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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM
Volume XII - Cleveland

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume XII

Cleveland, Ohio

FINAL REPORT

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FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data gathered in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. This, in turn contributes to a comparative analysis of data among the 14 areas in an attempt to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analyzed.

The 16 volumes comprising the overall study are as follows:

- Volume I - National Assessment of the Urban Particulate problem
- Volume II - Particle Characterization
- Volume III - Denver
- Volume IV - Birmingham
- Volume V - Baltimore
- Volume VI - Philadelphia
- Volume VII - Washington
- Volume VIII - Chattanooga
- Volume IX - Oklahoma City
- Volume X - Seattle
- Volume XI - Cincinnati
- Volume XII - Cleveland
- Volume XIII - San Francisco
- Volume XIV - Miami
- Volume XV - St. Louis
- Volume XVI - Providence

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ACKNOWLEDGMENTS

GCA/Technology Division wishes to sincerely thank those persons and organizations who made significant contributions to this effort. On-going project supervision was provided by Thompson G. Pace of EPA's Control Programs Development Division. The case study in Cleveland was greatly assisted by the cooperation and helpfulness of the staff of the Cleveland Air Pollution Control Division, particularly Howard Bergman, Robert Hermann, Steve Bondra, George Craig, Thomas Kinder, Gary Nied, Kenneth Murray, and Richard A. Dell.

EXECUTIVE SUMMARY

AIR QUALITY LEVELS AND TRENDS

The 1974 geometric mean TSP concentrations in Cleveland and Cuyahoga County ranged from less than 70 $\mu g/m^3$ outside the city and in residential areas to 70 to 90 $\mu g/m^3$ in densely residential areas and over 100 $\mu g/m^3$ in the industrial areas along the Cuyahoga River and the Lake Erie shoreline. Twelve of the 25 sites in the county exceeded the annual primary standard of 75 $\mu g/m^3$ and nine others exceeded the annual secondary standard, 60 $\mu g/m^3$. The 24-hour primary standard was exceeded on 73 sampling days (4.7 percent) and the secondary standard on 273 sampling days (17.6 percent). Citywide air quality monitoring began in 1967 and since 1970, 15 sites in the city have had an average decrease of 36.5 $\mu g/m^3$ in annual mean TSP concentrations.

REGIONAL SETTING

The City of Cleveland is located in Cuyahoga County in the northeastern corner of the State of Ohio and is on the southern shore of Lake Erie. Because of its location on one of the Great Lakes, Cleveland has become an important transportation, industrial, and manufacturing center. The terrain rises smoothly and gradually over 500 feet from the lake to the suburban heights of land. The Cuyahoga River cuts through the plain, bisecting the city and forming a rather deep and narrow north-south valley.

Cleveland is highly industrialized — the industries are mainly concerned with primary metals, fabricated metal products, machinery, tools, and automotive products but also include numerous other products.

METEOROLOGY

The climate is moderately cold, averaging 6150 heating degree-days per year, with moderate rainfall, an average of 35 inches per year. The presence of Lake Erie strongly influences Cleveland's climate and produces a lake breeze during the summer. Inversions occur frequently in the river valley.

Lake Erie is an important influence on Cleveland's meteorology and air quality. During the warmer months, Lake Erie affects adversely the transport and diffusion of shoreline emissions of pollutants — stable lake air flows inland and tends to pick up pollutants emitted along the shoreline by the industries, utilities, and highways located there, concentrating the pollutants and carrying them inland over populated areas. Frequent inversions occur in the Cuyahoga River valley, concentrating the emissions of the industries located in the valley. A significant correlation is observed between monthly TSP concentrations and wind speed ($r = -0.704$), a measure of dispersion. Transport of TSP into the area cannot be determined but is probably greatest with southerly air flow due to the presence of major industrial areas 27 and 50 miles south-southeast of the city.

URBAN ACTIVITY

There is a strong relationship between annual TSP concentrations and the predominant land use surrounding the monitoring sites — the 1974 geometric mean TSP concentrations of the industrial sites together averaged over 150 $\mu g/m^3$, the center city sites over 100 $\mu g/m^3$, and the residential sites 75 $\mu g/m^3$. The effects of other urban activities are probably obscured by the enormous influence of land use patterns on TSP concentrations.

REGULATIONS AND ENFORCEMENT

The Division of Air Pollution Control of the City of Cleveland is under contract to the Ohio Environmental Protection Agency to provide air pollution control services to Cuyahoga County. The state's air pollution regulations are in effect for the entire county and are generally more stringent than the city's air pollution code. The deadline for compliance with the regulations is April 15, 1977 — most industries and sources are not in compliance at present, some sources are not yet on file and probably many will not be in compliance by the deadline.

The Division of Air Pollution Control has experienced a number of problems in attempting to bring sources of particulate emissions into compliance. Neither the city's nor the state's regulations and enforcement procedures are entirely satisfactory for bringing sources into compliance promptly. Enforcement of the state regulations by Ohio EPA can be time consuming. Enforcement of the city regulations by the Division of Air Pollution can only be done on city problems and only where the city regulation is at least as stringent as the state regulation. The incinerator regulation is an emission standard and requires a lot of work to enforce on both the city and state levels. The Cleveland area has a very large number of air pollution sources, probably 20,000 — some sources have not been identified yet and some of those identified have not received attention yet. The state and city agencies have sometimes been unable to reach satisfactory agreements with companies on air pollution control and have become involved in lengthy hearings or have had proposed actions overturned on appeal. Long delays in achieving compliance have been experienced due to litigation, challenges of the SIP for particulates, and the lack of a SIP for sulfur oxides. Companies which had planned to achieve compliance by fuel switching have not been able to do so due to the energy shortage — they will continue to exceed the emission standards until the energy situation is clarified. Enforcement has resulted in the compliance of a few major problem sources but generally not the widespread compliance of many sources, both large and small.

EMISSIONS

It is apparent that industry is the major source of particulate emissions. The results of an EPA modeling study of particulates indicate that industrial processes and point source fuel combustion contribute more than 70 percent of the TSP concentrations above background levels at certain monitors in the city. Patterns of annual mean TSP concentrations correspond to patterns of industrial development — the highest concentrations of over 150 $\mu g/m^3$ were recorded in the highly industrialized Cuyahoga Flats area. Emissions reductions cannot be documented but do not appear to be large in relation to total emissions. Most of the reduction that has occurred seems to be the result of fuel switching.

NETWORK DESIGN

The design of the network is generally adequate for recording air quality in the various kinds of land development in the area, except that there does not appear to be a background site. The specific siting — the height, location, and exposure of the monitors — seems to be adequate.

CONCLUSIONS

The high TSP concentrations experienced in Cleveland and Cuyahoga County are the result of emissions from the large numbers of industries in the city and county, fugitive dust and emissions in the industrial areas of the city, and shoreline particulate emissions influenced by Lake Erie's effects on dispersion. TSP concentrations have been gradually decreasing over time due to decreasing emissions from coal combustion and, to a lesser extent, from industrial processes and fuel combustion. Problems with enforcing regulations have resulted in delays in achieving compliance. Considerable decreases in particulate emissions and TSP concentrations are expected before full compliance occurs, but is is likely that a few areas of the city and county will continue to exceed the TSP standards due to the topography, land use patterns and meteorology of the area and fugitive dust and emissions.

SECTION I

INTRODUCTION

CITY CHARACTERIZATION

The City of Cleveland is located in Cuyahoga County in the northeastern corner of the State of Ohio. Cleveland and Cuyahoga County are part of the eight-county Metropolitan Cleveland Intrastate Air Quality Control Region; the other major cities located in the AQCR are Akron and Canton (see Figure 1). The AQCR is located in the northeastern Ohio Air Pollution Control area (NEOAPC). Cleveland and Cuyahoga County are on the southern shore of Lake Erie. Because of its location on one of the Great Lakes, Cleveland has become an important transportation, industrial, and manufacturing center. The city is surrounded by several smaller, independent communities that are also highly industrialized (see Figure 2).

Topography and Climatology

Cleveland and Cuyahoga County form a part of the shoreline of Lake Erie. The terrain rises smoothly from the lake's elevation of 570 feet above sea level to over 1100 feet in the southern and southeastern sections of the county. The Cuyahoga River cuts through the plain, bisecting the city and forming a rather deep and narrow north-south valley.

The generally smooth, gradually sloping terrain has a minimal effect on air movement throughout the region. The presence of Lake Erie offers

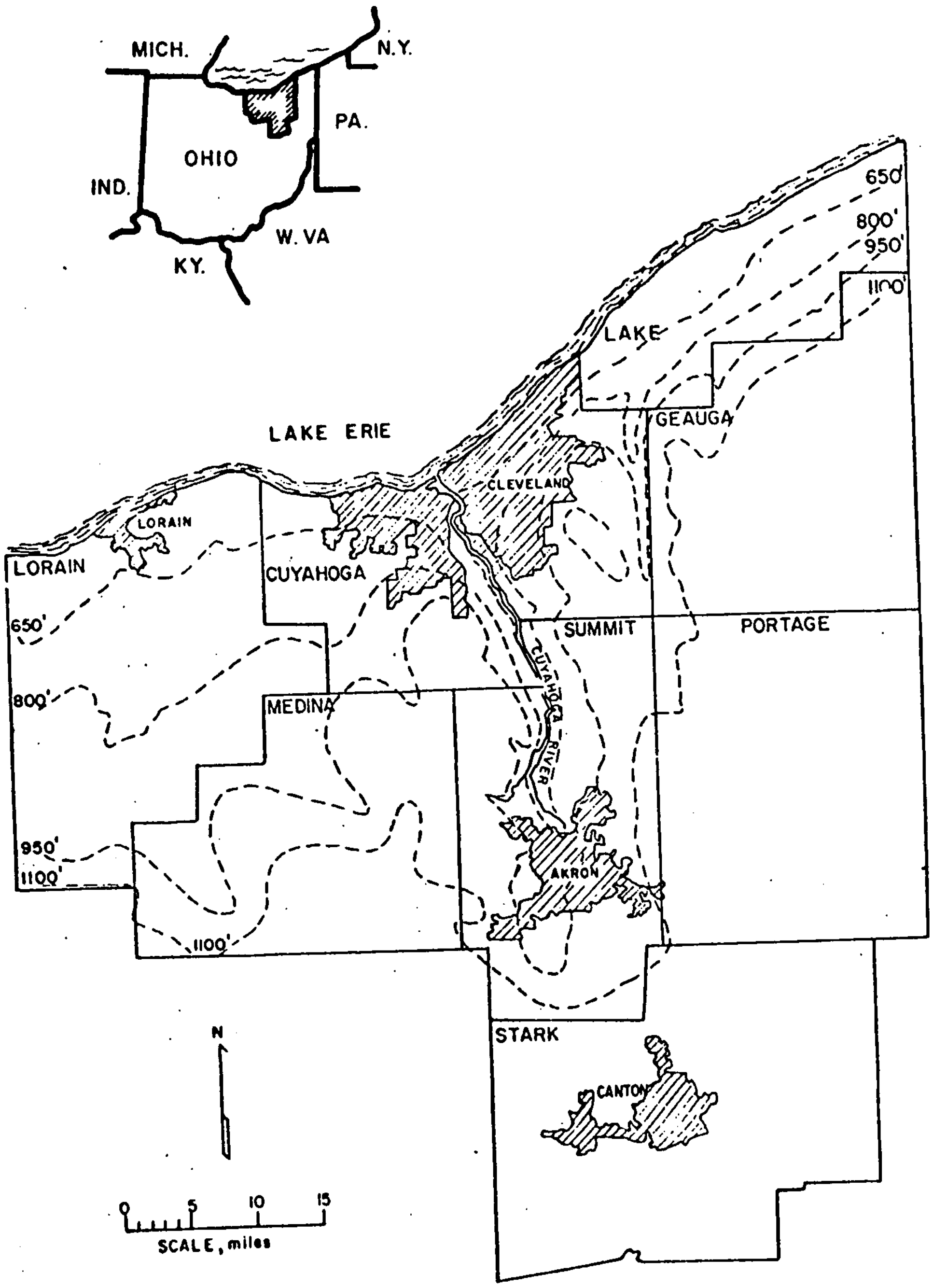

Figure 1. Greater Metropolitan Cleveland Intrastate AQCR

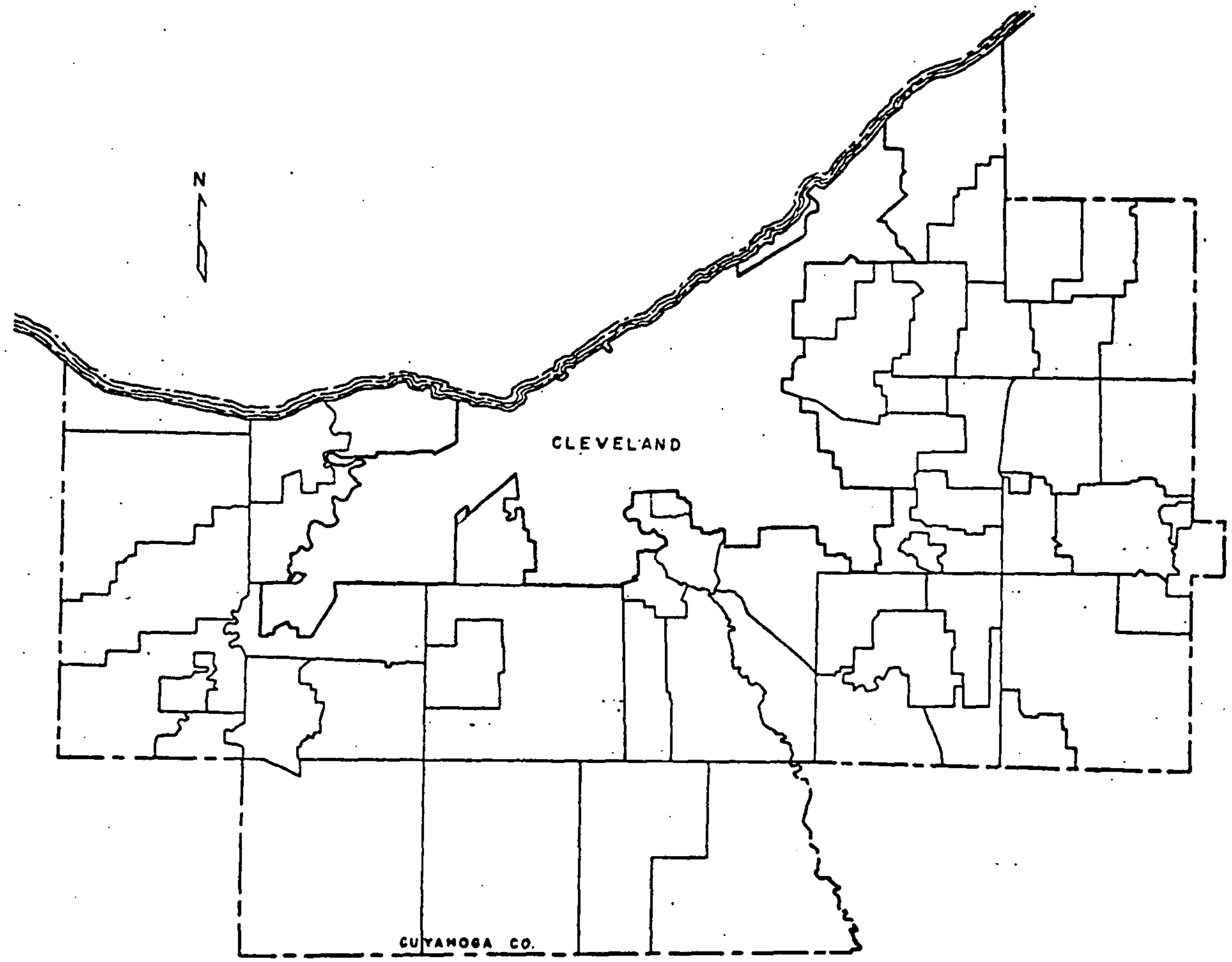

Figure 2. Cuyahoga County and the City of Cleveland

no hindrance to air masses moving in from Canada. Prevailing winds are from the south to southwest.

The climate is mainly continental in character, but strongly modified by Lake Erie. In the winter Cleveland lies in the path of many cold air masses advancing south and east from Canada but the accompanying low temperatures are usually moderated as the air mass crosses over the relatively warm waters of the lake. This also results in frequent winter cloudiness and snow. Persistence of the snow cover is seldom great due to the temperature which rarely remains freezing for any considerable length of time. In the summer Cleveland frequently experiences a lake breeze as winds from the lake blow in over the city during the day.

The average monthly temperature ranges from 27 degrees in January, the coldest month, to 71 degrees in July, the warmest month. Cleveland experiences relatively cold winters, averaging 6150 heating degree-days per year. Rainfall is moderate, an average of 35 inches per year, and well distributed throughout the year.

Land Use and Employment Patterns

Cleveland is the largest city in Ohio and the tenth largest in the United States. Its population is over 700,000. The Cuyahoga County population is greater than 1,700,000. The Cleveland area is highly industrialized as shown by the employment figures in Table 1 — manufacturing employs the largest number of people. The principal products are primary metals, fabricated metal, machinery, rubber and plastics, transportation equipment, and electrical equipment.

Table 1. EMPLOYMENT (NONGOVERNMENT, IN 1000's) IN SMSA

Agricultural, forestry, fisheries	2
Mining	3
Contract construction	44
Manufacturing	484
Transportation, public utilities	66
Wholesale trade	78
Retail trade	200
Finance, insurance, real estate	59
Services	199
Total	1,339

The central business district of the city is located near the Lake Erie shoreline and the Cuyahoga River. The largest industrial area is the Cuyahoga River Valley which extends from Lake Erie through the city and county and beyond to the City of Akron in Summit County. The largest industries are located in the Cuyahoga Flats, the part of the valley closest to Lake Erie. Other industrial areas are located along the Lake Erie shoreline and in several suburbs. Most of the rest of Cleveland, which is bisected by the Cuyahoga River, is densely residential. The surrounding communities are higher in elevation and generally suburban residential.

AIR QUALITY LEVELS AND TRENDS

The Division of Air Pollution Control of the City of Cleveland samples for suspended particulates at 21 sites in the city and 8 sites in Cuyahoga County outside the city. Figues 3 and 4 show the locations of the sampling sites by their local code number and information about the sites is summarized in Table A-3 in the Appendix. Many of the stations are located in residential areas and several in industrial areas. The heights of the monitors range from 4 to 65 feet; most are in the 20- to 50-feet range.

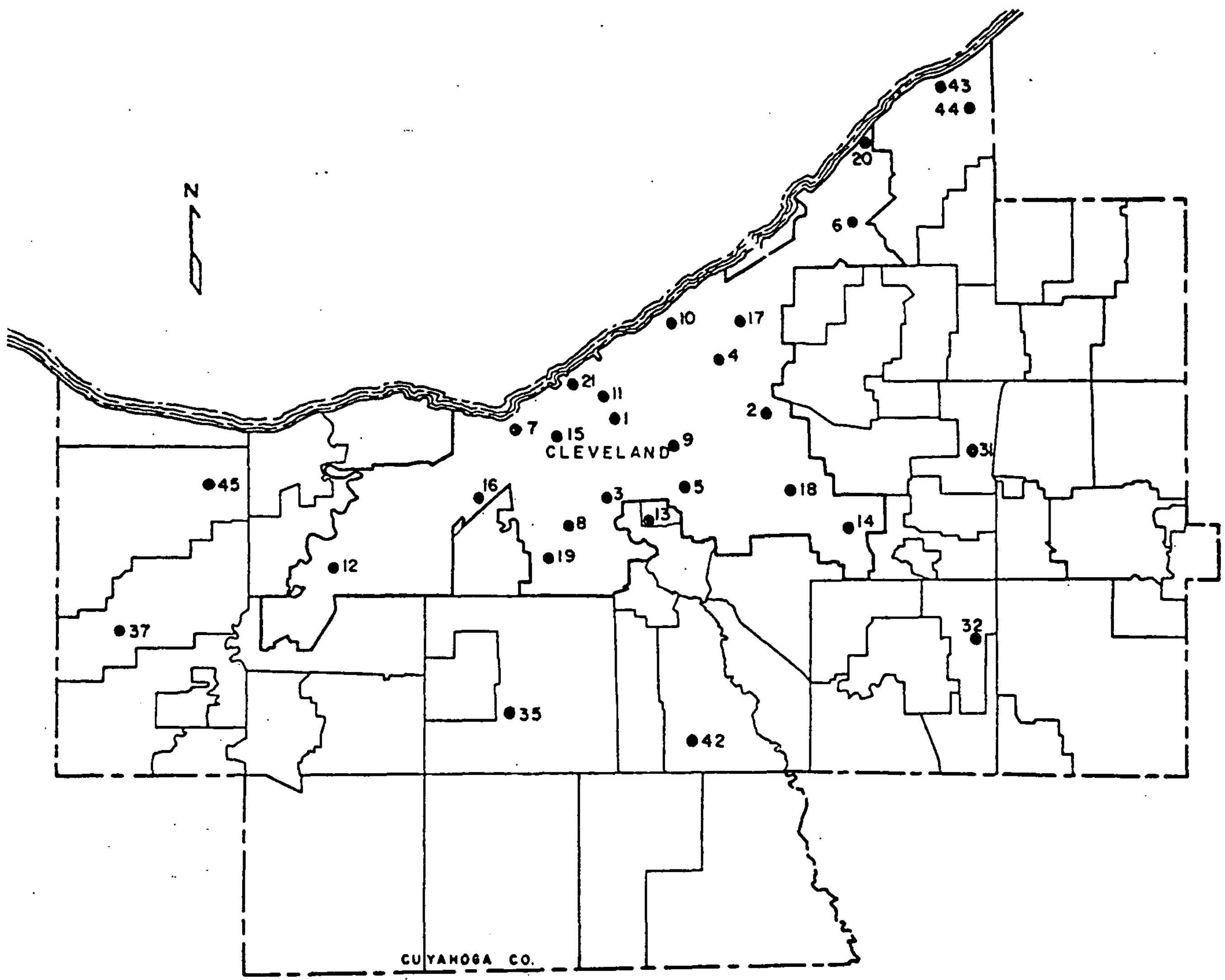

Figure 3. Locations of sampling sites in Cuyahoga County

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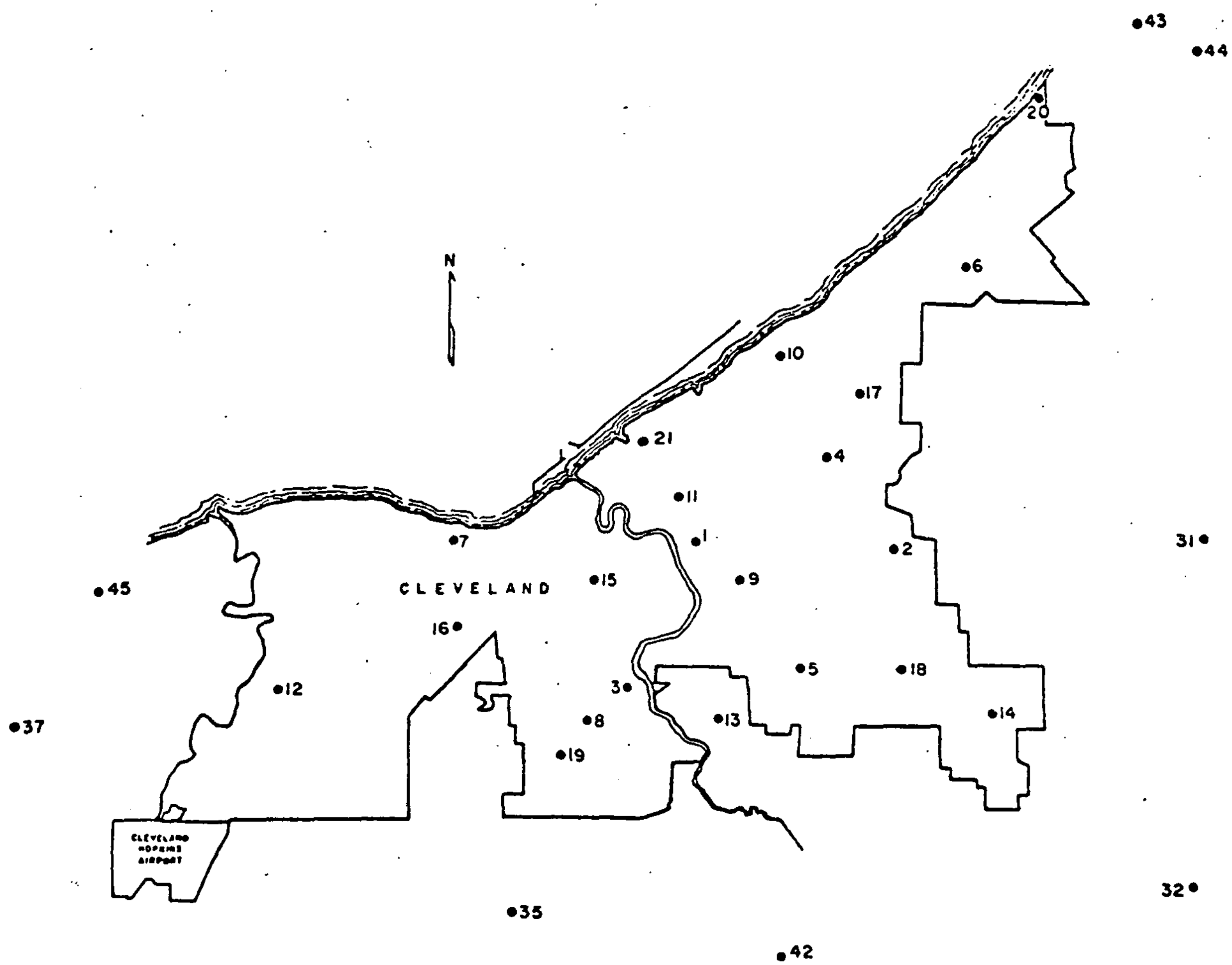


Figure 4. Location of sampling sites in the City of Cleveland

The 1974 annual geometric mean TSP concentrations are shown at their respective sampling sites in Figure 5. TSP concentrations ranged from 70 μg/m^3 and less at sites outside the city or in residential areas to 70 to 90 μg/m^3 in densely residential areas and over 100 μg/m^3 in the industrial areas.

