DRAFT

SUMMARY OF NATIONAL ASSESSMENT
OF THE URBAN PARTICULATE PROBLEM

Distributed At

Air Programs Regional Office Workshop
Southern Pines, N.C.

August 3-6, 1976

(This represents a portion of the draft final report on the 14 city TSP study conducted by GCA Corp. for OAQPS)

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(Please note - The Draft Final Report on the 14-city Suspended Particulate study entitled "Volume I - National Assessment of the Particulate Problem" contains Appendices A through G which support the following material.)

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ACKNOWLEDGMENTS

Numerous persons and organizations have made significant contributions to this overall study effort, and GCA/Technology Division wishes to sincerely acknowledge their participation. On-going project supervision has been received from Thompson G. Pace, Project Officer, of EPA's Control Programs Development Division. Professional staff members of the EPA Regional Offices and of the state and local agencies responsible for the case study cities have been uniformly cooperative and helpful.

Specific thanks are due to Dr. William E. Wilson and Ronald K. Patterson of the Environmental Sciences Research Laboratory, for sharing the results of their field research in several cities; to Dr. David S. Shearer and Dr. Richard J. Thompson of the Environmental Monitoring and Support Laboratory, for their analytical support; to Gerald Gipson of the Monitoring and Data Analysis Division for providing modeling results in several cities; and to David Dunbar, Edward J. Lillis, John D. Bachmann, and the staff of the Monitoring and Reports Branch for their on-going review and advice.

SECTION I

INTRODUCTION

This report presents the results of a study conducted under the auspices of the Control Programs Development Division of EPA's Office of Air Quality Planning and Standards. Its overall purpose was to assess the national particulate problem, based on case studies in 14 major urban areas, with emphasis on identifying the factors involved in the attainment or non-attainment of the National Ambient Air Quality Standards (NAAQS) for total suspended particulates (TSP). The study was intended to improve technical understanding of the TSP problem, to provide specific guidance to the states in TSP problem analysis and control strategy formulation, and to develop recommendations for EPA concerning future program direction and research needs. Consequently, this document is directed primarily at those managers and air quality planning specialists at EPA and the various state and local air pollution control agencies who are concerned with the development of TSP control programs.

GENERAL CONCLUSIONS

The study identified five factors that affect attainment and maintenance of the total suspended particulate (TSP) ambient standards. These are conceptually grouped as follows: three general categories of sources that contribute to the TSP loading at any given point, and two factors that act to modify the ambient levels measured. The three major categories of particulates are emissions from traditional sources, emissions from nontraditional sources, and natural and transported particulates. The two modifying factors are meteorology and monitoring network configuration and siting.

Traditional sources are those sources that have historically been of concern to the air pollution control community. Fuel combustion sources, solid waste disposal operations, and industrial process emissions, including both stack emissions and fugitive emissions, comprise this segment. Particulate emissions from traditional sources were found to be decreasing in relative significance as the quantities of such emissions are reduced. In spite of this, however, they are still the dominant problem in some urban areas with much heavy industry. The traditional sources that remain the greatest problem are the primary metals and mineral products industries, as well as fugitive emissions from all traditional sources.

Nontraditional sources include particulate sources that have not been controlled under existing State Implementation Plans or have been controlled inadequately. Particulate auto exhaust emissions, reentrainment of road dust, fugitive dust emissions from construction and demolition operations, dust from unpaved areas and other urban activities comprise this segment. A principal finding of the study was that particulates from these sources have prevented most urban areas from attaining the ambient standards at all sites, and that, unless controlled, they will continue to do so. Given the current downward trend in traditional source emissions, particulate matter from nontraditional sources will pose the greater problem in the on-going maintenance of the ambient standards.

Natural and transported particulates consist of those large-scale influences that are the contributors to what is frequently called "background." The long-range transport of both primary and secondary particulates, as well as naturally occurring particulates, are included in this portion. Often these particulate levels are inadequately considered in air quality planning, although their inclusion is essential for accurate quantitative planning. Such planning may well include regional scale strategies for reducing the impact of these sources on ambient levels.

Meteorological factors were identified as a partial determinant of the magnitude of ambient particulate levels. For example, precipitation can significantly affect annual average TSP concentration; a variation of as much as 20 $\mu g/m^3$ is seen over the normal range of precipitation values. Although not a factor subject to control, the variations in meteorological effects over time and in different locations must be considered in air quality management planning. The results of this study's analyses will help in doing this more quantitatively.

Network configuration and hi-vol siting affect the perception of particulate levels. Variations in siting practice and network configuration make comparisons of values between cities and neighborhoods difficult. These variations frequently distort the overall picture and constrain problem identification and subsequent strategy development which is essential for attainment/maintenance. Most of these variations are, however, within the general guidelines for monitor siting prescribed by EPA.

This study also addressed the methodological problem of quantifying the relative contributions of the various source types and categories. It is concluded that, at present, no single analytical technique, or any apparent combination, can be simply and routinely applied to a variety of situations to provide a reliable, unbiased determination of the nature or origin of the collected particles. It is possible to use microscopic and other monitoring and analytical techniques in concert to provide comprehensive particle identification analyses. However, the requisite analytical sophistication and cost constrain their use for widespread screening-level studies. Their utility is primarily in more precise study of already well-structured problems.

The study identified a number of needs for increased emphases and program re-directions. From a national perspective, two major overall control and research needs emerge:

- The regional-scale burden of transported and secondary particulates, especially sulfates, must be reduced.
- A broadly supported control effort directed at urban re-entrained dust and similar nontraditional particulate sources will be required in order to meet the present particulate standard.

STUDY APPROACH

The overall approach to the study involved the identification of those factors influencing the attainment or nonattainment of the standards, the assessment of their significance on a national basis, and the development of a recommended action program for EPA and the state and local control agencies.

The primary source of new information for this national assessment was a series of case studies in 14 major urban AQCR's. These studies involved analyzing, for each urban area, the air quality and emission data on TSP, meteorological data from the National Weather Service, the control regulations in the State Implementation Plans, planning materials maintained by EPA, and published technical articles or reference materials. Each city case study also involved a field visit to the city to conduct detailed inspections of most of the TSP monitoring sites in the area.

Although the primary purpose of the study was not to produce new analytical data, several specific analyses were performed. Selected hi-vol filters from each of the 14 case study cities were analyzed by optical microscopic techniques to provide information on the types and sources of the particles collected. Some of these filters were reanalyzed for quality control by the same or other microscopists and laboratories; others were analyzed by EPA for metals and nonmetallic inorganic ions by standard NASN analytical procedures. EPA provided information from special field studies in two of the study cities, including wind directional monitoring, diurnal variations in elemental composition, and particle sizing data. Data resulting from all these analyses are compiled in Volume II of this report, and discussion of the results is included in this volume or in the individual city volumes as appropriate.

ORGANIZATION OF THE STUDY REPORT

This document is Volume I of the final study report, which consists overall of 16 separately bound volumes. It summarizes the data from the other volumes and should be considered the primary product of the study. Volume II summarizes the analytical data developed during the study, and Volumes III through XVI are the working documents compiled for discussion purposes for each individual city. The subject of each volume is listed below:

- Volume I - National Assessment of the 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

The remainder of Volume I is organized as follows:

- Section II - Presents the general findings of the study. Summarizes the findings in each individual case study city and identifies the components of the five major factors influencing TSP levels.
- Section III - Presents the overall national assessment of the significance of each of the five factors. Places in perspective the components of each of these factors and quantifies their relative contributions to air quality.
- Section IV - Summarizes problem assessment techniques, the attainment factors identified in the city studies, and the implications of the study for control strategy development.
- Section V - Provides the detailed recommendations.
- Appendices - Various supportive and reference materials.

SECTION II

GENERAL FINDINGS OF THE STUDY

The individual reviews of the TSP attainment situation in the 14 study cities provided a wide range of general findings. Some of these findings are specific to individual cities, and others are generally applicable throughout the study cities. The analysis of these findings among the different cities serves as the basis for an interpretation of TSP attainment nationwide. This section summarizes the general findings from the city case studies (reported in Volumes III to XVI) and identifies the major factors affecting the TSP attainment problem.

STUDY CITY ANALYSIS

Selection Process

The 14 cities (AQCRs) used in the case studies were selected to represent a cross section of urban areas. Such factors as proximity to bodies of water, topography, meteorology, degree and type of industrialization, fuel usage, and air quality levels were considered. As shown in Figure 1, the study cities are dispersed around the contiguous 48 states, with many located in the East where a large portion of the population and industry of the United States is concentrated. In nature and density, they range from the old industrial cities of the east coast to the newer, less congested cities of the plains and west coast, and they include a cross section of the climatological regimes of the nation. The cities range in size from Philadelphia, the nation's

Figure 1. Geographical distribution of 14 study cities

fourth largest urban area, to Chattanooga, a small industrial city in the southern mountains. Basic statistics on population, topography, and employment for each of the 14 cities are presented in Table 1.

Two of the major factors that are important in understanding the potential for a TSP problem are the industrial nature and dispersion characteristics of an area. The industrial nature indicates the general level of emissions from major point sources, while the dispersion characteristics dictate the degree to which these emissions affect ambient levels of particulates; Table 2 lists the 14 cities classified according to the possible combinations of these two characteristics. Considered under the category of dispersion characteristics are non-urban particulate levels, extremes in rainfall, sea breezes, and topography. Therefore, cities such as Miami, San Francisco, and Providence, which are dominated by their proximity to the ocean, offer good dispersion qualities; cities with ventilation dominated by valley topography (Chattanooga, Birmingham, and Denver) are considered to have adverse dispersion characteristics. Industrialization was a judgmental categorization based upon the level of employment in the manufacturing sector, the nature of the manufacturing, and the density of emissions.

Table 3 summarizes air quality and Table 4 characterizes sources and emissions for the 14 cities, which are grouped by industrialization categories. Other tables and figures giving characteristics of the cities are included in Appendix A.

Methodology of City Visits

The core of the city case studies was one or more field visits to each city. Prior to visiting each study city, a variety of data summaries

Table 1. POPULATION AND PHYSICAL SETTING OF CASE STUDY CITIES

Urban area	1970 population			Population density per sq. mi.		Physical setting		Manufacturing employment (AQCR)	
	AQCR	Rank[a] in U.S.	Central city/county	SMSA	Central city/county	Large bodies of water	Topography	Magnitude, thousands	Percent of total
Philadelphia	5,635,406	4	1,948,609	1357	15,116	Delaware River	Slightly rolling	603	34.1
San Francisco	4,639,949	6	715,674	1254	15,904	Ocean, S.F. Bay	Significant hills	347	24 4
Washington, D.C.	2,862,912	8	756,510	429	12,402	Potomac River	Slightly rolling	53	7 2
Cleveland	3,383,879	9	1,721,300	1329	9,893	Lake Erie	Flat; river valley	484	36.1
St. Louis	2,476,757	10	622,236	547	10,201	Mississipi River	Slightly rolling	279	35.1
Baltimore	2,078,379	14	905,759	917	11,613	Patapsco River, Baltimore Harbor	Slightly rolling	184	29.3
Seattle	1,937,371	17	1,156,633	337	6,350	Puget Sound	Significant hills and valleys	139	26.7
Miami	2,435,089	18	1,267,792	621	9,763	Ocean; Everglades	Flat	144	10.5
Cincinnati	1,660,495	21	924,018	644	5,780	Ohio River	River valley, significant hills	195	37.7
Denver	1,252,007	24	514,678	366	5,418	–	Mountains to west; rolling to east; river valley	99	20.8
Providence	1,502,601	30	580,261	1347	9,896	Narragansett Bay	Slightly rolling	201	44.2
Oklahoma City	783,403	42	526,805	300	579	–	Flat	44	19.0
Birmingham	1,045,599	43	644,991	272	3,785	–	Valley between significant hills	92	31.1
Chattanooga	689,494	96	255,064	307	2,284	–	Valley between sharp ridges	128	52.6

[a]Based on Urbanized Area population.

Table 2. STUDY CITIES BY THEIR DISPERSION AND INDUSTRIALIZATION CHARACTERISTICS

Industrialization	Dispersion characteristics		
	Favorable	Moderate	Adverse
Light	Miami San Francisco	Oklahoma City Washington, D.C.	
Moderate	Providence	Seattle	Chattanooga Denver
Heavy		Baltimore Cleveland Cincinnati Philadelphia St. Louis	Birmingham

Table 3. SUMMARY OF SITES EXCEEDING AIR QUALITY STANDARDS

City	Total no. of sites with complete 1974 data	Annual standard: No. sites exceeding standard		Annual standard: Highest geometric mean, $\mu g/m^3$	24-hour standard: No. sites exceeding standard		24-hour standard: % total obs. > standard		24-hour standard: Highest value, $\mu g/m^3$
		Primary, 75 $\mu g/m^3$	Secondary, 60 $\mu g/m^3$		Primary, 260 $\mu g/m^3$	Secondary, 150 $\mu g/m^3$	Primary	Secondary	
Heavily industrialized									
Cleveland	25	12	21	175	6	15	4.7	17.6	534
Birmingham	13	11	11	144	7	11	NA	NA[a]	499
Philadelphia	10	7	9	122	4	8	NA	~8	624
Baltimore	29	9	14	134	6	14	0.9	7.6	NA
St. Louis	31	15	26	158	13	3	1.1	8.7	NA
Cincinnati	25	8	21	130	0	7	0.1	4.2	296
Moderately industrialized									
Chattanooga	12	5	5	101	1	7	0.9	6.9	434
Denver	22	14	21	131	13	22	NA	NA	565
Seattle	10	2	4	105	2	5	0.3	0.8	320
Providence	21	1	5	88	0	1	0	0.8	173
Lightly industrialized									
Washington, D.C	9	2	5	102	9	9	2.2	NA	527
Oklahoma City	14	5	6	107	5	13	0.7	5.5	NA
Miami	17	2	7	86	2	8	NA	NA	NA
San Francisco	17	0	2	74	3	10	0.2	1.3	286

[a] NA - Row data not available in format appropriate for summary.

Table 4. SOURCE AND EMISSIONS CHARACTERIZATION OF STUDY CITIES

City	Major point sources	Predominant fuels[a]		Traditional sources, emission density TPY/sq. mile	Compliance comments
		Residential	Industrial		
Heavily industrialized					
Cleveland	Steel mills, utilities, chemicals	Gas	Gas, coal	335	About 1/3 of major sources in compliance, smaller sources (including incinerators) unknown
Birmingham	Steel mills, cement	Gas	Gas	488	Most sources under compliance schedules, compliance about half complete
Philadelphia	Refineries, coking, smelting, chemicals	Oil	Oil, gas	245	Most sources in compliance
Baltimore	Steel mills, incinerators	Gas, oil	Oil	240	Most sources in compliance, a few under plans for compliance
St. Louis	Coking, steel mills, grain handling	Gas	Gas	411	Most sources thought to be in compliance, Missouri's compliance determination is not stringent
Cincinnati	Utilities, manufacturing	Gas	Gas, coal	135	Many sources in compliance, rest (including several large sources) expected within 2 years
Moderately industrialized					
Chattanooga	Foundries, cement, minerals	Electricity	Gas	88	Most sources in compliance
Denver	Utilities	Gas	Gas	60	Most sources in compliance
Seattle	Manufacturing	Oil	Oil	37	Most sources thought to be in compliance
Providence	Utility, foundries	Oil	Oil	30	Compliance status not certain - many seem to be in compliance
Lightly industrialized					
Washington, D.C.	Utility	Gas	Gas, oil	92	Most sources in compliance
Oklahoma City	Utilities, grain, asphalt	Gas	Gas	2	Most sources in compliance
Miami	Minerals	Electricity	Gas, oil	30	Most sources in compliance
San Francisco	Minerals, chemicals	Gas	Gas	60	Most sources in compliance

[a] *Those fuels whose usage is greater than 1/3 of total Btu's.*

and analyses were prepared and studied, using data on air quality, emissions, and compliance that were provided by the Project Officer from EPA's AEROS data banks. Air quality and emission data were studied for patterns and trends, both temporal and geographic. Emission and compliance data were used to consider patterns of enforcement and compliance.

