and monitoring stages of a clean-up effort. One process that can help mitigate the above is the development and use of advanced field screening techniques for detection of contaminants at a site, monitoring of the remediation program and post-closure monitoring.

Field screening instruments are nothing new to the environmental professional, and have been used for a number of years to provide fundamental, qualitative understanding of the contaminants present at a site. What is new, however, is the convergence of a number of recent technology developments in medical diagnostics, electronics, computer software, and industrial process control. These technology developments are contributing to the development of new field instruments capable of providing high-quality, qualitative and quantitative data. This field-generated data, in many instances, is claimed to be of the same quality or superior to that which originates from an EPA CLP laboratory.

Despite these recent developments there remain several problems or obstacles to overcome. One of the primary issues is defining what the end user would like to see in a field instrument, i.e. what capabilities would the instrument possess in precision, accuracy, portability, efficiency, ease-of-use, etc. By defining these needs up-front, researchers can proceed to develop future products that will meet the needs of the user community. A second key obstacle to the greater application and use of field-portable instruments is regulatory. The regulatory process has not kept up with the rapid technological advances that have taken place in the development of new instruments. Therefore, although field instruments are now capable of providing extremely high-quality data, there is a reluctance on the part of regulators to accept the use of this data, except for the most fundamental of uses.

This workshop, which you are invited to attend, will attempt to address these issues and others, to provide direction for the development and acceptance of new field screening technologies. Ultimately, it is our hope that this will lead to more effective and efficient clean-up of contaminated sites throughout the global environment.

*John Moore Jr.
Workshop Chairman*

WORKSHOP AGENDA

Field Screening for Environmental Pollutants: Defining User Instrumentation Needs

October 26, 1992

- 8:00-8:30 **REGISTRATION**
- 8:30-8:45 **Welcome and Introduction**
*Prof. Dennis Mc Laughlin, Associate Director, EPA NE Hazardous Substances
Research Center and MIT, Dept. of Civil Engineering*
Mr. John Moore Jr., MIT Sea Grant College Program
- 8:45-9:25 **Solute Transport Measurements in the Vadose Zone**
Dr. Lorne G. Everett, Metcalf & Eddy, Inc.
- 9:25-10:05 **Application of Field Screening Methods for Expediting and
Improving Underground Storage Tank (UST) Site Assessments**
*Prof. Gary A. Robbins, University of Connecticut, Dept. of Geology and
Geophysics*
- 10:05-10:20 **BREAK**
- 10:20-11:00 **Field Screening Applications for the Detection of Metals**
Mr. Richard K. Glanzman, CH2M Hill, Inc.
- 11:00-11:40 **Data Quality Objectives for Semi-Volatile Field Screening Techniques**
Mr. Ian M. Phillips, GEI Consultants, Inc.
- 11:40-12:20 **Field Instrumentation Uses and Needs of U.S. EPA**
Dr. Thomas M. Spittler, EPA Region One, Lexington Laboratory
- 12:20-1:30 **LUNCH**
- 1:30-2:10 **Field Analysis and Mobile Laboratory Configuration for Hazardous
Wastes**
Dr. Tim E. Moody, U.S. DOE/Westinghouse Hanford Company
- 2:10-2:50 **Problems, Both Reoccurring and Unique in the Collection of Field Data**
Mr. Charles A. Ramsey, EPA, National Enforcement Investigation Center
- 2:50-3:05 **BREAK**
- 3:05-3:40 **A Portable Mass Spectrometer for Collecting Field Data**
Prof. Harry F. Hemond, MIT, Dept. of Civil Engineering
Mr. Michael J. Ernst, MIT, Dept. of Civil Engineering
- 3:40-4:15 **On-Site Detection of Organic Contaminants by Thermal Desorption
Chromatography/Mass Spectrometry**
Prof. Albert Robbat, Jr., Tufts University Dept. of Chemistry
- 4:15-4:50 **Laser Spectroscopy Fiber-Optic Monitoring System for Fuel Contamination**
*Mr. Bruce J. Nielsen, U.S. Air Force Civil Engineering Support Agency,
Site Restoration R&D Branch*
- 5:30-7:00 **EVENING RECEPTION**
MIT Faculty Club

Field Screening for Environmental Pollutants: Defining User Instrumentation Needs

October 27, 1992

- 8:00-8:30 **LATE REGISTRATION**
- 8:30-9:05 **Environmental Applications of Fiber-Optic Based Chemical Sensors**
Prof. David R. Walt, Tufts University, Dept. of Chemistry
- 9:05-9:40 **Biotechnology-Based Diagnostic Methods for Detection of Environmental Pollutants**
Dr. Richard F. Taylor, Arthur D. Little, Applied Biotechnology Laboratory
- 9:40-10:25 **Legal Implications and Data Confidentiality**
Dr. Donald G. Scroggin Esq., Jenner and Block
- 10:25-10:40 **BREAK**
- 10:40-12:00 **Obstacles, Both Real and Imaginary, That Hinder the Use of New Field Instrumentation Technologies for Site Characterization and Remediation**
Dr. John R. Ehrenfeld, MIT, Moderator
Mr. John N. Driscoll, HNU Systems, Inc.
Mr. Brian Sogorka, New Jersey Department of Environmental Protection
Dr. Donald G. Scroggin Esq., Jenner and Block
Dr. Myron S. Rosenberg, P.E., CDM Consulting, Inc.
Mr. David Friedman, EPA, Office of Research and Development
Professor Gary A. Robbins, University of Connecticut

SYNOPSIS OF PRESENTATIONS

October 26

8:45

Solute Transport Measurement in the Vadose Zone

Dr. Lorne G. Everett, Metcalf & Eddy, Inc.

Environmental pollutants typically originate at the land surface and migrate to the water table. Groundwater monitoring, as a preventative technique for groundwater protection is therefore clearly illogical as a strategy. It is also unrealistic to design a groundwater remediation program without first removing the source of contamination in the vadose zone. In light of these points, vadose zone monitoring is critical to effective and efficient site assessment and remediation programs.

With vadose zone monitoring, an understanding of soil pore-liquid interaction is essential. For example, if unsaturated flow is not taking place, the remediation program has the luxury of time. If unsaturated flow is taking place, the chemistry of the pore-liquids must be understood to determine if contamination is migrating. A discussion of unsaturated flow phenomena, presented in light of changing water chemistries under various capillary pressures will be presented.

Field screening strategies based upon major weaknesses in soil sampling, pore-liquid sampling and soil gas sampling will be presented. Direct and indirect pore-liquid monitoring devices, including neutron probes, TDR, and capacitance probes will be described relative to operating ranges, installation procedures, and data interpretation. Design flaws of commercially available devices will be discussed along with recommendations for their correction.

Case studies for landfill monitoring and hydrocarbon stability or passive remediation will be presented. Identification of 11 new ASTM National Vadose Zone Standards will also be provided.

9:25

Application of Field Screening Methods for Expediting and Improving Underground Storage Tank (UST) Site Assessments

Professor Gary A. Robbins, University of Connecticut, Department of Geology and Geophysics

Significant emphasis is currently placed on obtaining high-quality laboratory analytical data to delineate groundwater and soil contamination at gasoline service station sites. Reliance on laboratory-derived data for decision-making has a number of significant drawbacks. It can foster protracted site assessments by requiring phases of investigation, due to the delay between when sampling occurs and when laboratory data are obtained and evaluated. This can lead to an exacerbation of problems in the dynamic vadose and saturated zone environments, making remediation even more difficult. Reliance on laboratory data prohibits on-site, real-time problem evaluation. This can lead to poorly located soil borings and monitoring wells, locking the investigation into these locations, often resulting in wasted time and money. The costs associated with laboratory analyses can also provide a disincentive for conducting a three-dimensional site evaluation. This has been shown to be especially important in locating entrapped

free product below the water table and in determining the vertical dispersion of contaminants in groundwater, which is needed for designing remediation systems.

Application of reliable field analytical techniques can overcome these problems and help improve the quality of the site assessment and effectiveness of remediation. Examples of techniques developed and used in research at the University of Connecticut include: soil gas surveying using total organic vapor detection instruments with a serial dilution technique, portable carbon dioxide and oxygen meters, and portable gas chromatographs; semiquantitative screening of water and soil for volatiles using the polyethylene bag sampling method with total organic vapor detectors; quantitative screening of soil and water using a VOA vial headspace technique and serial stripping method in conjunction with portable gas chromatographs; and screening water for inorganic water quality parameters resulting from hydrocarbon biodegradation using ion selective electrodes. Used in conjunction, these techniques provide both indirect and direct methods to resolve the investigatory issues arising from a reliance on laboratory data.

Based on discussions with state regulatory agents from over 40 states, there are a number of issues and concerns that must be resolved before field screening techniques are broadly accepted. These issues and concerns include the resolution of quality assurance, establishing a track record of experiences with field methods and comparisons to laboratory data, and resolving administrative problems arising from outmoded regulatory guidance and state reimbursement policies.

10:20

Field Screening Applications for the Detection of Metals

Mr. Richard K. Glanzman, CH2M Hill

Environmental scientists have applied considerable effort into the quality assurance and quality control of laboratory chemical analysis with fair to excellent results. However, interpretation of these analytical results assumes that the sample is representative of the field parameter(s) it is meant to describe. Representativeness and the need to develop field screening technologies that increase the effectiveness and efficiencies of remedial investigations (RI), feasibility studies (FS), and remedial actions (RA) has led to the development of three field screening technologies for the detection of metals that adapt laboratory instrumentation for field application. X-ray fluorescence (XRF), near infrared spectroscopy (IR), and anodic stripping voltammetry (ASV) instruments have been developed that are lightweight, durable, and reliable enough to be placed into the field environment to screen metals concentrations in all types of media, both in qualitative and quantitative modes.