Of the 25 monitors recording TSP concentrations during 1974, 12 sites exceeded the national annual primary standard (75 μg/m^3) and nine others exceeded the annual secondary standard (60 μg/m^3). The 24-hour primary standard (260 μg/m^3) was exceeded on 73 days of the 1373 sampling days (4.7 percent) and the 24-hour secondary standard (150 μg/m^3) was exceeded on 273 sampling days (17.6 percent) (see Table 2). Only four sampling sites did not exceed either 24-hour standard during the year.

The Division of Air Pollution Control began monitoring suspended particulates at 15 sites in 1967. The annual geometric means for 11 of these stations are plotted in Figure 6 to indicate the trends in particulate levels. Since 1967, the 15 sites have had an average decrease of 36.5 μg/m^3 (see Figure 7). The largest decreases occurred at the sampling sites near the industrial areas. On a year-to-year basis, the largest overall decreases have occurred since 1971 and overall increases occurred in 1968 and 1970. Trends in annual geometric mean TSP concentrations for all of the sampling sites in the county are included in the Appendix as Figures A-5 through A-9, grouped according to geographic areas. The TSP concentrations for the sites in a particular area tend to be close and to vary similarly, with a few exceptions due to local variations.

The NASN site in Cleveland has been operated since 1957. The smoothed trend, shown in Figure 8, is steadily downward from about 190 μg/m^3 in 1957 to the present 90 μg/m^3 with a slight leveling off between 1968 and 1971.

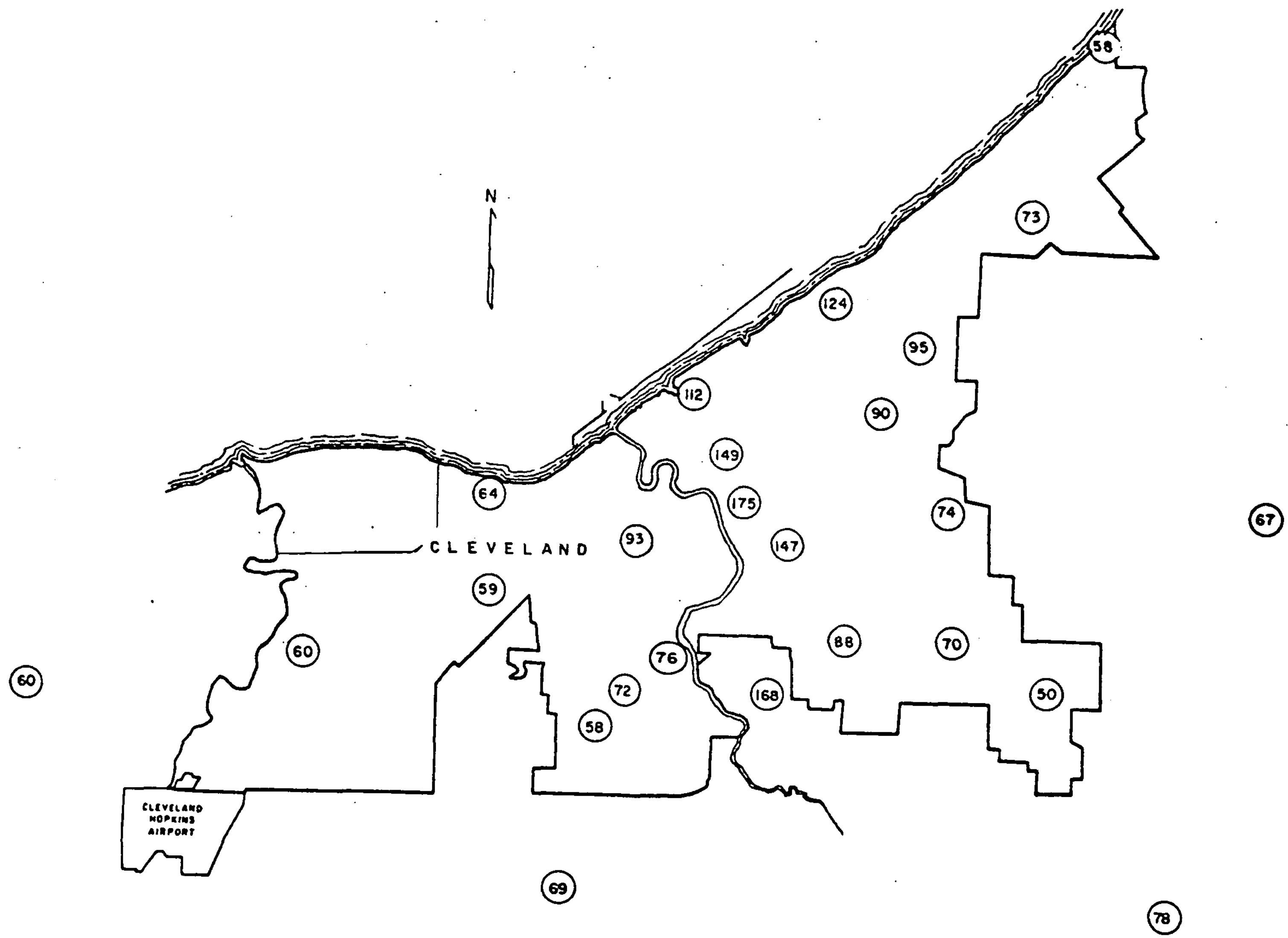


Figure 5. 1974 annual geometric mean TSP concentration in the City of Cleveland

Table 2. SAMPLING SITES AND COMPARISON OF RECORDED CONCENTRATIONS WITH THE STANDARDS

Predominant land use	Code	Sampling site	1974 geometric mean TSP	Number of days 24-hr standard exceeded	
				Primary	Secondary
Center city	4	Cleveland Health Museum	90	1	8
	21	Supplementary Ed. Center	112	10	26
Industrial	1	Air Pollution Control Lab.	175	19	45
	9	Fire station No. 13	147	7	36
	10	Fire station No. 19	124	3	27
	11	St. Vincent's Hospital	149	16	35
	13	Harvard Yards	168	11	42
Residential	2	Audubon J. H. S.	74	0	3
	3	Brooklyn Y.M.C.A.	76	0	2
	5	Cleveland Pneumatic Tool	88	0	7
	14	J.F. Kennedy H.S.	50	0	1
	15	P.L. Dunbar School	93	4	16
	18	J. Adams School	70	0	1

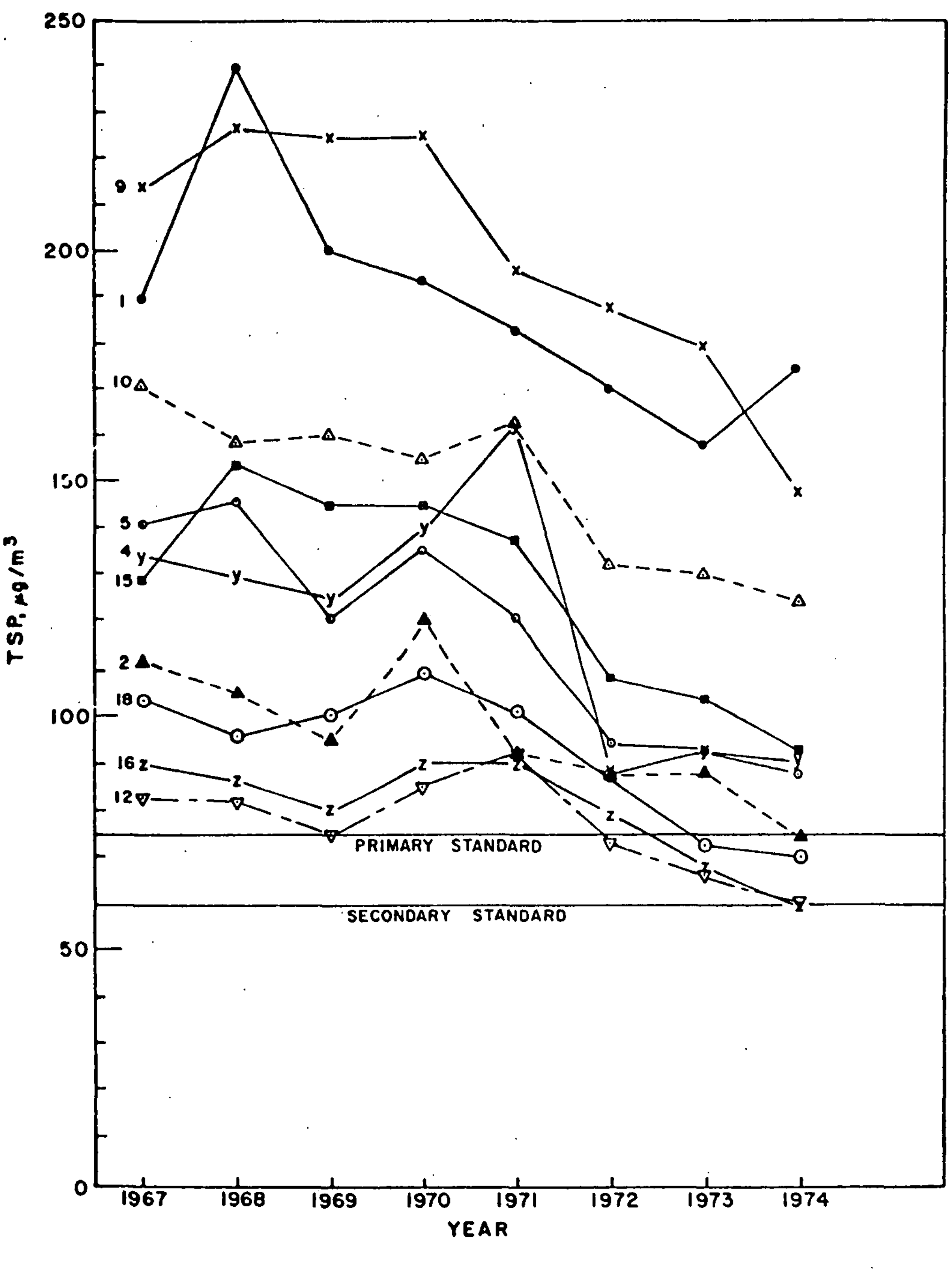


Figure 6. TSP trends

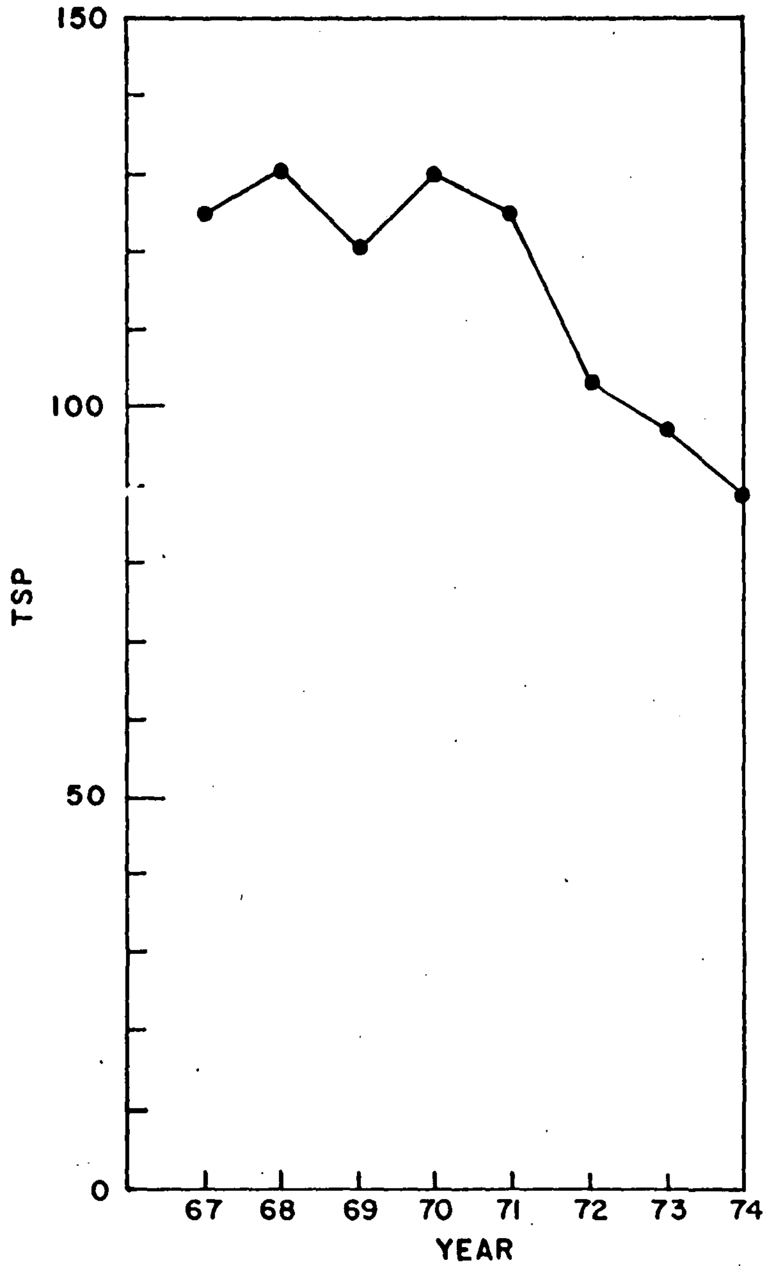


Figure 7. Averaged TSP trend (average of 15 sites in Cleveland)

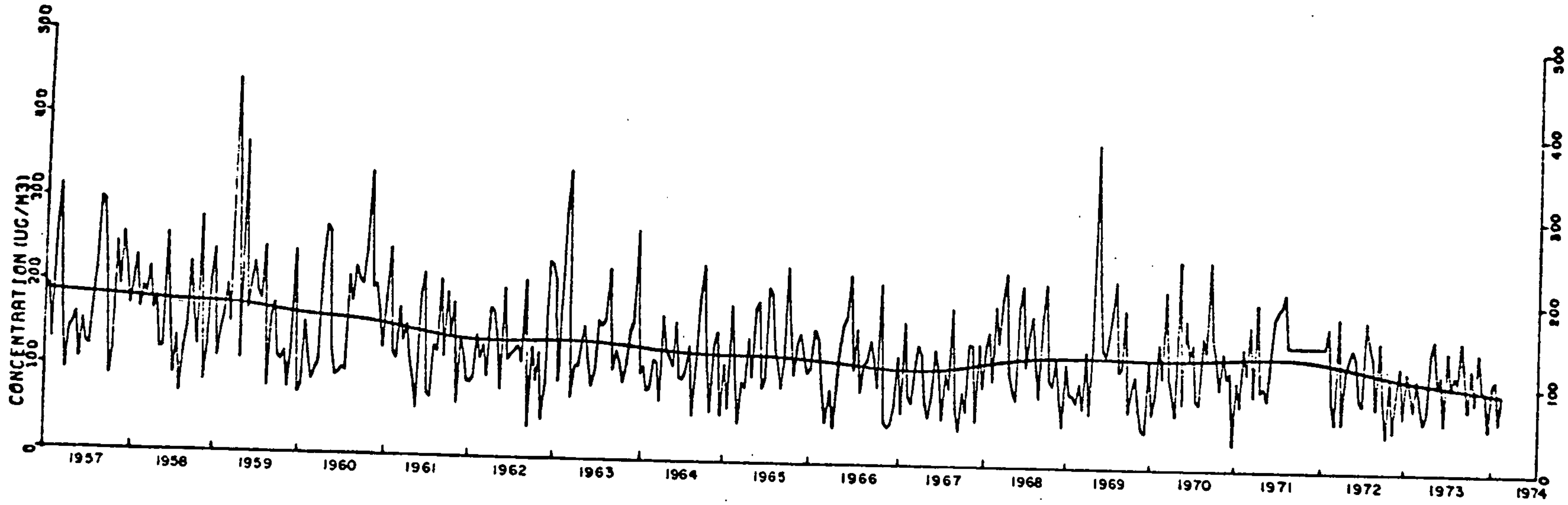


Figure 8. TSP trend at the NASN site (site 4)

SECTION II

ANALYSES

In this section the factors that might be expected to affect TSP levels in Cleveland and Cuyahoga County are considered. Analyses include: sources and emissions, regulations and enforcement, meteorology, urban activities, and network design and monitor siting.

EMISSIONS

Emissions Inventories

The Cleveland area is highly industrialized. Industries are mainly concerned with primary metals, fabricated metal products, machinery, tools, and automotive products, and the major manufacturing products are electric motors, rubber and plastic, petroleum products, stone, clay and glass, chemicals and paints, wearing apparel, measuring instruments, electric components, and food products.

The only recent point and area source emission inventory available is for the entire Cleveland AQCR (see Table 3). Since the AQCR is comprised of eight counties and includes several major industrial cities besides Cleveland, these inventories cannot give a good picture of emissions in Cuyahoga County. The AQCR inventories are presented, however, to show the overall importance of industry and industrial process and fuel combustion emissions in the AQCR. In 1975 total emissions of particulates in the AQCR were close to 500,000 tons per year; 48 percent of the emissions were from industrial processes and 36 percent were from industrial fuel combustion. All other source categories are dwarfed by the massive industrial contribution — next in importance are utility fuel combustion at 6 percent and transportation at 3 percent. It is probable that the total amount of emissions is an underestimate because of the magnitude of emissions and the large number of point and area sources.

Table 3. EMISSIONS INVENTORY FOR THE CLEVELAND AQCR (TONS PER YEAR)[1]

	1970 estimated emissions[a]	1975 predicted emissions[b]	Percent change in AQCR
Point sources	386,270	362,830	-6
Industrial process	240,790	238,040	-1
Fuel combustion			
Industrial	101,430	80,040	-21
Utility	30,400	30,510	0
Commercial/institutional	10,550	11,170	-6
Solid waste Incineration	3,100	3,070	-1
Area sources	181,380	129,350	-29
Fuel combustion			
Residential	2,920	2,300	-21
Commercial/institutional	12,520	7,410	-41
Industrial	135,710	95,810	-29
Solid waste incineration	16,320	7,630	-54
Transportation	13,510	15,730	+16
Miscellaneous	400	470	+18
Total	567,650	492,180	-13

[a] Source: NEDS.

[b] Source: Area source estimates by EPA
Point source estimates by PEDCo.

A NEDS inventory for total emissions in Cuyahoga County in 1973 is given in Table 4, but the estimates of industrial fuel combustion and process emissions are small when compared with the local agency's estimate of point source emissions alone so this inventory also cannot give a good picture of emissions in Cuyahoga County.

Table 4. CLEVELAND AND CUYAHOGA COUNTY EMISSIONS INVENTORY, 1973 NEDS (TONS PER YEAR)

Fuel combustion	126,035	
Residential		655
Electric generation		18,150
Industrial		96,336
Commercial/institutional		10,894
Industrial process	19,892	
Chemical		1,009
Primary metal		8,684
Secondary metals		1,135
Mineral products		8,917
Other		
Solid waste disposal	6,941	
Transportation	6,409	
Motor vehicles		6,210
Aircraft		129
Vessels		70
Total	159,277	

The Division of Air Pollution Control of the City of Cleveland keeps inventories of point sources larger than 25 tons per year. The most recent inventory is given in Table 5. This shows that the most important industrial sources are primary and secondary metals and fabricated metal products and that there are almost 40 sources emitting more than 100 tons per year of particulates.

Table 5. PARTICULATE EMISSIONS OF MAJOR SOURCES ($\geq$ 25 TPY) IN CUYAHOGA COUNTY, 1975

	Emissions, TPY	No. of sources
Steel mills	30,927	3
Metal products	16,209	4
Foundry and smelting	8,277	9
Motor vehicle parts	6,020	1
Utility	5,967	2
Incinerator	5,052	5
Institution	2,708	4
Machinery manufacturing	822	1
Chemicals	411	3
Pottery	369	1
Glass	259	1
Brick	228	1
Electrical products	150	1
Petroleum products	113	1
Paper	90	1
Grain	40	1
Total	77,642	39

Source: City of Cleveland Division of Air Pollution Control

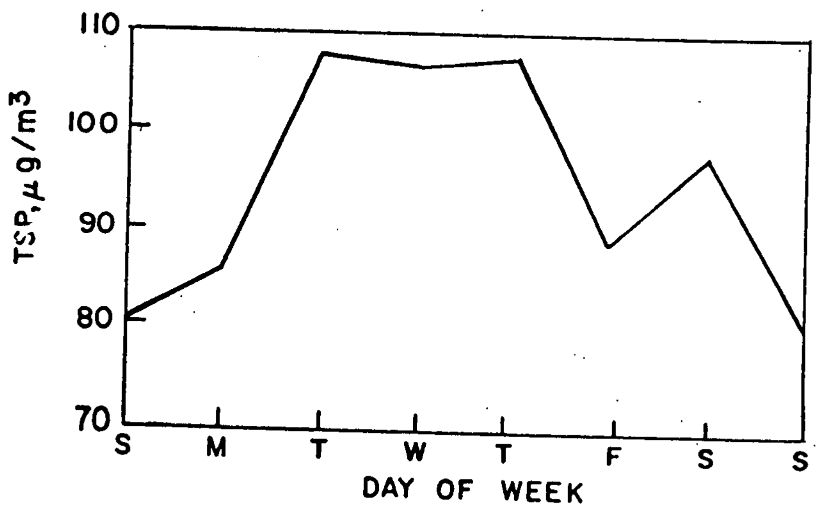
The available inventories are not adequate for showing the particulate emissions situation in Cleveland and Cuyahoga County. The air pollution control agency in Cleveland has not kept emission inventories in the past and only recently has begun to tabulate information on major point sources in the county. The contributions of area sources and smaller point sources have been generally ignored. In fact, many of these sources of particulates in the county have not been identified yet.

Particulate Emissions and TSP

Industry and power plants are the most important sources of particulate emissions in Cuyahoga County and, as such, the most influential factors with respect to TSP air quality. The effects on TSP concentrations can be seen when comparing the concentrations on weekends and weekdays — 88.5 $\mu g/m^3$, the average on weekends, and 99.3 $\mu g/m^3$, the average on weekdays (see Figure 9). The difference between the weekend and weekday averages is noticeable but not very large in comparison to other cities. The reduction is most likely due to traffic patterns, with most emissions continuing through the weekend (power plants and heavy industry).

The sampling sites nearest the industrial areas record the highest TSP concentrations in the county. Figure 10 shows the locations and 1975 emissions of the major industries in Cuyahoga County, along with the locations of the sampling sites. Sites 1, 9, 10, 11, 13, and 21 are the closest to the industrial areas in the Cuyahoga Flats and along the Lake Erie shoreline; all of them recorded annual TSP means greater than 100 μg in 1974 (see Table 2). When isopleths of the 1974 mean TSP concentratio are drawn on a map as in Figure 11, they center around the Cuyahoga Flat industrial area where the highest concentrations occurred.