The primary purpose of the field visits was to study in detail the hi-vol monitoring network and to gain a degree of understanding about the overall nature of the study city and the general patterns of land use, such as the relationships among industrial and residential areas. During the field visit, the study team also consulted with technical staff members from the appropriate pollution control agency concerning those areas where the EPA data base was incomplete or anomalous, and a member of the agency staff usually accompanied the visiting team on the monitoring site study visits. Additional efforts during the study visits in some cities involved seeking data on traffic volumes, street cleaning practices, etc., as appropriate to the particulate air pollution problem in the city. In most cases, historical hi-vol filters from agency files were also selected and brought back for analysis.

Following the field visit, the monitoring site information was reviewed and compiled into an overall site classification analysis. Other information and data obtained were integrated with that previously available, and an overall assessment concerning the factors affecting attainment was formed. The data summaries, analyses, and conclusions relating primarily to a single city were then compiled into a working document for each of the study cities; these documents comprise Volumes III through XVI of this report.

City Study Findings

The results and findings of the city case studies are quite varied in detail and in breadth of applicability. Those specifically relevant to only the individual city are presented in the separate volume for that city. Those that are of significance for the overall conclusions of the study are summarized here. Appendix A presents tabular summaries of other data relevant to the various study cities.

Baltimore - A heavily industrialized city, Baltimore has had an intensive pollution control program since the mid-1960s. This has contributed to a 50 $\mu g/m^3$ decrease in the annual average at the center-city NASN site over this time. Nonetheless, the annual primary standard is still exceeded at nine sites, mostly in the center city and harbor industrial areas. Under vigorous enforcement of very stringent regulations, most of the city's major industries and the municipal incinerators have reduced their emissions an average 70 percent; on the other hand, emissions from the iron and steel industry, which comprise 85 percent of the total point source emissions in the metropolitan area, have been reduced only 15 percent. One steel mill clearly contributes to TSP problems at several industrial sites; however, at the industrial site with the highest annual average (134 $\mu g/m^3$), local fugitive dust emissions also make a significant contribution to the elevated levels. Three or four sites located in the urban center appear to be above the standard without any particular local source influence. Part of this urban increment is probably due to the use of oil for residential space heating, one category of source which is not closely regulated; however, much of the TSP measured at these sites must simply be attributed to the dense level of activity in the urban area. TSP levels at the center city site are further elevated by immediately adjacent expressway construction.

Birmingham - The improvement in air quality has been substantial in Birmingham, but still only two suburban sampling sites met the annual primary standard in 1974. Values have fallen from around 300 to 145 $\mu g/m^3$ at the most polluted industrial site, and commercial and other industrial sites have shown similar decreases of roughly 50 percent. Four industrial sites reported 1974 annual geometric means over 125 $\mu g/m^3$ because of proximity to the predominant steel industry and the associated coking and foundry operations, which account for the bulk of point source emissions. Stringent regulations and vigorous enforcement have resulted through 1974 in about half the emission reduction ultimately expected, with the balance anticipated over the next 2 years as compliance plans are completed. The general effect of dense urban activity on TSP levels is not seen clearly in Birmingham because of the much larger industrial process contribution, but may well be a problem for future consideration.

Chattanooga - A moderately industrialized city, Chattanooga has also experienced a significant decline in TSP levels due to a trend away from the use of coal and, more recently, to vigorous control of industrial emissions. However, five of twelve sites, all in industrial or commercial locations, continue to exceed the annual primary standard with annual means between 80 and 101 $\mu g/m^3$. Of these, two are affected significantly by local industrial sources - a quarry and a cement plant - and the others by general downtown commercial activity or major traffic arteries. An overall difficulty relates to adverse topography and meteorology; particularly stringent emission control for both industrial and fugitive sources will be needed to meet the standards under the adverse dispersion conditions prevalent in Chattanooga.

Cincinnati - The TSP trend has been downward since the mid-1960s, with the NASN center-city site experiencing a 70 $\mu g/m^3$ decrease in its annual average. The major industries - transportation equipment, fabricated metals, paper, chemicals, and a small power plant - have made large reductions in particulate emissions, primarily by switching from coal to natural gas or otherwise reducing fuel combustion emissions. Nonetheless, seven sites still exceeded the annual primary standard in 1974 at locations in the central business district (CBD) and the industrial valley, with one site measuring 130 $\mu g/m^3$ as an annual average. All sources are expected to come into compliance over the next 2 years, during which time further reductions are expected. However, full compliance may not result in standards attainment because fugitive emissions and fugitive dust are likely to remain a significant source of particulates at several sites in the CBD and industrial areas unless control measures are taken.

Cleveland - Although there has been a fairly steady decrease in ambient TSP levels since the early 1960s, 1974 levels at 12 of 25 sites in the county violate the annual primary standard. The city is large and heavily industrialized, with an emission density of 335 tons per year per square mile, and has the highest annual average TSP levels of the cities studied (175 $\mu g/m^3$). Primary metals, fabricated metal products, machinery and transportation equipment are the predominant industries and, along with the utilities, the largest sources of particulate emissions. Control efforts have resulted in substantial emission reductions by a few problem sources, but overall they have not been effective. Most sources are either not under compliance schedules, not meeting conditions of their variances, or not under agency surveillance at all. While other factors may very well become apparent as the massive industrial contribution is reduced, it seems clear that the predominant reason for nonattainment in Cleveland is the current lack of control of industrial emissions. These include not only major point sources but also industrial fugitive emissions and the vehicle-entrained fugitive dust emissions associated with industrial areas.

Denver - In contrast to most other areas studied, the Denver AQCR has shown no definitive trends in TSP levels during the past 6 years. Despite its low level of industrialization, Denver has had TSP concentrations well above the annual standards since levels were initially monitored in 1957. In the long term, Denver County has shown approximately a 20 percent improvement in its air quality since 1965. However, in 1974 only one out of 22 sites, a site located in a rural area, met the secondary standard; 14 of the sites exceeded the primary standard. This general lack of attainment of the standards has been commonly attributed, in part, to the arid climate which allows easy reentrainment of fugitive dust. The highest annual mean (131 $\mu g/m^3$) was recorded at a site obviously influenced by fugitive dust, where 36 percent of the observations were above the secondary 24-hour standard and 14 percent were above the primary 24-hour standard. The impact of both fugitive dust and traditional industrial source emissions is spread throughout the region because of the poor ventilation and topographic characteristics of the region. In addition, an inadequate data base, from which the initial implementation planning was done, has contributed to the problem of attainment in the region. Several emission inventories have been compiled for the region over the years, but the lack of consistency between these inventories has prevented the determination of emission trends. Despite the problem of appropriate emission data, major sources are assumed to be generally in compliance with the regulations and the state agency is now pursuing fugitive dust sources.

Miami - The highest ambient TSP levels in Miami have been fluctuating near the standards for several years. The area is generally free of major TSP point sources; the largest emitters are stone and gravel quarrying operations. During 1974, two sites failed to meet the primary standard. The higher, with an annual geometric mean of 86 $\mu g/m^3$, was located in a light industrial-commercial area, on a major arterial highway, with an auto junkyard and a variety of other unpaved fugitive dust sources in the immediate vicinity. The other site was at a highway intersection in a rural area, near a major aggregation of cement plant operations. A special study conducted by the Dade County agency indicated, however, that the cause of the high levels was not the cement plants themselves, but rather the reentrainment by traffic of material spilled on the highway by the sizable number of trucks turning at the intersection.

Because of the general lack of point source emissions, the relative homogeneity of the area, and particularly the consistency of the monitor heights, Miami provided a good opportunity to study that portion of urban TSP levels that appears to result from aggregate urban activity. Two measures of urban activity were found to correlate well with the TSP values at the various sites: traffic volumes and the proportion of adjacent land used for streets and parking.

Oklahoma City - An institutional, light-industrial city where gas is the predominant fuel, Oklahoma City nonetheless has five of 14 sites where the annual primary standard is exceeded. TSP levels at the NASN site show only a slight downward trend over time, reflecting the low density of readily-controlled industrial sources and the inability to comprehensively control fugitive dust. The high levels at the sites over the standard can be attributed in part to either significant traffic exposure, adjacent construction, or (at three of the sites in the center city) a combination of central business district traffic and urban renewal activity. The dry climate and high winds tend to maximize natural entrainment of dusts, but the urban pollution problem is not primarily due to particulates from the surrounding rural area.

Philadelphia - Air quality has been steadily improving in the city; annual average TSP concentrations at the NASN site are down over 100 $\mu g/m^3$ since 1957. However, the annual primary standard was met at only three of the 10 monitors operating throughout 1974. Of these three monitors, all in residential areas of the city, only one met the secondary annual standard with a value of 59 $\mu g/m^3$. The large improvements in air quality have been directly paralleled by reductions in the inventoried emissions due to stringent controls on industry (fabricated metals, machinery, electrical equipment, petroleum) and large incinerators, phasing out of small incinerators and coal burning, and fuel switching in power plants. The lack of attainment of the standards, despite stringent regulations and effective enforcement, reflects the generally high level of TSP entering the city from outlying industrial activity (40 to 50 $\mu g/m^3$) and the activity associated with an urban environment, including space heating and vehicular traffic. Small residential boilers have not been under any control other than visible emission regulations. Vehicular traffic was shown to contribute up to 50 $\mu g/m^3$ to the measured levels of TSP for monitors close to the street. In addition, fugitive emissions from stockpiled materials and a grain-handling operation were believed to be major influences on the monitor with the highest annual mean (122 $\mu g/m^3$).

Providence - A downward trend in TSP concentrations has been occurring since the mid-1960s, and only one sampling site exceeded the annual primary standard in 1974. A utility, municipal incinerators, and some industrial processes - primary metals, fabricated metal products and electrical equipment - are the largest point sources of particulate emissions. Fuel switching and the closing of incinerators are apparently responsible for the emission reductions and the corresponding air quality improvement, although the compliance status of a number of sources is unknown. The one site which exceeded the annual primary standard with an average of 88 $\mu g/m^3$ is excessively influenced by a major expressway immediately adjacent. Oil-fired space heating is a significant source category which has not received much attention in light of the general standards attainment. Some portion of the overall favorable picture may be due to a generally high average sampler height compared to other cities and to relatively good dispersion characteristics.

St. Louis - The TSP trend has been downward since the mid-1960s with the NASN site experiencing a decrease of 80 $\mu g/m^3$ in its annual geometric mean. Fifteen sites, however, violated the annual primary standard in

1974. Transportation equipment, primary metal, fabricated metal products, and machinery industries are the largest sources of particulate emissions, and fuel switching and industrial process controls have accounted for much of the emission reductions. The majority of the sources in the Missouri portion of the AQCR are believed by the local agencies to be in compliance; however, the St. Louis City and County regulations are among the least stringent of those studied. The Illinois portion is less advanced in terms of degree of compliance, because control efforts started later, but it should become comparable to Missouri by maintaining its program of stringent regulations and strict enforcement. The fact that high TSP concentrations are still being experienced despite the presumed general compliance indicates that other factors are important. These include the relatively weak regulations and the lack of source testing as a method for compliance determination in Missouri, as well as the general tendency of dense center-city sites to be systematically higher due to urban activity.

San Francisco - San Francisco is the one study city that met the annual primary standards during 1974. Despite its large population and generally dense urbanization, the San Francisco AQCR has never had a serious problem with particulates, due largely to the very clean background air it receives from over the Pacific Ocean and the low level of heavy industrial activity. Air quality trends at the San Francisco NASN site have shown a decrease of about 20 $\mu g/m^3$ from a high of 73 $\mu g/m^3$ in 1957. This decrease of over 30 percent in above background levels is comparable to the trends reported for emission reductions. These emission reductions occurred in part (pre-1970) because of extensive fuel switching by the residential sector from coal and oil to gas and electricity and (since 1969) because of controls on industrial processes and burning of materials. These controls are no more stringent than the average found in the cities studied, but their success is maximized by an extensive, computerized enforcement program conducted by the Bay Area Pollution Control District. In addition, regulations have been revised over time as data indicate that more stringent controls are feasible and warranted. The combination of the above factors and the low level of emissions (170 tons/day for the entire AQCR) meant that only two monitors out of 17 exceeded the annual secondary standard, and no monitors violated either the 24-hour or annual primary standards. The highest annual geometric mean of 74 $\mu g/m^3$ was measured at a station highly influenced by fugitive dust. This monitor and many others in the network are often subject to poor ventilation conditions because of the valley topography; even so, the 24-hour secondary standard was exceeded less than 1 percent of the time in 1974.

Seattle - While it also has the advantage of being a west coast city, unencumbered with TSP transport from other areas, Seattle is further inland than San Francisco and significant industry is concentrated in a valley adjoining the city. However, the higher level of annual precipitation helps keep the TSP concentrations down around those measured in the San Francisco area. Air quality levels have shown fairly steady downward trends over the years with a 50 $\mu g/m^3$ decrease in the annual average at the NASN site since 1957. Of the 30 sites in the AQCR, the annual primary air quality standard was exceeded at two stations and the annual secondary standard was exceeded at another three sites. The highest concentrations (60 to 105 $\mu g/m^3$) occur in the industrial valley and the lowest levels (35 $\mu g/m^3$) in the residential areas out of the valley. Estimates of emissions indicate that most traditional source sectors - industrial processes, fuel combustion, solid waste disposal - have had some reductions contributing to a 40 percent overall reduction in inventoried emissions since 1969. These changes in emissions since 1969 have not been reflected in the air quality, which has seen increasing TSP levels in 1973 and 1974. The regulations under which process sources are controlled were found to be much less stringent than those normally applied; further major reductions could be expected if controls were brought up to the average stringency seen in other cities. Fugitive dust due to vehicular traffic has also been cited as one of the problems in the industrial valley. The monitor with the highest annual mean (105 $\mu g/m^3$) is located approximately 25 feet back from a heavily traveled road; a location 100 yards back from the road has levels about 40 percent lower.

Washington, D.C. - While Washington has never had the major TSP problem of other cities because of its nonindustrial nature, two sites in the city exceeded the annual primary standard in 1974. There has been a slight downward trend since the early 1960s as coal use decreased and higher grade fuels were substituted, but two center-city sites continued to exceed the primary standard in 1974. Control regulations are stringent, and large emission reductions have resulted from the closing of incinerators and fuel switching; most sources seem to be in compliance. The cause of nonattainment at the two center-city sites is a mixture of urban activities. Demolition and construction associated with urban renewal was prevalent for several years, and has been more recently supplemented by construction of the METRO transit system. In comparison with other cities, traffic would appear to be an expected problem. However, any clear demonstration of that influence is precluded by the extreme heterogeneity of monitoring site locations, with almost all monitors located very high, very remote from the traffic, or both.

Particle Characterization

As mentioned in Section I, optical microscopic examination was undertaken on selected hi-vol filters from each city. The filters were selected from several representative sites in each city and the results were subjected to quality control checks. A summary of the filter analyses and the results of the quality control are presented in Appendix B of this volume, and a more detailed presentation is included in Volume II of this report.

In Table 5, the microscopy results for each city have been averaged by the generic type of material present. These composite results show the highest percentage component to be mineral matter. Sources of mineral matter include windblown soil, reentrained dust from streets, fugitive dust from construction and demolition, and such industrial sources as primary metals and mineral products industries and material storage piles. Appendix B gives a more detailed breakout of these components. The higher values for mineral matter in Denver and Oklahoma City support the theory that fugitive dust sources are particularly important in arid areas.

It should be emphasized that the optical microscope does not allow identification of particles smaller than about 1 μm, so the analytical data is representative of only the supermicron portion of the particulate. Therefore, in applying the component percentages, it was assumed that 15 percent of the mass is invisible to the microscopist. Table 6 shows the results of this procedure as applied to a categorization of the components by site type for all sites studied in the 14 cities. All filters analyzed were selected from days with average or greater loadings.