XRF is a well-known technology for the elemental analysis of solids. Solids have a propensity for heterogeneous concentrations that is rarely acknowledged by laboratory analysis and even more rarely determined by field sampling. There are at least four field-portable XRF instruments that can be taken to the sample for elemental analysis. These instruments are typically capable of analyzing elements from aluminum to uranium in the periodic table in from less than a minute to a few minutes (depending on the practical quantitation limit desired). A typical metal can be reliably determined at approximately 50 mg/kg in 200 seconds or less. Several protocols are available depending upon instrument and application. Real-time analytical data is developed upon which geostatistical methods can be applied to determine representative sampling for court-defensible laboratory data. Mobile XRF instrumentation is capable of court-defensible, laboratory quality data at the field site. XRF instruments have been used for metals determinations in soils, stream sediments, vegetation, concrete and other

structural materials, and paint in environmental audits, RI, FS, and RA. Use in RA is in monitoring clean-up to an action level at the site. These instruments require variable amounts of training ranging from a few hours to a few days depending upon the data-quality objectives of the user. Particle size and matrix are the major problems that need to be addressed in the use of XRF. Examples and comparisons show field applications using several field-portable instruments screening most media will be presented.

Reflected IR instrumentation has been developed that can determine the form in which metals are occurring at the site. Specific minerals include oxides, carbonates, sulfates, and clays. Mineralogy (adsorbed and particulate forms) is particularly important in the fate and transport of metals at a site. Satellite and fixed-wing IR imagery has been used at several sites to map characteristics of metal occurrences. Fixed-wing and field portable IR instrumentation is used to determine, document, and map the actual mineralogy of the metals occurrence at the site. Field portable IR has been used along with the field portable XRF to document both metals concentrations and mineralogy at the site. Coupling the field portable instruments with a fixed-wing IR imagery and color photography establishes a baseline datum for a site against which subsequent industrial or remedial actions can be judged. Mineralogical spectra have been developed for most minerals, but x-ray diffraction may be necessary for some site specific minerals. Reflected IR is a surface measurement and, therefore, does not have an effective depth-of-penetration for mineralogical determinations below the actual surface of the particle. Adsorbed phase(s) can be discriminated from particulate-phase mineralogy by abrasion. The IR can also be used to determine the vegetative stress associated with metals concentrations. Examples of reflected IR instrument results will be presented.

Finally, a relatively new AVS instrument has been developed that can reliably determine dissolved metals in the 1 to 10 micrograms per liter range. This electrochemical technique has received a considerable amount of development and application at the laboratory scale. However, the advent of the field portable instrument allows laboratory quality determination of dissolved metals in surface water and groundwater at the site. Its use also extends into metals dissolved in organic forms (i.e. lead in fuel, zinc and lead in process liquors, etc.). This instrumentation can replace the current use of atomic absorption spectrometry for many of the metals. Ease of use and rapidity of analysis are the major advantages. The newness of the instrumentation is its major disadvantage. Examples of applications will be presented.

Acceptance of the metals concentrations data by regulatory agencies is the first and most serious potential disadvantage for the application of field portable instruments. XRF is the most readily accepted field screening technology for metals determinations by regulatory agencies. This instrumentation has and is being used at several Superfund sites to screen metals concentrations. Reflected IR has also been used at Superfund sites but much fewer than the XRF. The AVS has had little application at Superfund sites but several are in the planning stages. The sheer number of analyses needed to reliably document metals concentrations at a site by providing the necessary representativeness is the major driving force for the application of field portable instruments.

11:00

Data Quality Objectives for Semi-Volatile Field Screening Techniques

Mr. Ian M. Phillips, GEI Consultants, Inc.

[Paper not available at time of publication.]

11:40

Field Instrumentation Uses and Needs of U.S. EPA

Dr. Thomas M. Spittler, EPA Region One, Lexington Laboratory

This presentation will deal with currently available field instrumentation and its uses, as well as some desirable advances in the technology. Since other papers deal directly with semi-volatile and metals detection in the field, I will limit my comments on these matters.

Regarding detection of metals, there are presently three field instruments with the desirable feature of high-resolution (HNU, Outokompu and Texas Nuclear). Among other desirable features in this field are simplicity of operation, use of Compton scattering normalization for rapid and accurate quantitative analysis, and light-weight, compact design. One additional feature is having long-lived radioactive sources (e.g. Cm vs. Cd) to reduce ongoing maintenance costs.

In the field of semi-volatile analysis there are presently some instruments on the market with portability and adequate sensitivity for many kinds of analysis (PCB's, PAH's and some pesticides). Again, lower weight and simplicity of operation are desirable features. Field instruments that are nothing more than shrunk lab instruments with high power requirements and poor field design often do not hold up under field conditions. Improvements in detector sensitivity and versatility would help make field instruments more suitable for semi-volatile screening.

When it comes to field analysis of volatile chemicals, there is probably more need for programs within EPA to define their goals and purposes for field measurement than for instrument manufacturers to modify their instruments. By this I mean that often the field investigator is not given a clear idea of what should be measured and the limits of detection required for achieving field analysis objectives. Some of the available field instruments have remarkable sensitivity and adequate resolution to solve most problems. What is more often lacking is a clear directive on which constituents are significant and at what concentration.

The classical example is hydrocarbon contamination. Where hydrocarbons have entered the environment, one of the principal concerns is that soluble hydrocarbons will contaminate groundwater. Yet, often the determination of whether contamination is significant is based on the presence of total petroleum hydrocarbons (TPH). Where the spill involves soluble hydrocarbons (e.g. gasoline or diesel) there is an obvious threat because of the solubility of fuel constituents. On the other hand, if oil is spilled, most or all of the constituents are insoluble and will not constitute a threat to groundwater. Yet, both situations will yield high numbers in a TPH test. A more reasonable test would be for water-soluble hydrocarbons, and this test can be readily performed on contaminated soil using headspace analysis and very sensitive field gas chromatography.

Field screening as well as detailed analysis to delineate contamination and determine the efficacy of cleanup methods is very dependent upon the directives given to the field analyst. When prior agreement has been reached that certain key constituents should be tracked with no need to identify all possible constituents, a very cost-effective field study is possible. Screening can be rapidly and efficiently carried out using available two-column gas chromatography instruments. A longer column is first employed to identify the constituents of primary concern at the site. Then a short column is employed to rapidly assess the extent of these constituents both horizontally and vertically in the vadose zone and in the aquifer.

A further advantage derived from two-column instruments is that two completely different columns can be employed in the field to provide the field analyst with definitive identifications. This technique rivals the capabilities of gas chromatography/mass spectrometry (GC/MS) for identification and can easily surpass most GC/MS equipment in sensitivity. A third use of two-column technique is the pre-column backflush mode used in many Photovac GC's. This technique enables the analyst to measure what is most important and still keep the columns clean in the presence of high-boiling constituents.

Finally, the use of versatile field gas chromatography can provide field analysts with powerful tools for the protection of aquifers before they become seriously contaminated. The combination of high sensitivity, good resolution and versatility in field instruments enables the analyst to track contamination in soil as well as groundwater at very low levels. This approach is a key part of an effective groundwater protection strategy.

1:30

Field Analysis and Mobile Laboratory Configuration for Hazardous Waste

Dr. Tim E. Moody, U.S. DOE /Westinghouse Hanford Company

The proposed project specifies the analytical instruments and configuration of a mobile screening laboratory that will supply environmental data necessary to support the Remedial Investigation/Feasibility Study (RI/FS) process of the Hanford Reservation. The mobile screening laboratory is designed to facilitate the field screening of organic, inorganic, and general low level rad contaminants. The known and suspected contaminants of the 1200 waste sites comprising the 78 operable units and the analytical instruments required for their analysis are the basis for the instrument specifications, configuration, and functional design criteria of the mobile screening laboratory. The project will reduce the sample load to off-site laboratories, and provide a shorter turnaround for analysis, substantially reducing the Environmental Restoration Program analytical costs. The project will help to ensure the timely completion of the TPA milestones associated with the RI/FS work plans.

History

The present practice of analyzing samples at off-site laboratories under Contract Laboratory Protocols (CLP) or SW-846 protocols is expensive and time consuming. Moreover, it does not provide fast turnaround of analytical data necessary to promote flexibility in remedial investigations or to protect worker health and safety.

Although validated analytical data are necessary to support decisions associated with the RI/FS process, it is not necessary that all samples be analyzed to this level. The U.S. Environmental Protection Agency (EPA) supports the concept of field screening in which mobile labs and/or portable instruments or tests are used to identify potentially contaminated samples in the field. A small percentage of these samples are then submitted for more rigorous analyses in the off-site lab. The net effect is a significant reduction in the number of samples analyzed in the off-site lab, with accompanying cost savings, improved flexibility in conduct of the investigation program, and enhanced worker safety.

Mobile analytical labs are presently being developed and used by industry on CERCLA RI/FS projects. Experience in both EPA and industry have shown significant costs and schedule benefits to this approach. Such labs are commercially available for chemical compounds, and some experience has been gained in the use of mobile labs on radioactive and radioactive mixed waste investigations.

The quick turn-around nature of the mobile screening laboratory would be able to support more than one project at a time. On the Hanford Reservation, samples from most locations could be easily transported to the mobile screening laboratory in 45 minutes or less. Since no off-site shipment is involved, sample handling and packaging procedures would be greatly simplified.

The production of legally defensible Superfund data requires heavy documentation, extensive quality control, and time consuming analyses. The end result is an expensive analysis and a long time frame for the delivery of a data package. The screening scenario, which implements a mobile screening laboratory, drastically decreases the number of samples transported for off-site analysis, and the fast turn-around analysis time can provide results for a field situation requiring expeditious remedial action.

The acquisition of legally defensible data is through commercial labs that have undergone EPA on-site evaluations, performance evaluations (PE), chain of custody evaluations, and quality assurance (QA) audits of data. Meeting these requirements allows the laboratory to be eligible to participate in the Contract Laboratory Program. Data generated by CLP labs is further examined by the National Enforcement Investigations Center (NEIC) for validity of sample analysis, and if needed, is generated into sample profiles used in EPA enforcement litigation.

It is reasonable to assume that by utilizing statistical methods to correlate the data obtained from the analysis of split samples and performance evaluation (PE) samples from the mobile laboratory to that of a CLP laboratory, the defensibility of data obtained from the mobile laboratory can be realized.