Air Quality Modeling Study - Cleveland air quality was modeled in a study performed by the U.S. Environmental Protection Agency to assess the attainment of the TSP standards.[1] The model calculated, for 1972 and 1975, the TSP concentrations at various sampling sites and the contribution of the source categories provided by emission inventories to these concentrations. The 1975 emissions inventory was based on the 1972 inventory and took into account the impact of emission control regulations. Since fugitive emissions and fugitive dust emissions were not provided in the inventories, the model calibration and results are based on the assumption that such emissions are at a constant level throughout the area and thus, part of the background. The intercept



1974 citywide geometric mean TSP concentrations

Weekend	88.9 µg/m^3
Weekday	99.3 µg/m^3

Figure 9. Comparison of weekend and weekday TSP concentrations

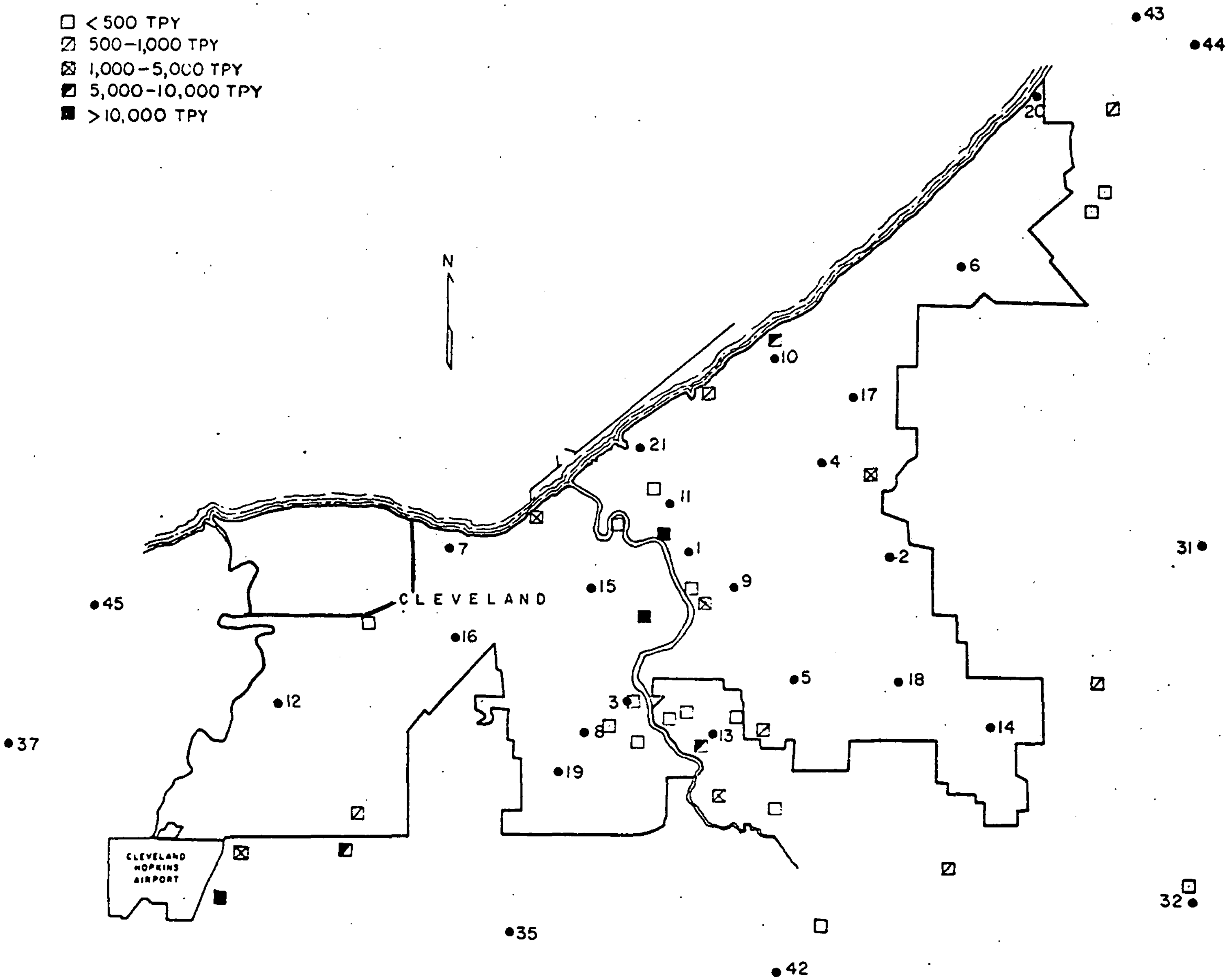


Figure 10. Locations of point sources, 1975

Figure 10. Locations of point sources, 1975

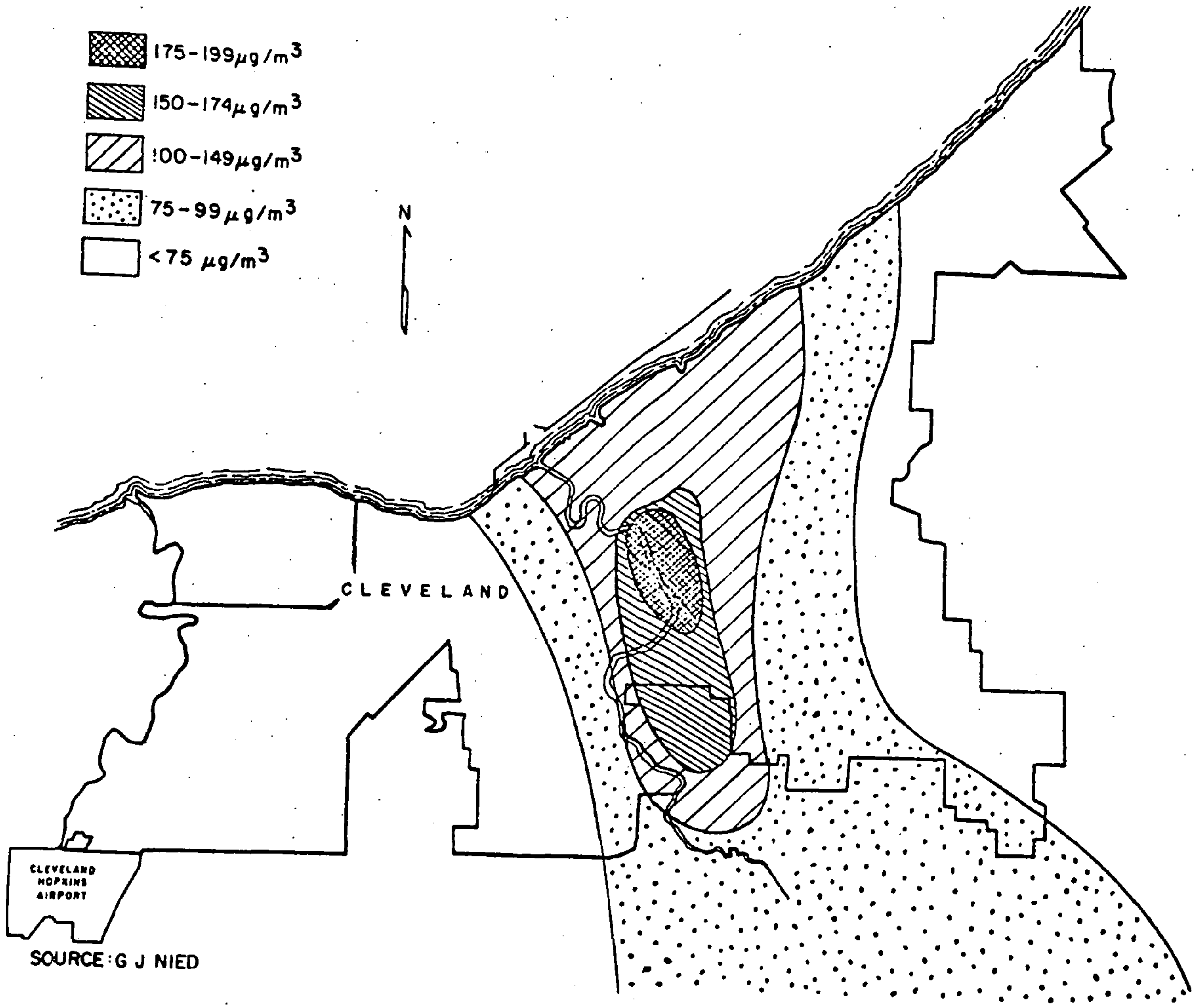


Figure 11. 1974 Geometric mean TSP concentration isopleths

of 1972 actual and modeled TSP concentrations was used as the background level in the study — the intercept was 44 $\mu g/m^3$.

The modeling results and analyses of them are presented in Table 6. These indicate that the sources most responsible for TSP concentrations above the intercept are industrial processes, point source fuel combustion and area sources. Industrial processes account for 40 percent or more of the source contribution above the intercept at all of the sites. In Cleveland, the major contributing process is the primary metals industry, mainly iron and steel mills. The predictions of 1975 TSP concentrations at the nine sites indicate that the national annual primary standard is expected to be exceeded at eight of the sites. These predictions were based on a projected 1975 emissions inventory which included some 100 point sources in the AQCR not in compliance with the regulations.

In order to determine how well the model predicts, the 1975 predicted TSP concentrations were compared with the 1975 TSP concentrations actually recorded. The comparison is shown in Figure 12. Of the nine sites, two were substantially (more than 10 $\mu g/m^3$) overpredicted and six were substantially underpredicted. The last column of Table 6 explains possible reasons for the discrepancies in prediction. The differences appear to be the result of inadequate simulation of localized conditions by the model — the effects of fugitive emissions and fugitive dust, the lake breeze effect and the effects of location in a residential area or on a height of land do not seem to have been taken fully into consideration.

The model predicted that air quality standards would not be met in 1975, based on the projected 1975 emissions inventory which included some 100 point sources not in compliance. In addition, the model found that it was unlikely that air quality standards would be met even when these sources came into compliance. This is due to the fact that the impact of the emissions of the noncomplying sources was found to be relatively

Table 6. RESULTS OF A MODELING STUDY OF PARTICULATE EMISSIONS IN CLEVELAND

TSP sampling site	1975 predicted TSP	1975 predicted minus intercept[a]	Percent contribution of major source categories[b]	1975 measured TSP	Prediction discrepancy[c]	Possible reasons for major prediction discrepancies
D Cleveland Health Museum	95	51	46% industrial process 28% area sources	94	+ 1	
E Cleveland Pneumatic Tool	100	56	51% industrial process 26% point source fuel combustion	89	+ 11	Residential area
F J. F. Kennedy High School	79	35	52% industrial process 30% area sources	51	+ 28	Residential area
G Fire Station No. 13	107	63	55% industrial process 27% point source fuel combustion	173	- 66	Fugitive emissions from nearby industrial valley (steel mills); fugitive dust from heavy traffic
H Brooklyn YMCA	74	30	47% industrial process 33% area sources	93	- 19	Nearby industrial valley
I Fire Station No. 19	91	47	51% industrial process 25% area sources	108	- 17	Commercial area; heavy traffic
J Air Pollution Control Lab	129	85	72% industrial process 16% point source fuel combustion	149	- 20	Fugitive emissions from steel mills; fugitive dust from railroad yards, unpaved roads and lots, and stock piles
K Harvard Yards	87	43	59% industrial process 19% point source fuel combustion 19% area sources	139	- 52	Fugitive emissions from steel mills; fugitive dust from railroad yards, unpaved roads and lots, stock piles and truck traffic
L PL Dunbar School	77	33	50% industrial process 29% area sources	92	- 15	Nearby industrial valley

[a]The intercept of the 1972 actual and modeled TSP concentrations was 44 $\mu g/m^3$. This was the minimum predicted value and was considered the background value for the study.

[b]This is the contribution of local sources to the TSP concentrations above the intercept.

[c]The difference between the 1975 actual and predicted TSP concentrations.

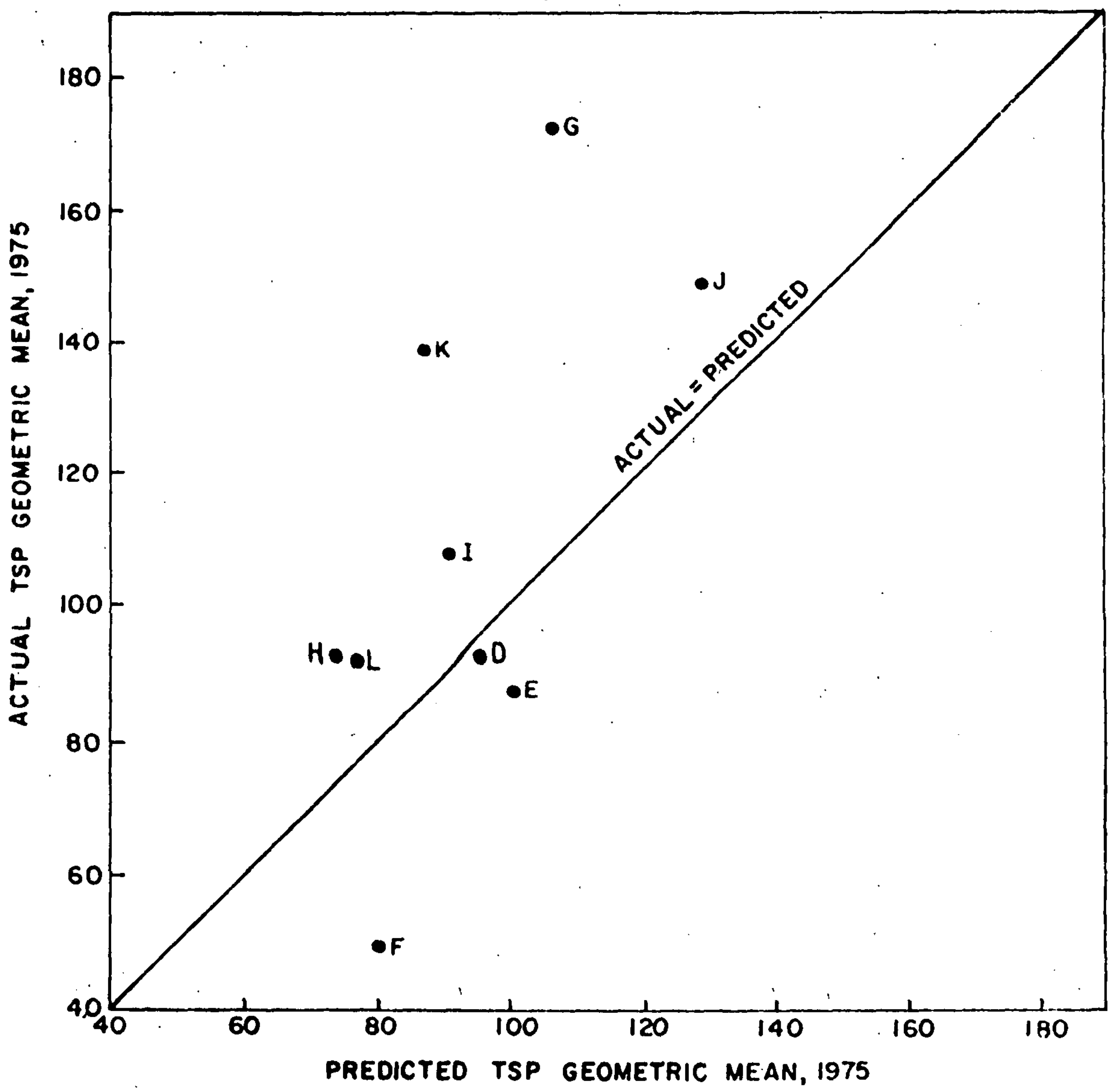


Figure 12. Comparison of actual and predicted
1975 TSP concentrations

small and that the greatest impact actually came from large numbers of sources which contributed almost equally to the high concentrations. These results should be viewed with caution because of the difficulties in identifying sources out of compliance and in estimating what compliance emissions will be. Nevertheless, they seem to indicate that air quality standards will be violated even after full compliance with the current regulations is attained.

Emissions Trends

Reductions in particulate emissions have been occurring for the past several years and will continue for several years to come. These reductions have involved fuel switching, controls on process and combustion emissions, and incinerators.

Since the second World War, conversion from coal to other fuels has been occurring (see Tables 7 and 8). Residential fuel usage was 42.8 percent coal in 1950 but dropped to 0.5 percent coal in 1970 while the usage of gas and electricity by homes greatly increased and oil usage remained the same. At one time, coal was the fuel used to heat schools — public schools have been switching gradually to gas so that now only 39 of the 184 schools in the city are using coal and these too will eventually change. Decreases in coal usage by industries and electric utilities
180 have also occurred but these have been smaller — down 12 percent for industry and down 8 percent for utilities. The relative importance of coal as a fuel for industry has decreased more than the actual usage of coal since industry is using more natural gas. Fuel switching is continuing but the recent fuel shortage has caused some companies to stop or reverse the process. One public utility and several industries had been planning to achieve compliance by switching from coal to another fuel. Since new allocations of oil and natural gas are not available,

Table 7. 1950 TO 1970 RESIDENTIAL FUEL USAGE — NUMBER OF DWELLING UNITS

Fuel	1950	1960	1970	Δ1950-1960 as % of 1950	Δ1960-1970 as % of 1950	Δ1950-197 as % of 1950
Cuyahoga (County)						
Gas	214,820	455,688	521,439	+112	+ 31	+ 143
Oil	11,750	13,333	11,758	+ 13	- 13	+ 0
Coal	169,700	24,159	2,914	- 86	- 12	- 98
Electricity	215	1,236	12,051	+475	+5,030	+5,505
Cleveland (City)						
Gas	128,840	244,773	235,605	+ 90	- 7	+ 83
Oil	4,345	2,823	2,301	- 35	- 12	- 47
Coal	126,170	19,444	2,117	- 85	- 13	- 98
Electricity	120	615	4,743	+413	+3,440	+3,853

Source: U.S. Census of Housing, 1950, 1960, 1970

Table 8. FUEL USAGE TRENDS IN CLEVELAND

Fuel	Unit	Industrial usage[a]			Electric utility usage[b]		
		1963	1972	% Δ 1963-1972	1964	1973	% Δ 1964-1973
Gas	10^6 ft^3	36,735	62,100	+69	—	—	—
Oil	1,000 bbl	1,636	719.5	-56	9	67	+644
Coal	1,000 tons	1,553	1,374	-12	1,424	1,305	- 8
Coke	1,000 tons	956	1,064.8	+11	—	—	—

[a]Source: Census of Manufacturers, 1963 and 1972. Fuels and Electric Energy Consumed (data is for SMSA level)

[b]Source: Steam Electric Plant Factors Book, 1965 and 1974, National Coal Association, Washington, D.C. (data is for CITY level)

these companies are exceeding the emission standards and will continue to do so until the energy situation becomes clear.

Reductions of particulate emissions due to emission controls on fuel combustion and industrial processes have also occurred. It is not possible, however, to determine from the available information just how much of a reduction in particulate emissions has occurred or in what industries or when. There are still many companies which are not in compliance with the regulations — it is anticipated that considerable reductions, perhaps as much as or more than the reductions to date, will occur as these come into compliance over the next few years. Some companies are on variances and in the process of coming into compliance, but not all are on schedule. Other companies are going through adjudication hearings or are challenging the approval of the State Implementation Plan or the state's regulations — they are not required to be in compliance while hearings or appeals are being conducted. Still others are awaiting the promulgation of a State Implementation Plan for sulfur oxides — they are reluctant to apply particulates controls while sulfur oxides controls have not been resolved due to the interdependence of the controls. Approval of a SIP for sulfur oxides and subsequently the promulgation of state regulations and the appeals will probably take a couple of years so compliance of these companies is several years away. Table 9 compares the particulate emissions of major sources by their compliance status and shows that a large proportion of the major source emissions come from sources not in compliance. These emissions will be reduced eventually, though how much it is not possible to determine from the available data.

Private and municipal incinerators are also being controlled, improved, or closed and replaced because of their particulate emissions. The large municipal incinerators include those operated by Cleveland, the Towns of Parma, Euclid, and Lakewood, and Cleveland's wastewater treatment plants.

The city's incinerator was closed and the rest are in the process of controlling particulate emissions. It is estimated that there are some 8,000 to 10,000 apartment incinerators, very few of which have been inspected and given a permit to operate or ordered closed. Closing incinerators or installing emissions controls on them have not been significan parts of the total emissions reductions to date.

Table 9. EMISSIONS OF MAJOR SOURCES (> 100 TPY) IN CUYAHOGA COUNTY BY THEIR COMPLIANCE STATUS IN 1975

	Number	TSP emissions, TPY
Permit to operate	49	4,259
Variance	41	19,305
Adjudication hearings	48	36,562
Total	138[a]	60,126

[a]The 138 point sources are in 50 or so companies.
Source: Division of Air Pollution Control, City of Cleveland.

On the AQCR level, as shown in Table 3, the largest decreases in emissio from 1970 to 1975 have been in solid waste incineration and fuel combustion. Total emissions, however, did not decrease much during the 5-year period. This gives an indication of where emission reductions probably occurred in Cleveland, but the magnitude of the reductions in Cleveland during that time cannot be estimated.

The ambient TSP trend has been downward since citywide monitoring began 1967. Fifteen sites had an average decrease of 36.5 $\mu g/m^3$, the largest annual decrease occurring between 1970 and 1971. This downward trend seems to be due to the emission reductions resulting from fuel switching by some industries, utilities, residences, and schools and emission controls on some industries.

REGULATIONS, ENFORCEMENT AND COMPLIANCE

Institutional Framework

In the State of Ohio, the Office of Air Quality of the Ohio Environmental Protection Agency is responsible for air quality. The Office of Air Quality, under the air pollution control law passed in 1972, promulgates regulations, issues permits and variances, conducts hearings and enforces regulations. The state is divided into areas for air pollution control, each of which has a district office of Ohio EPA. The district offices oversee the activities of local agencies, conduct field operations in counties where there is no local agency to perform them and review permits. In the Northeastern Ohio Air Pollution Control area (NEOAPC), the Division of Air Pollution Control of the City of Cleveland is the local agency under contract to the Ohio EPA to provide air pollution control services to Cuyahoga County, which includes the City of Cleveland. It is responsible for monitoring air quality, making inspections and maintaining surveillance of sources, investigating complaints, operating the state's permit system and overseeing the installation of control equipment.

The Division of Air Pollution Control was first organized in 1947 and originally worked on smoke abatement in Cleveland. The city had a set of regulations which could be enforced only in the city. In 1972, the State of Ohio adopted air pollution control regulations and assumed responsibility for air quality throughout the state. In 1973, the state negotiated a contract with the Division to perform field operations and to evaluate permits and variances in all of Cuyahoga County and advise on them.

Regulations

The state's air quality regulations are in effect for the entire state, except where local regulations are more strict due to local requirements. Cleveland's Air Pollution Code was last revised in 1969 and is not as stringent as the state's code. It is anticipated, however, that the city code will be revised in 1976 so that it will be as stringent as the state code and more stringent in a couple of areas. The state and city regulations pertaining to particulates are summarized in the Appendix (Tables A and A-2).

An overview of the state regulations shows that they are in general about average when compared with the regulations of most states in the nation. The visible emissions regulation allows emissions of no greater than 20 percent opacity, except that visible emissions up to 60 percent opacity are allowed for no more than 3 minutes in any hour.

The emissions standards for industrial processes and for fuel combustion are shown in Figures A-1 through A-3. The allowable emissions from incinerators are 0.1 pounds per 100 pounds of charge for incinerators with a capacity equal to or greater than 100 pounds per hour, and 0.2 pounds for incinerators of less than 100 pounds per hour for the state. These standards are about average when compared with those of other states. The city's incinerator regulation is less strict (see Figure A-4).

Open burning, with certain exceptions, is prohibited. Reasonable measures must be taken to prevent dust from materials handling from becoming airborne. Dust emissions from buildings or outdoors operations which are a nuisance shall be controlled by sealing off the buildings or operation and ventilating and treating the discharge. Permits to operate are issued for up to 3 years.

Enforcement

The Division of Air Pollution Control inspects sources at least once every 3 years for operation permit applications; major sources and sources with problems are inspected more frequently. Inspections involve the checking of visible emissions, possible new sources, and maintenance of emission controls. Point source emissions receive primary consideration and fugitive emissions receive attention if they are localized to some degree.

The Division has inspectors in radio-equipped patrol cars to investigate complaints and make visual inspections of sources.

The Division has a program of activities to be followed during a pre-alert. When the air quality index of one or more of the criteria pollutants reaches 175 (100 is an air quality level equal to the national primary standard and 200 is the alert level) and meteorological conditions indicate that a high index value is likely to persist for some time, a pre-alert is called. One or more of the 12 or so major sources are asked to cut back production by 10 percent in order to avoid alert conditions. Cooperation by the industries is voluntary but is generally good. There were, nevertheless, 15 days in 1974 when the air quality index was over 200.

Enforcement of the state regulations is performed by Ohio EPA. The Agency conducts litigation and hearings for variances and adjudication and issues permits, variances and consent orders. The Division of Air Pollution Control advises Ohio EPA on compliance and enforcement actions. If a company objects to a proposed action issued by Ohio EPA, it can request an adjudication hearing at which evidence is presented and from which a decision on actions to be taken is made. Since an adjudication hearing can be lengthy, the company and Ohio EPA may negotiate a consent order.

A Company may be prosecuted for violating its permit or not keeping to the compliance schedule of its variance, but it cannot be forced to comply with the regulations while hearings or appeals are taking place. For those companies which cannot come into compliance by the deadline of April 1977, a compliance order is issued by the Director of Ohio EPA — this is essentially a variance but it allows for progress towards compliance after the deadline which a variance, by law, cannot allow.

The Division conducts enforcement of city problems on the city level when possible. The city's regulations, most recently revised in 1969, are not as stringent as the state code in some areas but where they are the same or more stringent, they are used so that enforcement can be on the city level.

The local regulations apply only to sources within the city and can be enforced only in the city. The rest of the county receives state enforcement. The Division is planning to increase its role in actual enforcement in both the city and the county. In 1976, the Division will revise the city's air pollution code and bring it to at least the level of stringency of the state's code — few problems are anticipated in the adoption of the revised code. The Division also is planning to work for adoption of regulations by the county so that polluters in the whole county can be enforced locally.

<u>Compliance</u>

The compliance status of the major point sources in the county was given in Table 9 which shows that 65 percent of these particulate sources are not in compliance with the emission standards. The Division estimates that there are about 20,000 point sources in the county and about 10,000 incinerators. Only about 90 percent of the point sources and 20 percent of the incinerators are presently in the Division's files. Not all of those on file have been inspected or have received permits to operate so it is not possible to determine the overall degree of compliance of particulate sources in Cuyahoga County. The Division of Air Pollution Control believes that some of those which should be in compliance are not because their control equipment has not been maintained or was never adequate or because there are an excessive number of malfunctions as in the case of blast furnace slips.

The Division of Air Pollution Control has experienced a number of proble in attempting to bring sources of particulate emissions into compliance these are discussed in the remainder of this section.

As stated before, Cleveland's Air Pollution Code applies only to sources in the city and the state's regulations apply to the entire county and supersede the city's regulations when the latter are less stringent. Enforcement of the state regulations for a county problem or a city problem not under the jurisdiction of the city's code can be time consuming and allows the Division's participation only in an advisory role. The Division, therefore, conducts enforcement of city problems on the city level when possible (i.e., when the city regulation is at least as stringent as the state regulation). But there are disadvantages to this. Appeals of the Division's decisions are decided by a city appeals board which hears appeals from many other areas and does not have air pollution as its focus of concern. Also the city code calls for criminal, not civil, penalties for violations. The severity of the problem and the significance of the evidence must be greater, in general, to warrant prosecution.

Neither the city's nor the state's regulations and enforcement procedures are entirely satisfactory for bringing sources promptly into compliance. The Division is attempting to alleviate this problem by revising its air pollution code to at least the level of stringency of the state's code and by working for countywide adoption of its code so that problems in the whole county can be enforced locally.

Another problem is the inspection of incinerators. It is estimated that there are 10,000 incinerators in the county, only 2,000 of which have applied for permits. About half of these have actually been inspected, one-third of which were denied permits to operate. But it is not certain whether or not those which were denied operating permits have actually ceased operating. The Division has not been able to inspect and follow up on many applications and to track down those not yet on file. This is due in part to the incinerator regulation itself (both city and state). A lot of work is required to enforce the regulation because it is an emission standard and does not specify the types of incinerators allowed or prohibited. Each incinerator must be inspected for visible emissions or for the emission rate of particulates. When possible, incinerators within the city receive enforcement on the city level. In the rest of the county, however, since all enforcement cases, large and small, are taken to Ohio EPA, very few cases of incinerator violations have been presented to the state.

The very large number of air pollution emission sources in the county has itself created problems. The Division of Air Pollution Control feels that it is understaffed and therefore not able to identify and inspect all sources or to enforce the regulations for more than the larger point sources. Some sources have not yet been identified and some of those identified have not yet received attention. The Division spends most of its efforts on larger and point sources and has not been able to keep track of small or area sources.

The Ohio EPA and the Division of Air Pollution Control have sometimes been unable to reach satisfactory agreements with companies when dealing with them. Many times, a proposed action issued by Ohio EPA on the advice of the Division has not proven satisfactory to the companies involved. In 1975, more than one-third of the major point sources in Cuyahoga County were involved in adjudication hearings during which companies objecting to orders could present evidence. Adjudication hearings can be lengthy so a consent order between the company and the Ohio EPA may be worked out. On the city level of enforcement, the Division of Air Pollution Control has issued some proposed actions which were unsatisfactory to the companies involved and were overturned on appeal to the city appeals board.

Long delays in achieving compliance have been experienced due to litigation of companies not on permits or compliance schedules and to challenge of the SIP by companies. The compliance of several of the largest source in the county has been delayed while they challenged the U.S. EPA on the approval of the State's Implementation Plan for particulates (Section 30 challenge). The SIP has recently been upheld so presumably the compliance of these sources is underway. The compliance of several large industries has also been delayed by the lack of a SIP for sulfur oxides. Because sulfur oxides controls and particulates controls are interdependent, these companies will not control particulate emissions until the resolution of the sulfur oxides situation which is several years away. Even though a company is on a compliance schedule, that does not indicate that the company is keeping up with its schedule. Some companies have been missing compliance milestones but none so far have been prosecuted for this violation.