<u>Particle Size</u> — The average particle size for each of the major visible components is presented in Table 7. In general, mineral constituents had the smallest particle size, and biological materials and rubber the largest. The differences between sizes reported for the aggregate categories and the subcategories is not significant. Although the average size of the mineral fraction, 8 μm, is consistent with the average sizes of the principal components, the average size reported for combustion products, 5 μm, is noticeably lower than the average size of the individual components within that group. This is because the filters on which sizing of the individual components was done are not necessarily the same filters that comprise the aggregate combustion products group. For some filters the size range was reported only for the combustion products group as a whole because the individual components comprised less than

Table 5. COMPOSITE SUMMARY OF MICROSCOPIC ANALYSIS IN 14 CITIES, Percent

City	Minerals		Combustion products		Biological material		Miscellaneous	
	Average	Range	Average	Range	Average	Range	Average	Range
Heavily industrialized								
Cleveland	51	28-85	40	10-70	1	<1-5	8	tr-22
Birmingham[a]	66	14-90	22	2-86	2	0-8	10	0-50
Philadelphia[a]	64	6-93	33	6-89	1	0-10	2	0-30
Baltimore[a]	69	52-88	25	11-61	3	<1-11	3	0-26
St. Louis	75	21-99	21	1-79	<1	0-5	4	0-10
Cincinnati	51	24-88	44	9-84	1	<1-5	4	<1-20
Moderately industrialized								
Chattanooga	36	3-96	35	8-78	16	0-90	13	0-45
Denver	81	62-97	7	1-19	1	0-7	11	0-32
Seattle	60	30-96	27	1-62	3	tr-24	10	<1-40
Providence	64	28-92	22	4-68	1	0-5	13	0-35
Lightly industrialized								
Washington, D.C.	70	39-87	23	5-49	5	<1-47	2	<1-25
Oklahoma City	88	63-99	8	1-31	<1	<1-4	4	<1-30
Miami[b]	79	75-83	9	7-12	<k	<1	12	10-15
San Francisco	52	29-73	29	10-50	3	tr-10	16	0-35
All cities	65	3-99	25	1-89	3	0-90	7	0-50

[a]Excludes analyses of NASN site filters

[b]Analyses of NASN site filters only

Table 6. ESTIMATES OF AVERAGE FILTER LOADINGS BY SITE CLASSIFICATION

Components	Average loading, μg/m³			
	Commercial	Residential	Industrial	Undeveloped
Mineral	64	51	87	66
Combustion products	27	19	42	6
Biological material	2	3	3	<1
Misc. (mostly rubber)	9	5	9	<1
Assumed < 1 μm	19	14	25	13
Total	120	92	166	86

Table 7. COMPOSITE SUMMARY OF PARTICLE SIZE BY COMPONENTS

Component	Average size, μm	Average size range, μm	No. of filters included in averaging
Minerals	(8)	<1-62	153
Quartz	11	2-65	154
Calcite	9	1-45	148
Hematite	3	<1-39	89
Combustion Products	(5)	<1-58	92
Oil soot	13	4-106	107
Coal soot	30	6-66	52
Glassy fly ash	12	2-38	35
Biological Material	(24)	5-82	13
Pollen	35	13-39	15
Rubber	(43)	13-135	94

5 percent of the observed particulate. The average size of the biological material is quite large but understandable in terms of its source and aerodynamic shape. The very large average particle size reported for rubber, however, is somewhat harder to understand. The generation of large rubber particles by mechanical abrasion is easily understood, but it is difficult to explain how such large particles can be transported over substantial horizontal or vertical distances.

Quality Control — The reader is cautioned to review Appendix B regarding the results of quality control procedures used in the microscopic examination. Briefly, it was found that the replicability of the results of analyses of individual samples varied considerably with some results quite far apart. However, the compositing of results from many filters to obtain average results minimizes any systematic bias among microscopists and laboratories.

SUMMARY OF FACTORS AFFECTING ATTAINMENT

The purpose of the city case studies was to identify and study the various factors, problems, and issues concerned with attaining the TSP standards as they were experienced in each city. Since the 14 cities cover a broad range of city characteristics and hence represent a variety of situations with respect to TSP air quality and its determinants, analyses of the factors in the various cities can be drawn together for an overall assessment of the TSP attainment situation in the study cities and, by extrapolation, throughout the nation.

Following the analyses of the study cities, a number of factors were identified as significant for standards attainment. Many of these had been first identified in the preliminary literature review and were then followed up in the city studies; a few others were identified in the course of one or more of the city studies. The principal issues are listed below, grouped into five major categories that will subsequently provide a framework for the more detailed discussions in Section III.

Large Scale Influences

Large scale influences include those factors that dominate an area much larger than the urban areas being studied. They include natural, transported, and secondary particulates. The differing influences of these factors in various urban areas can cause significant differences in the ability to control the local TSP problem. Their effect on urban levels is generally estimated by measuring air quality in nonurban areas. The average nonurban particulate level for the 14 study cities is between 25 and 30 $\mu g/m^3$; however, values ranged from less than 15 $\mu g/m^3$ on the west coast to roughly 35 $\mu g/m^3$ in the metropolitan northeast. The three major large scale factors are described below:

- Natural particulates — A major factor that can have significant impact on standards attainment is the magnitude of the natural TSP level in the incoming air masses. The west coast cities benefit from having a very low (global) particulate level, while cities in the central plains or the east have additional continental contributions.

- Transported primary particulates — Cities in the eastern metropolitan complex have the further problem of manmade particulates being transported from neighboring urban areas without space for adequate dilution. Therefore, these cities have an impaired capability for managing their own air quality.

- Secondary particulates — Levels of particulates such as sulfates, nitrates, ammonium, and some organic compounds, which are generally believed to be formed as secondary particulates, indicate again that cities in the east are receiving increased TSP levels from other areas. These particulates are formed both in transport and locally from sources not traditionally controlled in TSP standard attainment strategies.

Traditional Source Factors

Much of the problem of standards attainment in several of the 14 study cities is attributable to emissions from those sources — industrial processes, fuel combustion, incineration — that have traditionally been considered subject to pollution control efforts. Cities with heavy industrial activity were found to have citywide TSP levels averaging from 10 to 50 $\mu g/m^3$ above the levels in cities with little or no industry; sites particularly close to heavy industrial activity averaged up to 25 $\mu g/m^3$ higher than other industrial sites. Specific nonattainment factors related to traditional source emissions include the following:

- Industrial emissions — In several cities, widespread industrial emissions were obviously the major share of the overall urban problem; in other cities more isolated industrial emission problems were responsible for local nonattainment. The most apparent problems were the steel industry, with associated coking and foundry operations, and the various minerals handling industries, such as cement and asphalt plants and stone and gravel quarries.

- Fugitive emissions — Several sites, generally near industrial areas, were significantly affected by fugitive emissions from such sources as materials stockpiles, coal loading operations, blast furnace slips, rock crushing and loading, and similar uncontained industrial processes.

- Fuel oil combustion — In several cities there was concern over the degree of impact from oil combustion. In coastal cities, oil is frequently used for space heating, and the smaller residential oil burners are typically not controlled as pollution sources. In midwestern cities where coal is used significantly, even very major oil-fired combustion units, such as utility boilers, may be ignored as sources because they are cleaner than equivalent coal-fired units.

- Fuel use trends — One positive influence on standards attainment in several cities is the on-going trend toward cleaner fuels, especially the shift from coal to gas in small units. This is a continuation of a trend spanning many years, fueled by factors of convenience and economic affluence.

- Lack of effective control — In at least one instance, a major factor in failing to attain the standards is the overall lack of any effective control program or enforcement effort.

- Lack of adequate time for control — In some instances, failure to meet the standards is due to having insufficient time since the inception of control efforts for even an outstanding control program to cope with a major TSP problem.

- Inadequate regulations — In some cases, relatively nonstringent regulations inhibit meeting the standards by requiring less reduction in emissions than is necessary to meet the standards.

- Inadequate compliance determination — In most of the study areas, the process of verifying that a source is in compliance and remains so appears to be somewhat haphazard. Most agencies have less firm knowledge on such matters than seems desirable.

- Inadequate data base — In some cases, planning for air quality management and standards attainment is inhibited by the lack of an adequate data base. Usually involving emissions rather than air quality data, this lack can be so extreme in some cases that it must be construed as a major misunderstanding as to the nature of the TSP problem being faced.

Nontraditional Factors

Even with the nonurban, large scale particulate concentrations and the emissions from traditional sources taken into consideration, analysis of many of the monitoring sites in the 14 study cities indicated that other factors, not traditionally considered, were producing TSP levels that were typically 25 to 30 $\mu g/m^3$ higher than expected. Such levels could often be attributed to specific sources such as construction activity or localized fugitive dust emissions, but in many cases the elevated concentrations were simply the result of the intense level of activity in urban areas. Specific factors identified include:

- Localized fugitive dust emissions — A number of sites in various cities were prevented from attaining the standard at least in part by emissions from bare unvegetated lots, unpaved parking areas and roadways, heavily traveled expressways, and similar local sources of entrained dust.

- General urban activity — In most cities, ambient TSP levels in the densest part of the city are higher than elsewhere with no single, obvious reason. This effect influences attainment at a number of commercial and dense residential sites in almost every city. The best immediate presumption is that this contribution represents the combined, well-mixed influence of higher levels of traffic, building construction, pedestrian activity, and other types of urban activity that tend to be greater in the more dense central part of the city.

- Construction activity — Several sites, often center city commercial sites, were hindered in meeting the standard by dust entrained from construction sites of various types, including urban renewal, small building construction, and highway and subway construction.

In addition to the above factors, which are all related to sources of particulate emissions, other factors were found to affect the real or apparent TSP problem. As discussed in the selection of the cities, the meteorology and climatology of a region can help to aggravate or ameliorate the TSP problem; the dispersion characteristics and precipitation levels are the most prominent influences. The design of the monitoring network configuration and the actual placement of monitors are also important in conceptualizing what the TSP situation is. The general findings from the city studies for these factors are summarized below.

Meteorology and Climatology

- Dispersion conditions — The overall pollutant dispersion characteristics can have significant effects in either direction; in the southern mountain area, the attainment is clearly more difficult because of adverse meteorology and topography, whereas in the coastal and great plains areas the opposite is true.

- Precipitation — Frequent, significant precipitation is apparently a help in attaining standards, while arid conditions are a detriment.

Monitoring Considerations

- Inappropriate sampler heights — One of the more common problems with hi-vol network design is the question of consistent, appropriate sampler heights. If the hi-vols are strikingly higher or lower than typical, the recorded TSP levels will be artificially decreased or elevated in comparison to other cities. Similarly, if there are striking height differences within one urban area, there will be difficulties in adequately planning for standards attainment and in accurately assessing progress.

- <u>Network design</u> — As the TSP levels vary from monitor to monitor, and generally around the city, it is important to ensure that those areas of maximum TSP concentration are monitored. Some cities located monitors with the help of extensive modeling efforts, while others picked convenient locations.

Figure 2 is a schematic sketch of the interrelationship of these five major groups of factors. It is intended as a minemonic device to emphasize that three of the factors are actual components of the particulate matter, while the other two are distorting influences.

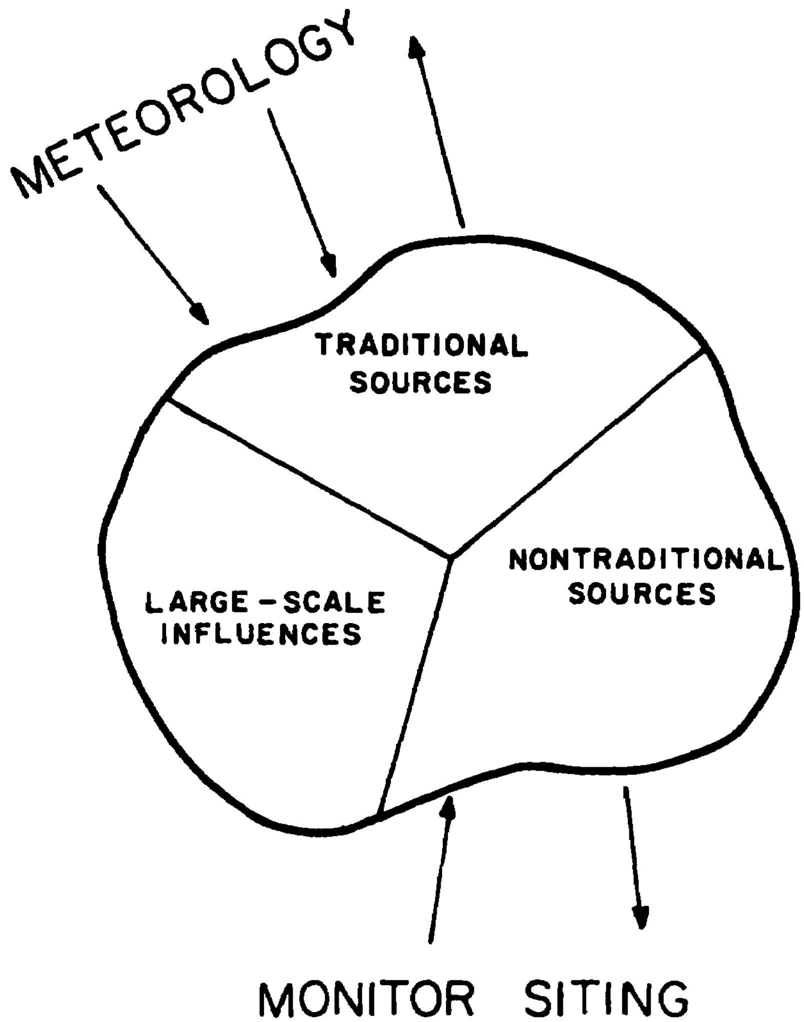


Figure 2. Schematic relationship among five major factors

SECTION III

ASSESSMENT OF FACTORS AFFECTING ATTAINMENT

This section assesses the significance of the five major factors identified with respect to the attainment or nonattainment of the ambient standards. For ease of readership, much of the more extensive analytical and discussion material has been collected into appendices, of which this section can be considered a summary.

Since the air quality standard makes no distinction among particulates from various sources, it is not possible to ascribe nonattainment to any particular source or source category, other than to the extent that the source or source category contributes to the measured TSP levels at the point in question. Consequently, the assessment of the contributions from the various factors can be seen as the determination of the contributions of the various factors to an overall typical TSP concentration. This viewpoint, along with a determination of how the various factors affect variations in TSP levels, provides a useful discussion framework, which is used throughout this section. The large number of monitoring sites (154) visited and studied throughout the country provide a unique opportunity for developing an understanding of the individual factors affecting the measured TSP levels. From an analysis of the data, the city characteristics, and the monitoring site locations, the components of the TSP at different types of sites were estimated.