Under a field screening scenario, a small percentage of split samples must always be analyzed by a standardized procedure in a fixed laboratory to guarantee accuracy. The utility of a field screening scenario is derived by having a small percentage of split samples analyzed by CLP protocol (which gives the most legally defensible data), and then correlating through a linear regression. Sending 10 percent for confirmatory analysis is an arbitrary figure. The figure for confirmatory analysis may be lower than 10 percent or as high as 20 to 30 percent, depending on the severity of contamination, type of contaminants, and matrix constituents of the sample. The USEPA has described this type of scenario for field screening in the Compendium of Superfund Field Operations Methods, EPA/540/P-87-001.

2:10

Problems, Both Reoccurring and Unique in the Collection of Field Data

Mr. Charles A. Ramsey, EPA, National Enforcement Investigation Center

Field analysis should be a part of most environmental investigations. Field instrumentation technology has advanced to yield analytical results with approximately the same accuracy as lab based instrumentation. However, a variety of problems do exist with field analysis that must be addressed before analysis begins. Among these problems are: the limitations of a sampling plan designed prior to any on-site visit, lack of regulatory consideration for sampling and analysis, the sampling error associated with field analysis, and reoccurring field problems.

Often a detailed sampling and analysis plan is developed before field work commences. In many cases the plan is developed by someone who has never been to the site in question

and has little field experience. The plan is then given to a contractor to implement verbatim. This system of developing the sampling and analysis plan is rarely useful because of the lack of consideration of site specific issues that will affect the sample plan.

Regulatory issues relating to field sampling should be given the same consideration as scientific issues of sampling. Field sampling and analysis is almost always tied to some type of regulatory compliance (and in many instances could potentially be used in litigation). However, in the planning and implementation of the sampling and analysis plan, these regulations are seldom considered. Some of the regulatory issues that must be considered include: obtaining specified confidence levels, minimum mass requirements, clean-up levels, and specific statistical tests to detect contamination. A lack of consideration to these regulatory issues invalidates many field sampling and analytical efforts and is a major source of costly rework.

A problem that also exists in field analysis (and in laboratory analysis as well) is the collection and analysis of the "proper" sample to provide true representativeness of the site. Sampling errors usually exceed analytical errors and thus must be considered as part of any environmental measurement program. Even with "point and shoot" types of field analytical equipment (e.g. portable X-ray fluorescence), thoughtful consideration of the "proper" area to analyze and the size/mass of that area are required. Many times these potential sampling errors are not considered and inconclusive data is generated at great expense.

Once all the above has been considered the site must still be physically accessed, while wearing all the appropriate safety equipment. Even with the most careful planning, it never seems to fail that a drum is rusted shut, the ground is too frozen to core, or someone has actually moved the material to be sampled. One can rarely fully prepare for all the possible problems that will be encountered while trying to collect field data. Therefore, the sampling and analysis plan, while guided by the regulatory concerns, must provide the flexibility to respond to all the unique environmental conditions inherent at every contaminated site.

3:05

A Portable Mass Spectrometer for Collecting Field Data

*Professor Harold F. Hemond, MIT, Department of Civil Engineering
Mr. Michael J. Ernst, MIT, Department of Civil Engineering*

New technology is needed for the identification of Volatile Organic Compounds (VOCs) in the environment. VOCs are soil and water contaminants found in most industrial areas throughout the developed world. Delineation of the concentrations and distribution of these chemicals in contaminated areas is essential. With current technology, it is very difficult and expensive to acquire the necessary information to characterize a VOC contaminant plume, especially in the subsurface environment.

A wide variety of analytical techniques exist for identification and measurement of VOCs. These techniques were assessed as to their appropriateness for field use by Jenkins et al. [1]. Their report highly encourages further development of field portable mass spectrometry as the technique with the "best combined identification capabilities and detection limits available from current analytical technology."

Field-Portable Mass Spectrometry

A mass spectrometer works by ionizing a small sample of analyte, propelling the resulting ion fragments through a mass filter, and detecting the amount of each ion fragment present. The most common mass filtering technique used in portable units is the radio frequency quadrupole design, while magnetic sector instruments are more common in the laboratory for high resolution applications. Related to the quadrupole technique is the ion trap method, which is finding more applications in the field. Other methods include time of flight, cycloidal magnetic sectors, and others. Each of the different mass filtering methods have advantages and disadvantages in terms of cost, weight, power consumption, and stability, which will be addressed.

Before mass filtering can take place, the sample must be transported from the environment to the mass filter. There are a variety of inlet systems available to extract VOCs from water or air samples in the lab. Some of these systems have been adapted to field use. However, there are few existing *in situ* interfaces to mass spectrometers suitable to the subsurface environment. In addition to transporting compounds to the mass filter, the inlet system often employs a method to separate the specific compounds in a mixture of VOCs prior to spectral analysis. This is normally achieved by adding a gas chromatograph to the system, thus increasing the complexity and power consumption of the unit.

Several field-portable mass spectrometers have been developed recently. Each of these units have different performance characteristics and are portable to varying degrees, from van-size to man-size. These units employ a variety of mass filters and inlet systems. The unit presented here employs a magnetic sector mass filter for lower power and simpler electronic control, a membrane inlet drivable probe capable of sampling in the saturated and unsaturated subsurface, and a mixture separation algorithm that processes the mass spectra of complex mixtures and determines the individual compound abundances mathematically, eliminating the need for gas chromatographic separation.

Drivable Probe Membrane Inlet Mass Spectrometry

Measurement and identification of volatile organic contaminants with *in situ* membrane inlet mass spectrometry begins with aqueous or gaseous concentrations of VOCs, whose molecules flow across a membrane, through a vapor transport line, into the mass spectrometer's inlet system. Once in the inlet system, these molecules may flow across a second membrane that further selects against air and water vapor, and end up in the source region of the mass spectrometer. In the source region, the molecules are ionized and sent through the mass filter to the detector where the ion signal is transformed into an electronic signal for further processing and identification.

Compound identification is achieved through a mathematical scheme developed by Doherty [2] and based on the simplex method of linear programming. This algorithm, named UNMIX, has been enhanced and is currently under test for analysis of typical environmental mixtures. Initial test results show that the algorithm can quickly and accurately determine the composition of a mixture in the absence of noise. Additional algorithms to reduce the impact of noise are currently under development.

The Future

Advances in two major areas are needed to make mass spectrometry a common environmental monitoring tool for the field. First, new instruments that are smaller, lighter, lower in power consumption, more rugged, simpler to operate, and less

expensive must be developed. Second, new inlet systems for these instruments must be developed to provide a reliable and versatile interface to the subsurface environment.

The development of new instruments is proceeding at a rapid pace as new electronic technologies emerge that promise to reduce the weight, cost, and size of portable mass spectrometers. One such technology that holds great promise is that of Charge-Coupled Devices (CCDs) as ion detectors. CCDs are low noise, low power units that are very sensitive photodetectors and may prove to be useful ion detectors in magnetic sector or cycloidal mass spectrometers. New ionization technologies, microcomputers, and other instrument advancements should enhance the portability of mass spectrometers.

The interface to the subsurface environment is an area of research that requires much more emphasis. Fast, *in situ* measurements are essential to accurately delineate subsurface contamination problems. A well-designed probe should allow rapid transfer of analyte to the surface while removing the large quantities of water vapor and air that inhibit the performance of mass spectrometers. Developing probes that are reliable and sensitive requires a deeper understanding of the relevant membrane and vapor flow processes, which requires a thorough modeling of prototypes. Current research efforts are focused on the modeling, building and testing of new subsurface probes.

References

1. Jenkins, R.A., M.P. Maskarinec, W.H. Griest, F.F. Dyer, C.-h. Ho, R.L. Moody, and M. V. Buchanan, **Technology Assessment of Field Portable Instrumentation for Use at Rocky Mountain Arsenal**, Analytical Chemistry Division, Oak Ridge National Laboratory, ORNL/TM-10542, 1988.
2. Doherty, Richard Edward, **An Algorithm for Mixture Component Determination for Use in Membrane Inlet Mass Spectrometry**, M.S. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, MA, 1987.

3:40

On-Site Detection of Organic Contaminants by Thermal Desorption Gas Chromatography/Mass Spectrometry

Professor Albert Robbat, Jr., Tufts University, Department of Chemistry

Much is speculated about hazardous waste site assessment and cleanup costs. It has been projected that by the year 2020, over 3,000 national Superfund sites will be listed by the U.S. Environmental Protection Agency, costing in excess of \$150 billion, with the Department of Energy and Defense facility and landfill cleanups estimated to exceed \$2 trillion and \$100 billion, respectively. This activity requires analytical data to support site assessment and remediation decision-making. For example, DOE estimates that it will spend between \$15-45 billion on analytical services over the next 30 years. DOE's current sample volume for hazardous waste constituent analyses exceeds 400,000 samples/year, with some of the larger DOE sites spending as much as \$10 million annually. In addition to federal programs, many sites have their own hazardous waste programs, and many Fortune 500 companies spend upwards of \$400 million annually on environmental services.

Current environmental management practices of collecting samples and sending them to the laboratory is inefficient, time-consuming, costly and can pose significant risk to

workers and the community. In fact, over the last 10 years, so little has been accomplished in Superfund, e.g., less than a dozen sites have been deemed "cleaned" by the EPA, that Congress has begun to press the EPA as to the barriers between first listing the site and then cleaning the site in a timely and cost-effective fashion.

Because much of the time delay and decision-making depends on obtaining analytical data from the site, we have worked over the last five years to develop field-practical technologies and methods that can detect EPA listed organic contaminants, rapidly and on site. The goal was to produce simple sample preparation procedures concomitant with technologies that can deliver rapid screening level data in 2 to 10 min. and more quantitative data in 20 to 40 min. per sample. Thermal desorption gas chromatography (TDGC) provides unmatched advantage over syringe injected sample introduction systems, common in lab instruments, because we can control what gets into the instrument by controlling the temperature of desorption. TDGC combined with mass spectrometry operated in the selective ion monitoring mode (TDGC/MS-SIM) provides unmatched detection over nonspecific GC detectors such as electron capture (EC), photoionization (PI) and flame ionization (FI). For example, we have shown (1) that 10 ng of a chlorinated pesticide (e.g., DDT) can be detected in the presence of 10,000 ng of polychlorinated biphenyls (PCBs).

