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A PRELIMINARY CLIMATOLOGY OF AIR QUALITY IN OHIO

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Eastern Region

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UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE EASTERN REGION
Garden City, New York

NOAA WEATHER SERVICE TECHNICAL MEMORANDUM ER-39

A PRELIMINARY CLIMATOLOGY OF AIR QUALITY IN OHIO

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INTRODUCTION

Nearly every person in the United States has become aware of many environmental factors which now or soon will affect our mode of living. Urbanization has resulted in a modification of the atmospheric environment especially within metropolitan areas. Extreme atmospheric stresses such as prolonged exposure to smog episodes represent a serious threat to the health of the urban population. Thus, all Meteorologists and Weather Service Specialists within the National Weather Service must become more aware of local air pollution programs and the modifying effects of urbanization on weather in their area of responsibility. This report gives information regarding urban air pollution in Ohio.

The Air Quality Act of 1967 charged the U. S. Department of Health, Education and Welfare (HEW) with the responsibility of forming Air Quality Control Regions throughout the United States. As a result of this Act, HEW has also done research related to recommending standards for ambient air. HEW made its recommendations to the States who are to establish standards for "their" regions.

Counties included in Ohio's Air Quality Control Regions are shown in Figure 1. Except for the Greater Metropolitan Cleveland Region all Ohio Air Quality Regions include counties from neighboring States. Following recommendations of HEW, the Air Pollution Control Board within the Ohio Department of Health has prepared suspended particulate and sulfur dioxide standards for 5 of its Regions. Before reviewing these standards there are some definitions of importance. As used in Ohio regulations:

"Air contaminant" means particulate matter, dust, fumes, gas, mist, smoke, vapor or odorous substances, or any combination thereof.

"Air pollution" means the presence in the ambient air of one or more air contaminants or any combination thereof in sufficient quantity and of such characteristics and duration as to injure human health or welfare, plant or animal life, or property or which unreasonably interfere with the comfortable enjoyment of life or property.

"Ambient air" means that portion of the atmosphere outside of buildings and other enclosures, stacks, or ducts which surrounds human, plant, or animal life or property.

"Ambient air quality standards" are the ambient air quality goals expressed numerically and intended to be achieved in a stated time through the applications of appropriate preventive or control measures.

Figure 1.
Air Quality Control Regions

Counties in Other States

1. Michigan (Monroe)
2. Pennsylvania (Crawford, Erie, Mercer)
3. Incomplete
4. Indiana (Dearborn, Ohio); Kentucky (Boone, Campbell, Kenton)
5. Kentucky (Boyd, Greenup, Lewis); West Virginia (Cabell, Wayne, Mason)
6. West Virginia (Jackson, Pleasant, Wetzell, Tyler, Wood)
7. West Virginia (Brooke, Marshall, Hancock, Ohio)

PARTICULATE STANDARDS

Ambient air quality standards for suspended particulates applicable to most Ohio counties included in the Air Quality Regions are:

(1) Maximum annual geometric mean concentration should not exceed 65 micrograms, μg, per cubic meter.

(2) Maximum 24-hour concentrations not to be exceeded more than one percent of the time on an annual basis is 200 micrograms, μg, per cubic meter.

(3) The 24-hour concentration should not exceed 260 micrograms, μg, per cubic meter more than 1 day per year.

Suspended particulates consist of smoke, dust, fumes, and droplets of viscous liquids, ranging in size from about .3 micron diameter upwards to about 100 microns. A high volume sampler is used in collecting suspended particulate samples. This sampler consists of a specially housed vacuum sweeper motor to which is attached a filter holder. Samples are collected for a 24-hour period (Midnight-Midnight).

Suspended particulates are our most conspicuous air contaminant because they are generally responsible for the visible consequences of air pollution, i. e., the dirt, grime and soiling of materials. The effects of particulate matter on health are more subtle. Particles absorb and adsorb gases such as sulfur dioxide and in our breathing process both may be carried deep into the lungs. For these reasons, along with ease in sampling, suspended particulates are monitored by most cities.