The most obvious difference among sites is the nature of the neighborhood in which they are located. Figure 3 shows the average of the annual concentrations at all the sites in the 14 study cities varied by the primary

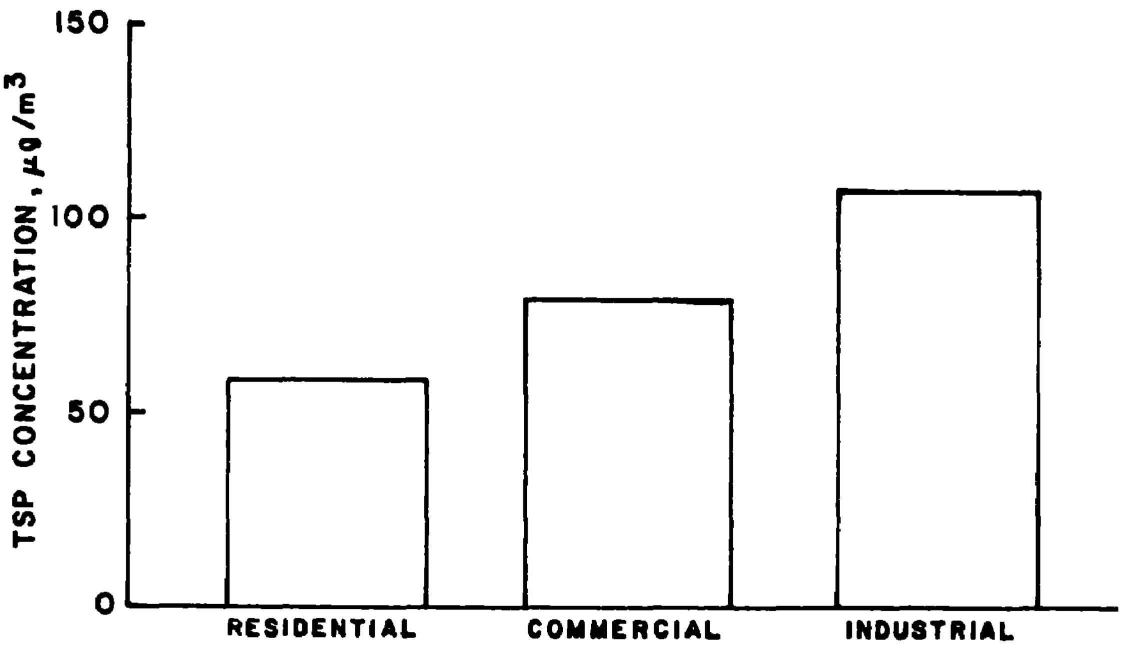


Figure 3. Average TSP levels by neighborhood type

neighborhood classification of residential, commercial, and industrial. Residential neighborhoods generally had TSP concentrations in the range of 50 to 70 $\mu g/m^3$; monitors at commercial sites recorded a wider range of values, principally between 60 and 110 $\mu g/m^3$; and industrial neighborhoods had the highest TSP levels, averaging between 80 and 150 $\mu g/m^3$.

To explain not only why these TSP levels are what they are but also why they vary as they do, the analyses conducted in this study drew upon the general findings from the city studies discussed in Section II. These findings identified major topics of concern for assessment of the TSP standards attainment problem on a nationwide basis: large scale considerations, traditional sources, nontraditional sources, monitoring considerations, and meteorology/climatology. This categorization structures the following discussion, which summarizes the findings of the cross-city analyses presented in the appendices.

BACKGROUND AND LARGE-SCALE CONSIDERATIONS

In reviewing the literature, and in considering the wide range of typical air quality levels over different parts of the country, it is apparent that there is a significant portion of TSP levels that varies over a geographical scale much larger than any one or even a few AQCRs. On an overall average basis, the levels of TSP measured in nonurban areas represent the concentration of particulates in the air masses before they arrive in an urban area; hence the wide range of nonurban values implies that comparable cities, located in different portions of the country, would require different degrees of control to attain and maintain the ambient standards. Therefore, quantitative air quality planning requires an understanding of these levels and how and why they occur.

Terminology

Variously, particulates either measured in or presumed to originate in nonurban areas beyond the jurisdiction of local or state agencies have previously been labelled in one way or another under the heading "background." The usage of the term, however, when examined carefully, is found to entail a number of somewhat different concepts. The official concept of background is defined in the Requirements for Preparation, Adoption, and Submittal of Implementation Plans (40 CFR 51.13):

> For purposes of developing a control strategy, background concentration shall be taken into consideration with respect to particulate matter. As used in this subpart, 'background concentration' is that portion of the measured ambient levels of particulate matter that cannot be reduced by controlling emissions from manmade sources; 'background concentration' shall be determined by reference to measured ambient levels of particulate matter in nonurban areas.

Unfortunately, this definition reflects to some extent the prevalent variation in usage of the word "background," and hence contradictory usage of the term continues. Under the first part of the last sentence, in which background is defined as the uncontrollable portion of TSP, EPA regulations provide for rollback calculations to ascertain the degree of emission control necessary for the attainment of the air quality standards. The rollback formula:

$$\text{reduction required} = \frac{\text{ambient - standard}}{\text{ambient - background}}$$

tacitly assumes that the background level is a lower limit below which the ambient concentration cannot be reduced. On the other hand, in air quality modeling efforts, the background is frequently defined as the difference between the measured concentrations and the calculated concentrations which includes into background any source not included in the inventory used. In still other circumstances, an agency may choose to regard as "background" any TSP coming across the boundary into their jurisdiction, regardless of whether that jurisdiction extends appropriately into nonurban areas.

Contradiction in the usage of the term background also arises from the latter part of the above citation referring to the actual measurement of background. Following that concept, the background levels most often used in air quality reflect measurements of the ambient air quality in some remote rural area; this may possibly be within the county, AQCR, or state, depending upon the jurisdiction of the planning agency; or may be very far away. Where possible, these measurements are made upwind of the prevailing flow of air so as not to sample the particulate contribution of the area. However, what these remote monitors are actually measuring is not necessarily an uncontrollable or nonmanmade level of TSP. Rather, these measurements simply reflect the particulate concentrations coming into the urban area, including not only the natural, uncontrollable particulates but also man's contribution to the nonurban particulate levels; these latter include emissions in rural areas, particles transported from distant urban areas, and secondary particulates.

To avoid confusion with previous use of the term background, the term nonurban particulate will be used in this report to refer to the latter part of the EPA definition presented above; i.e., the TSP concentration determined by measuring the ambient levels of particulate matter in nonurban areas. The major components of nonurban particulates are listed below:

- Natural particulate — TSP contributed solely by natural processes and thus truly uncontrollable; includes a global contribution, which includes both primary and secondary particles, and a continental contribution, primarily from wind erosion of soil.
- Transported particulate — TSP levels that arise due to emissions from man's activities in "upwind" urban and industrial areas; includes both primary and secondary particulates transported from one area to another.
- Local influences — TSP measured at nonurban monitors that is contributed by emissions in rural areas (dirt roads, agricultural tilling, space heating, rural industrial sources) and affected by the actual placement of the monitor (reentrained dust, small town activity).

Because the term background has also connoted TSP that cannot be explained through modeling efforts and TSP that cannot be controlled through control of primary particulate sources, the excess of secondary particulates measured in urban areas over the levels measured in nonurban areas will also be considered under this topic.

Natural Particulates

The emission and formation of particulates from natural sources result in low concentrations of ambient particulates that have always existed, regardless of man's influence. The most important of the natural sources of particulates are soil and rock debris, forest fires, plants, volcanoes and ocean salt spray; in addition, natural sources can emit gaseous pollutants which can react to form particulates. As shown by the estimates in Table 8, particulate emissions from natural sources and particulate formation from naturally occurring precursors far outweigh the contribution of manmade sources on a global scale.

Table 8. ESTIMATES OF PARTICLES SMALLER THAN 20 μm RADIUS EMITTED INTO OR FORMED IN THE ATMOSPHERE (10^6 metric tons/year)

Man-made	185 - 415	
Particles from direct emissions		10 - 90
Particles formed from gaseous emissions		
Sulfate from SO_2		130 - 200
Nitrate from NO_x		30 - 35
Organics from hydrocarbons		15 - 90
Natural	773 - 2200	
Soil and rock debris		100 - 500
Forest fires and slash-burning debris		3 - 150
Sea salt		300
Volcanic debris		25 - 150
Particles formed from gaseous emissions		
Sulfate from H_2S		130 - 200
Ammonium salts from NH_3		80 - 270
Nitrate from NO_x		60 - 430
Organics from hydrocarbons		75 - 200
Total	958 - 2615	

Of the natural sources of particulate emissions, sea salt is probably the largest emission source, but its greatest effect on TSP concentration occurs over the oceans; its contribution to TSP levels extends over land only a short distance. Over land, wind-entrained soil dust is the largest direct source of particulate emissions. Gaseous emissions from natural sources are scavenged through various chemical reactions and result in the production of significant quantities of aerosol materials over a broad area. Volcanic emissions can vary greatly from year to year but usually do not contribute a large proportion of the natural particulate emissions. The contribution of forest fires can only be estimated roughly at present; though it appears small in Table 8, it may be considerably more important with respect to air quality since such fires are frequently adjacent to urban areas. Pollens, spores, and bacteria are an insignificant fraction of the total emissions.

The primary distinction between the sources of natural particulates with respect to TSP levels is simply their location and to some extent the effective emission height and particle size. Generally, the natural particulate levels can be thought of as contributions from two types of sources: global sources and continental sources. Global particulates arise from the heated emissions from volcanoes and, to a lesser extent, forest fires, and from secondary particulates formed from natural gaseous emissions; these emissions are characteristically in the submicron range. Sea salt is also often referred to as a global particulate. Continental sources are wind erosion of rocks and soil; pollens and spores; and (overlapping global particulates) forest fires and secondary particulates, especially hydrocarbons from plant exudations.

The contribution from global sources is considered relatively constant across the North American continent in the range of 1 to 5 $\mu g/m^3$; for TSP strategy planning, the contribution from continental sources is much more important than that from global sources. Continental particulate levels are much higher and they vary across the continent. For example, in the Great Plains region of the United States, wind erosion of soil is estimated to produce a larger mass of particulates than all other sources in the nation and results in high dust concentrations over large areas. Most duststorms occur in the spring but air pollution from duststorms can be a problem in other seasons as well. The rainfall and soil erosiveness of an area are also influential with respect to the frequency and severity of duststorms.

Transported Particulates

The term transport refers to the movement of particulates over a greater distance than normally considered for dispersion modeling used for air quality planning. Transported particulates include primary particles, which are emitted directly into the air and secondary particles, which are formed from reactions of gases in the atmosphere. While natural particulates can also be transported considerable distances, this discussion of transported particulates is meant to center on particulates that originate from man's activities.

Transported Primary Particulates — The transport of primary particulates may be divided into two classes — short-range and long-range. Long-range transport occurs when the particulates are mixed into an air mass and travel several hundred kilometers or more without any removal mechanisms such as washout or rainout. This phenomenon of transport is directly related to meteorology because it requires a stable air mass moving across the country. An interesting case study of the transport of a particular air mass is described in Appendix C. This study demonstrates how long-range transport can produce abnormally high values of particulates over short periods, causing violations of the 24-hour standards. The degree to which it affects annual means is related to the frequency of such occurrences.

Short-range transport refers to the transport of particulates over less distance, ranging from a few to about 100 kilometers. It is primarily concerned with the movement of particulates across planning area boundaries; i.e., from the jurisdiction of one air pollution control agency into the jurisdiction of another. This problem has been recognized in the guidelines for the classification of areas with respect to deterioration of the air quality. For instance, an AQCR cannot be designated Class III (degradation up to the air quality standards) if such a designation will also result in degradation of the air quality of an AQCR designated Class I (minimum degradation).

Obviously, short-range transport of primary particulates is of principal concern in areas which have adjoining urban areas with insufficient rural areas between to allow for removal or dispersion of the pollutants. Such is the situation in the northeast where the air may sweep up past Baltimore, Washington, and Philadelphia into New York and up to Boston. In the study of Providence under this effort, high values of particulates, even in the less developed areas of the AQCR, were most often associated with winds from the direction of New York City. Meteorology is a complicating factor in this analysis because of variations in windspeed and rainfall with changing wind direction. However, it is likely that such conditions do exist.

Over even a smaller scale, transported primary particulates are important whenever air crosses from one region that is completely autonomous into another area that has separate control. Such a situation was found in Philadelphia in the course of this study. The Philadelphia Air Management Services has complete responsibility in Philadelphia County, while the Commonwealth of Pennsylvania Department of Environmental Resources has responsibility for the counties surrounding Philadelphia. Since the entire County of Philadelphia can be considered urbanized, the most remote site in the network is one located in a lightly dense residential neighborhood near the border of Philadelphia and Montgomery Counties. This site had an annual mean of 59 $\mu g/m^3$ in 1974, implying that there were virtually no means of avoiding violating at least the secondary annual standard as the air passed over the city. Another site, in a more industrialized corner of the county but also near the industrialized areas of Delaware County in Pennsylvania and Gloucester County in New Jersey, had an annual mean of 94 $\mu g/m^3$. The value at this site is especially important since it is in the southwest corner of Philadelphia County, the direction from which most of the air crossing the county would come.

Transported Secondary Particulate — As mentioned previously, secondary particulates are the products of chemical reactions occurring in the atmosphere. They can initiate in the gas phase or as a result of reactions between gases and already existing particles. They are a major source of the ubiquitous Aitken nuclei, or homogenous nucleation centers, that are essential for most of the condensation processes that take place in the atmosphere. They are also a prime component of urban smog.

Composition — The main ingredients in the formation of secondary particulates are sunlight and gases such as sulfur dioxide, ammonia, nitric oxide, water vapor, and hydrocarbons, which enter the atmosphere from both natural and manmade sources. Secondary particulates range in size from molecular clusters with diameters on the order of 0.005 μm to particles with diameters as large as several micrometers. Field studies of urban aerosols[2-4] have shown that the highest concentration of secondary particulates is usually in the range 0.01 to 1.0 μm. The concentration of particles in this size range can vary directly with intensity of sunlight and concentration of ozone.

The principal factors governing distribution by size over the respective rates of particulate formation and removal. The smallest particles, which are created constantly during the daylight hours, coagulate into larger particles. The overall life cycle of secondary particulates is difficult to determine; estimates range from 1 week to 40 days.[5] In the end, the particles are either removed from the atmosphere by precipitation or dry deposition. During this period, however, they may be transported vast distances from the source of the gaseous precursors.

Found in both urban and rural areas, secondary particulates are in general composed of three types of chemical compounds — sulfates, organics, and nitrates — which are briefly discussed below.

Sulfates. Sulfates are ubiquitous. A large fraction of the global aerosol is ammonium sulfate $(NH_4)_2SO_4$. Sulfates such as sulfuric acid (H_2SO_4), which is found in most urban aerosols, result from the reaction of SO_3 and water. The sulfate salts, such as $PbSO_4$, in turn, derive from the reactions of compounds such as ammonia or metallic oxides with sulfuric acid droplets.

Organics. The second major constituent of secondary particulates is produced by the reaction of hydrocarbons with oxidants (e.g., NO_2, O_3) in the atmosphere to produce peroxide radicals. Through a series of chain reactions, these radicals eventually form large organic molecules which condense to form droplets or solid particles.

Primary sources of hydrocarbons in urban areas are automobile exhaust and industrial effluents. In some rural areas, hydrocarbon emissions from natural sources may be significant. Terpenes are an example of such emissions; many terpenes are highly unsaturated, and in some cases they can even be oxidized in the dark by reaction with O_2. The particulates formed by oxidation of these organic vapors are sometimes the cause of the haze observed in rural areas.

Nitrates. Nitrogen oxides emitted into the air can be oxidized and react with water to form nitric acid in either vapor or droplet form. From this form, nitrates are created through reactions with gaseous or solid species.

Air quality impact — Secondary particulates can occur both over a long period of transport and apparently also fairly quickly in an urban area. As with primary particulates, secondary particulates can be important over both short-range and long-range transport. The long-range transport study in Appendix C found sulfate levels three times higher than normal; shorter transport of secondary particulates is known to contribute to high levels in the northeast.

Annual levels of sulfates and nitrates for nonurban areas near each of the 14 study cities are given in Table 9. Average values for each of the industrialization classifications, for the cities in the east (of the Mississippi River) versus the west, and for the cities in the north (heating degree days more than 4000/year) versus the south, have been calculated. While the heavily industrialized cities have the highest nonurban levels of secondary particulates, this division apparently results from the geographic location of the cities. The highest levels within each category of industrialization occur in cities east of the

Table 9. NONURBAN LEVELS OF SULFATES AND NITRATES IN THE 14 STUDY CITIES[a]

Cities	Nonurban levels		
	SO_4	NO_3	Total
Heavily industrialized			
Cleveland	10	1	11
Birmingham	7	1	8
Philadelphia	10	1	11
Baltimore	8	1	9
St. Louis	6	1	7
Cincinnati	11	1	12
Average	8.7	1.0	9.7
Moderately industrialized			
Chattanooga	6	2	8
Denver	2	0	2
Seattle	3	0	3
Providence	7	1	8
Average	4.5	0.8	5.3
Lightly industrialized			
Washington, D.C.	8	1	9
Oklahoma City	3	1	4
Miami	5	1	6
San Francisco	2	0	2
Average	4.5	0.76	5.25
East	8	1.11	9.11
West	3.2	0.4	3.6
North	7.2	0.78	6.0
South	4.6	1.0	5.6

[a]Best estimate averages based upon composite values of available NASN data.