Methods have been developed for the detection of PCBs, polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides, phenols and volatile organic compounds (VOCs, 2-4). Research will be presented illustrating field and laboratory data comparisons for split samples collected by the EPA. Results indicate that the screening methods provide comparable accuracy with measurement precision greater than EPA certified methods. On the other hand, the quantitative methods produce data of equivalent quality to the EPA-managed Contract Laboratory Program. Research is in progress to develop methods for the full list of acid/base/neutrals (i.e., the semi-VOC list).

Much has been written about the advantages of field detection (5-7), with little progress made by EPA to move their application forward. Research will be presented demonstrating the utility of these methods. For example, two field demonstrations will be discussed where the rapid screening level and quantitative PCB methods served to provide the basis for characterizing soil gradients over a 40 cubic ft. area and supported decision-making during a contaminated soil excavation program.

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4:15

Tunable Laser, Fiber-Optic Spectroscopy System for Monitoring Fuel Contamination

*Mr. Bruce J. Nielsen, U.S. Air Force Civil Engineering Support Agency,
Site Restoration R&D Branch*

Stringent groundwater monitoring requirements using traditional monitoring methods will place a tremendous burden on Air Force resources because of costs and manning requirements. Projected costs to monitor the Air Force's 4,500 Installation Restoration Program (IRP) sites at 315 installations will run into the millions of dollars. Field monitoring technology is a key element in preventing, identifying, and remediating contaminated sites and can reduce the overall remediation costs and long-term costs of required post-closure monitoring. Fixed systems for dedicated, continuous, *in situ* monitoring; transportable site investigation/monitoring systems; and sensor systems for use in cone penetrometers are under development.

Benzene, toluene, ethyl benzene, and xylene (BTEX) are found in many fuels and their water solubility is relatively high. The regulatory limits for BTEX in water are in the low part-per-billion (ppb) range. These volatile organic compounds are easily purged from solution during the sampling event and are subject to degradation and adsorption losses. A monitoring method that would eliminate or minimize discrete sampling, sample preservation, packing, shipping, sample preparation, and analysis requirements is highly desirable. A fiber-optic, spectroscopic BTEX detection method has the potential to provide inexpensive, real-time, *in situ*, remote field measurements.

Since 1989, the Air Force has been supporting the development of a novel, transportable laser system for fluorescence analysis of BTEX. The instrument is currently undergoing extensive field demonstrations as well as further development efforts to expand its contaminant detection capabilities beyond just BTEX.

The basis of the current method is direct fluorescence spectroscopy. The individual BTEX components selectively absorb ultraviolet light and go to an excited state. As the excited states decay, photons are given off at a characteristic emission (fluorescence) spectra. The selectivity derives from the fact that emission signal depends on two different wavelengths, when the molecule is excited and when the emission is monitored. Still an additional degree of selectivity is introduced when the excitation source is pulsed, since compounds will exhibit different fluorescence lifetimes.

Lasers are extremely desirable light sources for fiber-optic spectroscopic measurements because laser light sources can be pulsed and launched into the fiber with high efficiency. Unfortunately, most laser systems only offer one or a few fixed wavelengths, which limits its spectroscopic capabilities. Our system is unique, for it offers broad wavelength tunability in a field transportable package. Wavelength tunability provides the user with greater flexibility and specificity in the identification of contaminants in the field.

The initial effort, funded under a Broad Agency Announcement (BAA) awarded by the Air Force Civil Engineering Support Agency (AFCEA), Tyndall AFB FL, provided proof-of-principle for a field transportable, wavelength tunable pulsed laser system. Laser spectrometer transportability has been demonstrated by taking the system to locations in Minnesota and North Dakota. This system was used to perform preliminary contamination measurements at the Air National Guard in Fargo, North Dakota and at Tinker Air Force Base in Oklahoma.

In August of 1991 the system was transported by van to Oklahoma City, OK, for a small-scale field test. No special precautions are necessary for system transport other than tie downs. Upon arrival at the site, initial set-up time for measurements was less than one hour, with the bulk of the time spent unpacking auxiliary equipment. Deployment of the generator took just a few minutes, after which approximately 15 minutes was needed to warm-up the laser. Standards were run for calibration prior to the probe's insertion into the monitoring well. Once at a monitoring well location it took about five minutes to take a measurement. The field test took place with no air conditioning and daily temperatures in excess of 90°F. The operators suffered from the heat much more than the equipment. No significant problems were found in the system over 50 hours of running time.

Although the point of this initial field study was not to attempt an extremely accurate concentration determination (the purpose was to show the field operability of the system), the results were nonetheless encouraging. There was good correlation between our concentration values and those obtained by bailing the wells and analysis by gas chromatography. Differences are believed to be due primarily to the high turbidity.

Continuing research efforts are divided into three areas: (1) refinement of the transportable, tunable laser prototype for field investigations; (2) development work aimed at lower cost and simplified approaches for field monitoring; and (3) field testing. Project tasks include dye laser modifications to yield subnanosecond pulse durations, implementation of a phased-resolved fluorescence capability, and an investigation of resonance-enhanced Raman scattering for the detection of nonfluorescent analytes such as chlorinated solvents. An assessment of other multidimensional laser spectroscopic methods including excitation-emission matrix, wave-length time matrix, synchronous scanning, phased-resolved fluorescence, and resonance enhanced Raman will also be conducted.

The Air Force Site Characterization and Analysis Penetrometer System (AFSCAPS) will be initiating field demonstrations at Tinker AFB. Prototype's primary application will be for standard geophysical and petroleum contaminated site characterization. AFSCAPS will utilize the Tunable Laser/Remote Fiber-Optic Spectroscopy system developed for determining site contamination. The system will provide a graphical three-dimensional "snapshot picture" of the subsurface geophysics and contamination.

AFCEA is currently performing fundamental investigations of soil/groundwater matrices and model aquifers for fate and transport studies using the laser spectroscopy system. These investigations will also lead to documentation of the principles underlying the instrument and its application for distribution to Air Force personnel and others not familiar with the system.

October 27

8:30

Environmental Applications of Fiber-Optic Based Chemical Sensors

Professor David R. Walt, Tufts University, Department of Chemistry

Fiber-optic chemical sensors are comprised of an optical fiber with a chemically selective indicating layer located at the far, or distal, tip. Light is introduced into the proximal end of the fiber and is transmitted via total internal reflection through the entire fiber length with low attenuation and finally exits the distal fiber surface. Indicator layers located on the tip react with analytes of interest, including a wide

variety of ions and organics of environmental concern. The interaction of analyte with the indicating layer generates a color change, or in some other way affects the light exiting the fiber. The same fiber or a second collection fiber couples the returning light from the indicating layer to a detection system, where it is analyzed, processed, and reported as a concentration of the analyte of interest. Indicating layers can affect the light's intensity directly or they may employ various transduction mechanisms, including absorbance, fluorescence, polarization or lifetime of the indicator species.

Optical fibers offer significant advantages over conventional methods and other sensors for environmental monitoring. These advantages include their continuous monitoring capability, internal calibration, freedom from electromagnetic interference, multiplexing capability, small size and flexibility. There are a variety of challenges to implementing fiber-optic sensors posed by the environmental application. The measurement matrix, precision, detection limit, freedom from interference, power requirements, selectivity and sensitivity must all be taken into consideration when designing a particular sensor. Fiber-optic sensors typically have smaller dynamic ranges than other competitive techniques as a result of the intrinsic equilibrium basis on which the sensors operate. This limitation aside, sensors can be designed to monitor a particular threshold level which can then prompt further and more extensive analytical measurements once the sensors have exceeded this threshold. The continuous nature of such sensors and their threshold capabilities make them ideal candidates for post-site closure monitoring or alarm sensors. An extensive variety of sensors have been made to date. These include alkali and heavy metal ion sensors based on selective ionophores or chromophores; organic compound sensors for chlorinated organics or hydrocarbons involving reversible polymeric films; enzyme-based sensors that broaden the applicability and increase the selectivity of sensors; gas sensors, including sensors for oxygen, carbon dioxide and ammonia; pH sensors for acid determination, and antibody-based sensors enabling a high degree of selectivity and sensitivity to be brought to the arsenal of fiber-optic sensors. Many of these sensors work quite well in a laboratory environment, but few have made it into field tests and fewer still into the marketplace.

The implementation of fiber-optic sensors presents a challenge to the environmental monitoring effort. These sensors offer many advantages over conventional instrumentation. Their ultimate implementation will depend on the success of chemists to develop selective indicating layers; the construction of suitable electro-optical devices for long-term, unattended field operation; the implementation by engineers of field studies and sensor placement protocols; and finally on the acceptance by the environmental analytical community of these sensors to replace, supplant, or enhance their analytical capabilities.

9:05

Biotechnology-Based Diagnostic Methods for Detection of Environmental Pollutants

Dr. Richard F. Taylor, Arthur D. Little, Applied Biotechnology Laboratory

Biotechnology-based diagnostics and detection methods encompass immunoassay, nucleic acid probes and biosensors. First applied primarily in clinical diagnostics, these technologies and their derived products are now being extended to new areas, including food/chemical processing, agriculture and environmental analysis. The key, distinguishing feature of biotechnology-based detection methods is their use of biological molecules (enzymes, antibodies or receptors) as their primary detection element: the interaction of the analyte to be measured with the biomolecule begins the detection process.

Biotechnology-based detection methods utilize a variety of formats, ranging from traditional laboratory-based assays, to portable instruments and dipstrips. As the assays move out of the laboratory and into the field for on-site, real-time analysis, developmental emphasis is being placed on small, user friendly instruments having cost-effective, throw-away detection elements or reagents.