There has also been a problem with industry's attitude towards compliance — some have resisted compliance and enforcement efforts and a few have acted in concert with each other in opposing air pollution control action.

The use of fuel switching by some companies to achieve compliance has run into problems due to the shortage of energy. These companies had planned to use oil or natural gas but have returned to burning coal. They are exceeding the fuel combustion emission standards and will continue to do so until the energy situation is clarified.

Over the past several years, the major achievements of enforcement of the regulations appear to be a general 90 percent decrease in pollutant emissions by some companies after the 1962 revision of Cleveland's air pollution code and the compliance of a few major sources which have greatly decreased their emissions since 1970. It is not known how many companies actually reduced their pollutant emissions during the last decade, but a downward trend in TSP concentrations (Figures 6 and 7) during that time seems to indicate that some did. A few major problem sources have drastically reduced their emissions since 1970 but this probably only affects local air quality.

The major cause of particulate emissions reductions over the past decade, however, is probably fuel-switching, which was discussed in EMISSIONS and much of which is not the result of enforcement of regulations. Further and considerable decreases in TSP concentrations are anticipated as problems with regulations and enforcement are solved and compliance becomes more widespread.

METEOROLOGY

Because of the frequent migration of low pressure systems and the infrequent stagnations of large high pressure systems through the Great Lakes region, Cleveland would appear to be favorably located for the dispersion of air pollution. On the regional scale, the frequency of high air pollution potential forecast days is low. But on a more local scale, Cleveland frequently experiences poor dispersion of pollutants due to its location on the shore of Lake Erie and the presence of the Cuyahoga River valley.

Effects of Lake Erie

Cleveland is located along Lake Erie which influences the city's air quality in several ways. During the colder seasons of the year when the water is warmer than the surrounding land surface, incoming air masses from Canada are moderated in temperature by the lake and pick up moisture as they pass over it. Thus Cleveland experiences frequent cloudiness and snowfalls which tend to remove particulates from the air. In contrast, during the summer months the cool lake water is a stabilizing influence on incoming air masses and shoreline pollution problems are consequently enhanced.

A recent study[2] of the impact of the Great Lakes on shoreline meteorology has described three distinct mesoscale regimes which develop in conjunction with the onshore flow of stable lake air and lead to adverse dispersion conditions. The first of these regimes is the typical lake breeze circulation which develops on days with light onshore gradient winds and strong insolation. Under the influence of the lake breeze circulation, pollutants from low-level shoreline sources are carried inland in a relatively shallow mixing layer capped by an overlying lid of stable lake air, while elevated sources at the shoreline emit into the stable layer aloft and are brought to ground layer by fumigation farther inland. Recent trajectory studies with constant level balloons have indicated that under the influence of a persistent, well-developed lake breeze circulation cell, pollutants which are initially carried inland by the low-level onshore flow are transported upward and back over the lake where they may be returned by the lake breeze to the land.

The other two mesoscale regimes giving rise to high concentrations occur under onshore stable flow conditions when formation of the lake breeze circulation is prevented either by relatively strong gradient winds or by insufficient insolation. Under daytime conditions with strong insolation and steady onshore winds, the depth of the mixing layer increases away from the shoreline as heating by convection takes place, inducing the continuous fumigation of elevated sources. Without strong sunshine, on the other hand, such as under overcast conditions or during nighttime, a shallow mixing layer may persist for many miles inland with resulting plume trapping and the concentration of pollutants. The lake breeze occurs on about half of the days during the period April to October and the other two patterns occur much less frequently.

Cleveland's shoreline, like that of other Great Lakes cities, is highly urbanized and industrially developed. There are several electrical generating plants and a number of industries, some still burning coal, along the shore and just inland, where much of the city's population is also located. A major highway also hugs the shoreline. Thus, emissions of particulates are greatest where Lake Erie's effects on transport and diffusion of pollutants are most adverse. The effects of Lake Erie on Cleveland's air quality can be seen in the seasonal pattern of TSP concentrations in 1974 (see Figure 13). The highest TSP concentrations occurred during the summer quarter, the period when Lake Erie most limits the transport and diffusion of shoreline pollutant emissions. In 1974, the summer quarter averaged 112 $\mu g/m^3$ and the first, second and fourth quarters averaged, respectively, 82 $\mu g/m^3$, 90 $\mu g/m^3$ and 85 $\mu g/m^3$.

The effects of Lake Erie can also be seen when looking at Cleveland's dispersion characteristics. Throughout the year, the mean mixing height and the mean wind speed through the mixing layer are moderate. Summer mornings, however, combine both a low mixing height (370 meters) and a low mean wind speed (3.7 meters per second) for a high pollution potential. These seasonal differences in dispersion seem to correspond well with the seasonal differences in TSP concentrations. Monthly TSP concentrations showed a significant negative correlation with monthly wind speed (r = -0.704 in Table 10).

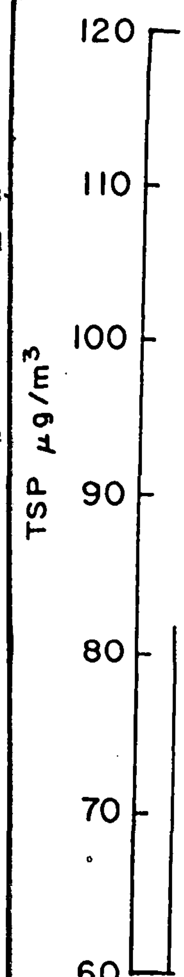


Table 10. CORRELATION OF TSP TRENDS WITH CLIMATOLOGICAL FACTORS

1. Correlation of citywide monthly TSP means for 1974 with other 1974 monthly measures.

TSP versus degree-days	r = -0.817
TSP versus precipitation[a]	r = -0.203
TSP versus wind speed[a]	r = -0.704

2. Correlation of citywide TSP trend (annual geometric mean) from 1967 to 1974 with other annual measures.

TSP versus time[a]	r = -0.861
TSP versus annual rainfall	r = 0.583
TSP versus heating degree-days	r = -0.682

[a]As expected.

Effects of Topography

The topography of Cleveland and Cuyahoga County also influences the air quality. The gradually sloping plain on which the county is located is

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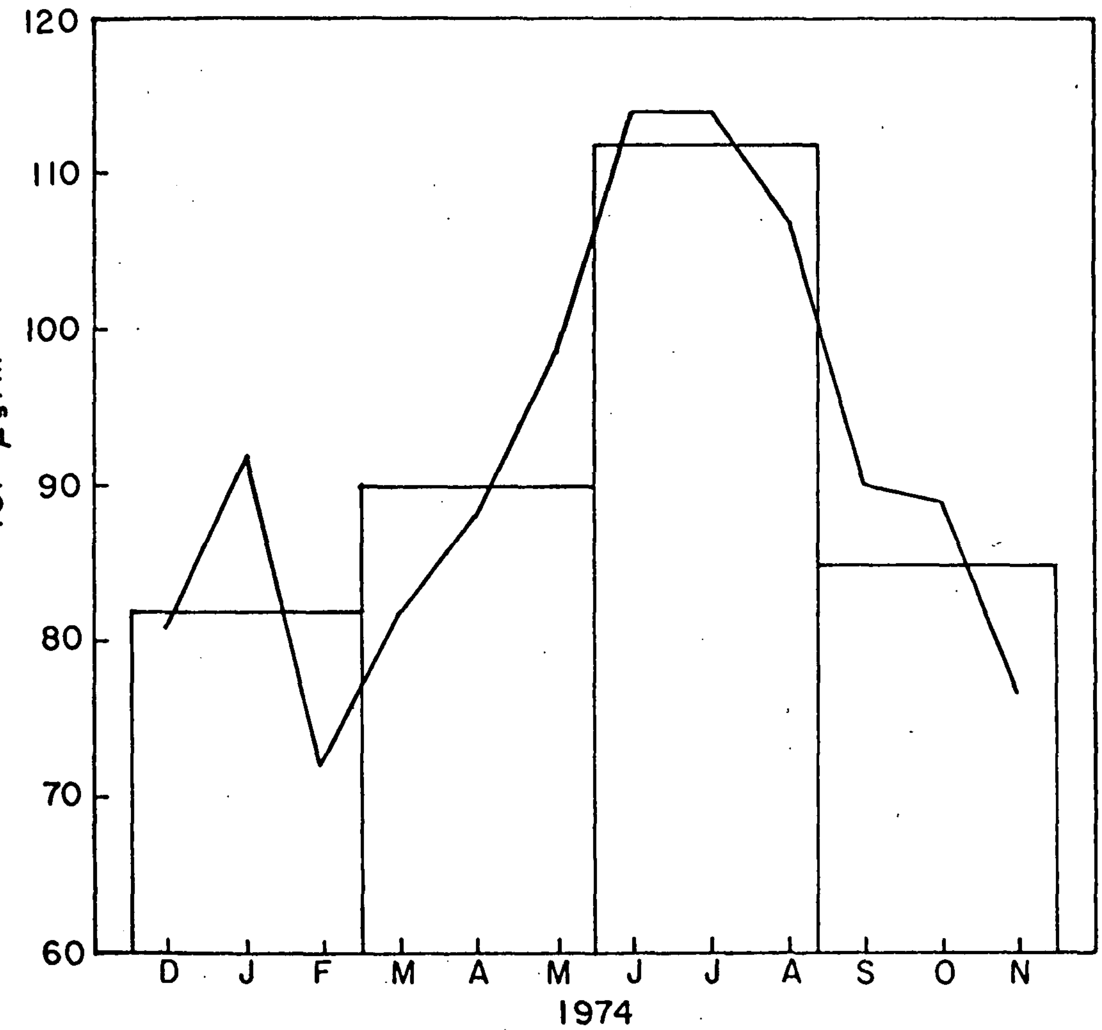


Figure 13. 1974 monthly and quarterly citywide mean TSP concentrations

cut by the relatively deep and narrow valley of the Cuyahoga River. The depth of the valley below the plain increases from about 100 feet in the Cuyahoga Flats area near the central business district to over 300 feet a the county line; the width is generally less than 1 mile (see Figure 1). The depth of the Cuyahoga River valley is sufficient to trap cold air at night and cause frequent inversions. Added to this tendency to trap pollutants in the valley is the fact that many industries are located in the valley. Therefore, the already high TSP concentrations due to industrial emissions would be magnified by the frequent inversions in the valley whi would limit the dispersion of particulates.

Climate Effects

The climate in Cleveland is moderately wet (average 35 inches precipitati per year) and the winters are relatively cold (average 6150 heating degre days per year). These are among the factors which can influence TSP concentrations. Precipitation and degree-day trends are shown in Figures 14 through 17 and compared with TSP trends in Table 10.

Over several years, TSP concentrations show the anticipated significant correlation with time — r equals -0.861 which means that TSP concentratio have been decreasing over time. But the correlations of TSP trends with annual rainfall and with annual degree-days have been the opposite of wha was expected — TSP concentrations seemed to be higher in years of greate rainfall and years of fewer degree days.

During 1974, TSP concentrations correlated as expected, though not signi cantly, with precipitation (r = -0.203) - TSP concentrations were lower months of greater rainfall. But the correlation with monthly degree-day was the opposite of what was expected - TSP concentrations were highest during the summer months when the number of degree-days is lowest and fu combustion emissions from space-heating are lowest. This is due to Clev land's shoreline location on Lake Erie, discussed earlier, which has an

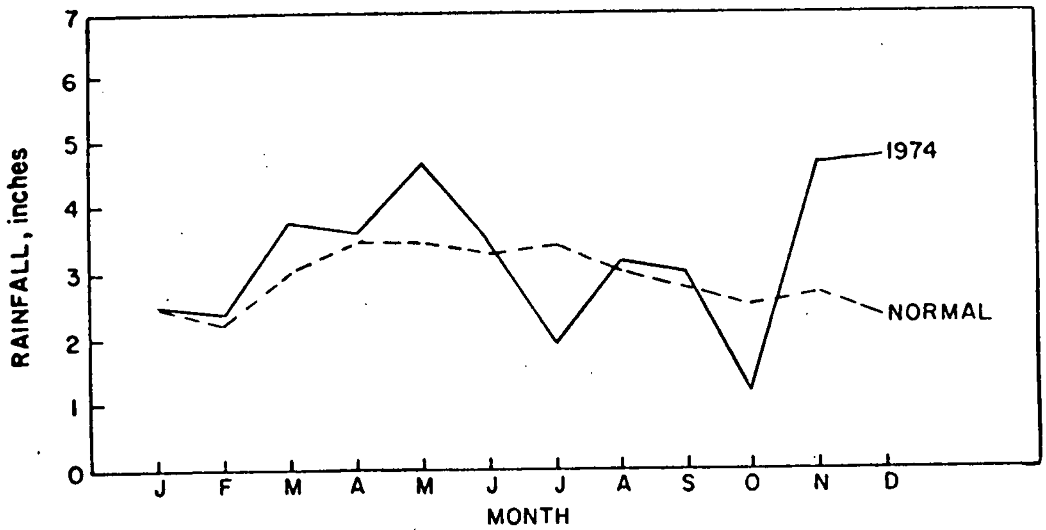


Figure 14. Monthly rainfall, 1974

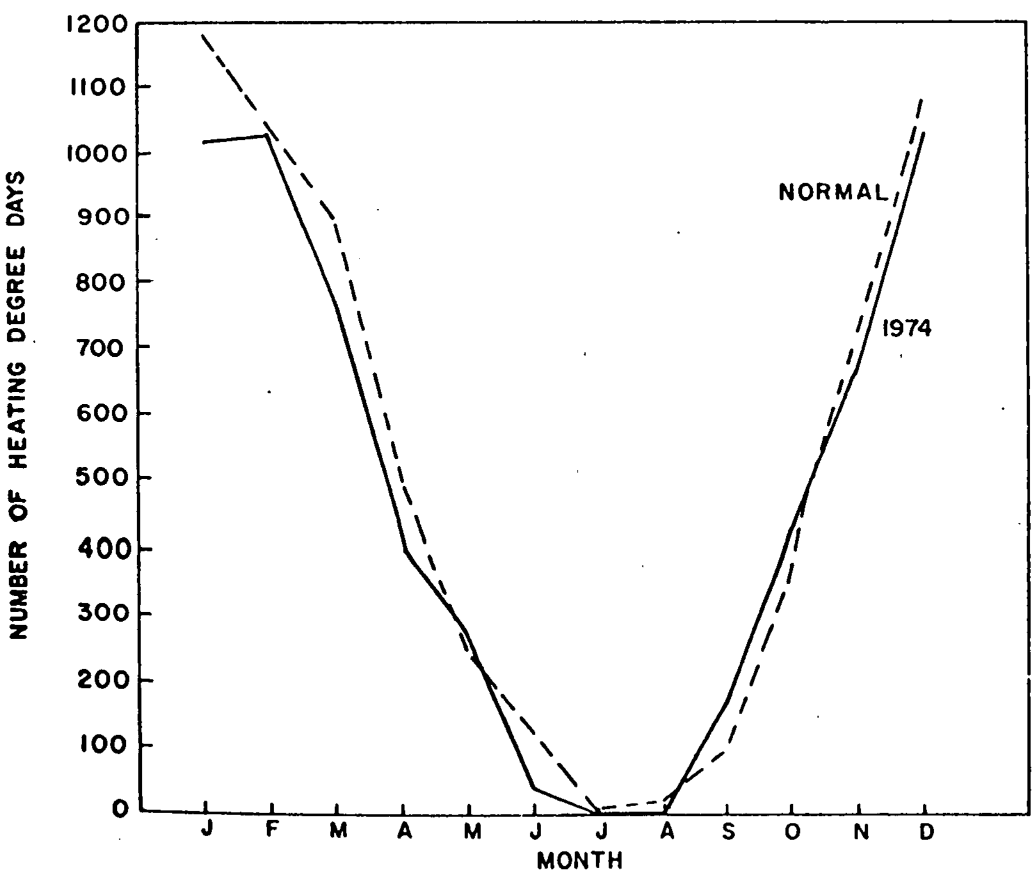


Figure 15. Monthly degree-days, 1974

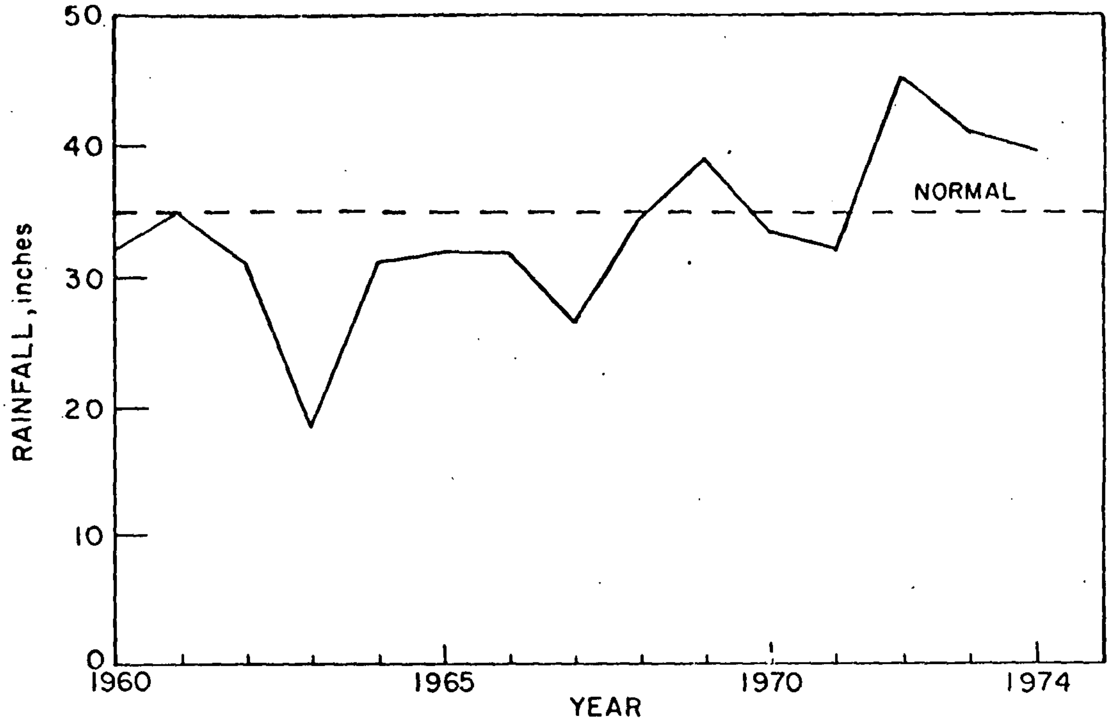


Figure 16. Annual precipitation

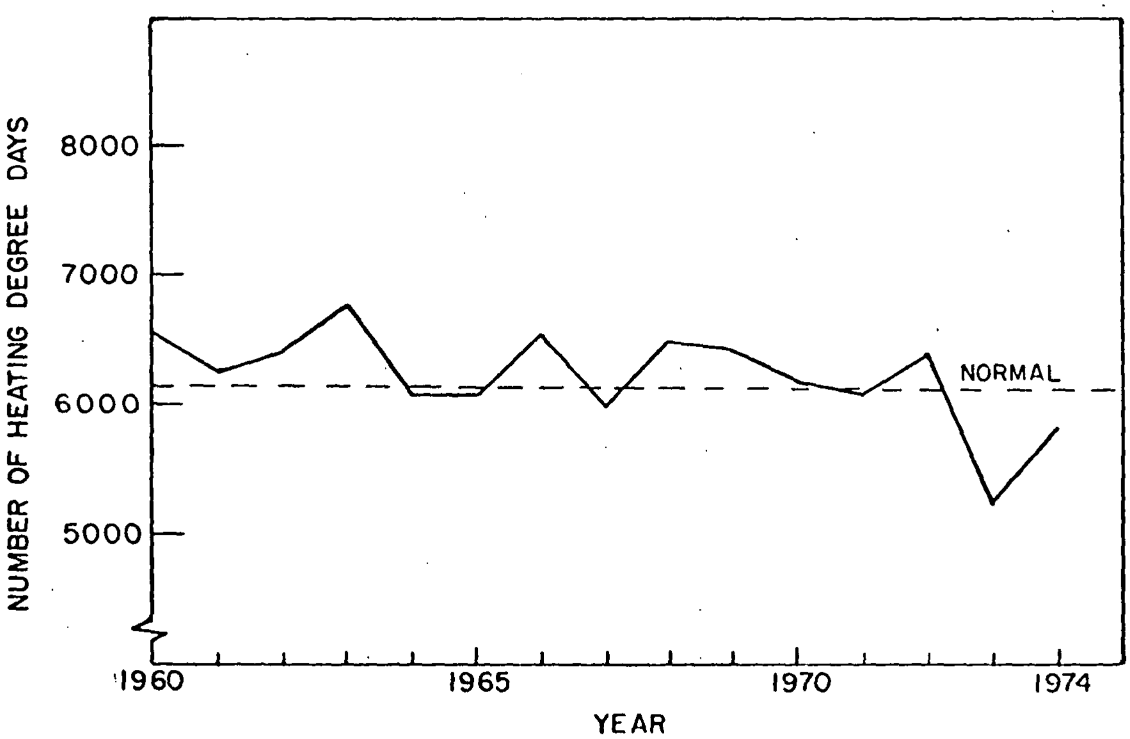


Figure 17. Annual heating degree-days

effect on monthly TSP patterns opposite to and far outweighing the effects of monthly degree-day patterns (see Figure 13 and Effects of Lake Erie).

Though precipitation and heating degree-days are known to influence TSP concentrations, apparently neither is important enough with respect to other factors to cause TSP trends in Cleveland.

Transport

Air movements are the means by which particulates are transported from the emission sources to the receptors — the population as well as hi-vol monitors. Figure 18 shows wind roses for two areas in Cleveland — the Lake Erie shoreline area at the Burke Lakefront Airport and the suburban area in the western part of the county at Cleveland Hopkins Airport. The two wind roses are similar, showing that the predominant wind direction is from the southwest and that the northern sector (winds off the lake) is also important. The lakefront wind rose indicates that winds off the lake occur somewhat more of the time than in the suburban area, also, that winds from the south occur more frequently, perhaps due to the wind channeling effects of the Cuyahoga River valley which is directly south of the Lakefront Airport and which runs in a generally north-south direction.

Transport of particulates into the Cleveland area is probably low at most times due to the nature of the surrounding areas - Lake Erie to the north and northwest, largely agricultural areas to the southwest. Particulates transport could become important under certain circumstances, though there is not enough data at present to determine the relative contribution of transport to Cleveland's air quality. During the summer, Cleveland is sometimes influenced by the Bermuda High - air from the western side of the high pressure system sweeps up from the Deep South where particulates tend to be picked up. Cleveland is occasionally downwind of the industrial areas of Akron and Canton which are, respectively 27 and 50 miles south-southeast of the city. And sometimes, Cleveland is downwind of its own emissions, when its pollutants are carried out over Lake Erie and returned

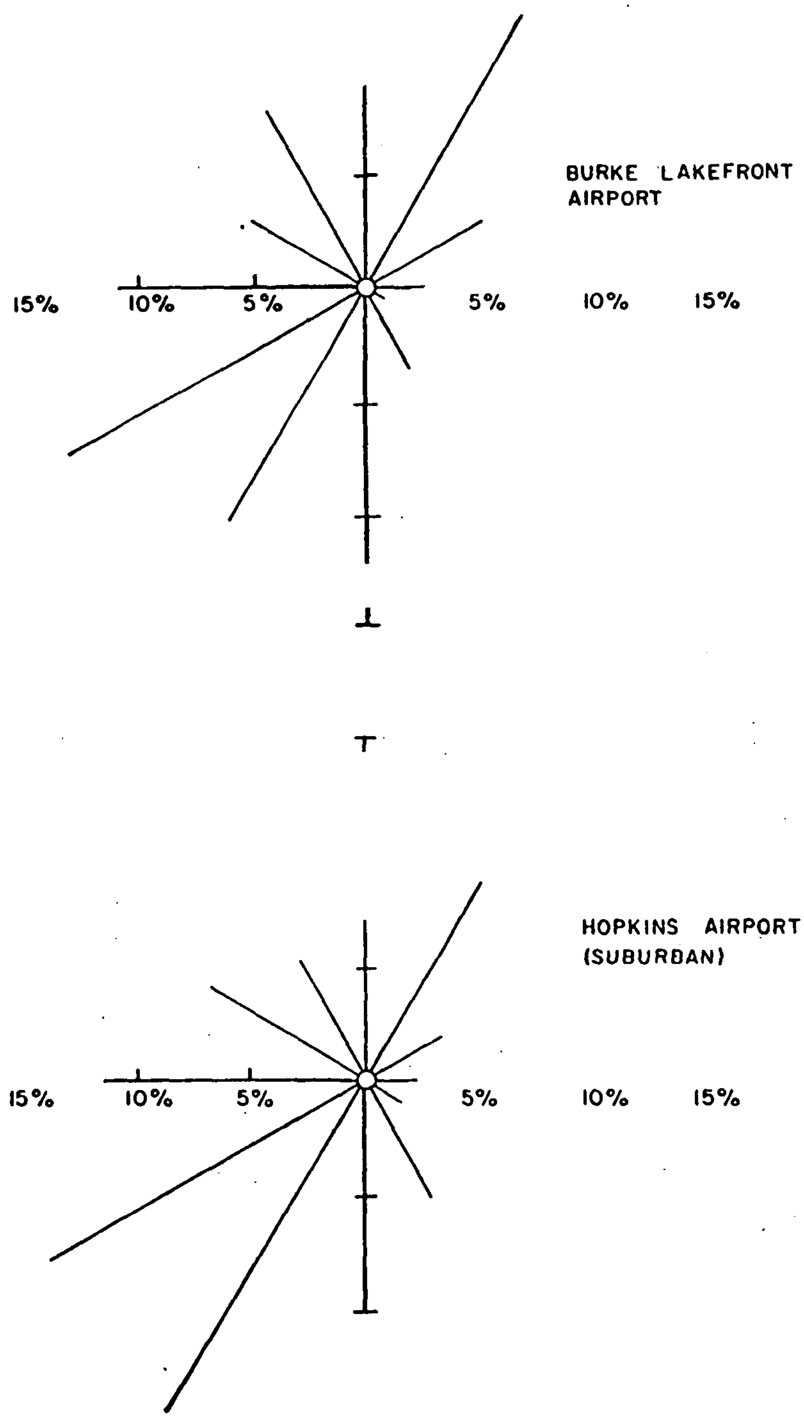


Figure 18. Annual wind roses (percent of time)

by the lake breeze or when inland areas are impacted by shoreline emissions carried inland.