Mississippi, where the density of industrialization is greatest, and also in the northern cities, where space heating is more important. In the two dichotomous breakdowns - north versus south, east versus west - the impact of geographic location on the nonurban values is obvious. A logical extrapolation of these data would be that nonurban secondary particulates are highest in the northeast and lowest in the southwest.

Other Factors

As mentioned previously, two other factors are important when considering nonurban TSP levels and the use of such levels in air quality planning. Nonurban levels can reflect local influences that are not of concern when planning control strategies for an urban area because the particulate matter is not actually carried into the urban area. At the same time, secondary particulates formed locally in an urban area are not accounted for in nonurban monitoring, and therefore, these urban secondary excess levels are not appropriately incorporated in traditional air quality planning.

Local Rural Influences - Local influences on nonurban levels can be traditional emissions such as from local space heating and rural industrial activity; but, more likely, these local influences are artifacts of the monitor placement so that the TSP levels are subject to reentrainment from dirt roads, agricultural tilling, or natural wind erosion. Similarly, TSP levels reported as nonurban levels may be from monitors located in small, rural towns; these monitors would also be measuring the particulates generated by man's activities (traditional and nontraditional sources) in the town.

Emissions from dirt roads in the major counties in the study AQCRs are discussed later under the topic of Nontraditional Sources. That analysis suggests that the current inventories for dirt roads provides an exaggerated picture of the importance of unpaved rural roads to the air quality in an urban area. The current inventories suggest that emission levels due to dirt roads in urban counties are usually much higher than the total traditional source emission levels in urban areas. Obviously the air quality impact from these sources is not equivalent to that from traditional sources; otherwise, the TSP concentrations in rural areas would be expected to reach or exceed those in urban areas.

Similar findings apply to the inventoried emissions for agricultural tillings. While the emissions from tilling were never as great as those from dirt roads in the 14 AQCR's studied, in some areas the levels are quite high; e.g., in the San Francisco Bay Area AQCR, emissions due to tilling are inventoried at almost 190,000 tons per year. Since tilling does not occur throughout the year but only at certain seasons, any impact from tilling would be expected to be short-term, perhaps causing elevated levels for a month at a time.

Urban Secondary Excess - Secondary particulates formed in the urban area as a result of local emission sources have been ignored in control strategies applied to air quality planning; i.e., control of TSP concentrations has been approached solely by reducing directly emitted particulates. Presumably, the amount of secondary particulate formed is related to the amount of precursors, so that higher levels of secondary particulates may be expected to be found in the more industrialized regions. For sulfates, the amount of space heating with fuels high in sulfur may be important in winter.

Because of the different control approaches that are open to an individual air pollution control agency, it is helpful to separate out the secondary particulates formed within the jurisdiction of the agency from those formed in transport to the region. The annual levels of sulfates and nitrates for urban and nonurban areas in each of the 14 study cities are given in Table 10 and averages have been calculated for the same breakdowns given in Table 9. The data in Table 10 demonstrate that air entering the city is the predominant factor in determining the sulfate levels in a city but that nitrate levels can increase by a factor of three in the city. Since

Table 10. URBAN AND NONURBAN LEVELS OF SULFATES AND NITRATES IN THE 14 STUDY CITIES[a]

Cities	Nonurban levels			Urban levels			Urban excess		
	SO_4	NO_3	Total	SO_4	NO_3	Total	SO_4	NO_3	Total
Heavily industrialized									
Cleveland	10	1	11	10	3	13	0	2	2
Birmingham	7	1	8	14	3	17	7	2	9
Philadelphia	10	1	11	14	4	18	4	3	7
Baltimore	8	1	9	10	3	13	2	2	4
St. Louis	6	1	7	12	3	15	6	2	8
Cincinnati	1[illegible]	1	12	12	3	15	[illegible]	2	3
Average	8.7	1.0	9.7	12.0	3.2	15.2	3.3	2.2	5.5
Moderately industrialized									
Chattanooga	6	2	8	11	2	13	5	0	5
Denver	2	0	[illegible]	5	3	8	3	3	8
Seattle	3	0	3	7	2	9	4	2	6
Providence	7	1	8	9	2	11	2	1	3
Average	[illegible]	0.8	5.3	8.0	2.3	10.3	3.5	1.5	5.0
Lightly industrialized									
Washington, D.C.	8	1	9	12	3	15	4	2	6
Oklahoma City	3	1	4	3	2	5	0	1	1
Miami	5	1	6	5	1	6	[illegible]	[illegible]	[illegible]
San Francisco	2	[illegible]	2	5	2	7	3	2	5
Average	[illegible]	[illegible]	5.25	6.25	2.0	8.25	1.75	1.25	3.0
East	8	[illegible]	9.11	10.78	[illegible]	[illegible]	2.78	1.56	4.33
West	[illegible]	[illegible]	[illegible]	6.4	2.4	8.8	[illegible]	2.0	5.2
North	7.2	[illegible]	6	[illegible]	2.8	[illegible]	[illegible]	2.11	5.0
South	[illegible]	1.0	5.6	2.0	5.9	[illegible]	[illegible]	1.0	4.0

[a] Best estimate averages based upon composite values of available [illegible] data

sulfates are the predominant secondary pollutant, the average increase in secondary particulates is on the order of 60 to 70 percent. As may be expected, the largest increases (urban excesses) are seen in the highly industrialized areas where secondary particulate levels inside the city average 6 $\mu g/m^3$ above those in the nonurban setting; lightly industrialized areas have half of this increase. On the whole, cities may have concentrations elevated 5 to 15 $\mu g/m^3$ due solely to sulfates and nitrates. Two important points concerning Tables 9 and 10 are that some sulfates may be directly emitted as primary particulate, and secondary organics may also be significant, but adequate measurements were not available.

National Assessment

As has been shown above, particulate levels exist which are beyond the control of individual state and local air pollution control agencies. These levels of TSP enter the jurisdiction of an agency along with the air mass that is carrying them. The particulates entering a region may be the result of a facility a few miles upwind of the jurisdiction, of another city 50 km away, of sources generating precursors to secondary pollutants hundreds of miles from the region, or of natural nonurban sources such as sea salt, pollen, and wind-driven dust. While the smaller scale transport problems may often be adequately handled by cooperation between adjoining state and local agencies or by EPA regional office intervention, the larger scale influences either cannot be controlled or need direction and planning on the national level. These larger scale problems are addressed below.

The concentration of particulates in rural areas of the country has been monitored for many years as part of the National Air Surveillance Network (NASN). Figure 4 presents composites of values reported at various nonurban NASN sites from 1970 through 1973. The data in this figure indicate the wide range of annual means being reported. In addition to the problem of transported primary and secondary particulates, some of the range in TSP values is expected to be due to inconsistent and, in some cases, poor

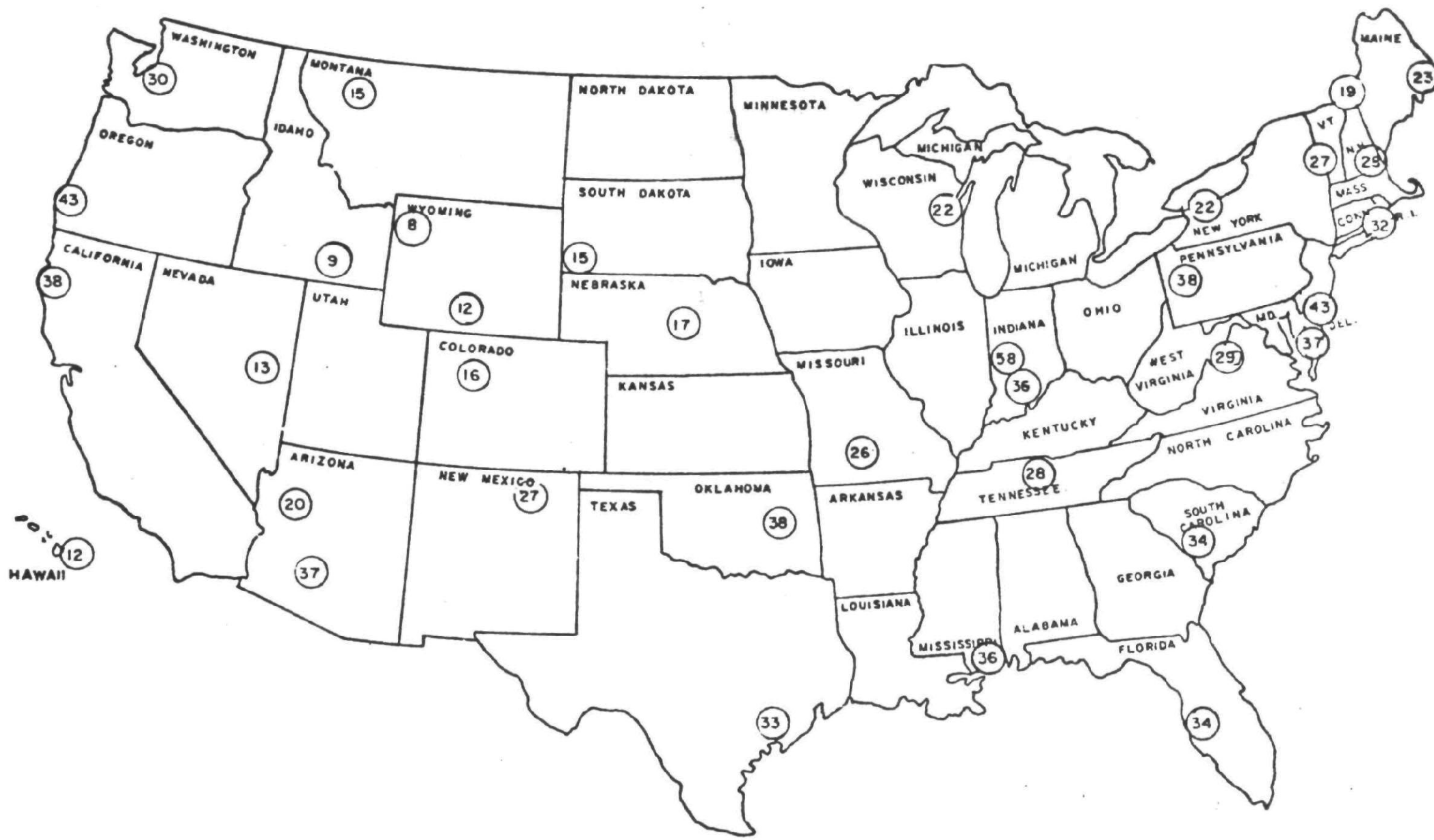


Figure 4. Composite annual geometric mean TSP levels at nonurban NASN sites from 1970 through 1973 ($\mu g/m^3$)

monitor siting. For instance, the high values reported at the monitors on the west coast (California and Oregon), which would be expected to have values half of those reported based upon global and continental particulate levels, are recorded by monitors located on the ground. As discussed later under reentrainment, such low siting is expected to result in highly exaggerated values. The high value of 58 $\mu g/m^3$ reported in Indiana is due to a nearby power plant influencing the levels in the rural area.

The impact that transported secondary particulates have on these nonurban sites can be seen in Figure 5, which presents the nonurban sulfate and nitrate levels for 1974. Almost no nitrates and very little sulfates are found in the western part of the country, yet secondary particulates consistently add more than 5 $\mu g/m^3$ to the TSP loading at nonurban sites east of the Mississippi River. These data reiterate the findings of the 14 city case studies: secondary particulates in nonurban areas can add significantly to the TSP burden on cities in the east and northeast.

The transported primary particulates cannot be so easily addressed on the national scale for several reasons. One reason is that the density of nonurban NASN monitors is too low to provide adequate information on the change of TSP levels between major urban areas. Such an analysis would have to include monitors operated by state and local agencies in order to be close to the density of monitors needed, and these data were not available on a nationwide or even regionwide basis. Therefore, the conclusions on transported primary particulates must stand solely on the earlier discussion and the analysis provided in Appendix C.

Another problem already mentioned, monitor height, not only means that transport cannot be accurately determined but also brings many of the reported nonurban values into question. Most of the monitors in the nonurban network apparently are located at heights below 10 feet, with many of them in the 3 to 6 foot range. Such monitors are more likely to be influenced by nearby disturbances than by any particulates being transported into the region.

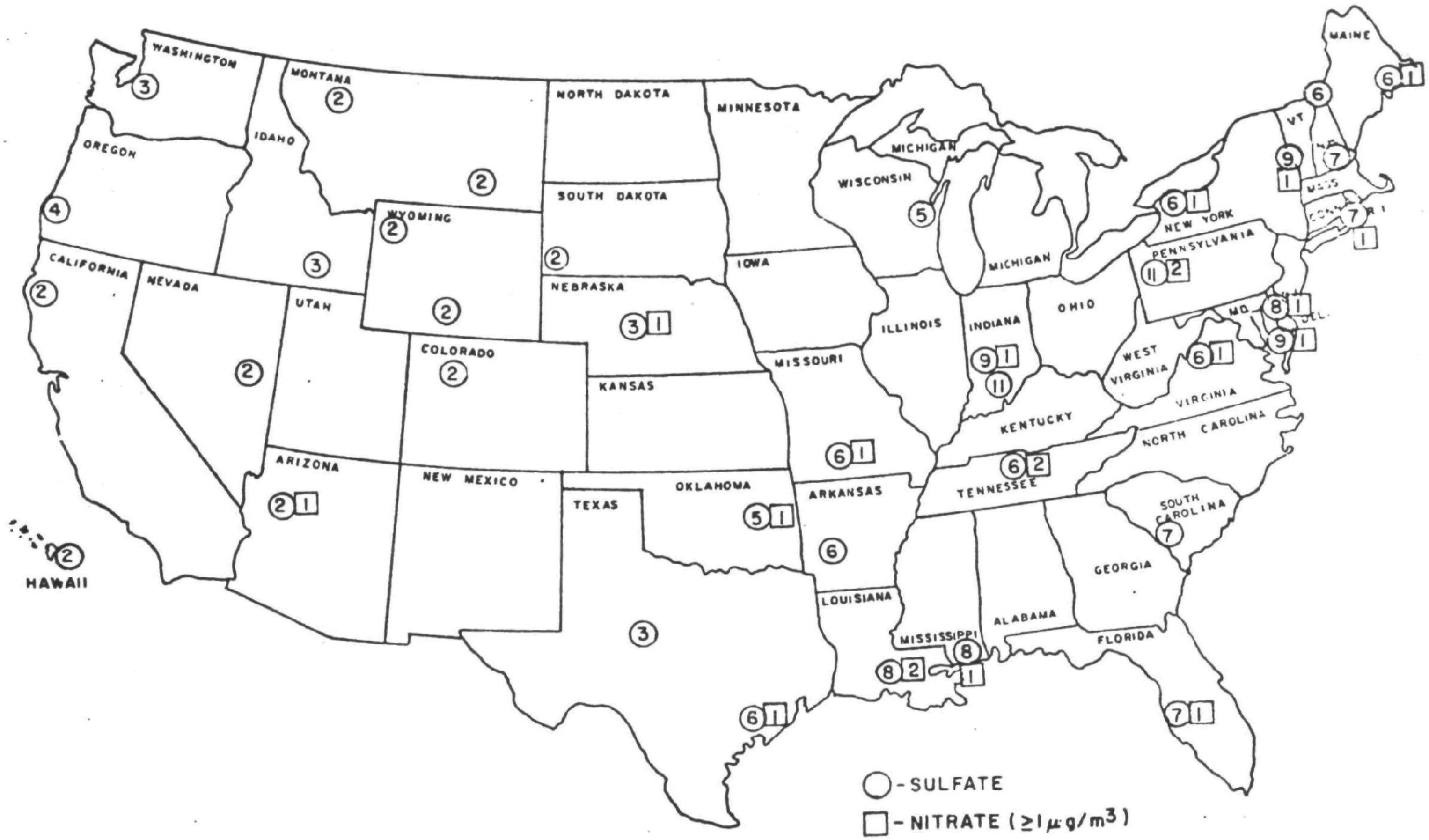


Figure 5. Annual geometric mean sulfate and nitrate levels at nonurban NASN sites — 1974

Despite these problems, some estimate of the variations in the nonurban levels can be made from the findings of this study. Figure 6 provides a conceptualized diagram of the contributions to nonurban levels as one moves across the country. Global particulates are assumed to be constant across the country. Continental particulate is lowest on the west coast, where the land area has not had a chance to contribute significantly, and highest in the midwest due to the high winds and more arid conditions. The occurrence of some off-the-ocean air masses is felt to bring down the continental contribution a little in the east.