Immunoassay is the best established biotechnology-based detection method. Immunoassays utilize antibodies to detect specific antigens (analytes) and link the antibody-antigen binding event with a detection method. First introduced as radioimmunoassay, enzyme-linked, fluorescence and chemiluminescent immunoassays are now replacing RIA in the laboratory and are the basis for a number of non-clinical, fieldable assays. For example, immunoassay kits now are commercially available for pesticides, herbicides, mycotoxins, PCBs, dioxin and pollution-indicating bacteria. Enzyme-linked immunoassays are the primary technology of choice, resulting in visible color changes, when an analyte is present, within 30 minutes or less. The primary drawback to such immunoassays remains their multiple step (heterogeneous) format, requiring a number of reagent addition and washing steps that can prove difficult in the field.

Nucleic acid probes utilize specific synthetic DNA or RNA fragments to detect complementary DNA or RNA in the target organism. As an emerging detection technology, nucleic acid probe assays are still relatively complex and are carried out primarily in laboratories. Currently they are limited to the detection of bacteria and viruses and their primary applications have been in the clinical laboratory. Limited efforts have been made to apply probes to food and environmental monitoring for pollution-indicator microorganisms.

Biosensors are real-time (or near real-time) measuring and detection devices that use biomolecules as their detection component and electronic components to transduce, amplify and report the detection event. As detection devices, biosensors have high specificity and sensitivity, and are being designed to operate in the field using a reagentless and low-cost format. The first biosensors, enzyme electrode-based biosensors, were introduced in 1972 and are currently used in laboratories and industry for monitoring analytes such as carbohydrates, alcohols, amino acids and other substances. Enzyme electrode-based biosensors operate by measuring the loss of reactants or the production of products during an enzymatic reaction. Since the early 1980s, a new generation of biosensors has emerged based on the direct binding of the analyte to be measured with an antibody or receptor. These "bioaffinity sensors" are proving to be more sensitive, longer-lived and more rapid than enzyme electrode-based biosensors. Aside from enzyme electrode-based biosensors for a variety of fermentation and food products, few biosensors are commercially available as yet for other applications such as environmental analysis and monitoring. However, specific biosensors have been reported with potential environmental applications, including those for the detection of microorganisms, herbicides, pesticides and toxins. The primary technological hurdles to commercialization of biosensors remain stabilization of the biomolecule on the transducer interface and upscaling biosensor fabrication to mass production.

Biotechnology-based detection methods promise to provide new means to rapidly monitor target analytes under real-time conditions. This capability will lead to the application of these technologies to environmental monitoring and analysis. By the end of this century, we predict that biotechnology-based detectors will be used routinely for such applications.

9:40

Legal Implications and Data Confidentiality

Dr. Donald G. Scroggin Esq., Jenner and Block

[Paper not available at time of publication.]

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Arendale, W.F., Hatcher, R., Johnson, K.E. & Nielsen, B.J., **Calibration of Fiber-Optic Chemical Sensors**, Second International Symposium, Field Screening Methods for Hazardous Wastes and Toxic Chemicals, Las Vegas, NV, February 12-14, 1991.

Barnard, S.M. & Walt, D.R., **Optical Immunosensors Using Controlled-Release Polymers**, *ACS Symposium Series*, in press, *Polym. Mater. Sci. Eng.*, Vol. 64, 1991, pp. 288-289.

Barnard, S.M. & Walt, D.R., **Chemical Sensors Based on Controlled-Release Polymer Systems**, *Science*, Vol. 251, 1991, pp. 927-929.

A novel chemical sensor has been developed in which the polymer ethylene-vinyl acetate is used as a controlled-release system to deliver reagents to the sensing region of an optical fiber for a homogeneous competitive immunoassay based on fluorescence energy transfer. A competition reaction is used to enable continuous measurements of the solution antigen concentration. More generally, the technique allows irreversible indicating chemistries to be used in the construction of chemical sensors that can measure continuously for long periods. Although the sensor configuration has not been optimized in all respects, data are presented for a model system in which a fluorescein-labeled antibody and Texas Red-labeled immunoglobulin G (IgG) are used.

Barnard, S.M. & Walt, D.R., **A Fiber-Optic Chemical Sensor with Discrete Sensing Sites**, *Nature*, Vol. 353, 1991, pp. 338-340.

Barnard, S.M. & Walt, D.R., **Fiber-Optic Organic Vapor Sensor**, *Environmental Science & Technology*, Vol. 25, 1991, pp. 1301-1304.

Fiber-optic sensors and supporting field-portable instrumentation that are capable of an *in situ*, continuous measurements of volatile organic compounds in groundwater and soil samples have been developed. The sensors are based on the polymer absorption of organic vapor and result in fluorescence enhancement of an immobilized fluorophor. Laboratory tests have characterized the effects of various volatile organic compounds and temperature on sensor performance. Preliminary *in situ* field data are presented from a jet fuel contamination site. The lowest detection limit is 10 ppm with a response time of 2.5 min with 7.5% signal change.

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Goyet, C., Walt, D.R. & Brewer, P.G., **Development of a Fiber-Optic Sensor for Measurement of pCO₂ in Sea Water: Design Criteria and Sea Trials**, *Deep-Sea Research*, Vol. 39, No. 6, 1992, pp. 1015-1026.

Measurement of the partial pressure of CO₂ in sea water (pCO₂) is usually accomplished by gas chromatography or infrared spectrometry. Both techniques require large, complex and power-demanding apparatus. In this paper we explore the possibility of developing small, low-power sensors. We have developed and tested a prototype pCO₂ sensor for seawater based upon the fluorescence of a combination of dyes encapsulated within a gas permeable silicone membrane at the tip of a single optical fiber (about 10 μ l). Experiments carried out both in the laboratory on standard solutions and at sea show a precision of 3% in the range 400-500 ppm pCO₂. To our knowledge, this is the first demonstration of an optical pCO₂ sensor for detecting oceanic signals. This technology is complementary to optical detection of pH and points the way toward full characterization of the CO₂ system within this measurement framework.

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Hemond, H.F., **A Backpack-portable Mass Spectrometer for Measurement of Volatile Compounds in the Environment**, *Rev. Sci. Instrum.*, Vol. 62, No. 6, 1991, pp. 1420-1425.

Environmental measurements of volatile pollutants and metabolic gases are preferably made *in situ*. *In situ* measurement provides immediate information to the investigator while minimizing disturbance and eliminating the need for sample collection,

preservation, and transport. A self-contained mass spectrometer, capable of being carried by one person, has been designed and built for this purpose. The instrument is based on a compact crossed-field analyzer using a high-energy-product magnet and control circuitry optimized for low power consumption using a 12-V dc primary power source. An internal, rechargeable battery can provide up to several hours of operation in the field. Provision is made to facilitate the addition of an interface, via RS-232, to a compact battery-operated laptop microcomputer. A variety of inlet configurations is possible, the simplest being a probe, containing a small silicone-rubber membrane, that may be inserted into a gas- or water-containing environment of interest.

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Robbat, A. Jr., Liu, T.-Y., and Abraham, B.M., **On-Site Detection of Polycyclic Aromatic Hydrocarbons in Contaminated Soils by Thermal Desorption Gas Chromatography/Mass Spectrometry**, *Analytical Chemistry*, Vol. 64, 1992, pp. 1477-1483.

Thermal desorption gas chromatography/mass spectrometry (TDGC/MS) was evaluated for on-site detection of polycyclic aromatic hydrocarbons (PAHs). Field-practical sample cleanup procedures and TDGC/MS methods were developed for rapid, qualitative and quantitative measurement of PAHs (3-20 min/sample) based on selected ion

monitoring or total ion current mass spectrometry. Six soil samples from a hazardous waste site were analyzed by TDGC/MS in the field and by standard EPA laboratory methods. Interlaboratory comparison revealed comparable data between the field and laboratory results.

Robbat, A. Jr., Liu, T.-Y. & Abraham, B.M., **Evaluation of a Thermal Desorption Gas Chromatograph/Mass Spectrometer: On-Site Detection of Polychlorinated Biphenyls at a Hazardous Waste Site**, *Analytical Chemistry*, Vol. 64, 1992, pp. 358-364.

A thermal desorption gas chromatograph/mass spectrometer (TDGC/MS) has been evaluated for on-site detection of polychlorinated biphenyls (PCB) in soil/sediment. The MS was operated in the selected ion monitoring mode for the simultaneous detection of PCB congeners 1-8, octachlorinated naphthalene, and deuterated polycyclic aromatic hydrocarbon standards. The linearity of the detector was established over three orders of magnitude of compound thermally desorbed. Methods were developed which provided screening level (semiquantitative) analyses in 2-5 min/sample and more quantitative analyses in less than 20 min/sample (including sample preparation time). Method detection limits were established at sub ppm levels. The TDGC/MS was transported to a U.S. Environmental Protection Agency (EPA) hazardous waste (Superfund) site and operated by battery. Several samples were collected and compared between laboratory GC/MS and field TDGC/MS measurements. Findings indicate that the field methods provide data quality comparable to methods mandated by the EPA for the analysis of soils as prescribed by Superfund.

Robbins, G.A., Bristol, R.D. & Roe, V.D., **A Field Screening Method for Gasoline Contamination Using a Polyethylene Bag Sampling System**, *Ground Water Monitoring Review*, Fall 1989.

A headspace screening technique using a reclosable polyethylene bag and a total organic vapor detector is presented for assessing gasoline contamination of water and soil. The technique is shown to possess a well-founded theoretical basis that predicts linear correlation between headspace measurements and volatile constituent levels, providing pertinent conditions are stable or controlled. Laboratory analyses were performed with aqueous aromatic standards, contaminated groundwater, and soil spiked with benzene and gasoline to develop and test the method. The technique has been found to possess detection limits in the low $\mu\text{g/L}$ and fractions of mg/kg range for water and soil, respectively. The method was tested at two field sites. Good correlations were obtained between field screening results and laboratory analyses with respect to delineating the areal distribution of aromatics in the groundwater, monitoring well purging, and determining the vertical distribution of aromatic levels in soil.

Robbins, G.A., Deyo, B.G., Temple, M.R., Stuart, J.D. & Lacy, M.J., **Soil-Gas Surveying for Subsurface Gasoline Contamination Using Total Organic Vapor Detection Instruments. Part I, Theory and Laboratory Experimentation**, *Ground Water Monitoring Review*, Summer and Fall 1990.