Particulates transport within the Cleveland area is shown by the pollutant roses constructed for some of the particulates sampling sites. The pollutant roses indicate some of the local sources of particulates and are given in Figures 19 through 25 and discussed below.

Site 1, Air Pollution Control Agency - The pollutant rose shows several peaks above 150 $\mu g/m^3$. The largest is above 200 $\mu g/m^3$ and occurs with winds coming from a direction of 120 to 200 degrees - this corresponds to a large nearby steel mill. Another peak from 250 to 300 degrees corresponds to another steel mill.

Site 10, Fire Station 19 - The largest peak, from 260 to 300 degrees, points toward the City's Municipal Light Plant. TSP concentrations above 150 $\mu g/m^3$ dominate the sector from 180 to 340 degrees, the direction of the Cuyahoga Flats industrial area. A small but noticeable peak occurs between 10 and 40 degrees and corresponds to another power plant.

Site 11, St. Vincent's Hospital parking lot - This site is located at the edge of a parking lot and next to an exit ramp of an expressway. The large paved parking lot is due east and corresponds to a peak about 200 $\mu g/m^3$ in the pollutant rose. The expressway is west of the site and the pollutant rose shows a contribution of about 150 $\mu g/m^3$ from that direction but no peak. A broad peak over 160 $\mu g/m^3$ exists for winds from 150 to 230 degrees, the general direction of Cuyahoga Flats industrial area. TSP concentrations are lowest for wind directions pointing toward the lake - 280 to 360 degrees.

Site 13, Harvard Yards - This site is surrounded by point and area sources, as indicated by the high TSP concentrations for all compass directions of the pollution rose. The several peaks correspond to nearby major point sources - smelting operations lie in the general direction of 110 to 220

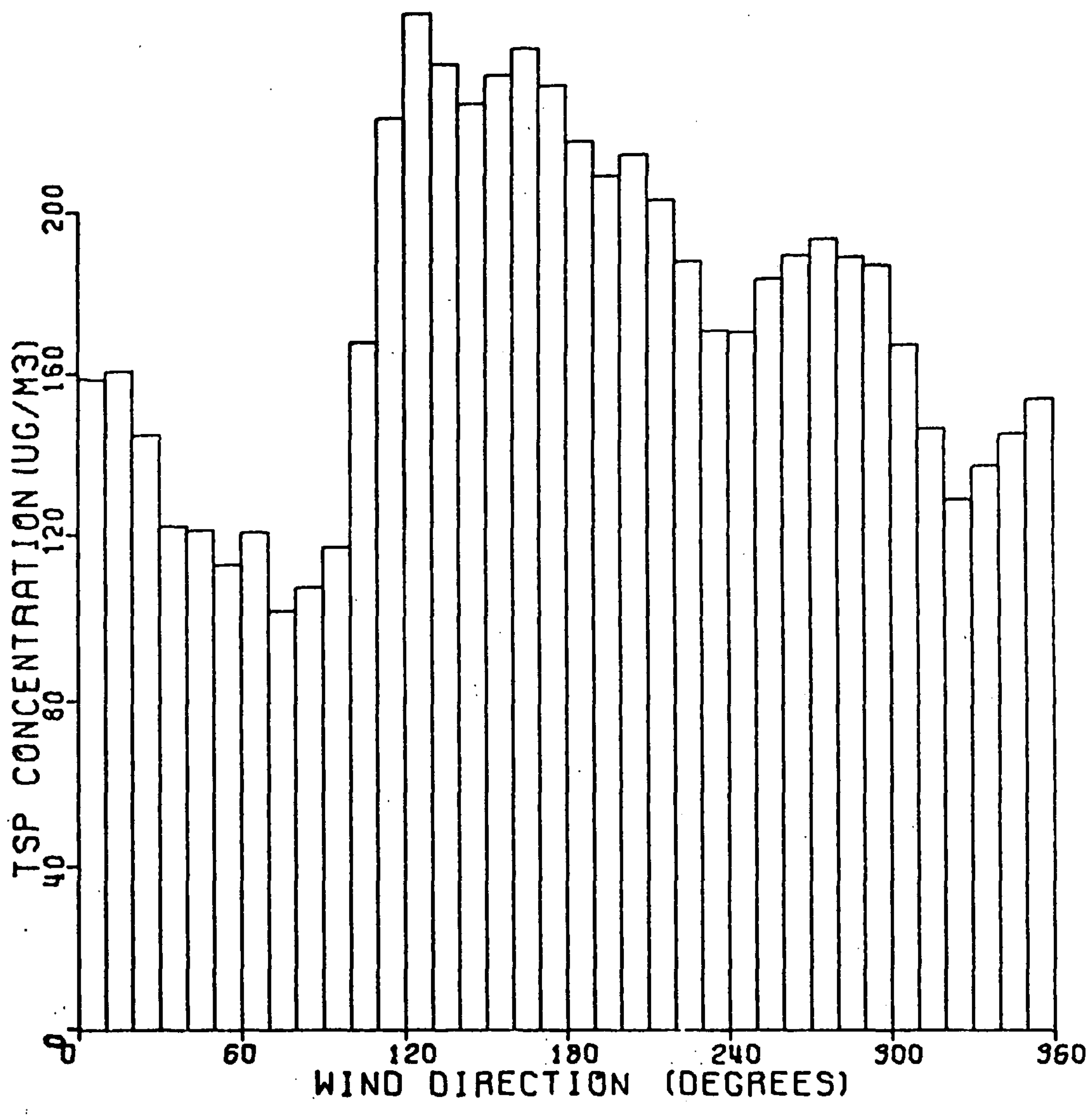


Figure 19. Pollution rose - Air Pollution Control Agency (site 1)

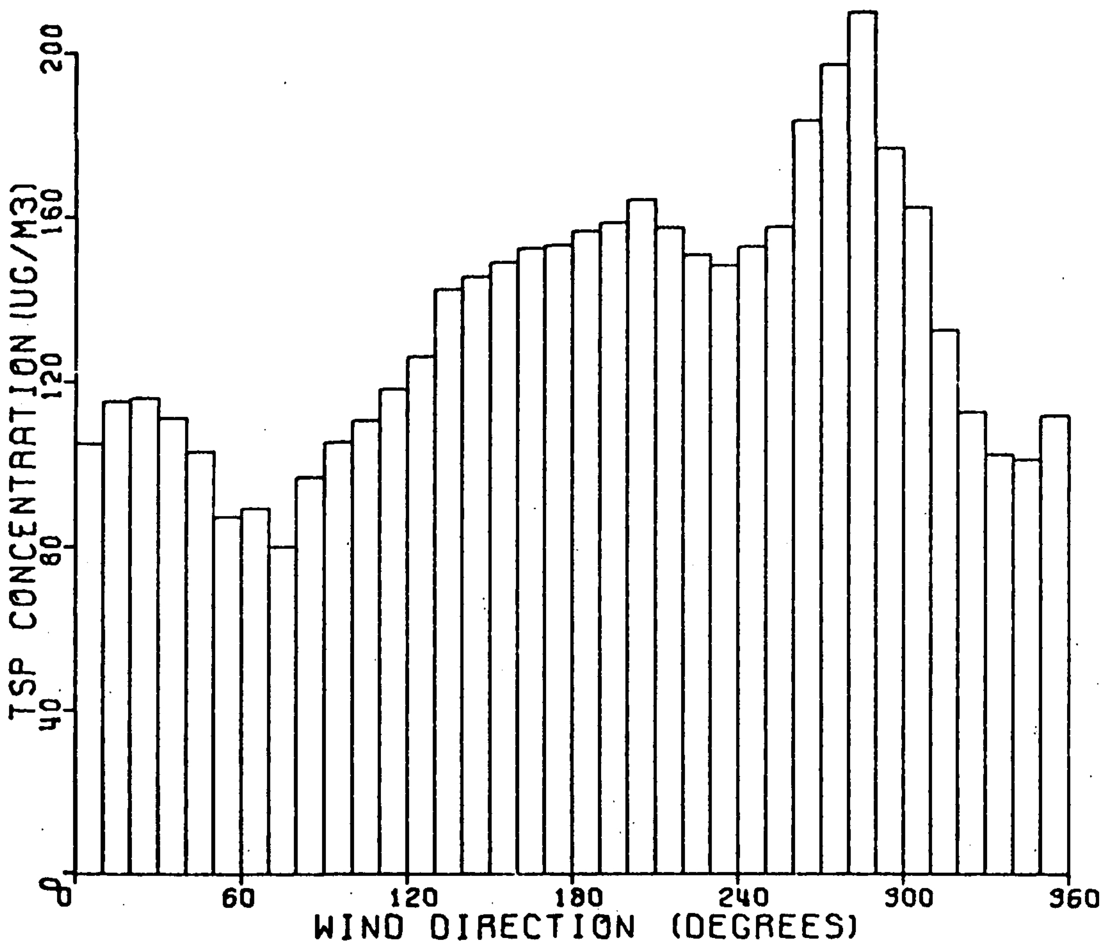


Figure 20. Pollution rose - Fire No. 19 (site 10)

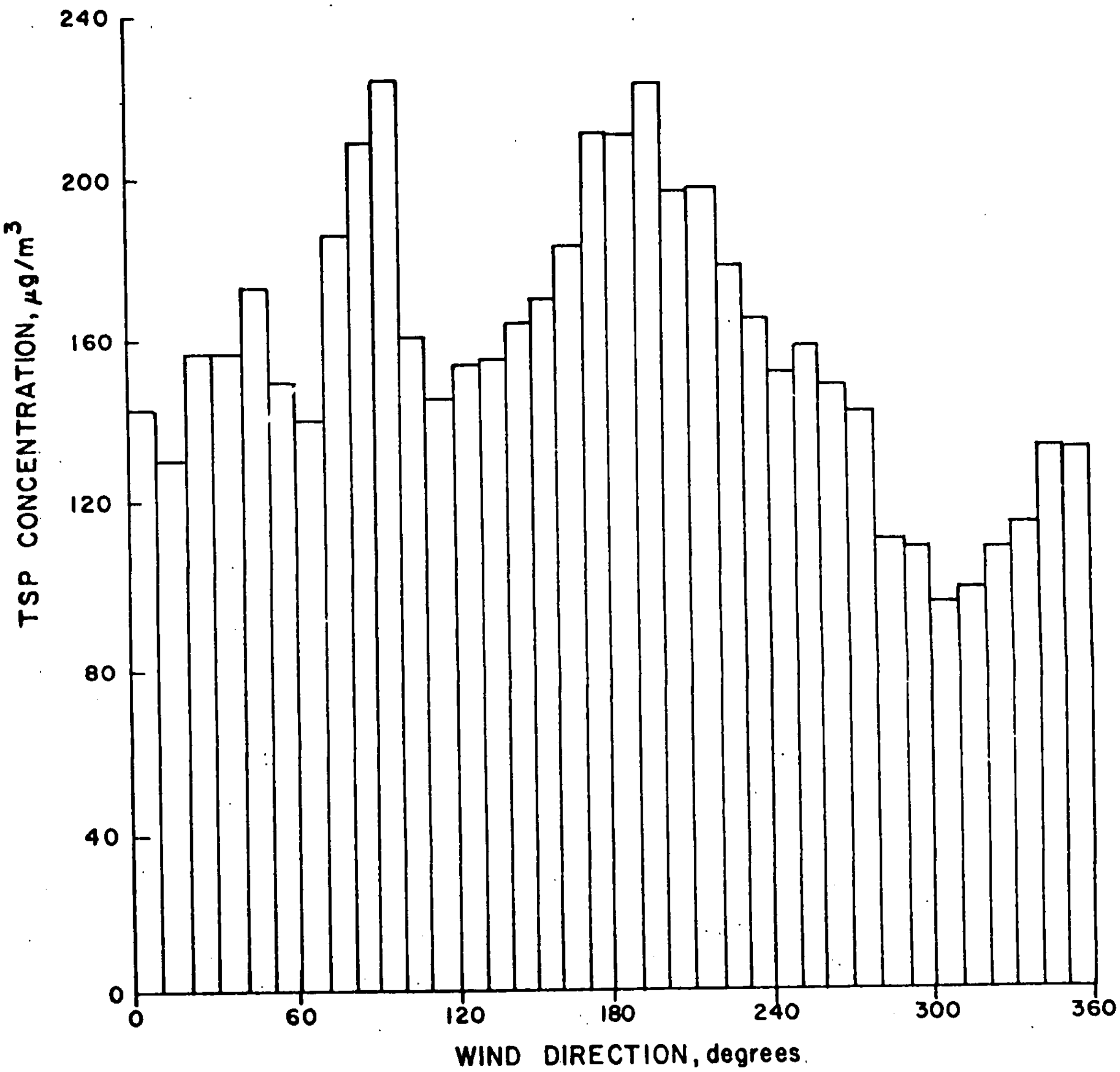


Figure 21. Pollution rose - St. Vincent's Hospital parking lot (site 11)

Source: G. J. Nied

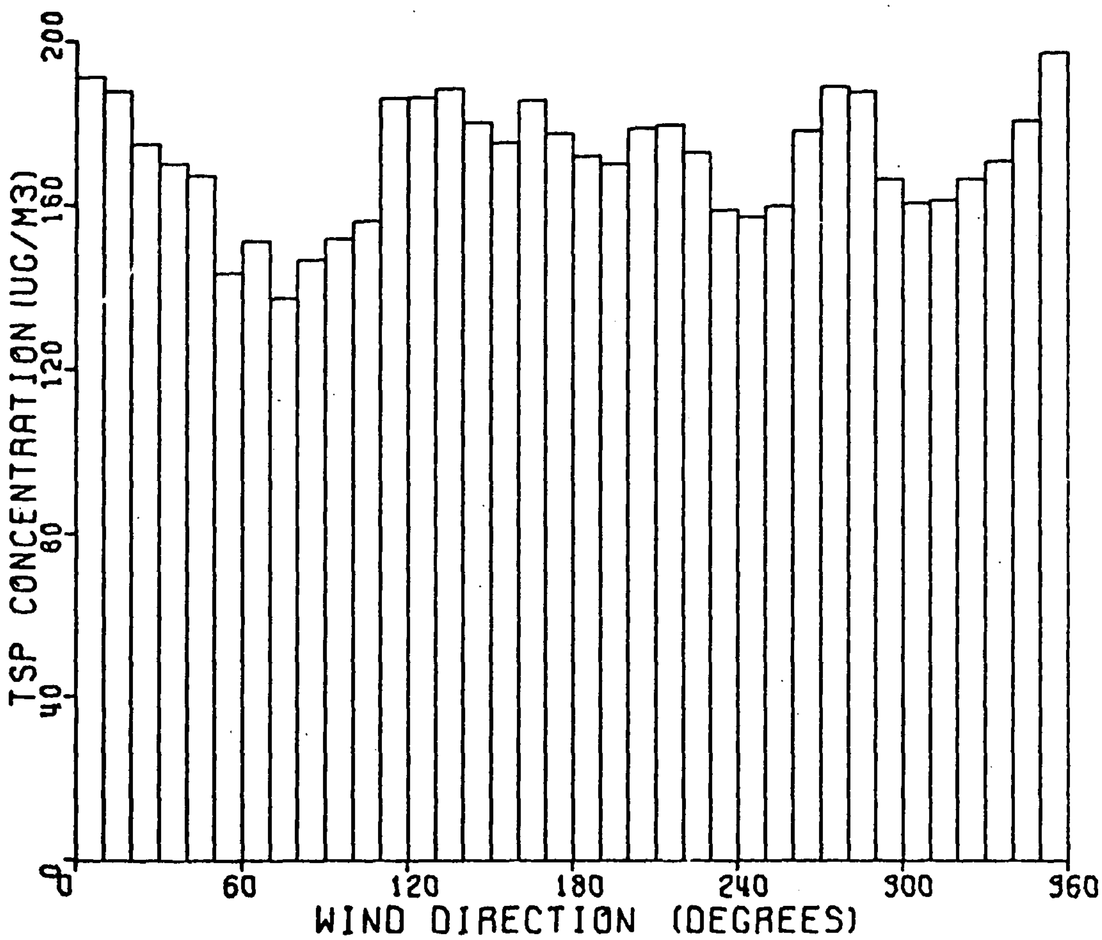


Figure 22. Pollution rose - Harvard Yards (site 13)

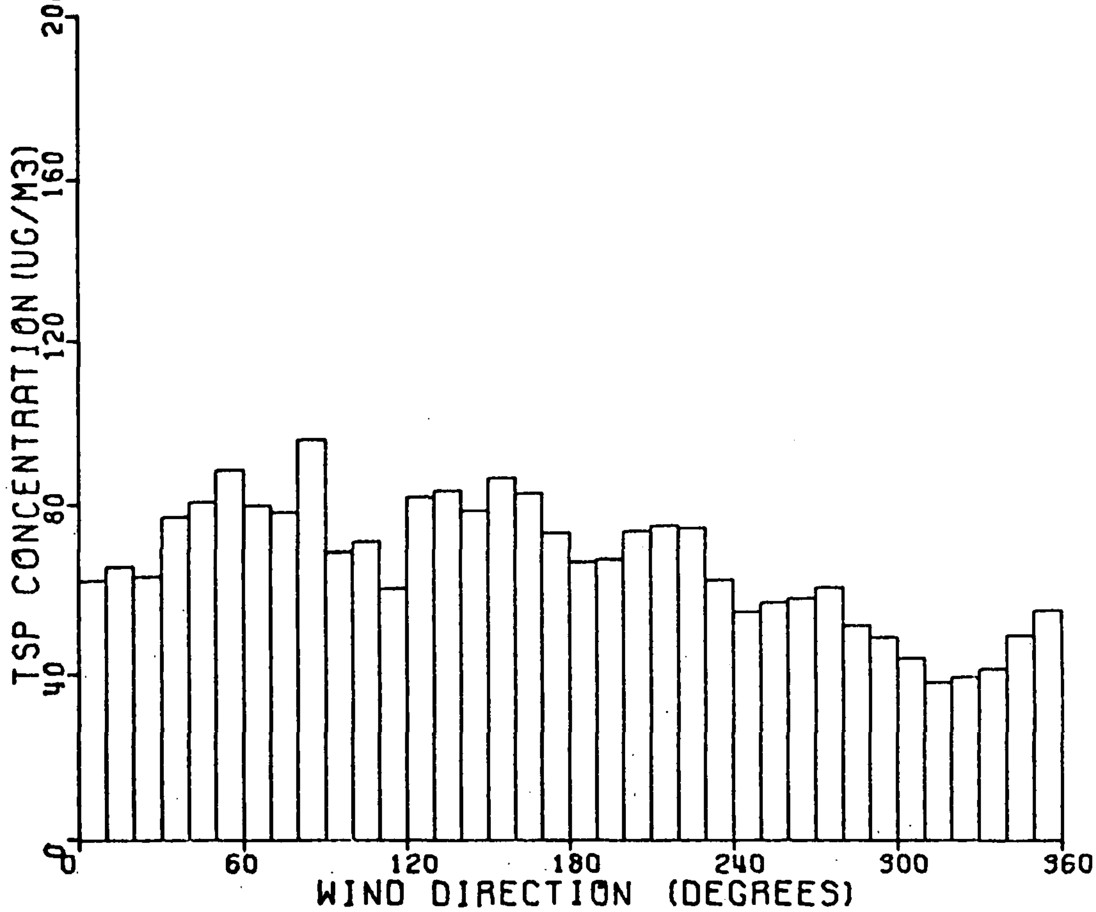
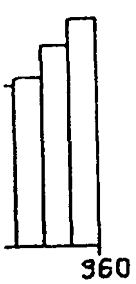


Figure 23. Pollution rose - Almira (site 16)



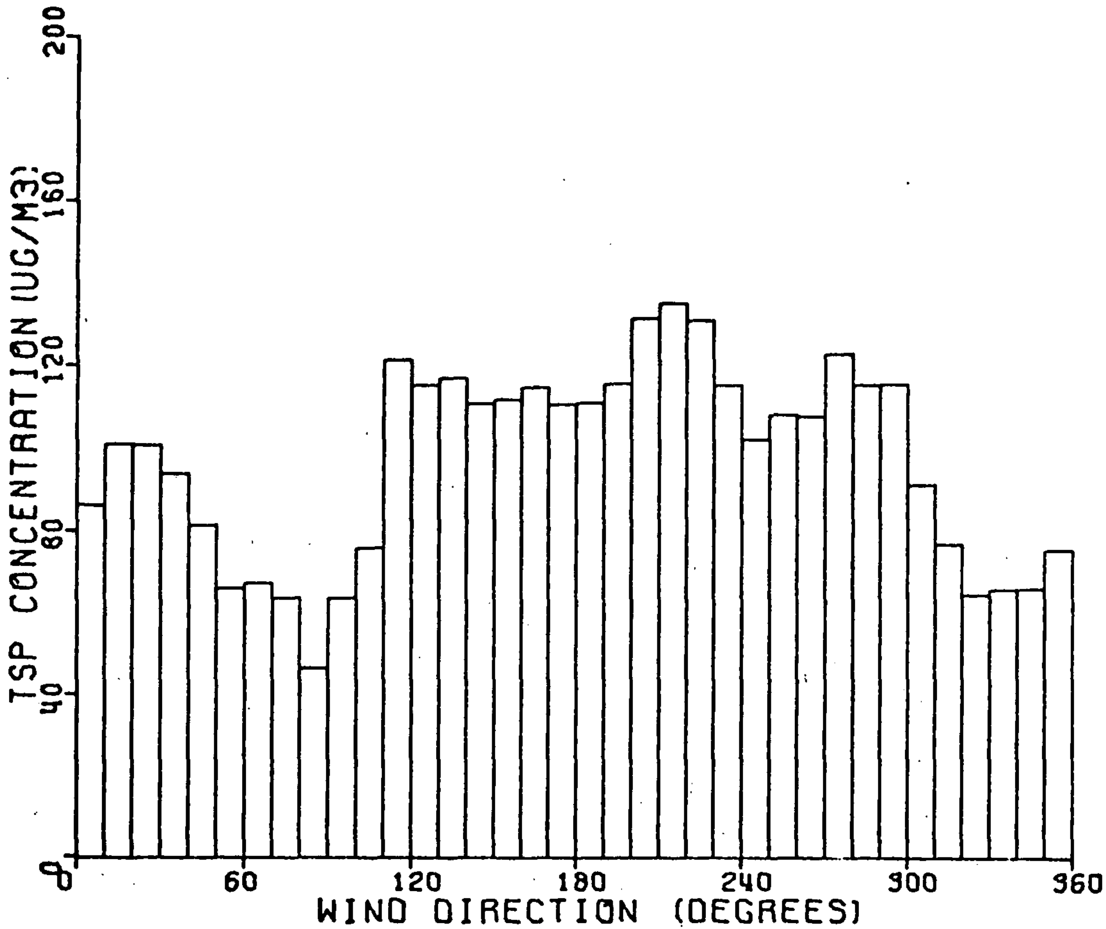


Figure 24. Pollution rose - Fire No. 29 (site 17)

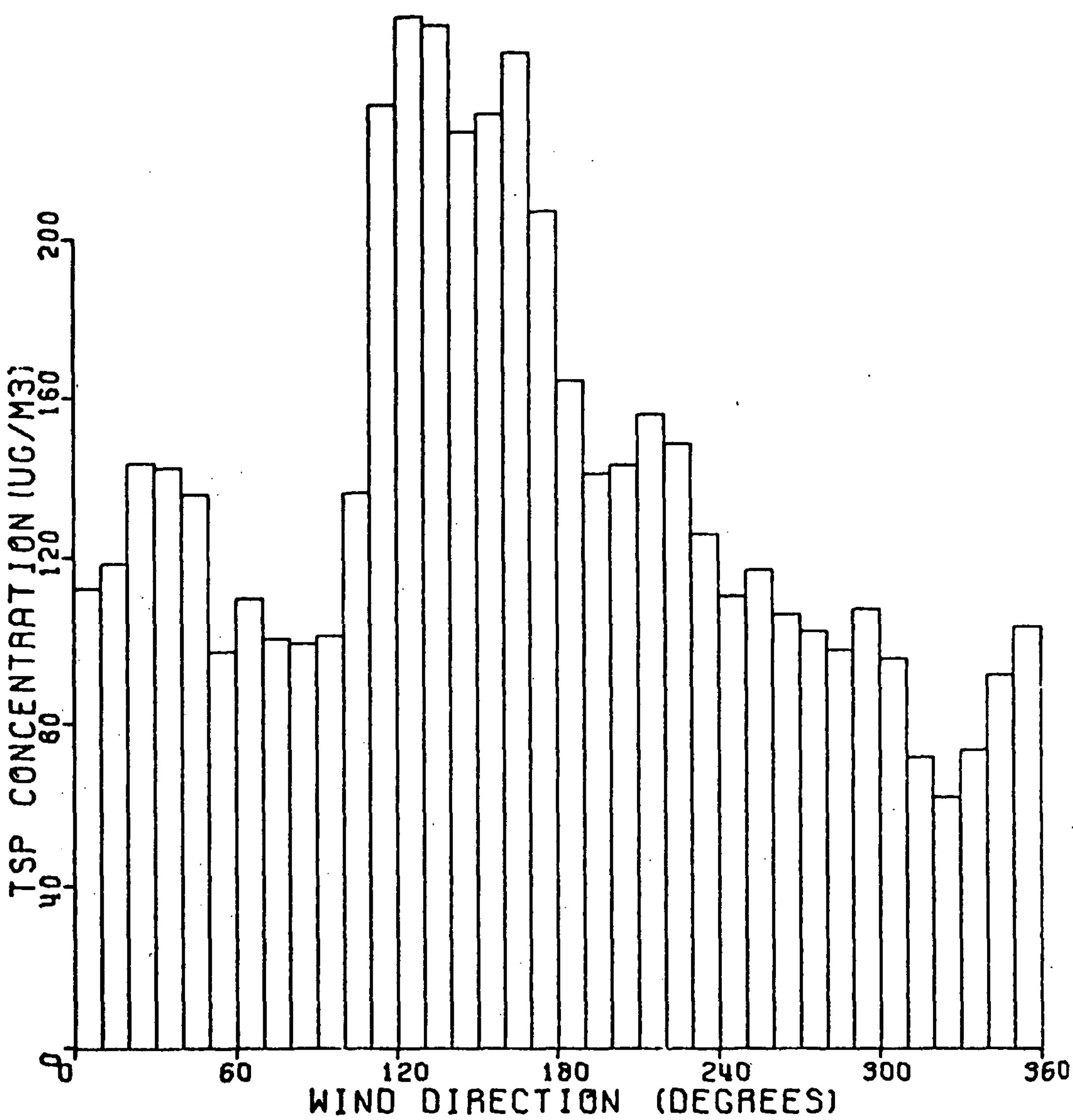


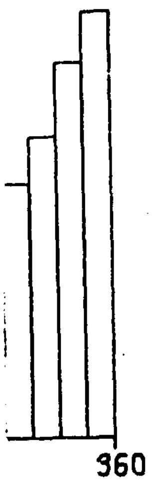
Figure 25. Pollution rose - Supplementary Education Center (site 21)

degrees, aluminum and chemical industries from 270 to 290 degrees, and the Cuyahoga Flats industrial area from 350 to 30 degrees.