Transported secondary particulates contribute only a few micrograms in the west and midwest. However, in the east, nonurban levels of secondary particulates are averaging around 10 $\mu g/m^3$. Although the long-range transport case study presented in Appendix C is for Oklahoma City, the impact of transported primary particulates on annual TSP levels in the west and midwest is felt to be minimal. In the east where cities are more concentrated, transported primary particulates are more serious, averaging about 5 $\mu g/m^3$ on an annual basis throughout the east but potentially much higher in the congested northeast.

On top of all these contributions, another few micrograms have been added to reflect the local influences occurring on a large scale basis in the rural areas (space heating, traffic, agricultural activity, etc.). This additional level does not include immediate impacts from nearby sources (power plants, roads) or from possible reentrained dust due to low monitor height.

PARTICULATES FROM TRADITIONAL SOURCES

The most obvious of the many factors affecting attainment of the TSP standards are the particulate emissions from three major categories of pollution sources — fuel combustion, industrial processes, and solid waste disposal operations. These three source categories have long been considered significant pollution problems, and have traditionally been the

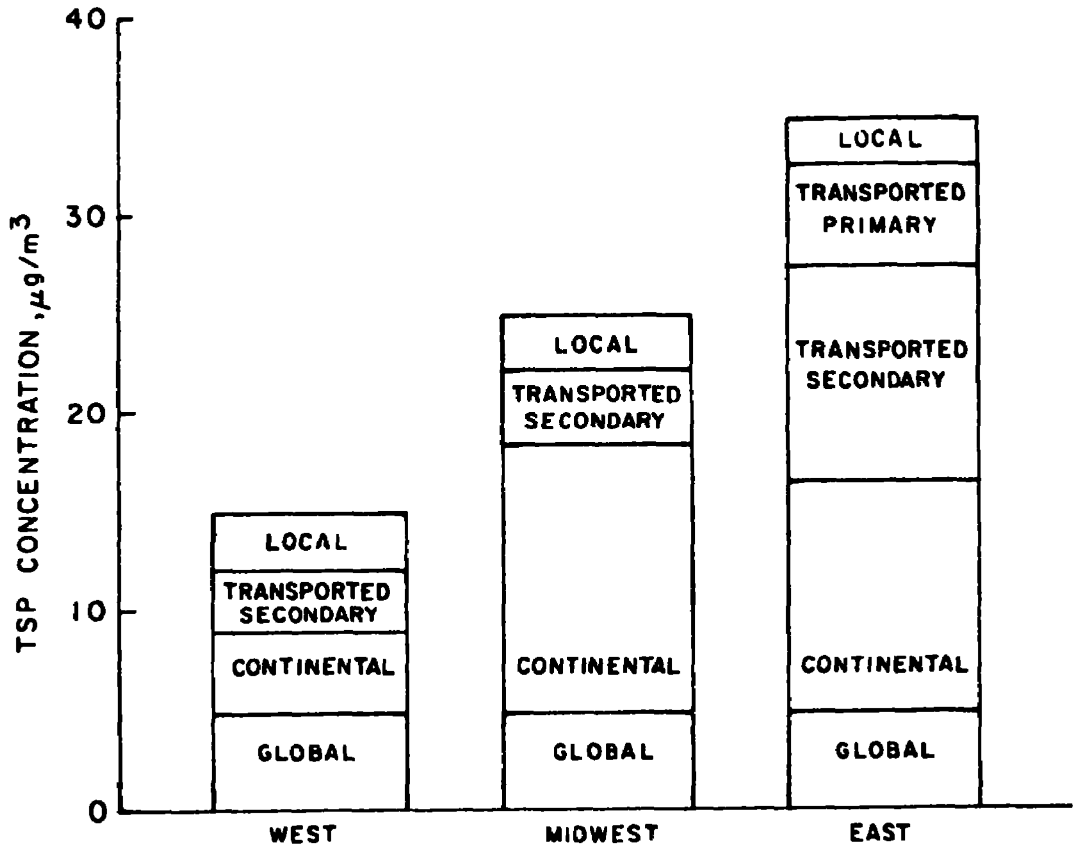


Figure 6. Average estimated contributions to nonurban levels in the East, Midwest, West

primary concern of air pollution control efforts; consequently, they have been labeled "traditional sources" for purposes of this study. This section summarizes the assessment made of the significance of traditional source emissions as a factor in the nonattainment of the TSP standards; Appendix D presents summaries of the data assembled and the analyses made to develop the assessment.

In general, the impact of traditional sources on nonattainment depends very heavily on the nature of the urban area in question. The 14 case study areas included both cities where traditional sources totally dominate the picture and cities where they are not now, and probably never were, a major share of the problem. Based on analysis of aggregate emission inventories, emission densities, and compliance trends, it is possible to summarize the impact of traditional sources in the 14 case study areas as follows:

I. Three areas, all heavily industrialized, still have a major problem with traditional sources;

II. Three areas have reduced emissions from traditional sources to the point where they are no longer totally dominant, although continuing further reduction and on-going surveillance is still required;

III. Four areas have reduced formerly moderate levels of traditional source emissions (mostly from fuel use for heating and light industry) to near insignificance;

IV. In four areas, traditional sources probably never were a serious problem.

While these specific proportions are not necessarily reflected in the overall national picture, there are certainly a number of urban areas throughout the country in each of these categories.

A comparison was also made of the emission parameters leading to this classification with air quality levels in the various urban areas, expressed as city wide average TSP concentrations. With adjustments made for differing nonurban levels and secondary particulates, essentially no difference in typical air quality between the third and fourth categories listed above was indicated, with the average for both groups being 35 $\mu g/m^3$ above nonurban levels (Denver was excluded as an anomaly). This approximates the contribution of nontraditional sources as discussed later. The three heavily-industrialized cities still dominated by traditional source emissions had an average city wide TSP level of 66 $\mu g/m^3$ above nonurban, suggesting that about 30 $\mu g/m^3$ is the maximum potential city wide reduction, even with very stringent traditional source control. The three cities (category II) that have made significant but as yet incomplete traditional source reductions averaged 48 $\mu g/m^3$ above nonurban levels, suggesting that there is still 10 to 15 $\mu g/m^3$ of traditional source influence on city wide averages which could be reduced somewhat with further control of traditional sources. Figure 7 displays the relationship between emission density and air quality, and illustrates the clustering of the study cities into the categories. It is important to remind the reader that these results must be interpreted as only semi-quantitative and extrapolated with care. Although it is believed they provide a good national aggregate assessment of the role of traditional sources, this analysis does average over different neighborhoods and over vastly different cities with significaly different sources and control programs, and meteorology.

With respect to the three major categories of traditional sources - fuel combustion, industrial processes, and solid waste disposal - the relative contributions also varied significantly with the nature of the different urban areas. The fuel combustion contribution to inventoried emissions ranged from less than 20 percent in clean-fuel, industrialized areas to well over 90 percent in totally nonindustrial areas, with industrial processes accounting for most of the balance. Solid waste disposal emissions were generally less than 5 percent.

Fuel Combustion

The magnitude of fuel combustion emissions depends primarily on the amounts and types of fuels burned, but the degree to which they are or can be controlled primarily depends on the installation size — point sources and

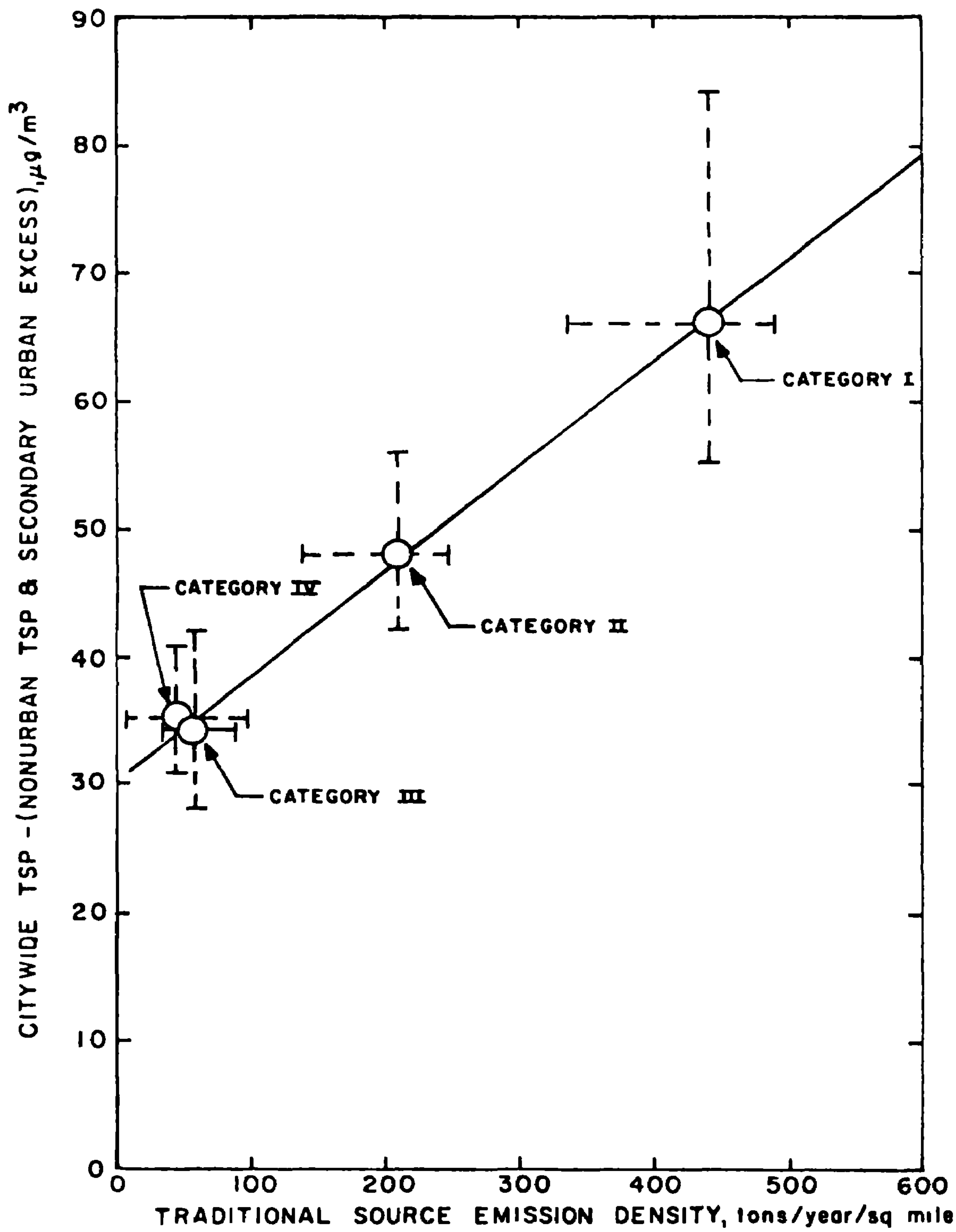


Figure 7. Relationship between city wide average TSP levels and traditional source emission density

area sources - and sometimes on the type of source - electric power, industrial or residential. The overall pattern of the fuel combustion emissions was generally as would be expected, with greater emissions in areas where coal and heavy oil are more prevalent, and in areas where major electric power or industrial combustion sources remain uncontrolled. Substantial further reductions in particulates from these sources are expected under present regulatory plans. In addition, there is a significant range in the stringency of emission regulations applied to combustion sources, so that in many areas there is room for further reductions by tightening the standards.

One particular aspect of fuel combustion emissions control to which the study sought an answer is the question of residential space heating. The use of coal in residential units has declined almost to the point of insignificance, but in coastal cities the use of oil (rather than gas) is common, and is likely to remain so. Since small oil burners are generally controlled only through visible emissions enforcement, if at all, the degree to which they might contribute to the TSP problem is an important open question. In the cities selected for the study, it proved impossible to separate the extensive residential use of oil from other fuel use and industrial sources by means of the air quality and emission data analysis techniques primarily used. However, it did prove possible to make a rough estimate of the impact from heating oil based on the microscopic analysis of hi-vol filters from the various cities. Composited results for each city, while subject to significant caution in interpretation, did indicate elevated levels of oil soot in those cities — Providence, Washington, Seattle, and Baltimore — where they would logically be expected. An approximate comparison of these results with those in the other cities suggests a contribution to TSP levels of no more than 5 $\mu g/m^3$. While this is a small portion of the typical urban levels of 75 to 100 $\mu g/m^3$, it is a significantly larger portion of the 30 to 35 $\mu g/m^3$ "working range" between typical nonurban levels and the secondary standard.

Industrial Processes

The second major category of traditionally considered pollution sources are industrial process losses, as distinguished from emissions from industrial fuel combustion emissions. Process emissions are divided into stack emissions and fugitive emissions, the latter being those indirect emissions from doors, windows, etc., material storage piles, or other outside activity on the plant property. Historically, primary concern has been directed at stack emissions, which are more easily identified, quantified, and controlled, and have, in the past, been the major sources of particulate emissions from industry.

Stack Emissions — The degree of the process emission problem is dependent on the industrialization of the area in question. In the heavy industrial cities where control of process sources is still being pursued, these sources, along with industrial fuel use, dominate the air pollution picture. In those industrial cities where emissions from process sources have been generally controlled, they tend to remain roughly half the total inventory. The process weight regulations concerning stack emissions from process losses are not amenable to significant tightening, and further reductions of inventoried emissions will generally need to come from enforcement of existing regulations, adoption of tighter regulations for specific types of sources, and control of fugitive emissions. The industry categories that continue to pose the greatest stack emissions problem are the primary metals and minerals processing industries.

Fugitive Emissions - Fugitive industrial emissions have been traditionally recognized, but only minor control efforts have been pursued to date. In many operations, especially where dry materials handling is prominent, emissions are generated in processes both inside and outside of plant facilities, but on plant property, which are either ignored or insufficiently controlled so that significant particulate emissions are generated. For industrial processes that operate outdoors, such as coke ovens and rock crushing operations at quarries, these pollutants are directly emitted to the ambient air. Even when such processes are enclosed, the pollutants emitted into the working environment may escape to the atmosphere through windows, doors, roof ventilators, or even unsealed cracks in walls. In either case, those pollutants that enter the outside ambient air have been defined as fugitive emissions.

Fugitive emissions result from a wide variety of circumstances, including poor operation or maintenance of process equipment. For example, fugitive emissions can be the result of leakage from warped doors on coke ovens as well as the oven charging operation itself. Storage piles and handling operations for sand and gravel, coal, grain, and other materials that are kept in the open can become fugitive sources when a strong wind blows over them. Similarly, dirt and gravel parking lots and roadways on industrial property can become major sources of particulates due to either wind erosion or traffic.