Factors influencing the response of total organic vapor detection instruments used in soil-gas surveying for subsurface gasoline leakage were investigated through performing theoretical assessments and laboratory experiments. Theoretical assessments indicate that total organic vapor measurements will depend on response conditions and the relative concentration of constituents in soil gas, in addition to absolute constituent levels. Laboratory tests conducted using flame ionization, photoionization and explosimeter devices indicated that conditions influencing their

responses included instrument flow rate and soil-air permeability when performing direct-probe sampling; the linear range of the instrument; the multicomponent nature of gasoline vapors; and levels of oxygen, nitrogen, carbon dioxide and relative humidity in soil air. If an instrument's response to these conditions is not taken into account, survey results may be misleading. To circumvent adverse instrument responses, a serial dilution technique is presented.

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Mass balance models were developed to examine how monitoring well purging influences the collection of representative groundwater samples. Modeling indicates that monitoring wells may provide only qualitative information on the absolute and relative abundances of solutes in groundwater. Solute concentrations in a purged well may vary by over an order of magnitude depending on well construction, purging procedure, vertical concentration distributions of solutes in the groundwater and the hydrogeological properties of the aquifer. Further, these dependencies limit setting *a priori* criteria for purging, using simple field measurements for monitoring purging completeness and extrapolating the results of empirical purging studies. Water samples obtained from typical monitoring wells using standard purging procedures may underestimate groundwater contamination by orders of magnitude. Mass balance effects that occur during purging can complicate the interpretation of physical, chemical and biological conditions and processes occurring within an aquifer. Recognizing that solute concentrations are likely to vary in three dimensions, the quantitative assessment of groundwater requires sampling at discrete depths within an aquifer.

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Stuart, J.D., Wang, S., Robbins, G.A. & Wood, C., **Field Screening of BTEX in Gasoline-Contaminated Groundwater and Soil Samples by a Manual, Static Headspace GC Method**, Second International Symposium, Field Screening Methods for Hazardous Wastes and Toxic Chemicals, Las Vegas, NV, February 12-14, 1991.

A manual, static headspace GC method has been developed and used in the field for the screening of gasoline-contaminated groundwater and soil samples. This developed, static headspace method has focused primarily on the analyses of benzene (B), toluene (T), ethylbenzene (E), and the three xylene isomers (X) (often collectively abbreviated as BTEX). However, this method also allows for the determination of methyl-*t*-butyl ether (MTBE), trichloroethylene (TCE) and tetrachloroethylene (PCE) in the headspace above the aqueous layer as detected by a photoionization detector (PID) of a field-portable gas chromatograph. Good agreement was found between the field, static headspace method, a laboratory-based manual, static method and a laboratory-based, purge-and-trap method. The results of field screening for BTEX, MTBE, and PCE at several sites in the New England area will be presented.

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The extension of a generic immobilization technology for the fabrication of antibody- and receptor-based biosensors is reported. The biosensors utilize polymerized protein films containing the antibody or receptor and appropriate stabilizers to coat an interdigitated electrode transducer. Changes in the electrical field of the coated electrodes are related to specific interactions between the immobilized biomolecule and the analyte to be measured. A portable electronics module has been developed into which the coated electrode chips are inserted and challenged with analyte. Within 5-10 s, an output reading (change in impedance, phase angle, current or voltage) is obtained that is related to analyte concentration. The use of parallel, non-antibody or non-receptor containing control chips allows automatic correction for background and non-specific binding. The biosensors can detect low ng ml⁻¹ levels of analyte in serum or other liquids. Such antibody- and receptor-based biosensors are applicable to the determination of a wide range of analytes for analytical, clinical, environmental and process control applications.

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BIOGRAPHIES OF PRESENTERS

Mr. John N. Driscoll
HNU Systems, Inc.

Mr. Driscoll is the founding president of HNU Systems, Inc. and also the founding president of the Massachusetts Environmental Business Council. Mr. Driscoll is responsible for a wide range of scientific and technical developments in field instrumentation for the analysis of hydrocarbons, pesticides and metals. Among these developments, Mr. Driscoll is credited with the development of the first series of instruments based on photoionization and the first commercial photoionization detector for gas chromatography, introduced to the market in 1976.

Mr. Michael J. Ernst
MIT, Department of Civil Engineering

Mr. Ernst is a research assistant within the Division of Water Resources and Environmental Engineering at the Department of Civil Engineering, MIT. From 1983-1985, Mr. Ernst was with the Peace Corps, working as a mathematics teacher in Kenya. Prior to the Peace Corps, he worked as a control systems analyst for the Boeing Co.

Mr. Ernst received a B.S. in Electrical Engineering from Colorado State University.

Dr. Lorne G. Everett
Metcalf & Eddy

Dr. Everett joined Metcalf & Eddy in 1989 and is currently chief scientist and vice president. Dr. Everett participates in numerous CERCLA and RCRA activities and is a key member in Metcalf & Eddy's Technical Advisory Teams. His specific expertise is in site characterization, monitoring and remediation within the vadose zone. In addition to his responsibilities with Metcalf & Eddy, Dr. Everett is a Professor, and Director of the Vadose Zone Monitoring Laboratory at the University of California, Santa Barbara. Dr. Everett is also serving as ASTM Section Chairman for Vadose Zone Monitoring.

Dr. Everett received a B.S. in Chemistry and Water Sciences from Lakehead University, and his M.S. and Ph.D. from the University of Arizona.

Mr. David Friedman
U.S. EPA, Office of Research and Development

Mr. Friedman has been involved in environmental testing for 17 years, initially with the Food and Drug Administration and for the past 13 years with the Environmental Protection Agency (EPA). Until 1989, he was Chief of the Methods Section of the Office of Solid Waste and was responsible for all testing methodology employed in the Resource Conservation Recovery Act (RCRA) program. He now works in EPA's Office of Research and Development (ORD), helping to establish a common set of test methods for use in all environmental monitoring programs. Until recently he served as the Executive

Secretary of the EPA Environmental Monitoring Management Council Steering Committee.

Mr. Friedman earned his B.S. and M.S. degrees in chemistry from Brooklyn College and Lehigh University, respectively.

*Mr. Richard K. Glanzman
CH2M Hill, Inc.*

Mr. Glanzman is a senior geohydrologist/geochemist in the Geosciences Discipline with CH2M Hill in Denver. He is experienced with the fate, transport, and remediation of metals, solvents, polycyclic aromatic hydrocarbons, pesticides, radioactive materials, mixed wastes, and food manufacturing wastes utilizing surface impoundments, soil applications, landfills, waste solidification, and subsurface injection. Risk assessment and remedial actions which Mr. Glanzman has overseen involve air, water, and solids matrices. He works with both CERCLA and RCRA regulated wastes, sites, and facilities.

*Professor Harold F. Hemond
MIT, Department of Civil Engineering*

In 1991, Professor Hemond became a full Professor with MIT's Department of Civil Engineering, Division of Water Resources and Environmental Engineering. Prior to MIT, Professor Hemond served in a variety of positions including Deputy Director of Water and Related Resources at Connecticut College and as a commissioned officer and instructor at the U.S. Coast Guard Academy. His research interests are primarily fate and transport mechanisms of contaminants in the natural environment.

Professor Hemond received a B.S. in Electrical Engineering from Worcester Polytechnic Institute, an M.A. in Botany from Connecticut College, and his Ph.D. in Environmental Engineering from MIT.

*Dr. Tim E. Moody
Westinghouse Hanford Company, Environmental Restoration Engineering*

Dr. Moody is a senior scientist with the Westinghouse Hanford Company. Westinghouse Hanford Company is the contractor responsible for the remediation of the U.S. Department of Energy's Hanford Reservation. Dr. Moody is the project manager for the development of a mobile, field screening laboratory for the RI/FS analysis of organic and inorganic hazardous waste at Hanford Reservation. He is also project manager of the research project that is evaluating the application of supercritical fluid extraction for large-scale remediation of contaminated soils.

Dr. Moody received an M.S. in Soil Mineralogy and a Ph.D. in Soil Chemistry.

*Mr. Bruce J. Nielsen
U.S. Air Force, Civil Engineering Support Agency, Site Restoration R&D Branch*

Since 1986, Mr. Nielsen has served as an environmental research engineer with the U.S. Air Force Civil Engineering Support Agency (AFCEA). Within AFCEA, Mr. Nielsen conducts research to solve the unique environmental problems of the Air Force in

groundwater and soil contamination, hazardous waste treatment and site remediation. Currently, Mr. Nielsen is exploring advanced techniques including fiber-optic spectroscopy for monitoring underground petroleum tanks.

Mr. Nielsen received a B.S. in Biology from Moorhead State University and an M.S. in Environmental Engineering from North Dakota State University.

Mr. Ian M. Phillips
GEI Consultants, Inc.

Mr. Phillips is a senior environmental chemist with the consulting firm, GEI Consultants, Inc. At GEI, Mr. Phillips is responsible for the management and design of complex sampling and analytical programs as well as data validation. In addition, he is responsible for the internal quality assurance program for GEI's Environmental Division. Before joining GEI, Mr. Phillips served as an analytical chemist for 7 years at the consulting firm, Enseco. While at Enseco, he performed a wide range of chemical analyses, including PCB's, pesticides, herbicides, volatile organics, and petroleum fingerprinting.

Mr. Phillips received a B.S. in Chemistry from Vassar College and an M.S. in Environmental Engineering from the University of Lowell.

Mr. Charles A. Ramsey
U.S. E.P.A., National Enforcement Investigations Center

Currently, Mr. Ramsey is a chemist for EPA's National Enforcement Investigations Center (NEIC). At NEIC, Mr. Ramsey is responsible for developing representative sampling plans that integrate field analytical equipment for field contamination surveys, and provide expert advice to attorneys and federal enforcement agencies in support of civil and criminal environmental investigations. Mr. Ramsey was employed in a variety of positions prior to joining EPA that included data communication specialist for MCI and custom engineer for IBM.

Mr. Ramsey received a B.A. in Chemistry from the University of Denver, an M.S. in Mineral Resources Ecology from Colorado School of Mines and is pursuing a Ph.D. at the Colorado School of Mines in Mineral Economics and Operations Research.