Since 1957 an agency of HEW, (the Public Health Service and later the National Air Pollution Control Administration*), has maintained the National Air Surveillance Network. Through this network suspended particulate data collected from samplers located in the central business and commercial district of most major U. S. cities are available (3, 4) for comparison. In downtown locations, measured concentrations tend to be among the higher concentrations found in the city and, therefore, cannot be interpreted as being the urban average. Most city air pollution departments began to maintain an urban network of high-volume samplers in the middle or late 1960s.

Using data from the National Air Surveillance Network it is possible to make comparisons between air quality standards for suspended particulates as set by the Ohio Air Pollution Control Board and data collected at Ohio cities.

*By Executive Order now a component of Environmental Protection Agency (Dec. 1970)

Table 1 gives a comparison between 1959 and 1968 suspended particulate geometric means as determined from least squares regression lines of 1959-1968 annual geometric means. (Geometric mean gives a more typical average than the arithmetic mean because it is less affected by extreme values. The geometric mean is smaller than the arithmetic mean since it is a function of the nth root of the product or logarithm of the individual values). From Table 1, it is clear that while the trend in suspended particulate pollution in downtown areas is down, the annual values for all downtown sampling sites are still well above the Ohio ambient standard of 65 micrograms per cubic meter. In terms of relative frequency more than 80 percent of all suspended particulate samples collected during the period 1959-1968 at Ohio cities listed in Table 1 exceeded 65 micrograms per cubic meter.

Table 1. Comparison of 1959 and 1968 suspended particulate geometric means as determined from least squares regression line of 1959 through 1968 annual geometric means.

	Geometric Mean ($\mu g/m^3$)		Percent Change
	1959	1968	
Akron	129.4	112.4	-13.1
Cincinnati	130.5	116.9	-10.4
Cleveland	151.1	127.0	-15.9
Columbus	110.6	99.5	-10.0
Dayton	116.1	110.9	-4.5
Toledo	103.8	83.2	-19.8
Youngstown	137.2	122.6	-10.6

Table 2. Comparison of 1959 and 1968 suspended particulate geometric standard deviations as determined from least squares regression line of 1959-1968 annual geometric standard deviations.

	Geometric Standard Deviation		Percent Change
	1959	1968	
Akron	1.66	1.62	-2.2
Cincinnati	1.45	1.55	+6.9
Cleveland	1.55	1.49	-3.9
Columbus	1.46	1.51	+3.2
Dayton	1.52	1.74	+14.5
Toledo	1.53	1.60	+4.7
Youngstown	1.56	1.57	+0.7

Even though there has been a distinct downward trend in suspended particulate loadings over center-city locations during the period, 1959-1968, there has been no systematic change in the geometric standard deviations of suspended particulates (i. e., based on geometric standard deviations as determined from least squares regression lines of 1959-1968 annual geometric standard deviations). Table 2 shows the observed trends in geometric standard deviations for selected center-city sites within Ohio. Increases in geometric standard deviations are suggestive of a more irregular distribution of particulate sources. Wind direction thus plays a more important role in particulate loadings at these fixed center-city points such as Dayton and Cincinnati. Spirtas and Levin (2) say that no single factor can explain the downward trends of suspended particulate levels at downtown sampling stations but urban sprawl might be a major factor. This suggests the growth in industry, commerce, and population might also result in increased particulate loadings in outer fringes of metropolitan areas.

Even though most of us are familiar with metric weights, a more vivid picture of the annual geometric particulate standard 65 μg per cubic meter is needed. Schramm (1) uses the following illustration: Assume an average size home with eight rooms is void of all particulate matter. If a person smoked a regular size cigarette and the ashes from this cigarette were mixed evenly throughout the home, the particulate loading would be approximately equal to 65 $\mu g/m^3$.

Maximum 24-hour suspended particulate loadings for each year during the period 1959-1968 are shown in Table 3. Of the 67 samples contained in this table, 33 exceeded the ambient air quality standard of 260 $\mu g/m^{-3}$.

Table 3. Maximum 24-hour suspended particulate loadings ($\mu g/m^3$) for the period 1959 through 1968.