<u>Site 16, Almira</u> — This site is about 3 miles from the industrial area of Cleveland but its pollutant rose appears to show the effects of transport from the city. TSP concentrations are highest for the direction corresponding to the direction in which the downtown and industrial areas lie — 50 to 160 degrees.

<u>Site 17, Fire Station 29</u> — TSP concentrations greater than 100 $\mu g/m^3$ occur for the sector between 110 and 300 degrees — a medical center is south of the site and a power plant lies in a west-northwest direction.

<u>Site 21, Supplementary Education Center</u> — The largest peak is above 200 $\mu g/m^3$ and occurs with winds coming from the direction of the Cuyahoga Flats industrial area — 110 to 170 degrees. Another peak from 20 to 40 degrees points toward the power plants. The site is located near Lake Erie — the low TSP concentrations occurring with winds from the direction of the lake, 270 to 10 degrees, indicate the absence of sources in that direction.



URBAN ACTIVITY

<u>Land Use Patterns</u>

The pattern of land use in Cleveland is influenced by the Cuyahoga River, Lake Erie, and the topography. Near the mouth of the Cuyahoga River on Lake Erie is the central part of the city. The major industrial areas are located along the Cuyahoga River in the valley formed by the river and along the Lake Erie shoreline. The densely residential areas which are the older part of the city lie close to the shoreline and the river valley and extend to the heights of land surrounding the city. The less densely populated suburban areas are built on the higher land which rings the city.

Annual mean TSP concentrations tend to follow the land use patterns, being highest in the Cuyahoga River valley, high in the center city and densely populated, older sections, and relatively low in the suburbs (see Figures 5 and 11). Table 11 summarizes the 1974 annual mean TSP concentrations at the different types of sites. The industries sites averaged together over 150 $\mu g/m^3$, the center city with over 100 $\mu g/m^3$, and the residential sites 75 μg

Table 11. TSP VERSUS LAND USE (AT VISITED SITE)

Predominant land use	Average of 1974 TSP means $\mu g/m^3$	Sites
Center city	101	4, 21
Industrial	152	1, 9, 10, 11, 13
Residential	75	2, 3, 5, 14, 15, 18

The different kinds of land use activities surrounding a monitoring site, especially industrial development, are felt to be the urban activities most influencing the TSP concentrations recorded there. The effects of factors such as traffic volume and construction and demolition activities are probably obscured to a large extent. As the influence of point source and fugitive industrial emissions decrease, due to enforcement and controls, these other urban factors will become more important.

NETWORK DESIGN AND MONITOR SITING

Sampling for TSP is conducted at sites throughout Cuyahoga County, with most of the sites being located in the city. Figure 3 shows the locations of sampling sites and information about them is summarized in Table A-3 in the Appendix. The various kinds of land use in the county are represented by the site locations — the center city by sites 1, 4 and 21; residential and commercial areas in the city by sites 2, 3, 5 to 8, 12, 14 to 16, and 18 to 20; suburban areas by sites 31, 32, 35 and 37 in Beachwood, Bedford Heights, Parma and North Olmsted, and industrial areas in the city by sites 9 to 11, 13 and 17. Industry tends to be concentrated along the Cuyahoga River and the Lake Erie shoreline.

The design of the network is generally adequate for recording the variety of air quality situations in the county. The city, suburbs, and industrial areas seem to be well covered by hi-vol monitors. There are, however, no sampling sites located in areas which could be considered undeveloped and monitoring background TSP levels. The sampling sites farthest from the city appear to be located in residential or commercial areas of suburban towns.

The specific siting of the hi-vol monitors also seems to be generally adequate. Eleven of the 25 sites in Cuyahoga County were visited in order to assess hi-vol exposure and possible local sources which could be influencing the TSP concentrations which were recorded. The site characteristics are summarized in Table 12. The characteristics of these sites were assumed to be representative of the monitor siting characteristics. The exposure of the monitors is generally good, without obstructions by the building on which the monitor is located or other surrounding buildings. The heights of the monitors range from 4 to 65 feet, with most in the 20 to 50 foot range. This is generally adequate except for those at the extreme lower and upper ends of the height range. The ground-level monitors may be excessively influenced by strictly local sources whereas the highest monitors (over 50 feet or so) may be recording lower particulate concentrations due to the height. One of the monitors recording annual levels over 100 $\mu g/m^3$ (site 11) was at ground level but two others (sites 13 and 21) were over 60 feet high. The elevation of the monitors is influential on the recorded TSP concentrations in that it is an indication of where the monitor is with respect to the industrial sources — near the valley or shoreline (below 700 feet), in the city (700 to 900 feet), or outside the city (above 900 feet).

Table 12. SAMPLING SITE DESCRIPTIONS

Site number	Location	1974 TSP geometric mean	Predominant influence	Total elevation	Height	Land use
1	Air Pollution Control Lab	175	Industrial	610	20	Surrounding – industrial and fugitive sources (steel mills, railroad yards, unpaved roads, bare ground, stock piles)
3	Brooklyn YMCA	76	Residential	738	50	Surrounding – residential; industrial valley – 3/4 mile E and NE
4	Cleveland Health Museum	90	Residential	699	24	Surrounding – residential; heavy traffic; hospitals nearby
5	Cleveland Pneumatic Tool	88	Residential, Industrial	789	59	Surrounding – residential; scattered light industry (machine shops, junk yards); high school; industrial valley – 2 miles W
9	Fire Station No. 13	147	Industrial	703	23	Surrounding – residential; heavy traffic; industrial valley – 1/4 mile W (steel mills)
10	Fire Station No. 19	124	Industrial	651	25	Surrounding – commercial; utilities – 1 mile NE and 3/4 mile NW; heavy traffic; Lake Erie – 1/2 mile N
11	St. Vincent's Hospital	149	Industrial	690	4	Parking lot – E; highway – W; industrial valley – 1/4 mile S to W
13	Harvard Yards	168	Industrial	700	60	Surrounding – industrial (steel mills, stock piles, unpaved roads and lots, truck traffic, railroad yard)
14	J. F. Kennedy School	50	Residential	1,070	60	Surrounding – residential; supermarket, parking lot
15	P. L. Dunbar School	93	Residential	701	20	Surrounding – residential; industrial valley – 1-1/2 mile N and E
21	Supplementary Education Center	112	Center city	705	65	Surrounding – commercial; Lake Erie – 3/4 mile NW; heavy traffic; industrial valley – 1 mile S

IMPLEMENTATION PLANNING

Institutional Framework

The air pollution control program in Cuyahoga County has been run by the Division of Air Pollution Control of Cleveland under contract to the Ohio Environmental Protection Agency since 1971. Prior to that time, the Division of Air Pollution Control was responsible only for air quality within the City of Cleveland.

The City of Cleveland has had air pollution control regulations and a program of enforcement since the 1940s. When the State of Ohio adopted air pollution control regulations in 1972, these superseded all local regulations except those which were more stringent than the state regulations.

Under the present arrangement, the Division of Air Pollution Control provides air pollution control services to all of Cuyahoga County, enforces the city regulations in the city when applicable, and advises the Ohio EPA on enforcement matters on the state level.

Implementation Planning Methodology

Measured TSP air quality was the basis for classifying Cleveland as Priority I (see Figure 26). Cleveland had prepared control plans in 1967 and 1970 using air quality diffusion modeling and this was used in the preparation of the Cleveland demonstration region in the Ohio State Implementation Plan.

The State of Ohio used the AQDM (air quality display model) or "worst case" approach in preparing the SIP. Three demonstration regions — Dayton, Zanesville and Cleveland — were chosen for the three priority levels and each was modeled. Each of the three regions was to be representative of other regions in its priority level. Cleveland was selected

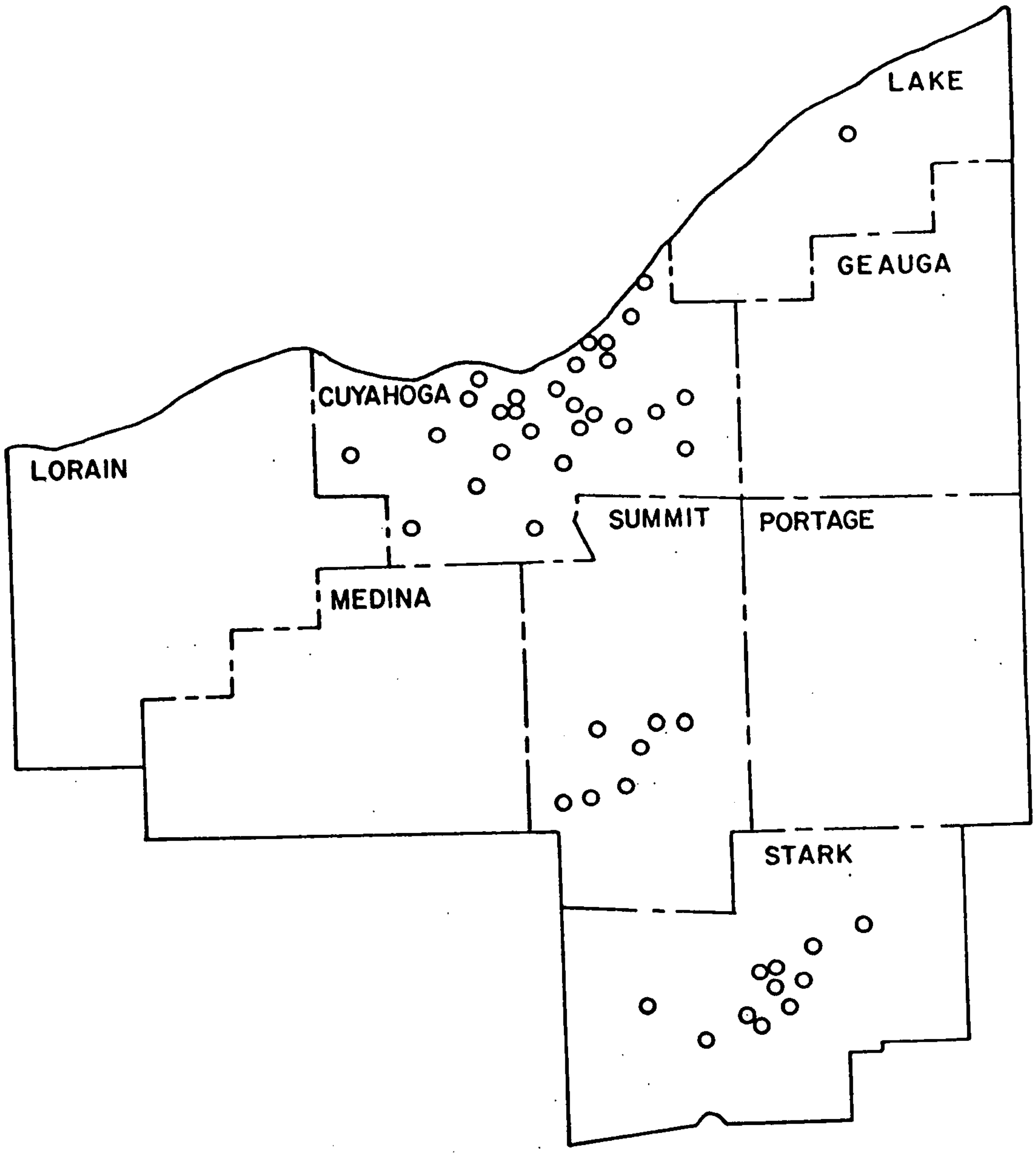


Figure 26. Locations of air quality monitors used to determine the priority classification of Cleveland AQCR

as the worst region for particulates based on existing ambient air quality data. The air quality data was obtained from monitors located in the areas of highest concentrations and the emissions data was obtained from the 1970 NEDS Emission Inventory (see Figure 26 and Table 13). Regulations which achieve the desired air quality in this region should therefore also achieve the standards in the other Priority I regions.

The emission reductions necessary to meet the air quality standards were determined by proportional reductions. The highest TSP concentrations in Cleveland were an annual geometric mean of 225 $\mu g/m^3$ and a 24-hour value of 658 $\mu g/m^3$. Based on the highest annual value, proportional reduction calculations indicates that a 79 percent reduction in particulate emissions would be necessary to attain the Federal primary standard and an 87 percent reduction of the secondary standard (See Table 14). Proportional reductions to meet the daily standards were not as high as those based on the annual value.

<u>Resulting Regulations</u>

Based on the control strategy started in 1970 using diffusion modeling in the Cleveland Region, a regulation requiring strict control of combustion sources, especially large units, and an increasingly restrictive degree of control for larger industrial processes was developed (see Figures A-1 and A-2). The regulations were adopted January, 1972 for Priority I regions.

Table 13. EMISSIONS INVENTORY SUMMARY FOR PARTICULATES, 1970

Source category	Cleveland AQCR
I. Fuel combustion	
A. Residential fuel-area source	
1. Coal	3,580
2. Distillate oil	403
3. Natural gas	1,906
4. Wood	
5. Other	
6. Total	5,889
B. Comm.-Instl. & Industrial	
1.a Bituminous coal - area source	104,884
1.b Bituminous coal - pt. source	58,497
2. Coke	
3.a Distillate oil - area source	821
b Distillate oil - pt. source	112
4.a Residual oil - area source	96
b Residual oil - pt. source	572
5.a Natural gas - area source	675
b Natural gas - pt. source	732
6. Process gas - pt. source	
7.a Other - area source	
b Other - pt. source	2,109
8. Total	168,498
C. Steam-electric power plant	
1. Anthracite coal	
2. Bituminous coal	30,960
3. Distillate oil	
4. Residual oil	
5. Natural gas	16
6. Other	
7. Total	30,976
D. Total fuel combustion	205,363
II. Process Losses	
A. Point sources	45,151
III. Solid waste disposal	
A. Incineration	
1.a On Site - area source	3,290
1.b On site - pt. source	1,307
B. Open burning	
1. On site - area source	7,992
C. Total solid waste disposal	12,589
IV. Transportation - area source	
A. Motor vehicles - gasoline	6,336
Motor vehicles - diesel	188
B. Off highway fuel usage	
C. Aircraft	1,226
D. Railroad	66
E. Vessels	196
F. Gasoline handling evap. losses	
G. Other	
H. Total transportation	8,012
V. Miscellaneous - area sources	
A. Agricultural burning	
B. Solvent	
C. Total miscellaneous	
VI. Grand total	
A. Area source	131,659
B. Point source	139,456
C. Total	271,115

Table 14. CLEVELAND AND OTHER PRIORITY I REGIONS — REQUIRED EMISSION REDUCTIONS

Air quality standard μg/m³		Maximum measured concentration μg/m³		Required emission reductions[a]		Existing emissions (x10³ TPY)	Emissions required to meet standards (x10³ TPY)		Estimated emissions after applying controls (x10³ TPY)
Annual geometric mean	24 hr	Annual geometric mean	24 hr	Primary	Secondary		Primary	Secondary	
60	150	225	658	79%	87%	271	60	36	54

[a]Calculated by $\frac{(A-C)}{(A-B)}$ 100 based on annual average. (A = measured concentration, B = background (35 μg/m³), C = desired level (standard)).

$\frac{225 - 75}{225 - 35}$ (100) = 78.95 percent

$\frac{225 - 60}{225 - 35}$ (100) = 86.84 percent

Estimation/Projection Methodology

The regulations were applied to all point sources in the Cleveland Region and reduced emissions were tabulated. Estimates of area source emission reductions were also made based on the degree of control achieved by point sources. Applying the regulations and taking growth between 1970 and 1975 into account, it was determined that emissions by 1975 would be about 80 percent below the 1970 emissions. Thus, it is assumed that the Federal primary standard can be met with the application of these regulations. Since calculations indicate that the Federal secondary standard cannot be achieved with the regulations, Ohio was given an extension to develop a sufficient control strategy for the Cleveland Region.

The emissions inventory used in the Implementation Plan is an early version of the NEDS inventory for 1970. A later NEDS inventory for 1970 containing a more complete source listing is shown in Table 3. It can be seen that the later inventory indicates that total emissions equal 567,000 tons per year whereas total emissions in the earlier inventory equal 271,000 tons per year. The total emissions in the inventory used in the Implementation Plan are less than half of the total emissions of a later and probably more accurate version. It appears, then, that the emission reduction calculations and the recommended regulations were based on an inventory which underestimated emissions by a considerable amount. In that case, the emissions control program of the SIP would fall short of achieving the reductions necessary to attain TSP standards.

REFERENCES

1. A Modeling Study to Assess Attainment of the SO_2 and TSP NAAQS in the Cleveland AQCR. Source Receptor Analysis Branch, Monitoring and Data Analysis Division of OAQPS, Office of Air and Waste Management, U.S. Environmental Protection Agency. April 1976.

2. Cole, H. S. and W. A. Lyons. The Impact of the Great Lakes on the Air Quality of Urban Shoreline Areas. Proc 15th Conf. Great Lakes Res. 1972: 436-463.

SECTION III

SUMMARY AND CONCLUSIONS

SUMMARY

Air Quality Levels

The 1974 geometric mean TSP concentrations in Cleveland and Cuyahoga County ranged from less than 70 $\mu g/m^3$ outside the city and in residential areas to 70 to 90 $\mu g/m^3$ in densely residential areas and over 100 $\mu g/m^3$ in the industrial areas along the Cuyahoga River and the Lake Erie shoreline. The annual particulates standards were exceeded at a majority of the 25 sampling sites — 12 of the sites exceeded the primary standard of 75 $\mu g/m^3$ and nine others were over the secondary standard of 60 $\mu g/m^3$. The 24-hour standards were exceeded frequently — the primary standard (260 $\mu g/m^3$) on 73 sampling days or 4.7 percent of the total and the secondary standard (150 $\mu g/m^3$) on 273 sampling days or 17.6 percent of the total.

The TSP concentrations experienced in Cleveland are among the highest in the State of Ohio and are the result of the interaction of three factors - a large amount of industry and the meteorological characteristics and land use patterns of the city.

The Cleveland area is highly industrialized, the major industries being primary metals, fabricated metal products, machinery, tools and automotive products. An accurate emissions inventory for Cuyahoga County is not available so total point and area source emissions cannot be determined.

But it is estimated that there are over 20,000 larger sources in the county, almost 700 of which emit more than 25 tons per year of a criteria pollutant. The sampling sites in or close to the industrial areas in the Cuyahoga Flats and along the Lake Erie shoreline all recorded mean TSP concentrations greater than 100 $\mu g/m^3$ in 1974. And an air quality modeling study performed by EPA showed that industrial processes and point source fuel combustion were the most important sources contributing to the TSP concentrations above background levels at certain sites — the contributions were over 70 percent. In addition, uninventoried fugitive dust and emissions in the industrial areas are probably important sources of particulates and resulted in the underpredictions of the modeling study.

Many of the industries are located in the Cuyahoga Flats area and along the Lake Erie shoreline. A few major industries are located in the suburbs on the heights of land or in the Cuyahoga River valley, south of the city. Several electrical generating plants are located along the shore. The populated areas of Cleveland directly adjoin and, in some places, surround the industries.

The presence of Lake Erie adversely affects the transport and diffusion of pollutants along the shoreline, the most deleterious effects occurring during the warm months. A study showed that under certain conditions when stable lake air flows inland, a marked reduction in the mixing layer depth occurs. Fumigation of elevated plumes and/or plume trapping of low and intermediate level sources will result. Under these conditions, the effects of the Lake Erie shoreline particulate sources are magnified and felt by the populated areas of the city and suburbs just south of the shore. The highest TSP concentrations are experienced during the summer months, probably the result of the inland flow of lake air on the shoreline emissions. In addition, frequent inversions in the valley limit the dispersion of particulates emitted by the industries located there.

Air Quality Trends

The 15 sampling sites which have been operating since 1967 have had an average decrease of 36.5 $\mu g/m^3$ from about 125 $\mu g/m^3$ to 90 $\mu g/m^3$ in 1974. This downward trend has been the result of fuel switching and, to a lesser extent, enforcement of the regulations. The lack of emission inventories makes it difficult to determine where changes occurred and what the present problem areas are.

Coal, at one time, was the predominant fuel for residential space-heating, industries and utilities. Since the second World War, conversion from coal to other fuels has been occurring in Cleveland as in other cities. The number of residences using coal has dropped to an insignificant level. Decreases in coal usage by industries and electric utilities have also occurred but these have been smaller. The recent fuel shortage has slowed the conversion to cleaner fuels. Several industries and a public utility which were planning to convert as a pollution control measure have been unable to and continue to exceed emission standards.

The enforcement of the regulations, resulting in control of particulate emissions, has not been as successful as is necessary for full compliance. There is a very large number of air pollution sources in the city and county — the Division of Air Pollution Control feels that it is understaffed and is not able to identify and inspect all sources or to enforce regulations for more than the larger point sources. Long delays in achieving compliance have been experienced with some of the companies and industries with which the Division has been working. This is due to lengthy litigation hearings at the state level, adjudication hearings over proposed actions issued by the state or local agency and disputed by the company involved, challenges of the SIP for particulates by industries the lack of a SIP for sulfur oxides and the fuel shortage. Delays have also been experienced with companies which are on compliance schedules but have not been keeping up with the schedule — none so far have been prosecuted for this failure. Neither the city's nor the state's regulations and enforcement procedures are entirely satisfactory for bringing sources promptly into compliance.

Enforcement of the regulations has involved problems but it has resulted in some decreases in emissions. There appears to have been a general 90 percent decrease in pollutant emissions by some companies during the last decade — how much of a decrease and by how many companies is not known. Since 1970 a few major problem sources have drastically reduced their emissions but this probably only affects local air quality.

CONCLUSIONS

Cleveland and Cuyahoga County experience TSP concentrations which are among the highest in the State of Ohio. The high TSP concentrations are the result of emissions from the large numbers of industries in the city and county, fugitive dust and emissions in the industrial areas of the city, and shoreline particulate emissions influenced by Lake Erie's effects on dispersion. TSP concentrations have been gradually decreasing over time due to decreasing emissions from coal combustion and, to a lesser extent, from industrial processes and fuel combustion. Problems with enforcing the regulations have resulted in delays in achieving compliance. It is difficult to determine where emissions have been reduced and what the emission problem areas are for future work because there are no adequate inventories for Cuyahoga County. Further and considerable decreases in particulate emissions would be anticipated if regulations are enforced and progress towards full compliance is made. The high TSP concentrations presently experienced will probably also decrease considerably as emissions decrease. But it is likely that some of Cleveland's characteristics — Lake Erie's effects on meteorology, the land use patterns, the industrial valley, and fugitive emissions and dust — will prevent the TSP standards from being attained in certain areas of the city.

APPENDIX A

SUPPLEMENTARY INFORMATION

Table A-1. REGULATIONS OF THE OHIO AIR POLLUTION CONTROL BOARD

AP-3-06 — Air Quality Control Regions in the state are classified according to priority (I, II, or III) based upon measured ambient air quality.

AP-3-07 — Visible emissions darker than Ringelmann 1 or 20 percent opacity are not permitted. Visible emissions not darker than Ringelmann 3 or 60 percent opacity are permitted for not more than 3minutes in any 60 minute period.

AP-3-08 — Open burning of refuse is prohibited with certain exceptions.

AP-3-09 — Reasonable precautions shall be taken to prevent from becoming airborne particulate matter from materials handling transport or storage, or the use, construction, or demolition of buildings or roads. If emissions from a building or equipment cause a nuisance, the Board may order sealing off, ventilating, and treating the discharge.

AP-3-10 — Emissions from incinerators shall not exceed 0.1 pounds per 100 pounds of charge for incinerators of greater than or equal to 100 pounds per hour, or 0.2 pounds per 100 pounds of charge for incinerators of less than 100 pounds per hour capacity.

AP-3-11 — Emissions of particulates caused by fuel combustion in fuel-burning equipment in excess of the quantity shown in Figure A-1 are prohibited.

AP-3-12 — Emissions of particulates from any source in excess of the amount shown in Figure A-2 are prohibited.

Table A-2. CLEVELAND AIR POLLUTION CODE

Chapter 7 — A permit is required for the construction or modification of any process or equipment that may be a source of air contaminant. If work is not begun within 6 months nor completed within 1 year after the permit is issued, the permit shall expire.

Chapter 9 — An inspection and a permit are required for the operation of any process or equipment that may be a source of air contaminant. Inspections shall occur at least once every 2 years. Breakdowns of equipment must be reported. Variances must be applied for and approved.

Chapter 11 — Visible emissions of a shade darker than Ringelmann 1 from a new source (built or installed after 31 December 1971) are not permitted; or of a shade not darker than Ringelmann 2 are not permitted for more than 3 minutes in any hour. Visible emissions of a shade darker than Ringelmann 2 from an existing source are not permitted; or of a shade not darker than Ringelmann 3 are not permitted for more than 5 minutes in any hour. Visible emissions from refuse burning equipment, diesel locomotives, or diesel-powered steamships darker than Ringelmann 1 are not permitted.

Chapter 13

Section 1 — Particulate emissions from fuel-burning equipment using less than 10 million Btu per hour total input shall not exceed 0.6 lb per 1 million Btu heat input. Emissions from sources with heat input greater than or equal to 10 million Btu per hour shall not exceed those allowed as shown in Figure A-3.