Professor Albert Robbat, Jr.
Tufts University, Department of Chemistry

Professor Robbat is an Associate Professor of Chemistry and an Adjunct Professor of Chemical Engineering at Tufts University. Prior to joining the Tufts faculty, Professor Robbat was a research associate for the Department of Energy. His current research interests are in methods development, field analytical chemistry, instrument design and chemometric methods of analysis for identifying contaminant organic compounds in complex environmental matrices.

Professor Robbat received a B.S. from the University of Massachusetts and a Ph.D. in Analytical Chemistry from Pennsylvania State University.

*Professor Gary A. Robbins
University of Connecticut, Department of Geology and Geophysics*

Professor Robbins is an Associate Professor at the University of Connecticut. Before joining the faculty at the University of Connecticut, he was an Adjunct Professor at the University of California, Riverside and California State University, Fullerton. His research interests include perfecting field measurement techniques for volatile organics, assessing gas diffusion in the vadose zone and identifying factors that influence hydrodynamic dispersion of contaminants in porous and fractured media.

Professor Robbins received a B.A. from Brooklyn College, an M.S. from Brown University and a Ph.D. from Texas A&M University.

*Dr. Myron S. Rosenberg
Camp Dresser & McKee, Inc.*

Dr. Rosenberg is a vice president within the CDM organization. He is currently responsible for CDM's work with the petrochemical industry, specifically the environmental impacts of oil refinery and oil terminal operations. Dr. Rosenberg's expertise is in the fate, transport and remediation of subsurface contaminants. At this time Dr. Rosenberg serves on the ASTM Task Group addressing corrective action and site assessment standards and procedures. He is also serving as vice chairman of the ASCE national committee to develop the manual "Hazardous Waste Site Investigation."

Dr. Rosenberg received a B.S. in Materials Science and Engineering from Cornell University and an M.S. and Ph.D. in Civil Engineering from MIT.

*Dr. Donald G. Scroggin, Esq.
Jenner and Block*

Dr. Scroggin is a partner in the Washington D.C. law offices of Jenner and Block. He provides counseling and litigation services for a variety of industrial and commercial clients with an emphasis on: regulation of hazardous pollutants under the Clean Air Act and the Clean Water Act, use of cancer risk assessments in regulatory programs, dredge and fill permitting and wetland issues and compliance with the National Environmental Policy Act. Prior to joining the law profession in 1978, Dr. Scroggin was an assistant professor of chemistry at Williams College and a visiting professor to Harvard University.

Dr. Scroggin received a B.S. in chemistry from Centenary College, a Ph.D. in physical chemistry from Harvard University, and a J.D. from Yale Law School.

*Mr. Brian Sogorka
New Jersey Department of Environmental Protection, Bureau of Environmental
Evaluation and Risk Assessment.*

Mr. Sogorka is Section Chief of the ECRA Review Unit, Bureau of Environmental Evaluation and Risk Assessment within New Jersey's Department of Environmental Protection. His responsibilities include the review and approval of sampling and remedial plans of industrial facilities. Mr. Sogorka is also active in program development activities that include laboratory deliverable requirements and quality

control. Mr. Sogorka is a lead author of the recently proposed New Jersey regulations "Technical Requirements for Site Remediation."

Mr. Sogorka received a B.S. in Biology from Bucknell University and an M.S. in biology (Aquatic Toxicology) from Montclair State University.

Dr. Thomas M. Spittler
U.S. E.P.A., Region One, Lexington Lab

Dr. Spittler is currently a senior research scientist at the EPA Lexington Laboratory for Region One. Prior to this position, he was the director of this laboratory for eighteen years. Before joining EPA, Dr. Spittler was the laboratory director for the City of Chicago Department of Environmental Control. Dr. Spittler has broad experience, stretching over almost two decades, in the use of field instrumentation and has given many lectures, seminars and papers on this topic.

Dr. Spittler received an A.B. from Spring Hill College and his M.S. and Ph.D. in inorganic-analytical chemistry from Loyola University.

Dr. Richard F. Taylor
Arthur D. Little, Inc., Applied Biotechnology Laboratory

Dr. Taylor is a Senior Consultant and Manager of the Applied Biotechnology Laboratory in the Product Technology Section of Arthur D. Little, Inc. Dr. Taylor joined Arthur D. Little in 1977. Since that time, he has focused on the application of biomolecules, biochemical processes and analytical methods to new biotechnology products in the areas of separations, protein immobilization, drug delivery and diagnostics. Dr. Taylor has directed a variety of laboratory-based and consulting studies in biotechnology.

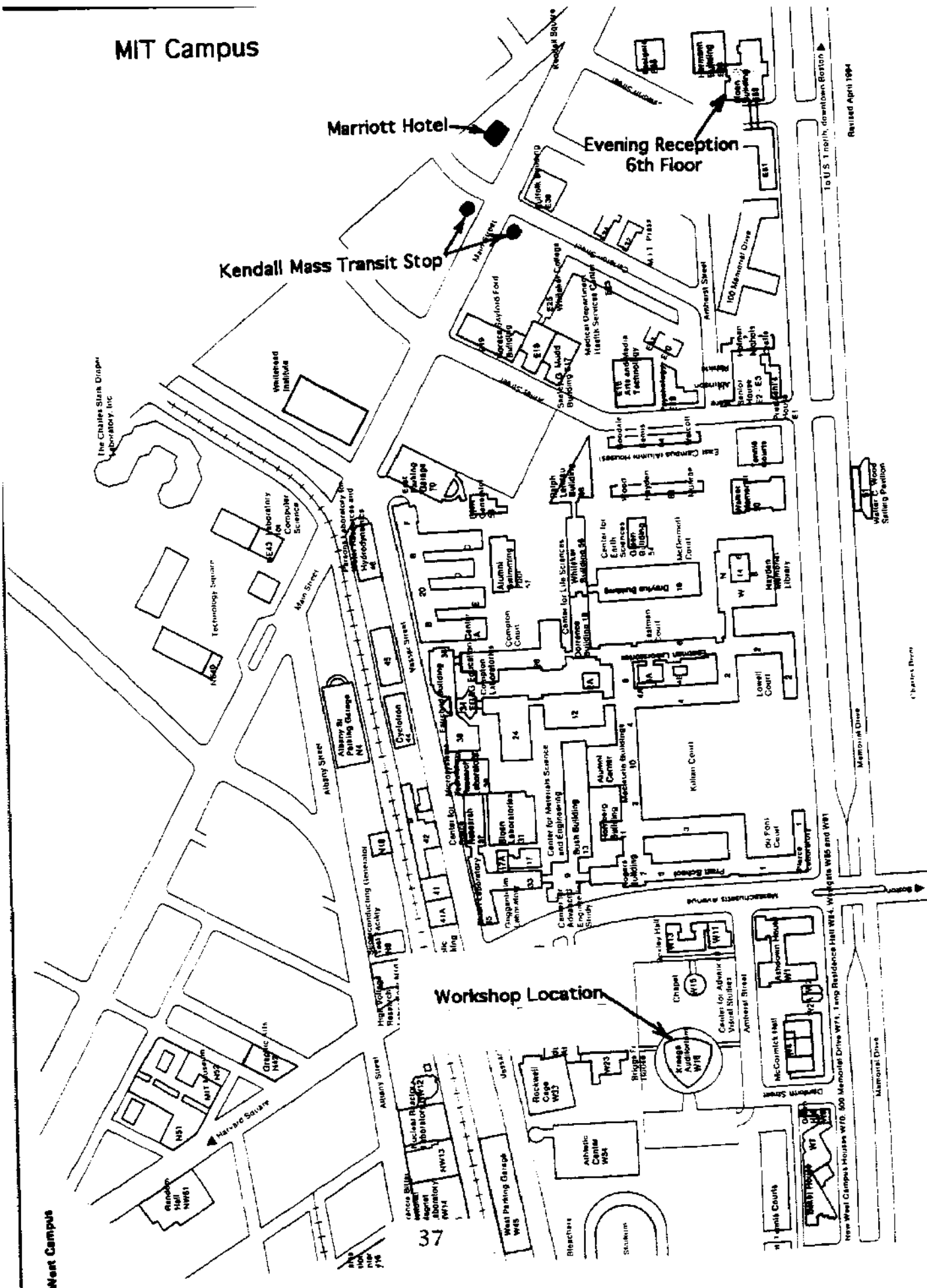
Dr. Taylor received his B.S. in chemistry from the St. Lawrence University in 1968, and his Ph.D. in biochemistry from the University of New Hampshire in 1972.

Professor David R. Walt
Tufts University, Department of Chemistry

Professor Walt recently became a full professor at Tufts University. He is currently Chairman of the Chemistry Department at Tufts, a position he's held since the Fall of 1989. Professor Walt's research interests are in the development of fiber-optic sensors for a variety of applications, including medical diagnostics, environmental contaminant monitoring, and oceanographic research. Professor Walt is also conducting research in the development of biocompatible vascular prostheses, immunochemistry and preparation of bichromophoric polymers.

Professor Walt received his B.S. in Chemistry from the University of Michigan and his Ph.D. in Chemistry and Pharmacology from the State University of New York at Stony Brook.