Year	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	Mean
Akron		294	210	338	288	207	307	287	228	218	264
Cincinnati	336	316	189	294	204	331	255	399	225	227	278
Cleveland	445	336	246	212	344	275	235	227	189	233	274
Columbus	272	190	374	211	227	446	221	253	168	147	251
Dayton	239	327	215	274	198	275	274	406	293	229	273
Youngstown	277	371	298	602	397	264	272	406	235	320	344
Toledo	193			204	412	185	175	243	125	144	210

It has been estimated that the mean level of suspended particulate for center-city areas is about four times that for nonurban areas (3).

Large particles which settle rapidly near their point of origin are called dustfall. They range in size upward from about 20 microns. Urban dustfall (settleable particulates) sampling networks have been operated by all major cities in Ohio for several years. Settleable particulates are trapped in a plastic bucket exposed outdoors for a month. Analysis is made by evaporation of the precipitation, drying and weighing of the residue. Table 4 gives the average seasonal extremes within Akron, Cincinnati, Columbus, Dayton and Toledo metropolitan areas. For each season, the average high values are the sums of highest observed dustfall readings within the metropolitan dustfall network for each month in the season divided by the years of record times 3. Excluding Toledo, the ratio (high/low) of seasonal extremes in dustfall within Ohio urban areas varies from 3.8 to 8.5. There is no discernible seasonal pattern among the data contained in Table 4.

SULPHUR DIOXIDE STANDARDS

Ambient air quality standards for sulphur dioxide (1) applicable to most Ohio counties included in HEW Air Quality Control Regions are:

(1) The maximum annual arithmetic mean concentration should not exceed 40 micrograms per cubic meter* (0.015 parts per million by volume).

(2) The maximum 24-hour concentration not to be exceeded more than one percent of the time on an annual basis is 266 micrograms per cubic meter* (0.1 parts per million by volume).

(3) The maximum one hour concentration not to be attained more than one hour per year is 797 micrograms per cubic meter* (0.3 parts per million by volume).

Most pollution authorities believe the sulphur oxides to be the most serious forms of air pollution in the United States today. Equipment for continuous sampling and recording of atmospheric concentrations of sulphur dioxide, SO_2, and other gaseous pollutants is quite expensive to purchase and maintain. Devices utilizing coulometric methods are used for continuous sampling of many gaseous pollutants. Bubblers are also often used in finding 24-hour concentrations. In the past 3 years most large cities in Ohio have obtained continuous monitoring equipment capable of sampling SO_2 in the air but only Cincinnati has more than 5 years of continuous air monitoring data.

*At a temperature of $70^{\circ}F$ and a gas pressure of 14.7 pounds per square inch.

Table 4. Mean seasonal extremes in settleable particulates (tons per square mile per month) for four Ohio cities.

Period of Record	Average Number of Stations	Winter# High	Winter# Low	Winter# H/L*	Spring High	Spring Low	Spring H/L	Summer High	Summer Low	Summer H/L	Fall High	Fall Low	Fall H/L
					Akron								
1962-69	16	49.4	5.8	8.5	47.0	10.0	4.7	45.3	8.9	5.1	46.4	7.1	6.5
					Cincinnati								
1960-69	16	33.5	8.9	3.8	37.4	8.8	4.3	28.9	7.6	3.8	30.5	7.9	3.9
					Columbus								
1964-69	23	30.6	5.6	5.5	42.4	8.3	5.1	33.1	8.6	3.8	30.3	7.2	4.2
					Toledo								
1962-69	27	111.0	4.7	23.6	100.4	8.6	11.7	89.6	5.5	16.3	101.3	5.1	19.9

*high/low
#December-February

Table 5. Range of annual and selected maximum sulphur dioxide concentrations in ppm for selected U. S. cities, 1962-67.