Fugitive emissions have generally been assumed to be small in comparison to stack emissions. However, with stack emissions coming under controls that may provide up to 99 percent reduction, the relative importance of fugitive emissions has been growing, and they may now comprise a significant portion of nationwide emissions. For example, EPA has estimated that total fugitive emissions of particulate from electric arc furnace charging can be 5 to 50 times the amount of the stack emissions emitted downstream of the control device.

Even if the quantity of fugitive emissions from a process is small in comparison with the stack emissions, the low height at which they are typically emitted means that very little dilution occurs and fairly high ambient levels are created. Consequently, even though adequate emission estimates are lacking, fugitive emissions appear to be a significant and increasing problem. A very rough estimate based on comparing TSP levels at various monitoring sites (see Appendix D) suggests their aggregate impact in industrial neighborhoods is typically on the order of 25 $\mu g/m^3$.

Reduction of fugitive emissions will likely require a new approach to regulatory control of such emissions. Currently, regulations for control of fugitive emissions are of three general types: nonspecific nuisance regulations, quantitative property-line regulations, and regulations that prescribe specific control measures in specific circumstances. The majority of regulations in the country are of the first type, defining dust as a nuisance and often requiring "reasonable precautions" to prevent emissions. While flexible and capable of being strong enforcement tools, such regulations have not in fact proven effective on an overall basis. The other two types can be more effective, though clearly not without serious enforcement efforts. Property-line regulations in particular require enforcement and measurement techniques that are even more difficult than those required for stack emission sources. Although both alternative types are apparently somewhat better than nuisance regulations, there were only limited areas where they are used, and no areas where an extensive, effective control effort was underway.

Solid Waste Disposal

Of the several methods of solid waste disposal, incineration and open burning have traditionally been the most common in urban areas and, therefore, the most significant sources of particulate emissions. Under pressure from pollution regulations, however, the larger point sources of solid waste disposal emissions, municipal incinerators and large industrial installations have been controlled or replaced, while the smaller residential and commercial incinerators and open burning in dumps are typically tightly regulated and often banned. With the continuing trend toward landfills, recycling, and the use of combustible rubbish as a fuel supplement, solid waste disposal is expected to continue to decline in significance as a factor in attaining the NAAQS.

Surveillance, Compliance and Enforcement Programs

An integral part of the impact that emissions from traditional sources may have on standards attainment is involved with the nature and effectiveness of the pollution control effort applied to them. Since fuel combustion, industrial processes and solid waste disposal have long been viewed as important sources of particulate emissions, maintaining surveillance over these traditional sources and enforcing regulations concerning them have been major activities of many control agencies since their inception. The nature of the control programs varies significantly, involving various combinations of source registration, permit systems, inspections, and so on.

The achievements of surveillance and enforcement programs depend on the matching of enforcement activities to the nature of the particulate emission problem. Among the 14 cities, the largest actual reductions in emissions from traditional sources have been achieved in those cities where surveillance and enforcement programs are comprehensive and vigorous. The activities of such programs generally included the following: constant surveillance and patrols, frequent inspections of problem sources, a general knowledge of all of the traditional sources, rigorous compliance determination, prompt action when a violation or upset occurs, issuance of compliance orders that are strict yet reasonably attainable in the opinion of an appeals board, and strict enforcement of compliance schedules.

The stringency of the regulations being applied is obviously important in determining the reductions in particulate emissions actually obtained. Study findings indicate, however, that somewhat more important are the enforceability of the regulations, the strictness of the enforcement, and especially the manner in which compliance is determined. The enforceability of regulations affects the ease and speed with which emissions are controlled, and is influenced by the types of regulations in effect.

For example, in dealing with numerous small incinerators, a standard specifying certain types of equipment is much easier to enforce than an emission standard which requires monitoring; in dealing with coke ovens, an efficient standard is one that specifies maintenance and operating conditions; in dealing with fugitive emissions, a source-specific regulation is more effective than a general nuisance regulation. The enforceability of regulations is also related to the institutional channels through which any hearings and appeals proceed. Enforcement is more effective and more efficient when control activities and enforcement proceedings are conducted by the same governmental level — or at least by well-coordinated and geographically proximate agencies.

Another important concern is the matter of compliance determination. It is not at all clear that reports of full or near compliance actually mean that all or most traditional sources are in compliance with the regulations. While it was not a major purpose of the present study, some understanding of the methods used for compliance determination was obtained during discussions of overall compliance status. Only a few of the agencies conduct or require actual stack tests and then not on a routine basis. More commonly, compliance determination is done on the basis of walk-through inspections and theoretical calculations based on process loads, emission factors, control efficiency specifications, and similar data. While this type of compliance determination is appropriate for some sources and control measures when done by well-trained agency personnel, it is equally inappropriate for other, more complex sources with untried control technology, particularly when performed by relatively inexperienced agency personnel.

Air Quality Impact

A primary objective of the study was to develop an understanding of the impact that traditional sources have on TSP levels. Specifically, it is important to place traditional sources in a proper perspective with respect to the problem of standards attainment. The type of analysis based on citywide levels that was presented in Figure 7 is adequate for a broad, general perspective; however, a more careful analysis involving individual monitoring sites was also undertaken in order to provide a more detailed and comprehensive picture. This effort, involving over 150 hi-vol sites, considered in detail the nature of the site neighborhoods and the air quality levels recorded, and has provided an overall perspective which is used throughout this section to structure the summary discussion. Figure 8 indicates the quantitative impacts in various types of neighborhoods estimated to result from traditional source emissions. The figure estimates the impact at residential, commercial, and industrial sites in cities with two different levels of traditional source prominence, following the grouping presented in Figure 7. The higher portion of the bars represent the three cities where traditional sources are still dominant (Category I), and the lower portion the cities where significant control has taken place (Category II); in the other two categories, where traditional sources are largely absent or controlled, no apparent impact was seen. With respect to other parameters, such as meteorology, the estimates should be viewed as representing a hypothetical average city. The traditional sources in a heavily industrialized, not yet controlled city add 10 $\mu g/m^3$ at a typical residential site, 19 $\mu g/m^3$ at a commercial site, and about 70 $\mu g/m^3$ at an industrial site. Roughly, about 20 $\mu g/m^3$ of the latter may be attributed to fugitive sources.

PARTICULATES FROM NONTRADITIONAL SOURCES

The above discussion focused on sources traditionally considered for control of ambient levels of particulate matter; i.e., sources which are generally stationary point sources, or fugitive emissions. These traditional sources were shown to cause levels of TSP that were far in excess of the national ambient air quality standards. However, even in cities where TSP emissions from traditional sources are relatively small, citywide averages are 30 $\mu g/m^3$ or more above nonurban levels, and the secondary annual standard is being violated. Monitors in apparently clean

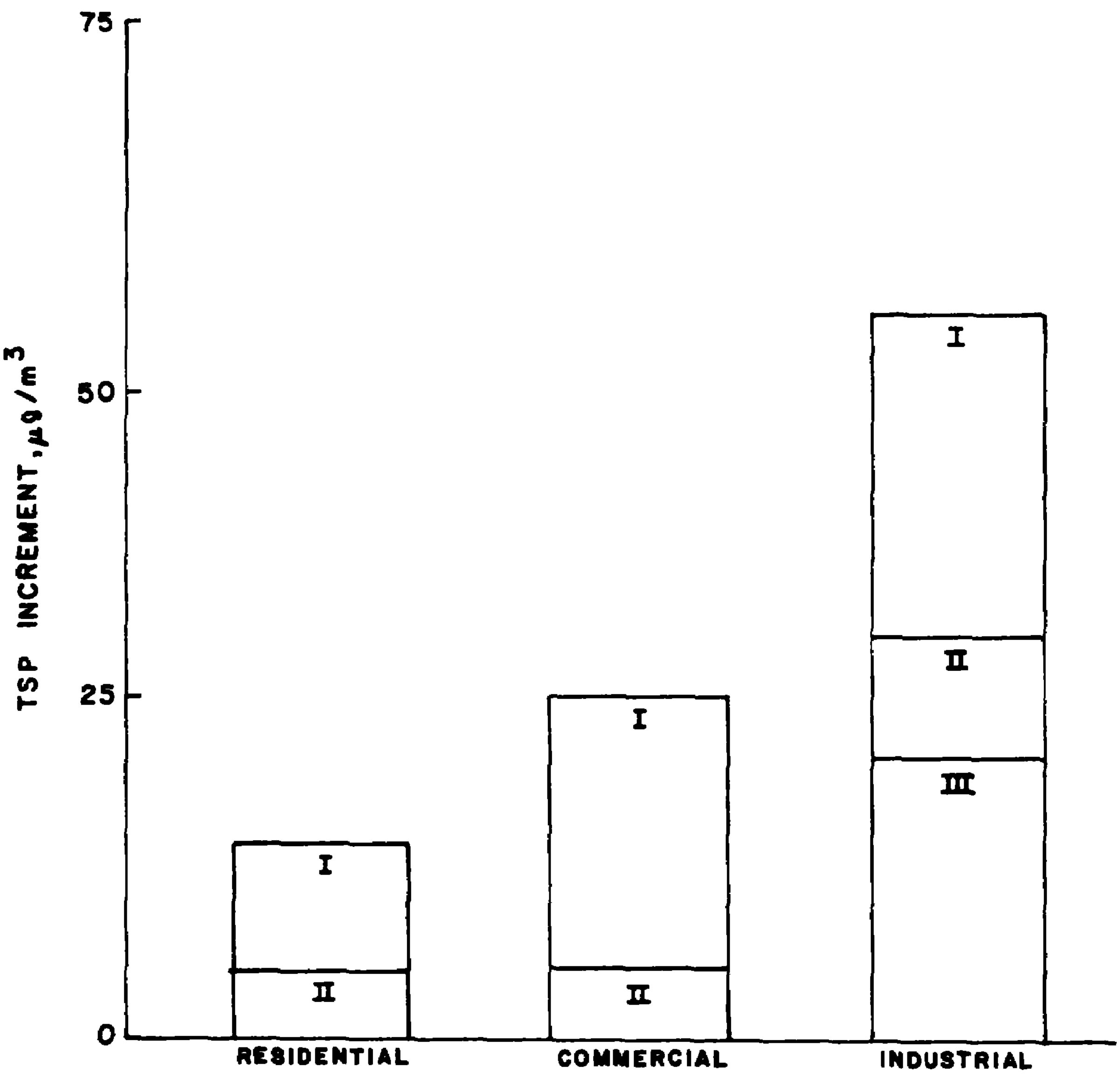


Figure 8. Traditional source increments in different *site types*

areas of a city or in smaller, nonindustrial cities have measured high TSP concentrations which cannot be explained by modeling with traditional source emissions or which fail to decrease as expected under controls of the State Implementation Plans. These findings indicate that a certain level of particulate in cities is caused by the concentrated activity in an urban area. These activities are here collectively designated "nontraditional" sources; i.e., those sources not traditionally considered in air pollution control strategies.

Nontraditional sources of particulates may be divided into two categories. One category consists of obvious, distinct sources of emissions that have not been normally considered as sources; these include construction and demolition activities, emissions from tailpipes, and tire wear. The other category refers to the more general problem of activity in the city and the characteristics of the urban setting that allow particulates to become entrained or reentrained.

Before the discussion of these categories, two terms merit differentiation: fugitive emissions and fugitive dust emissions. Both refer to general, nonstack emissions of particulates. However, fugitive emissions (included under traditional sources) result from industrial-related operations and escape to the atmosphere through windows, doors, and vents rather than through a primary exhaust system. Fugitive <u>dust</u> emissions, on the other hand, are generally related to natural or man-associated dusts (particulate only) that become airborne due to the forces of wind, man's activity, or both. Fugitive dust emissions include windblown particulate matter from paved and unpaved roads, tilled farm lands, and exposed surface areas at construction sites. Natural dusts that become airborne during dust storms are also included as fugitive dusts.

Estimates of emissions from nontraditional sources in several comprehensive reports tend to indicate that the total level of particulates from several of these activities are an order of magnitude larger than those from traditional sources. This study did not include any major effort to develop additional emission factors; rather, it concentrated on a review of the previously published literature plus analysis of air quality data collected to determine the impact of such sources on ambient TSP. Appendix E provides the detailed results of much of this analysis, the following discussion summarizes the findings.

Reentrained Particulates

In an urban area, particulate matter accumulates on the various city surfaces due to fallout, and especially heavy loads on streets can result from dirt and mud carryout from unpaved parking lots and roads, spillage from trucks, and sand and salt applied for snow control. This particulate matter can then become entrained and at least temporarily suspended in the ambient air due to wind erosion or man's activities disturbing the surface.

Natural Reentrainment - Natural reentrainment of particulates occurs when wind is strong enough to lift particulates from the surface. Due to the mechanics of wind erosion, such movement is more likely to be initiated in an urban area where hard, flat surfaces are exposed to the sweeping action of the wind. Based upon the analysis presented in Appendix F of this report and other literature, winds above 10 to 12 miles per hour are likely to be contributing to the TSP levels. Above this speed, the reentrained dust maintains the TSP level above what would be projected based upon the balanced dilution effect of the ventilation accompanying the wind. Therefore, the analysis in Appendix F indicates that the overall impact neither increases or decreases the daily TSP levels. However, cleaner surfaces (determined by comparisons after rainfall) did allow the dilution effect to reduce levels further than when the wind was blowing over dirtier surfaces (measured on days before which there was no rainfall).

Vehicular-induced Reentrainment - The most important contribution to reentrainment caused by man in an urban area is the disruption of surface dust by motor vehicle activity. The wheels of the vehicles not only impart kinetic energy to particles on the road but also grind up the larger, nonsuspendible particles into smaller ones and break up the cohesive bonds of the dust. Such activity in an urban area occurs primarily on paved roads with additional local impacts expected due to dirt and gravel roads and parking lots. The amount of particulate reentrained by motor vehicles is directly related to the amount of dirt on the road, its suspendibility (sand versus dust), the speed of the vehicles, and the level of activity (often expressed as ADT - average daily traffic).

Vehicular activity on paved roads - The data gathered in the course of this study provided several opportunities for making estimates of the impact of vehicular-induced reentrainment by comparisons of comparable monitoring sites. The best data were the result of special studies that had been or were being conducted by the local agencies to determine for themselves the impact of traffic on the measured TSP levels. Generally, this was done by monitoring in one location but at either different heights or distances from the road, or both. The analyses of these data for each city are given in the individual city reports and the cross-city analysis is provided in Appendix E.

The findings from these data indicated that there was a direct relationship between the daily TSP concentrations and average daily level of traffic (ADT) and an inverse relationship between TSP and the distance of the monitor from the traffic, measured by the slant distance $\left(SD = \sqrt{(\text{height})^2 + (\text{distance})^2} \right)$. A comparison of the ADT/SD to the TSP concentration implied that a linear relationship could be assumed to exist with good correlation.

As is discussed more extensively in Appendix E, this relationship between ADT and slant distance has a significant impact on the interpretation of TSP levels measured by a hi-vol anywhere near a street with significant traffic. The data assembled in this study were not quite adequate to support development of a quantitative relationship suitable for accurate calculations;

however, it is possible to provide rough estimates of the impact of vehicular traffic on nearby hi-vols. The data in Table 11 are meant to provide approximate values suitable for identifying sites with potential problems and roughly judging the magnitude of the problem.

Table 11. APPROXIMATE IMPACT (IN $\mu g/m^3$) OF VEHICULAR TRAFFIC ON NEARBY HI-VOL SITES

Traffic volume, (ADT)	Slant distance of hi-vol from street (feet)			
	20	50	100	150
1,000	5	2	—	—
5,000	25	10	5	3
10,000	50	20	10	7
30,000	100	50	25	15

Vehicular activity on unpaved areas - In many urban areas dirt or gravel roads and parking lots are used by individual establishments or in industrial areas because of the expense of adequate paving. These areas can be sources of dirt for carryout to paved areas and may also serve as areas for naturally reentrained dust. In addition, vehicular activity on these areas can bring about man-induced reentrainment.