Section 2 — Particulate emissions from refuse-burning equipment of less than or equal to 175 pounds per hour of refuse charged shall not exceed 0.4 lb per hour. For installations charging more than 175 pounds per hour of refuse, Figure A-4 shows the allowable particulate emission limitation.

Section 3 — Particulate emissions from process equipment in excess of the permitted emissions as shown in Figure A-2 are prohibited.

Chapter 15

Section 1 — Open fires are allowed with written approval of the Commissioner.

Section 3 — Materials handling in the open air which allows particulate matter to become airborne which exceeds Ringelmann 1 or a TSP concentration of 500 $\mu g/m^3$ at or beyond the property line for 1 hour or more is not allowed.

Section 4 — Emissions which are a nuisance are prohibited.

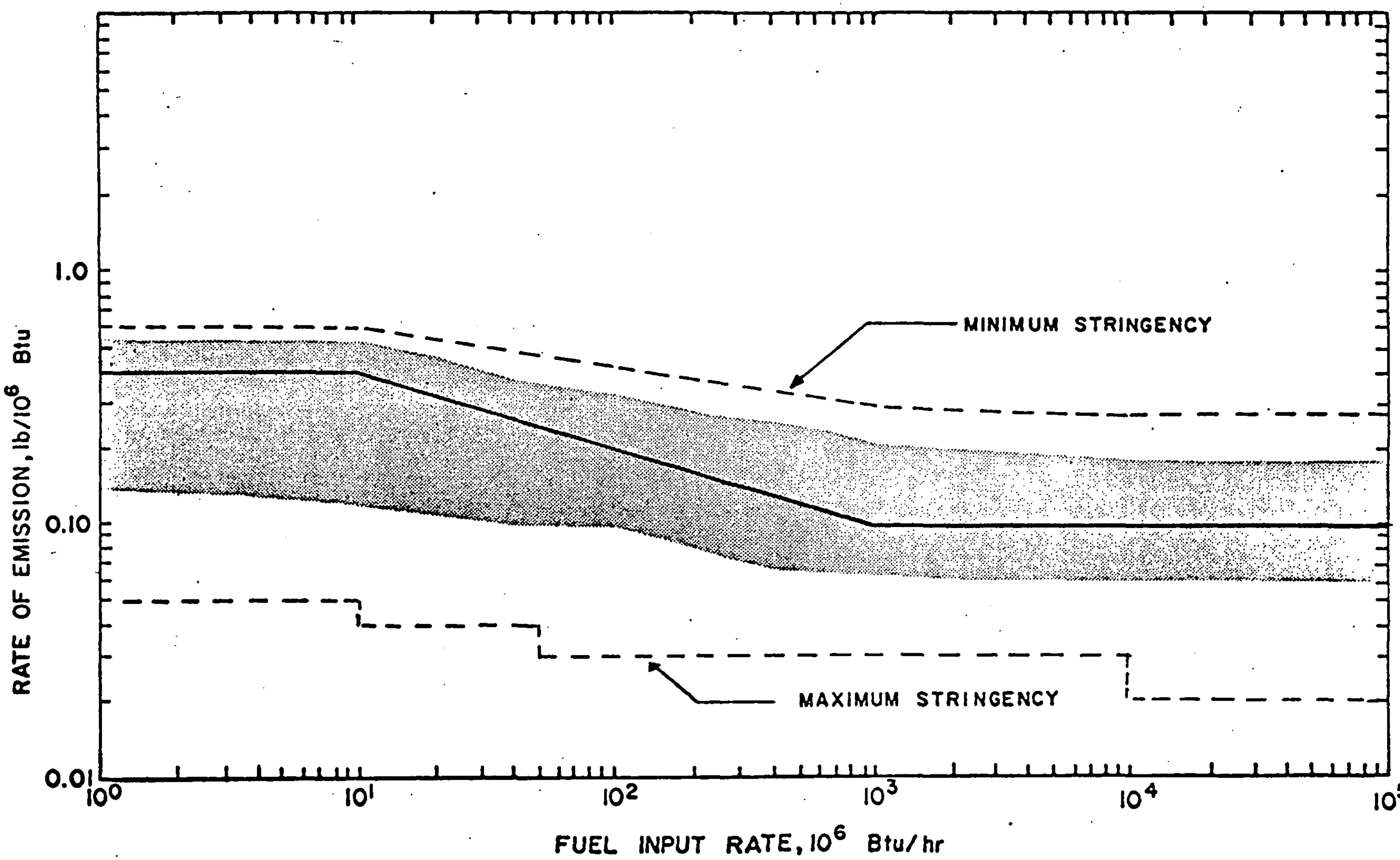


Figure A-1. Fuel combustion emissions regulation for Cleveland and the State of Ohio

Figure A-1. Fuel combustion emissions regulation for Cleveland and the State of Ohio

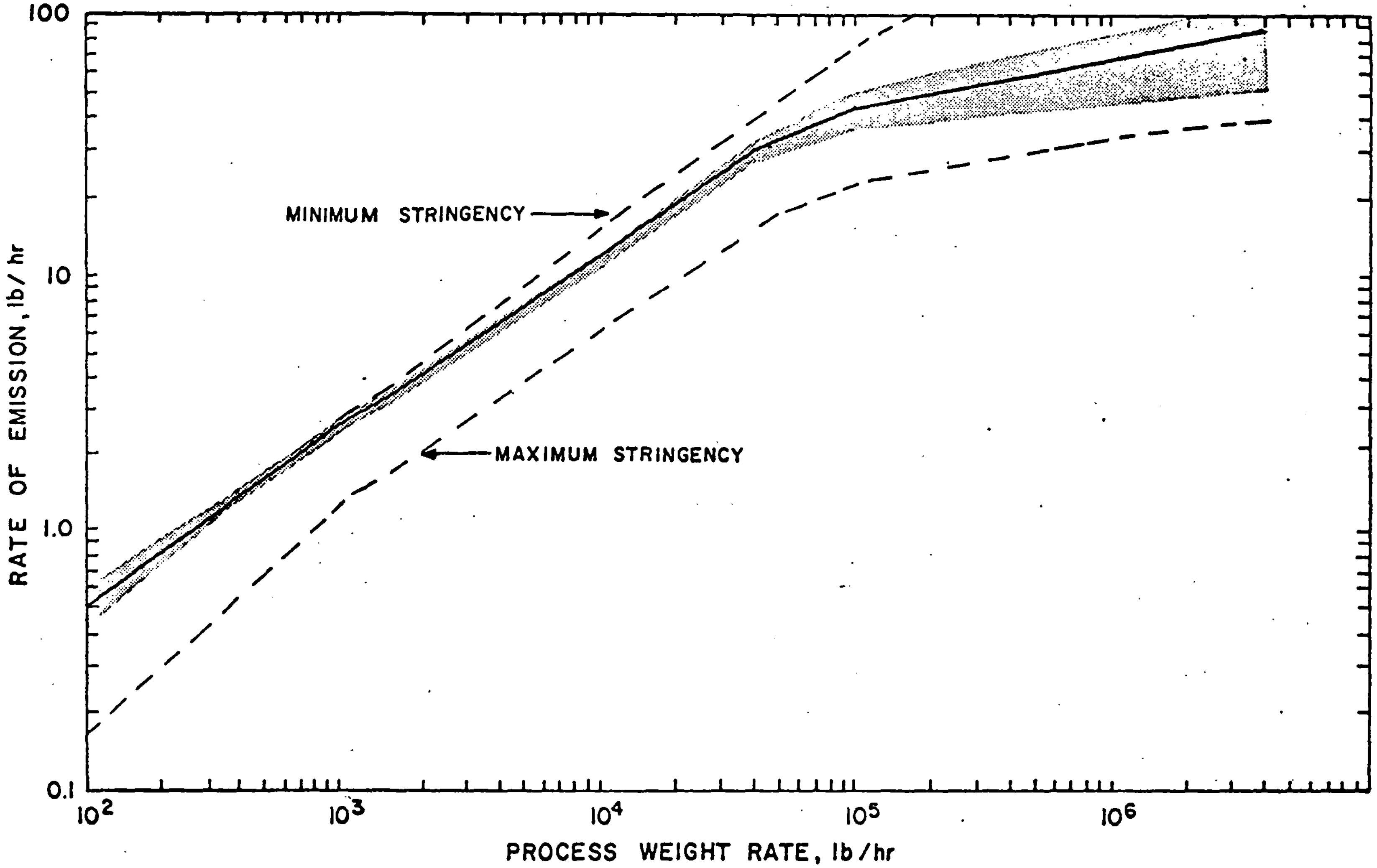


Figure A-2. Process weight regulation for the State of Ohio and the City of Cleveland

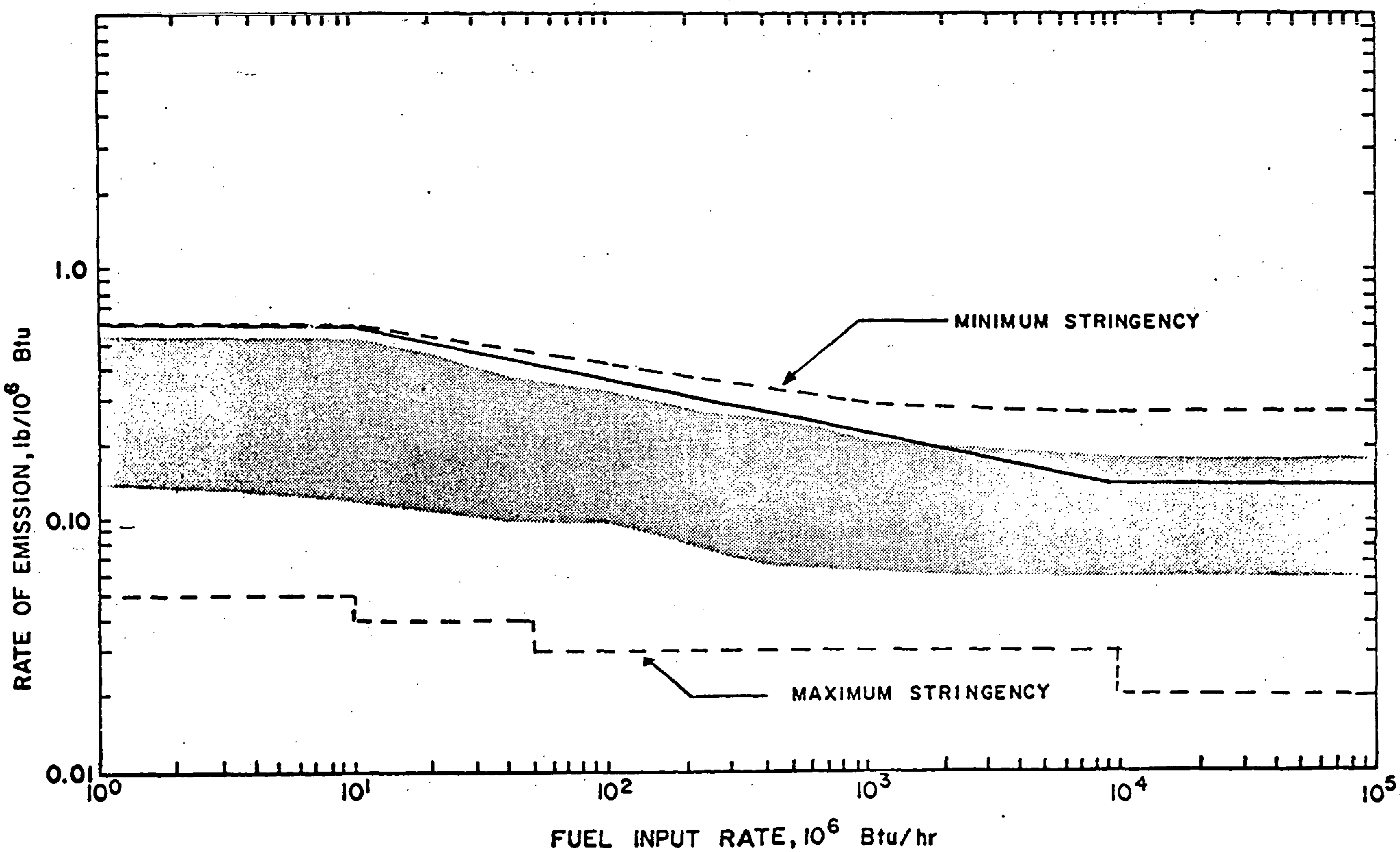


Figure A-3. Fuel combustion emissions regulation for the City of Cleveland

FUEL INPUT RATE, 10^6 Btu/hr

Figure A-3. Fuel combustion emissions regulation for the City of Cleveland

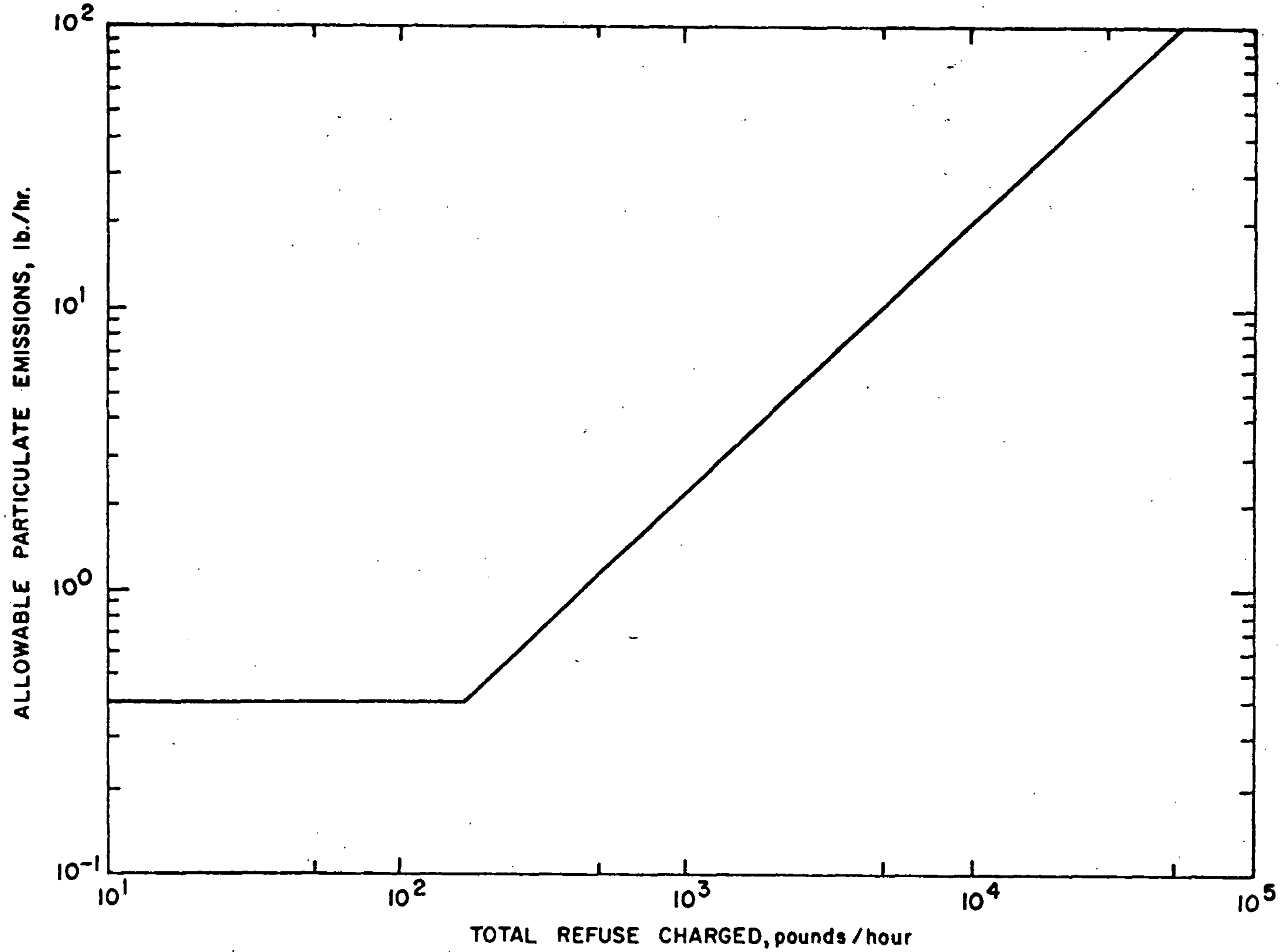


Figure A-4. Refuse burning equipment emissions regulation for the City of Cleveland