	Range of annual values	Range of maximum monthly averages	Range of maximum daily averages
Chicago	.082-.175	.242-.349	.400-.789
Cincinnati	.025-.038	.046-.060	.067-.175
Denver	.005-.021	.020-.030	.038-.069
Philadelphia	.069-.097	.124-.153	.325-.460
SanFrancisco	.009-.017	.010-.028	.046-.077
St. Louis	.043-.064	.052-.093	.178-.262
Washington	.045-.055	.081-.106	.181-.254

Table 5 shows the range of average and maximum sulphur dioxide concentrations for selected U. S. cities during the period 1962-1967. While the annual SO_2 center-city data for Cincinnati were low as compared to other locations the annual values still exceeded the ambient air quality standards given above. None of the other SO_2 air quality standards were exceeded at the Cincinnati location.

The air quality standards applicable to most Ohio counties included in the HEW Air Quality Regions give SO_2 standards in terms of micrograms or parts per million (ppm) by volume. Listed below is a formula which may be used to convert micrograms of SO_2 to ppm by volume under an atmospheric pressure of 14.7 pounds per square inch and a temperature of 70 ^{o}F.

$$ppm = .000375 \mu g \qquad (1)$$

The approximate conversion factor for any gaseous pollutant from micrograms to parts per million by volume is

$$ppm = \mu g V / W \cdot 10^6 \qquad (2)$$

where

μg = weight of pollutant in micrograms
W = molecular weight of pollutant
V = volume of one mole of gas at a given temperature (V = 22,400 at 0^oC and 24,500 at 25^oC)

During the period 1964-67 most major Ohio cities began to maintain a network of lead peroxide candles (cylinders wrapped with gauze and covered with a lead peroxide paste, PbO_2.). These candles are placed in a louvered shelter and are left for a full month. At the end of the month chemists report the results as milligrams of sulphur trioxide, SO_3, per 100 centimeters per day. Such figures bear no relation to the amount of sulphur trioxide in the atmosphere as the greater part of the lead sulphate is derived from SO_2 in the air. Thus, results obtained from lead peroxide candles are usually regarded as a measure of the concentration of SO_2 in the air.

Table 6 summarizes the average seasonal $SO_3/100cm^2$/day (as obtained from lead peroxide candles) extremes for relatively short periods of record within the Akron, Columbus, and Toledo metropolitan areas. Little can be said concerning these data because of the short records. It is possible to convert average monthly values of milligrams sulphur trioxide per 100 centimeters squared per day to parts per million sulphur dioxide by multiplying the monthly figure by .035. For example 1.2 milligrams $SO_3/100cm^2$ /day would be approximately equivalent to .04 parts per million by volume of sulphur dioxide per day.

Table 6. Seasonal extremes in sulphate levels (milligrams SO_3/100 cm^2/day) for three Ohio cities.

Period of Record	Winter# High	Winter# Low	Winter# H/L*	Spring High	Spring Low	Spring H/L	Summer High	Summer Low	Summer H/L	Fall High	Fall Low	Fall H/L
						Akron						
1/67-5/70	2.50	.91	2.7	2.01	.73	2.8	1.54	.38	4.0	2.06	.60	3.4
						Columbus						
4/64-5/70	3.31	.39	8.5	3.25	.20	16.3	1.82	.14	13.0	2.50	.22	11.4
						Toledo						
11/65-12/69	1.22	.42	2.9	1.30	.45	2.9	1.07	.25	4.3	1.34	.30	4.5

#December -February
*high/low

SUMMARY

By means of this report the author hopes to further acquaint National Weather Service personnel in the Eastern Region with (1) established standards for ambient air in Ohio and (2) observed trends in Ohio urban pollution levels for which standards have been set. To date, Ohio has established air quality standards for suspended particulates and sulphur dioxide. The data presented in this report indicate the trend within most Ohio urban areas since the early 1960's has been toward lower suspended particulate and dustfall loadings. Little can be said regarding the trends in sulphur dioxide levels because of relatively short periods of sampling.

Additional air quality standards for Ohio will come. High on Ohio's list are proposed standards for the oxides of nigrogen. With the establishment of more ambient air quality standards, increased sampling in time and space of all pollutants will follow. Such data will then provide the basis for a more comprehensive report on the "Climatology of Air Quality in Ohio."

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