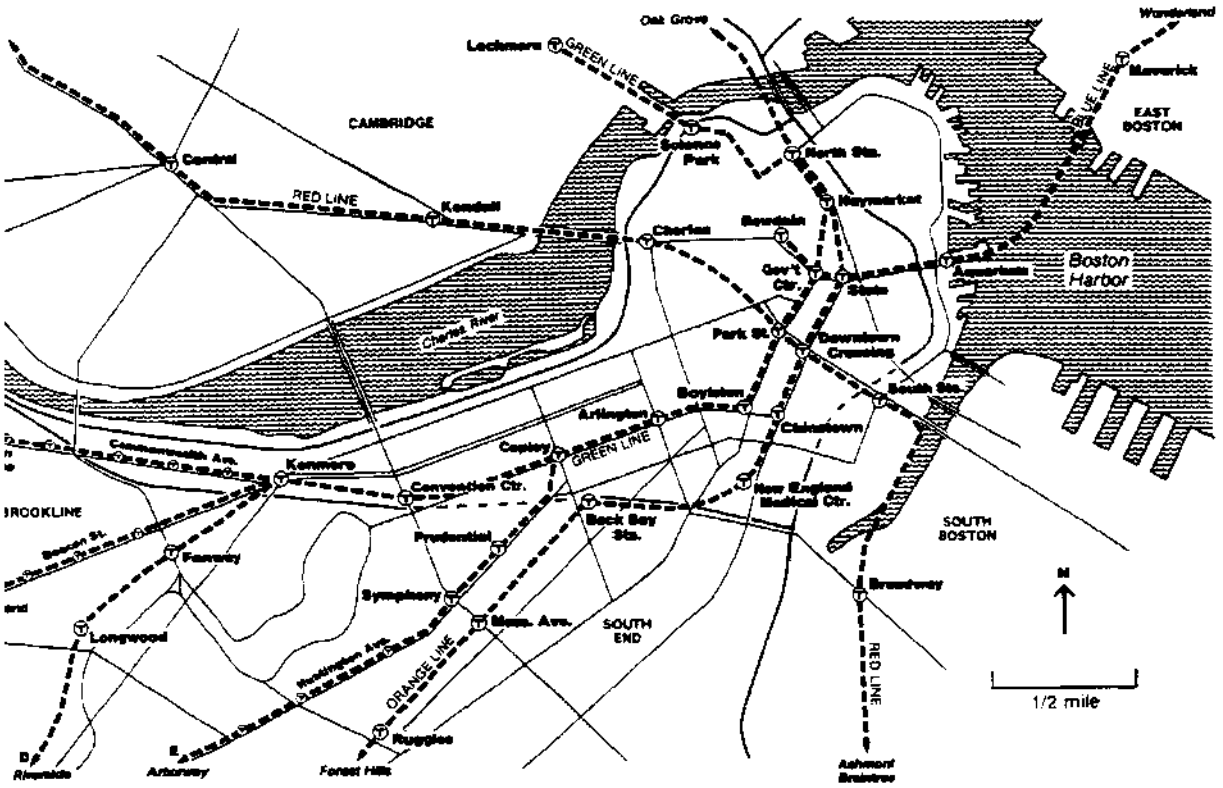
MIT Campus



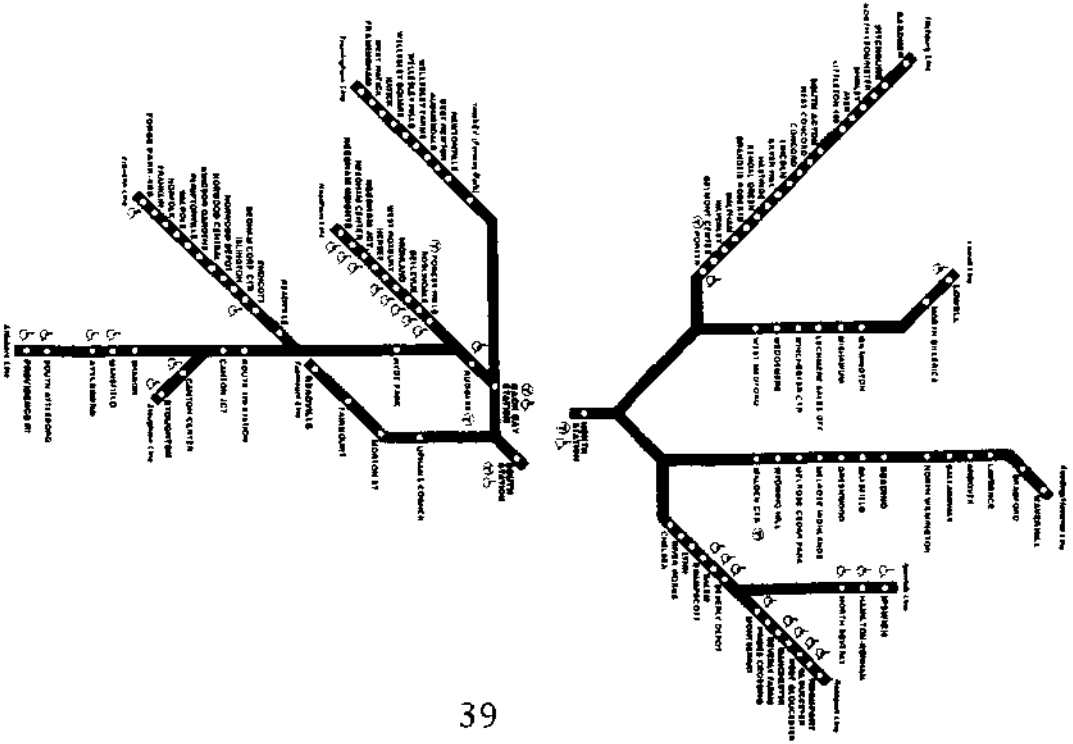
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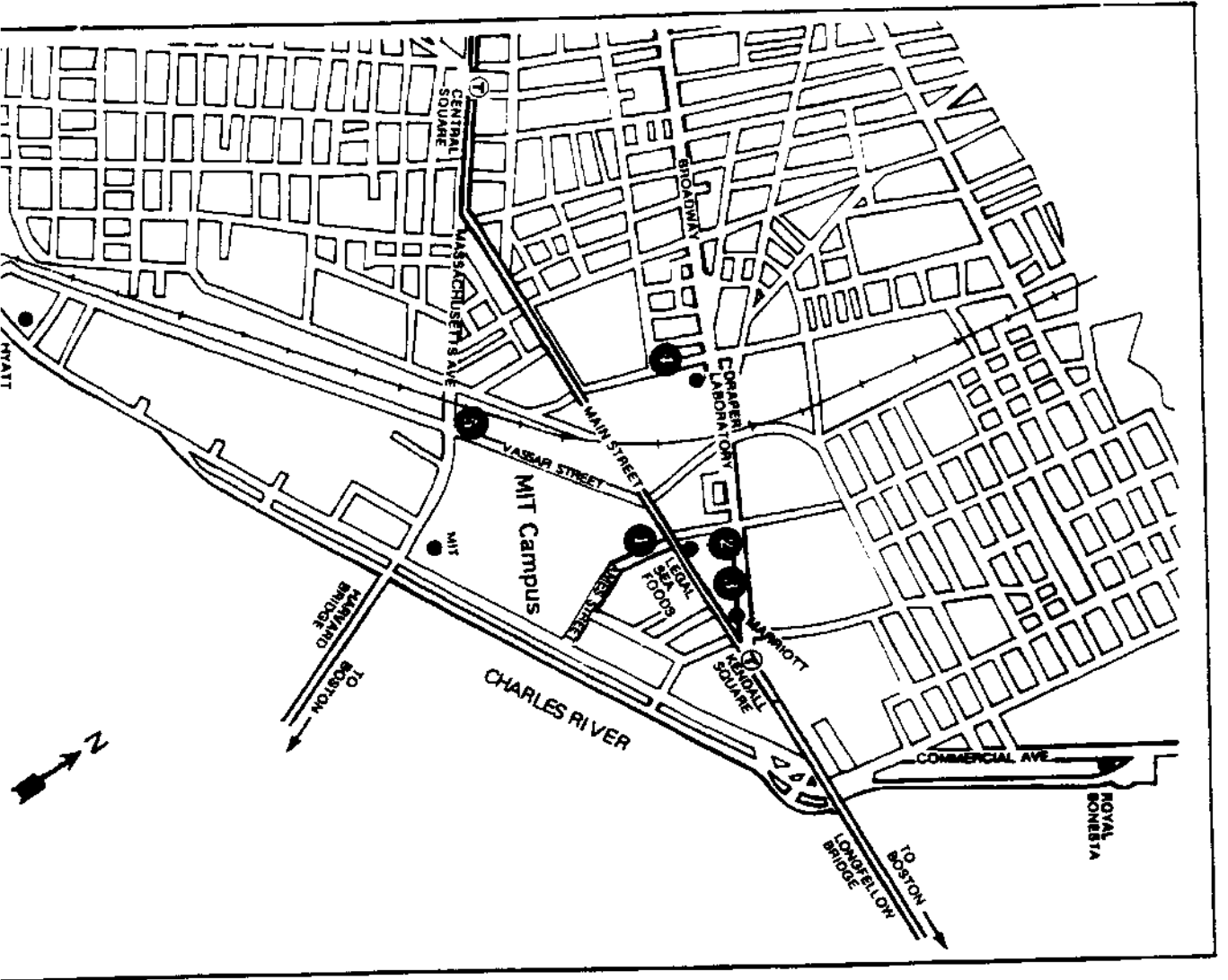
New West Campus Houses W70, 500 Memorial Drive W71, Long Residence Hall W74, West Campus W75 and W76

Mass Transit for Boston/Cambridge



Commuter Rail System





MIT Campus Vicinity Parking

- 1 Ames Street Lot
Ames and Main Street
225-0847
- 2 Cambridge Center Garage
5 Cambridge Center
Broadway and Ames Street
(off of Main St., next to Legal Sea Foods)
492-1956
- 3 Cambridge Center Marriott Hotel
2 Cambridge Center (Valet parking)
494-6600
- 4 Polaroid Parking Garage
Adjacent to Draper Employee Parking
Garage
Technology Square
- 5 Vassar Street Lot
Vassar St. and Massachusetts Ave.
(next to BayBank Automated Teller
machine)

NOTE:
There is limited Draper Lab visitor parking available.
Many area hotels provide shuttle service to Draper Lab.

ACCOMMODATIONS:*

Cambridge Marriott
2 Cambridge Center
Cambridge, MA 02139
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1-617-494-6600

Hyatt Regency
Memorial Drive
Cambridge, MA 02142
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1-617-492-1234

Royal Sonesta Hotel
5 Cambridge Parkway
Cambridge MA 02139
1-800-SONESTA
1-617-491-3600

Howard Johnson
777 Memorial Drive
Cambridge, MA 02142
1-800-654-2000
1-617-492-7777

*Listed in descending order of proximity to workshop location.