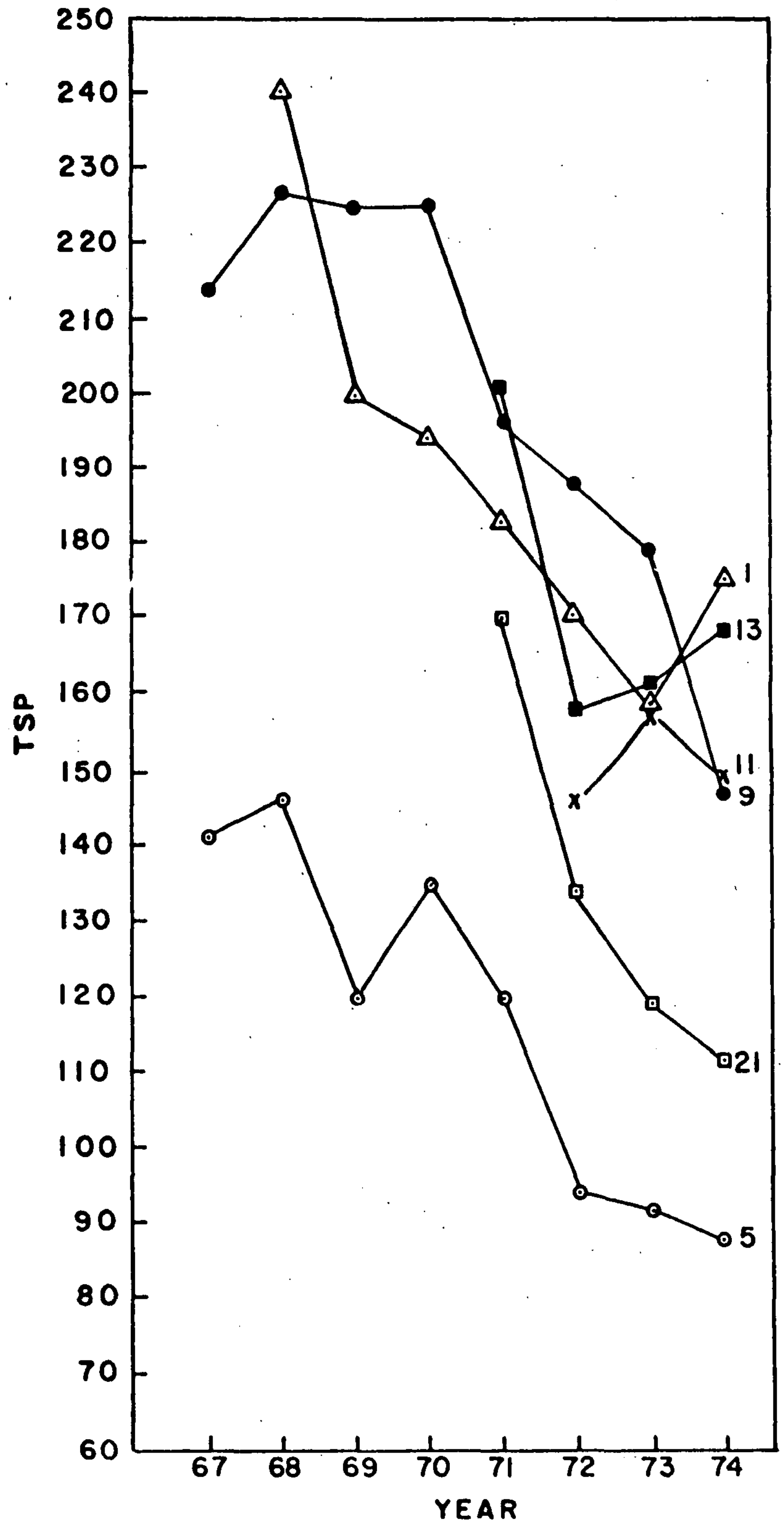


Figure A-5. TSP trends — center city, Cleveland

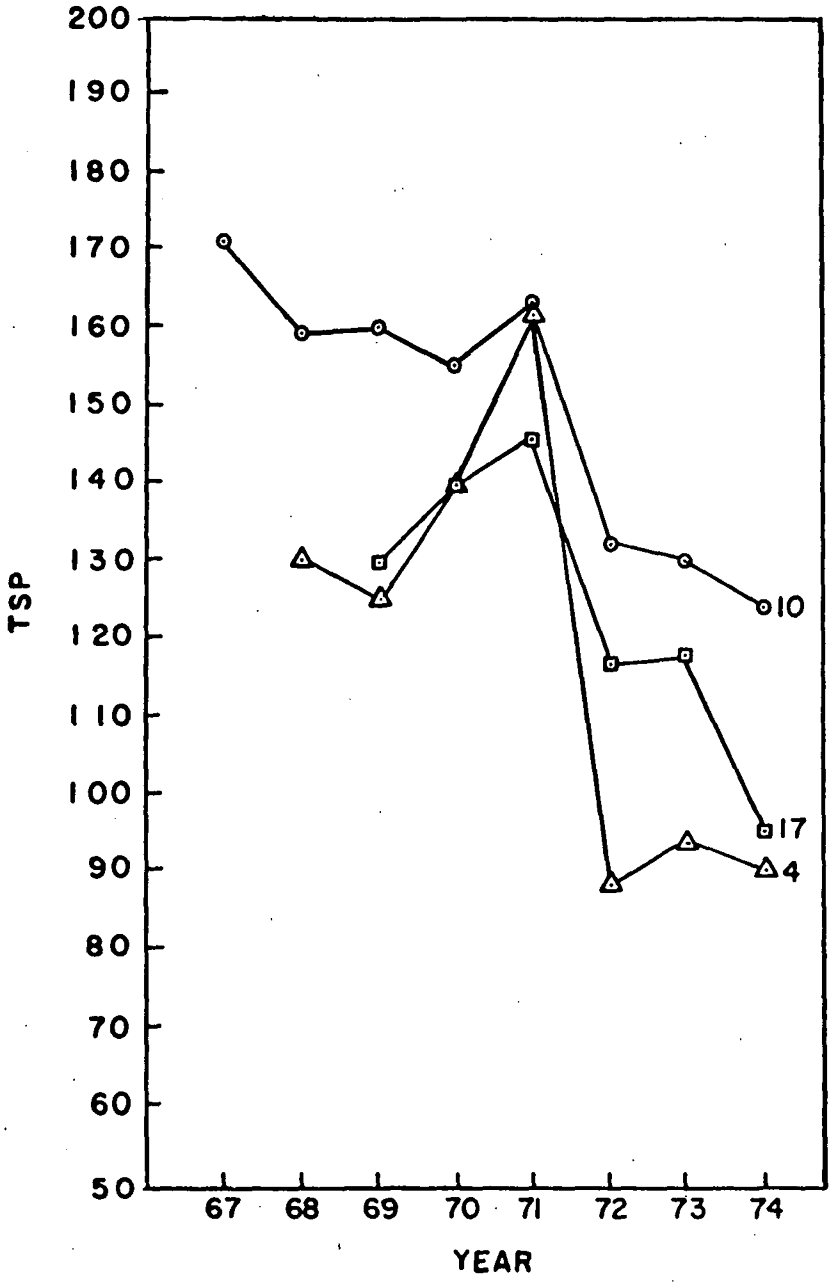


Figure A-6. TSP trends — east of center city, Cleveland

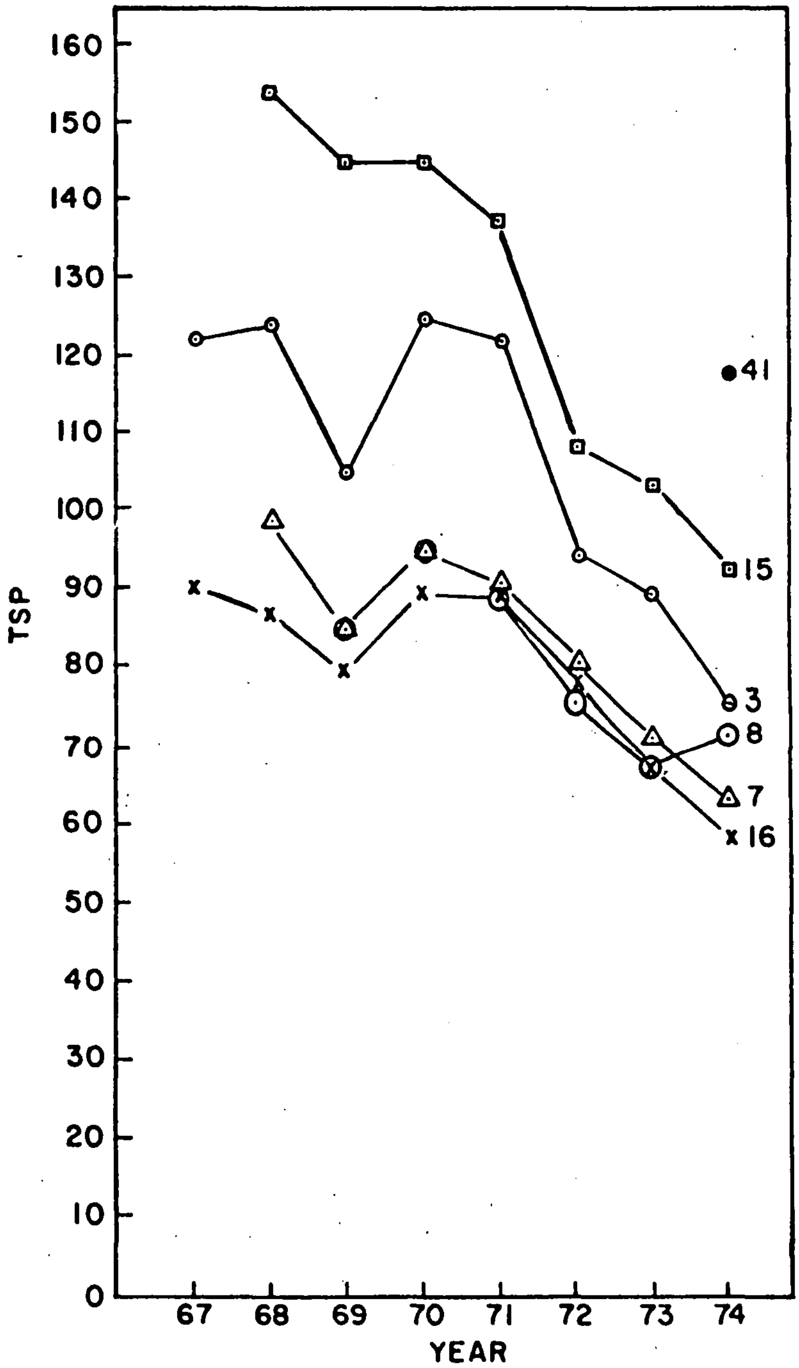


Figure A-7. TSP trends - west of center city, Cleveland

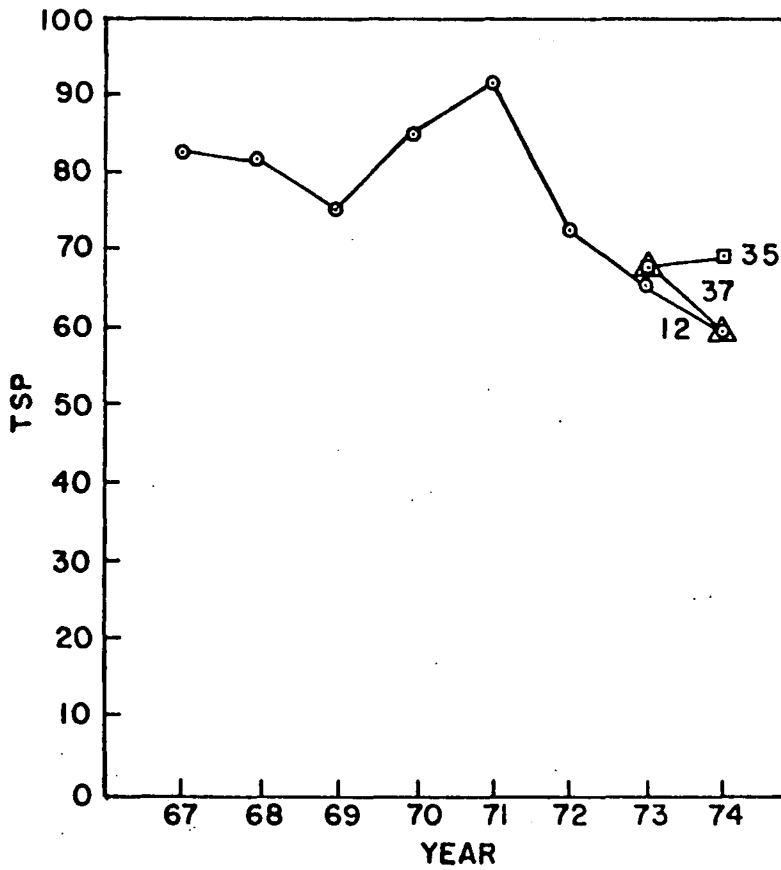


Figure A-8. TSP trends — south of Cleveland

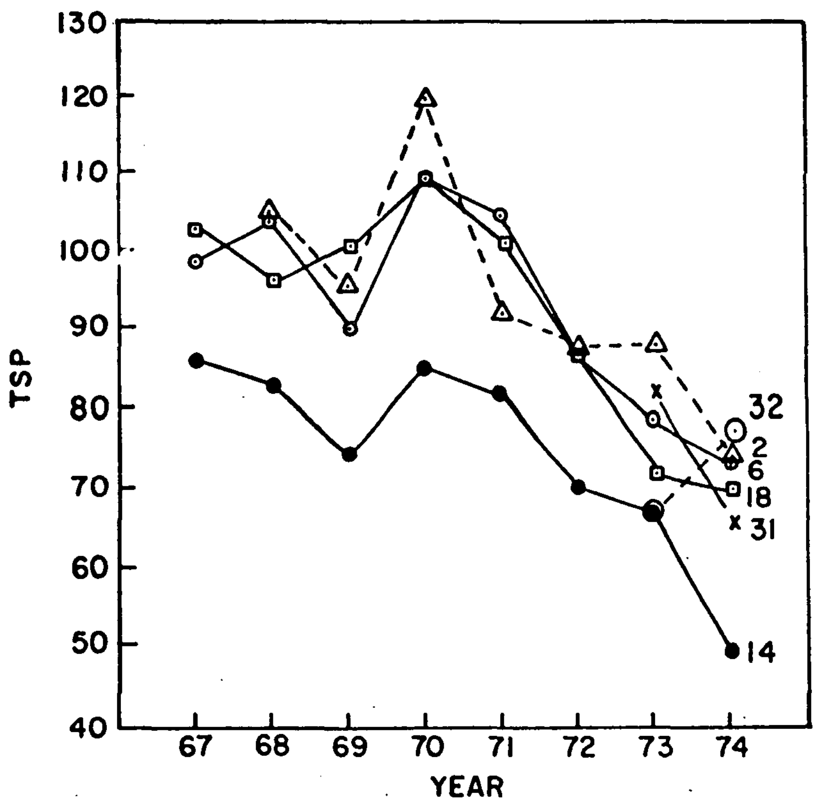


Figure A-9. TSP trends — east of Cleveland

Table A-3. SAMPLING SITE INFORMATION

SAROAD code	GCA code	Site name	Address	City	Easting	Northing	Site characteristics	Height	Start date
36 1300 013 H06	1	Air Pollution Control Lab	2785 Broadway	Cleveland	443.8	4592.4	C-I	20	67
36 1300 024 H01	2	Audubon J.H.S.	3055 E. Blvd.	Cleveland	449.1	4591.5		44	69
36 1300 009 H01	3	Brooklyn YMCA	W. 25th and Denison	Cleveland	441.4	4588.7	S-R	50	66
36 1300 001 H01	4	Cleveland Health Museum	8711 Euclid Ave.	Cleveland	447.9	4594.7	C-R	24	69
36 1300 005 H01	5	Cleveland Pneumatic Tool	E. 77th and Marble	Cleveland	446.4	4589.3	S-R, I	59	66
36 1300 003 H01	6	Collinwood H.S.	E. 152nd and St. Clair	Cleveland	452.1	4600.1		48	66
36 1300 011 H01	7	Cudell Recreation Center	W. Blvd. and Detroit	Cleveland	437.2	4592.0		30	66
36 1300 010 H01	8	Estabrook Recreation Center	Fulton and Memphis	Cleveland	439.6	4588.1		30	66
36 1300 008 H01	9	Fire Station No. 13	4749 Broadway	Cleveland	445.1	4591.3	S-R, I	23	67
36 1300 012 H01	10	Fire Station No. 19	E. 55th and St. Clair	Cleveland	445.6	4596.8	C-C, I	25	66
36 1300 033 H01	11	St. Vincent	E. 22nd and Woodlawn	Cleveland	443.5	4593.6	C	4	70
36 1300 007 H01	12	George Washington School	16210 Lorain	Cleveland	432.0	4589.0		25	67
36 1300 026 H01	13	Harvard Yards	4510 E. 49th	Cleveland	444.8	4588.2	C-I	60	69
36 1300 006 H01	14	J. F. Kennedy H.S.	17100 Harvard	Cleveland	452.9	4588.6	S-R, C	60	67
36 1300 027 H01	15	P. L. Dunbar School	2200 W. 28th	Cleveland	441.2	4592.2	S-R	26	69

Table A-3 (continued). SAMPLING SITE INFORMATION

SAROAD code	GCA code	Site name	Address	City	Easting	Northing	Site characteristics	Height	Start date
36 1300 020 H01	16	Almira School	W. 98th and Almira	Cleveland	437.3	4590.1		35	66
36 1300 017 H01	17	Fire Station No. 29	E. 105th and Superior	Cleveland	448.6	4596.6		30	67
36 1300 015 H01	18	J. Adams H.S.	3817 E. 116th	Cleveland	442.7	4589.2		50	66
36 1300 021 H01	19	J. F. Rhodes H.S.	5100 Biddulph	Cleveland	439.7	4586.6		40	60
36 1300 028 H01	20	St. Joseph H.S.	18491 Lake Shore	Cleveland	454.1	4604.7		37	69
36 1300 029 H01	21	Supplementary Education Center	1365 E. 12th	Cleveland	442.6	4594.8	C-C	65	70
36 0420 001	31	Beachwood	2551 Fairmont	Beachwood	458.4	4592.7		22	73
36 0460 001	32	Bedford Hgts. Fire	5661 Perkins	Bedford Hgts.	458.3	4583.7		20	73
36 5340 001 H01	35	Parma City Hall	6611	Parma	437.6	4581.5	S-C	35	73
36 4980 001 H01	37	N. Olmsted Fire Station	25128 Lorain	N. Olmsted	421.0	4584.2	S-R	18	73
	41	St. Theodosius		Cleveland					74
	42	Independence		Independence					74
	43	Noble School		Euclid					74
	44	Thomas Jefferson		Euclid					74
	45	Westlake		Westlake					74

APPENDIX B

PARTICLE CHARACTERIZATION

For most of the study cities members of the GCA study team acquired hi-vol filters from the 1974 filter banks of the cognizant local agencies. In addition, several filter samples for 1974 and selected earlier years were obtained from state and federal filter banks. Although some filters underwent chemical and/or detailed physical analysis, the principal purpose of obtaining filters was to utilize optical microscopy to identify each of the constituents that comprised more than 5 percent of the particulate mass. The selected filters, which were representative of several different site types and TSP levels within each study area, were returned to a clean room at GCA/Technology Division and carefully inspected for artifacts and evidence of sampler or filter malfunctions.

Each filter was then assigned a randomly generated five digit number which served as the only identifier for the filter sample so that each analyst had no information concerning the city, site, TSP loading or probable local sources associated with the sample. Furthermore, the use of two laboratories for the microscopy, coupled with the randomly generated identifying numbers, permitted a fairly comprehensive quality control program in the form of blind replicate analyses. Since both laboratories utilized more than one analyst, these procedures resulted in as many as four microscopists observing samples from the same filter and, in some cases, the same analyst examining replicate samples from the same filter as many as three times.

The results of this quality control effort, which are presented in Volumes I and II, warn against relying very heavily on the results of any one filter analysis. However, the random match-up between analyst and filter sample should minimize systematic bias in composited results.

Twenty-one filters from five sites were selected for analysis in Cleveland and the meteorological data from the Hopkins International Airport for the selected sampling days are summarized in Table B-1. To gain some insight into the contribution of secondary particulates, much of which is too small to be observed by the microscopists, the annual average sulfate and nitrate concentrations for the NASN site are shown in Table B-2. The results for each of the filters submitted for routine analysis are presented in Table B-3. The results for the filters at each site have been averaged to give a composite of the particulate composition as shown in Table B-4. Six filters underwent replicate analyses, and the results are presented in Table B-5.

The composite particulate characterization for all filters from Cleveland that underwent routine analysis, presented in Table B-6, shows that minerals predominate but that the contribution of combustion products is also high. Indeed only one other study city was found to have higher average percent combustion products and only two cities displayed as low or lower levels of minerals. The combustion products category is comprised primarily of glassy fly ash and coal soot which reflects the substantial utilization of coal by industry and utilities.

The Supplementary Education Center in the downtown area showed considerably higher levels of minerals than the other sites. This is most likely the result of local fugitive emissions from the nearby parking lots and urban renewal areas. Rubber was also detected on most filters although its average citywide contribution amounted to less than 10 percent and only eighth highest in that category of the 14 study cities. The J.F. Kennedy High School had the highest average percent rubber although the TSP levels are generally low at that site.

Table B-1. METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (CLEVELAND HOPKINS INTERNATIONAL AIRPORT)

Date	Precipitation, in.		Wind speed, mph		Wind direction, deg	
	Day of obs.	Preceding day	Average	Resultant	3-hour observation	Resultant
3/18/74	0.08	t	13.8	10.4	290, 300, 260, 260 240, 200, 200, 190	240
4/17/74	0	0	7.3	5.8	220, 220, 210, 240 300, 300, 230, 210	250
4/29/74	t	t	11.7	9.3	190, 220, 210, 220 290, 270, 310, C	240
6/04/74	0	0.05	7.6	7.0	180, 220, 190, 210 240, 220, 180, 170	200
6/28/74	0.32	0	7.1	5.2	60, 110, 140, 90 30, 60, 80, 170	80
7/31/74	0	t	7.5	5.7	250, 220, 230, 230 280, 290, 320, 180	250

Note: C = Calm
t = Trace

Table B-2. ANNUAL AVERAGE CONCENTRATIONS OF SULFATE AND NITRATE IONS AT THE CLEVELAND, OHIO, NASN SITE NO. 361300001 ($\mu g/m^3$)

Year	Sulfate		Nitrate	
	Arithmetic mean	Geometric mean	Arithmetic mean	Geometric mean
1972	16.62[a]	15.34[a]	3.63[a]	3.05[a]
1973	12.46[a]	11.66[a]	4.05[a]	3.03[a]
1974	10.50[a]	9.97[a]	1.34[a]	1.02[a]

[a]Indicates insufficient data for statistically valid year.

Table B-3a. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CLEVELAND AND VICINITY (SUPPLEMENTARY EDUCATION CENTER — NO. 21)

Date	18 March 1974			17 April 1974			29 April 1974			4 June 1974			28 June 1974			31 July 1974		
TSP (μg/m^3)	71			264			172			472			160			121		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(8)	2-90	10	(8)	1-60	12	(5)	<1-50	12	(6)	<1-50	15	(4)	<1-62	12	(7+)	<1-60	10
Quartz	3+			1+			2			1			1			3		
Calcite	2+			3			2			2			1			4		
Feldspars	1			1-														
Hematite	1			3			1			3			2			1-		
Mica	1-																	
Combustion Products	(1+)	<1-60	15	(2-)	<1-48	1	(4)	<1-45	9	(4-)	<1-150	30	(6)	<1-60	15	(2)	<1-48	6
Soot:																		
Oil																		
Coal				1+			1			1			1-			1-		
Coked coal soot	1-																	
Glassy fly ash	1-			1-			3			2+			5+			1		
Incinerator fly ash																		
Burned wood																		
Burned paper																		
Magnetite																1-		
Biological Material	(0+)			(0+)			(0+)			(0+)			(0+)			(0+)		
Pollen																		
Spores																		
Paper																		
Starch																		
Misc. plant tissue																		
Miscellaneous	(1-)	10-45	31	(0+)			(1)	8-130	30	(1-)	2-30	18	(0+)			(1-)		
Iron or steel										1-								
Rubber	1-						1									1-		

Table B-3b. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CLEVELAND AND VICINITY (HARVARD YARDS — NO. 13)

Table B-3b. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CLEVELAND AND VICINITY (HARVARD YARDS — NO. 13)

Date	18 March 1974			17 April 1974			29 April 1974			31 July 1974		
TSP ($\mu g/m^3$)	150			327			238			244		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(5)			(4)			(4)			(7)	<1-45	10
Quartz	2	5-90	30	1+	5-80	30	2	10-50	25	3		
Calcite	1+	1-125	25	1	2-60	20	1	5-50	20	3		
Feldspars	1-	1-100	25	1	2-50	20	1-	5-50	20			
Hematite	1	1-50	10	1	1-50	20				1		
Mica												
Combustion Products	(3)			(5+)			(5+)			(3-)	<1-80	1
Soot:												
Oil	1	1-40	25	1	20-100	30	1+	10-200	100			
Coal				1+	5-80	30	2+	2-70	30	1-		
Glassy fly ash	1	5-100	35	1-	5-40	25	1+	4-40	20	2		
Incinerator fly ash	1-	1-75	40	1	5-100	30						
Burned wood												
Burned paper												
Magnetite				1+	5-50	25						
Biological Material	(0+)			(0+)			(0+)			(0+)		
Pollen												
Spores												
Paper												
Starch												
Misc. plant tissue												
Miscellaneous	(2)			(1)			(1-)			(1-)		
Iron or steel	2	5-75	40									
Rubber				1	20-150	70	1-	10-50	25			

Table B-3c. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CLEVELAND AND VICINITY (FIRE STATION NO. 13 — NO. 9)

Date	18 March 1974			29 April 1974			4 June 1974			25 June 1974			31 July 1974		
TSP (μg/m³)	243			339			141			134			163		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(6)	<1-30	8	(8+)	<1-20	6	(3)			(3)			(3)		
Quartz	2			1			1-	5-60	20	1-	2-35	25	1+	10-75	30
Calcite	2			2+			1+	2-75	25	1+	1-15	8	1-	2-45	20
Feldspars							1-	2-50	15	1-	1-20	10	1-	5-100	25
Hematite	2			5			1-	1-100	15	1-	<1-15	5			
Mica															
Combustion Products	(4)	<1-180	9	(1)	<1-45	5	(5+)			(7)			(5)		
Soot:															
Oil	1						1	5-100	35	3			2-	10-100	30
Coal	2-			1-			2-	5-100	25	1+			2	5-75	30
Glassy fly ash	1			1-			1+	4-60	20	2+			1-	5-60	30
Incinerator fly ash							1-	1-70	20						
Burned wood															
Burned paper															
Magnetite							1-	5-50	20				1-	1-40	15
Biological Material	(0+)			(0+)			(0+)			(0+)			(0+)		
Pollen															
Spores															
Paper															
Starch															
Misc. plant tissue															
Miscellaneous	(0+)			(1-)			(2-)			(0+)			(2)		
Iron or steel													1-	5-20	10
Rubber							2-	20-100	40				1+	20-100	40

Table B-3d. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CLEVELAND AND VICINITY (J. F. KENNEDY HIGH SCHOOL — NO. 14 AND CLEVELAND [illegible]

Table B-3d. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CLEVELAND AND VICINITY (J. F. KENNEDY HIGH SCHOOL — NO. 14 AND CLEVELAND HEALTH MUSEUM — NO. 4)

Site	J. F. Kennedy High School — No. 14									Cleveland Health Museum — No. 4								
Date	18 March 1974			17 April 1974			29 April 1974			4 June 1974			28 June 1974			31 July 1974		
TSP ($\mu g/m^3$)	42			93			86			162			117			102		
Components	Quantity, tenths	Size range, µm	Avg. size, µm	Quantity, tenths	Size range, µm	Avg. size, µm	Quantity, tenths	Size range, µm	Avg. size, µm	Quantity, tenths	Size range, µm	Avg. size, µm	Quantity, tenths	Size range, µm	Avg. size, µm	Quantity, tenths	Size range, µm	Avg. size µm
Minerals	(4+)			(3)			(4+)			(3+)			(3+)			(6-)		
Quartz	2+	5-75	30	1	2-50	30	2	5-100	25	2	5-70	30	1+	5-35	15	2	5-120	35
Calcite	1	5-75	30	1	1-30	20	1	1-75	25	1-	1-30	10	1	1-40	20	2	2-60	30
Feldspars				1-	2-50	20	1	1-70	20				1-	5-60	25	1	2-75	25
Hematite	1-	1-25	10				1-	1-75	10				1-	1-30	10	1	1-75	15
Mica																		
Other										1-	5-50	20						
Combustion Products	(3+)			(5+)			(3+)			(6+)			(4+)					
Soot:																		
Oil	9	5-75	30	2+	5-100	30	1	10-100	25	2	2-50	20	1	10-100	40	1	10-70	25
Coal	8	5-80	30	2	5-60	30	1+	5-150	35	1+			1+	5-100	30	2	1-100	35
Glassy fly ash	1+	2-50	15	1+	2-25	10	1	5-60	30	2+	2-40	15	1-	5-40	20	1-	5-50	20
Incinerator fly ash	1-	1-50	20				1	5-100	30				1	1-150	30			
Burned wood																		
Burned paper																		
Magnetite										1-						1-	5-25	15
Biological Material	(0+)			(0+)			(1-)			(0+)			(1-)			(0+)		
Pollen							1-	20-50	30									
Spores																		
Paper																		
Starch																		
Misc. plant tissue																		
Miscellaneous	(2)			(1)			(1+)			(0+)			(1+)			(1-)		
Iron or steel																		
Rubber	2			1	20-200	50	1+	20-100	50				1+	20-100	35	1-	20-120	50

Table B-4. COMPOSITE SUMMARY OF FILTER ANALYSES FOR SELECTED SITES IN CLEVELAND AND VICINITY

Site	Supplementary Education Center — No. 21		Harvard Yards No. 13		Fire Station No. 13 — No. 9		Cleveland Health Museum No. 4		J.F. Kennedy High School No. 14	
No. of filters	6		4		5		3		3	
	Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity percent	
Components	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Minerals	(65)	40-82	(50)	38-70	(47)	28-85	(42)	35-56	(41)	32-45
Quartz	21	10-35	22	15-31	11	5-20	18	15-20	19	12-25
Calcite	24	9-40	16	8-29	16	6-26	12	7-18	12	10-12
Feldspars	2	0-9	5	0-8	3	0-5	5	2-8	6	2-10
Hematite	17	4-30	7	2-10	17	2-50	6	2-10	4	2-6
Mica	<1	0-1			tr	0-tr			<1	0-1
Other	1	0-1			tr	0-tr	1	0-4		
Combustion Products	(31)	13-60	(40)	26-54	(44)	10-70	(49)	37-65	(43)	35-55
Soot:										
Oil			9	0-15	14	0-30	13	8-20	12	8-20
Coal	8	0-13	11	0-25	14	4-20	16	15-19	14	8-20
V.F. soot					tr	0-tr				
Coked coal soot	1	0-6								
Glassy fly ash	21	4-55	12	5-21	13	5-25	13	5-25	11	5-15
Incinerator fly ash			4	0-10	1	0-4	3	0-8	5	0-10
Burned wood										
Burned paper										
Magnetite	1	0-5	4	0-15	2	0-6	4	2-5	1	0-2
Biological Material	(<1)		(1)		(<1)		(2)		(2)	
Pollen	tr	0-tr	1	0-2	tr	0-tr	<1	0-1	2	tr-5
Spores	tr	0-tr	tr	0-tr	tr	0-tr			tr	0-tr
Paper	tr	0-tr	tr	0-tr	tr	0-tr	<1	0-1	tr	0-tr
Starch	tr	0-tr	tr	0-tr	tr	0-tr	<1	0-1	tr	0-tr
Misc. plant tissue	tr	0-tr	tr	0-tr	tr	0-tr	<1	0-1	tr	0-tr
Miscellaneous	(4)	tr-10	(9)	4-22	(9)	(tr-22)	(7)		(14)	10-20
Iron or steel	1	<1-5	5	0-20	2	0-5	<1			
Rubber	3	0-9	4	2-9	6	0-16	7	tr-15	14	12-20
Graphite					1	0-2	<1	0-1		

Table B-5. RESULTS OF REPLICATE ANALYSES OF CLEVELAND FILTERS

Site	Fire Station No. 13 — No. 9		Harvard Yards — No. 13					Supplementary Education Center — No. 21					
Date	4 June 1974		18 March 1974			31 July 1974		29 Apr. 1974		4 June 1974		28 June 1974	
TSP ($\mu g/m^3$)	141		150			244		172		472		160	
Laboratory	A	B	A	A	B	A	A	A	B	A	B	A	A
Analysis	1	1	1	2	1	1	2	1	1	1	1	1	2
Components													
Minerals	(31)	(31)	(50)	(63)	(45)	(70)	(63)	(50)	(39)	(59)	(64)	(40)	(42)
Quartz	6		20	25		31	27	19		12		10	11
Calcite	14		15	25		29	28	20		18		9	9
Feldspars	5		5										
Hematite	6		10	15		10	7	10		29		20	21
Mica								1					
Other							1					1	1
Combustion Products	(53)	(66)	(28)	(27)	(54)	(26)	(32)	(40)	(60)	(36)	(35)	(60)	(57)
Soot:													
Oil	12	} 14	12		} 11				} 5		} 6		
Coal	15			1		5	8	9		12		5	5
Glassy fly ash	16	} 52	10	18	} 43	21	24	31	} 55	24	} 29	55	50
Incinerator fly ash	4		6										
Burned wood													
Burned paper													
Magnetite	6			8			1						2
Biological Material	(<1)	(3)	(<1)	(<1)	(1)	(<1)	(1)	(<1)	(1)	(<1)	(1)	(<1)	(<1)
Pollen	tr					<1	<1	<1					
Spores							<1						
Paper	tr		tr									tr	
Starch	tr							tr					
Misc. plant tissue	tr			<1			1						
Leaf trichomer								<1		tr		<1	<1
Miscellaneous	(16)	(<1)	(22)	(10)	(<1)	(4)	(4)	(10)	(<1)	(5)	(<1)	(<1)	(1)
Iron or steel			20	8		<1	4	1		5		tr	1
Rubber	16		2	2		3		9					<1

Table B-6. CITYWIDE COMPOSITE SUMMARY OF FILTER ANALYSES IN CLEVELAND

No. of filters: 21

Components	Quantity, percent Average	Range
Minerals	(51)	28-85
Quartz	18	5-35
Calcite	17	6-40
Feldspars	4	0-10
Hematite	12	2-50
Mica	<1	
Other	<1	
Combustion Products	(40)	10-70
Soot:		
Oil	9	0-30
Coal	12	0-25
Misc. soot	<1	
Glassy fly ash	15	4-55
Incinerator fly ash	2	0-10
Burned wood		
Burned paper		
Magnetite	2	0-15
Carbon black		
Other		
Biological Material	(1)	<1-5
Pollen	1	0-5
Spores	<1	
Paper	<1	
Starch	<1	
Misc. plant tissue	<1	
Leaf trichomer		
Miscellaneous	(8)	tr-22
Iron or steel	2	0-20
Rubber	6	0-20
Other	<1	

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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[ABST]RACT

[This] document is one volume of a sixteen-volume report presenting an overall [asse]ssment of the particulate problem, which was conducted by GCA/Technology [Divi]sion for EPA.

[This] particular document is one of fourteen single-area volumes that provide [work]ing summaries of data gathered in the fourteen urban areas studied. These [area] reports primarily provide documentation and background information for [Volu]me I of the study - National Assessment of the Particulate Problem - Final [Repo]rt. Volume I should be considered the primary output of the report.

[K]EY WORDS AND DOCUMENT ANALYSIS

DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
[Part]iculate Matter	Optical Microscopy	
[Tota]l Suspended Particulate	Secondary Particulates	
[Emis]sion Sources	Fuel Combustion	
[Cont]rol Methods	Process Emissions	
[Air] Quality Measurements	Fugitive Emissions	
	Fugitive Dust	
	Monitor Siting	
	Meteorology	

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