A comparison of the published emissions from unpaved roads with those of traditional emissions is given in Appendix E for those central counties analyzed in the course of this study. That analysis implies that the unpaved road emissions in counties which are not totally urbanized can be 10 to over 30 times the emissions from traditional sources. Even in urbanized areas, where unpaved roads are not common, the fugitive dust from unpaved roads may be over 10 percent of the traditional emissions in the county.

Based on the discussion on reentrainment from paved roads, which indicates that the impact of fugitive dust from vehicular activity decreases quickly with distance, it is felt that these numbers are inappropriate for direct use in air quality planning. If these fugitive dust emissions are treated the same as traditional emissions and used in rollback or dispersion modeling calculations, there would be excessive, undeserved emphasis placed on these sources and a potential deemphasis of the control of traditional sources. While these amounts of particulate may be temporarily reentrained due to vehicular activity, they are not suspended for any length of time. If they were, the rural areas of counties would be expected to have TSP levels as high as those found in the cities; such is obviously not the case. Therefore, the use, if any, of these numbers would have to be limited to inputs to models which adequately reflect the deposition and other removal of the particulates.

Specific Urban Sources

Certain activities in urban areas have not been considered major contributors to the TSP levels and therefore have received little attention in the formulation of control strategies for particulates. Yet these sources may be considered true emission sources because the particulates arise directly as a result of the individual activity rather than as a by-product, and several recent studies have suggested that these sources may be having more of an impact than previously thought. Of particular interest in a crowded urban area are transportation sources - the tailpipe emissions from automobiles and the emission of rubber due to tire wear. In addition, construction/demolition activities that are constantly occurring in cities add to the total TSP levels measured. Each of these sources is discussed below.

Transportation Sources - Although particulates from the transportation sector have been inventoried, they have seldom been regulated except through ordinances prohibiting smoking vehicles and Federal restrictions on aircraft. Controls on motor vehicles have centered around emissions of carbon monoxide, nitrogen oxides, and hydrocarbons, which are one to two orders of magnitude greater than emissions of particulates. In addition, particulates from the transportation sector have generally been assumed to be insignificant when compared with emissions from traditional sources. However, as emissions from traditional sources have been reduced under implementation planning, their proportionate contribution to the TSP problem has been reduced so that particulates from the transportation sector have become increasingly more important.

Tailpipe emissions — Attempts to separate out the contribution of motor vehicles to the total TSP measured have centered around the use of lead as a tracer element. In most urban environments where lead, copper, and zinc smelters, grey iron foundries, or other major point sources of lead are not prevalent, ambient lead levels are assumed to be due almost entirely to vehicular activity. Therefore, if the ratio of TSP emissions from tailpipes to the suspended lead emissions is known, the ambient levels of lead can be multiplied by this ratio to provide the ambient TSP contribution due to total tailpipe emissions. Based on several studies reviewed in Appendix E, this ratio may be assumed to range from 3 to 5 depending upon the vehicle type and age mix.

Ambient lead levels are routinely measured in major cities through analysis of NASN filters, and many state and local agencies also perform their own studies for lead. (California has an air quality standard for lead of 1.50 $\mu g/m^3$ for a monthly average.) Ambient lead levels contained in the National Aerometric Data Bank (NADB) indicate average annual concentrations ranging from 0.5 to 2 $\mu g/m^3$ with a few cities measuring 3 to 4 $\mu g/m^3$. These lead data suggest that tailpipe emissions are contributing from 1 to 20 $\mu g/m^3$ to the total particulate levels measured. Data collected from the individual cities studied under this effort indicate lead values in the middle range of those reported above; i.e., around 1 $\mu g/m^3$. Therefore, it may be assumed that tailpipe emissions are generally contributing 3 to 5 $\mu g/m^3$ to the ambient levels.

Special sampling studies conducted by EPA in Miami and St. Louis as part of this study provided data on particle sizes by elemental composition. Results in both cities indicated that the lead particles being sampled are extremely small. Only a small percentage are greater than 4 μm in diameter, and the largest percentage was collected in the last impactor stage, implying the particles had an effective aerodynamic diameter of less than 0.25 μm. This small diameter means that the lead would be dispersed and transported much as a gas with very little fallout with distance. Therefore, it may be expected to be measured at rooftop levels or even in more remote areas.

As part of this special study conducted by EPA in Miami, 2-hour elemental concentrations were compared with the hourly traffic counts for 1 week. These data illustrated the expected relationship of increasing lead concentration (as high as 4.6 $\mu g/m^3$ for a 2-hour average) with increasing traffic, especially in the early morning when rush-hour traffic started and before mixing height and wind speed increases caused a drop in lead concentration.

A compilation of all the sites for which some lead data were available provided 49 monitors from six cities (Baltimore, Miami, Oklahoma City, Philadelphia, San Francisco, Washington) with annual average lead concentrations as well as individual filter analyses from several sites in the other cities discussed above. Those monitors with annual data were grouped according to their site classifications and then averaged to provide a mean concentration. Because the monitoring sites had a wide range of local influences affecting the measured lead levels, Figure 9 presents not only the mean values for each of the site classifications but also the range of values found. Since there were only four monitoring sites each for the classification of rural and industrial, these averages and ranges may not be representative of situations found in other cities.

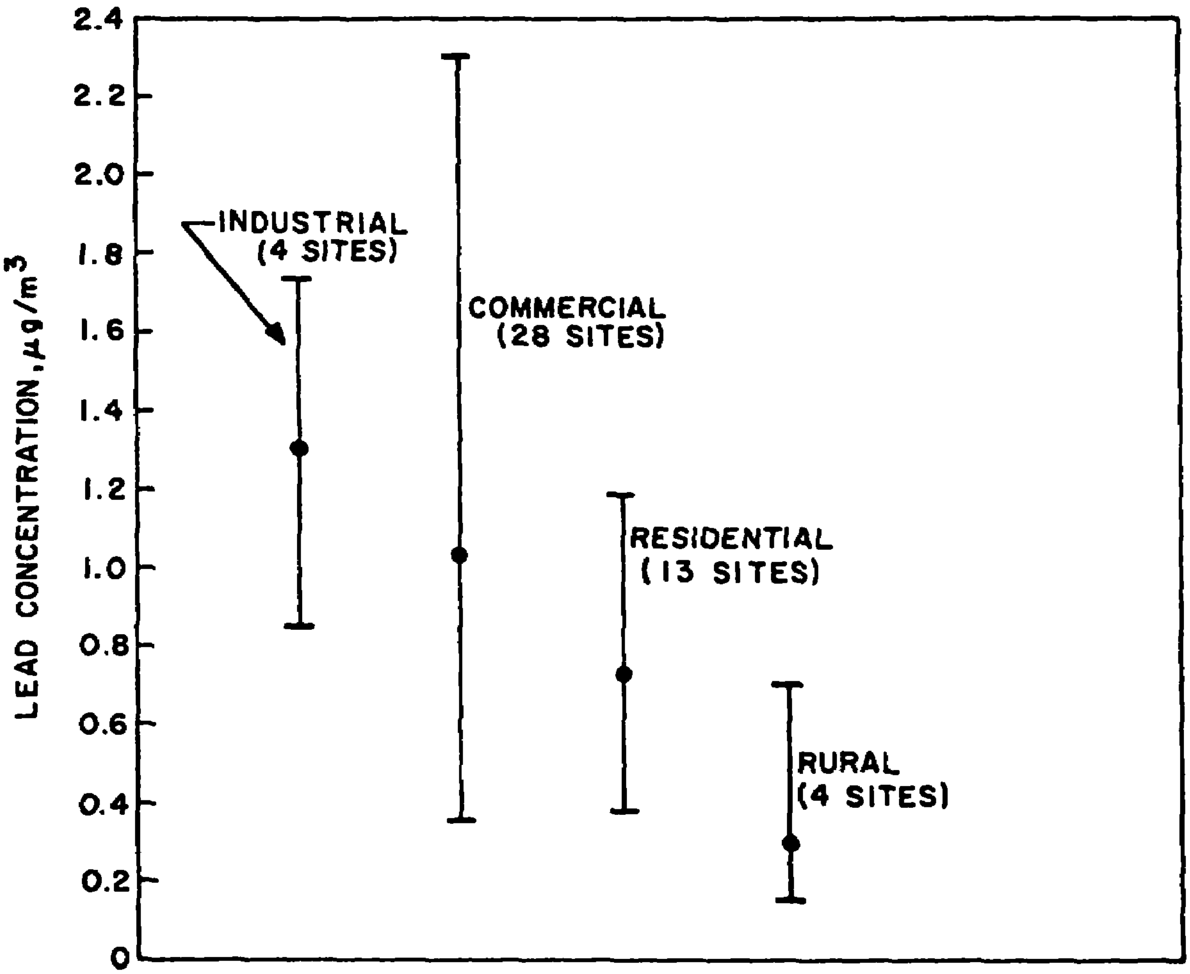


Figure 9. The range and average lead concentrations found at monitoring sites

Tire wear - Aside from direct tailpipe emissions and reentrainment dust, automobiles are known to generate particulates simply from the deterioration of the body and parts. Rust, corrosion, and friction of one part on another are all known sources. However, their magnitude is small compared with the wear that is seen on tires. In the U.S., an estimated 660,000 tons of tire-tread are worn away each year. Since over half of all vehicle-miles traveled (VMT) is in urban areas, approximately 350,000 tons of rubber are added to the urban environment every year. Considering the size and widespread nature of this source, its impact on air quality warrants study.

Although filters were selected from each city for microscopic analysis, neither the selection of a few filters nor the accuracy of the microscopy were believed to be sufficient to characterize the cities. However, the numerous filters from among the cities were considered to be adequate for averaging contributions according to the various classifications for the monitoring sites.

By using the percentage contribution of rubber tire fragments to the total visible loading on the hi-vol filter (diameter > 1 μm) and assuming approximately 85 percent of the loading was visible, average rubber loadings can be calculated for each site type. These average values, along with the range of values observed, are plotted in Figure 10. This figure shows that co-mercial sites, generally most esposed to traffic, have the highest contribution of rubber while undeveloped or rural sites barely measure any rubber.

In the course of the careful evaluation of the monitoring network in each city, monitoring sites were also rated on the basis of local influences, including paved roads. Sites with an expected paved road influence (10 in all) had rubber concentrations twice as high as sites for which no such influence had been noted - 9.9 and 4.9 $\mu g/m^3$ respectively.

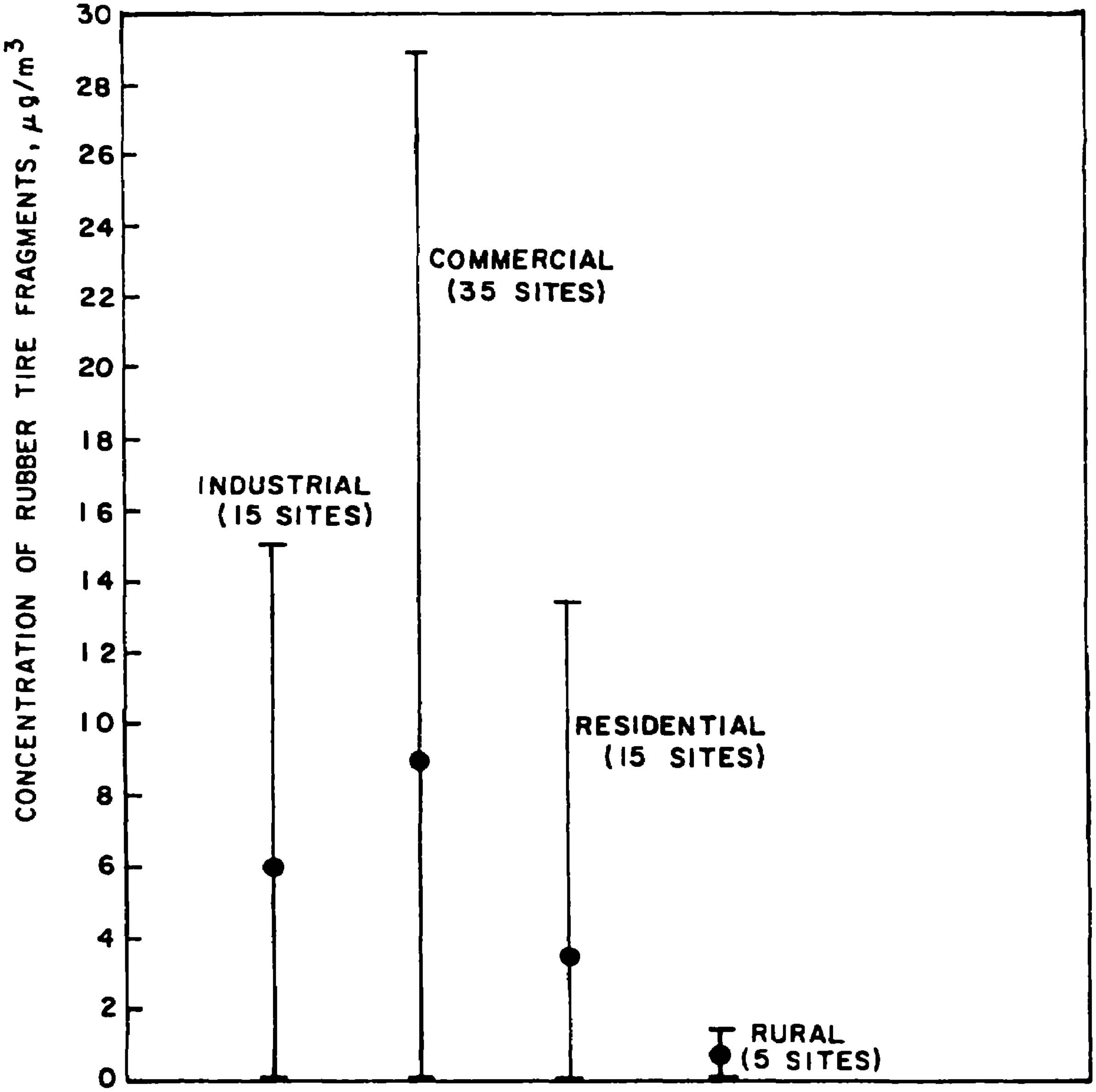


Figure 10. Average and range of TSP loadings due to tire wear at different monitoring site classifications

The values found for rubber in the course of this study are several times what were expected based on the literature reviewed. The reason for this discrepancy is not apparent. This experiment may have been better formulated than previous ones to give a good cross-section of values, or the high levels may be an artifact of the monitoring site and filter selection. Currently, however, there is no reason to doubt the validity of these data.

Of some interest in planning for control is the particle size distribution of the rubber. As shown in Table 7, the average size range of the rubber tire fragments (13 to 135 μm) is much larger than that of any other particulate identified. Some particles were found to be 200 μm in length. Normally, such large particles are not considered suspendible for any length of time and are too large to be of concern for respiratory effects. Despite their size, however, no difference was discernible in average concentrations of rubber by monitor height. Several monitors 50 to 100 feet above ground level measured levels of rubber in the 5 to 15 $\mu g/m^3$ range while other, lower monitors recorded no rubber.

Construction/Demolition - The movement of materials associated with construction and demolition activities usually results in the emission of particulates into the ambient air. Major demolition programs, whether using a ball and crane or blasting (low-yield), will emit particulates up to a height equal to that of the building being removed. Construction involves much more movement of materials continuously for periods of several months to over a year. Emissions are generated by a wide variety of operations over the duration of the construction, including land clearing, blasting, ground excavation, and on-site traffice, as well as the construction of the facility itself.

The study findings in Appendix E illustrate that construction activity does have an impact on very local TSP levels but that the effect is not readily predictable. Construction will generally elevate concentrations downwind from the site for distances up to a mile; the amount of increase is related to the level of activity, type of activity, distance from the activity, and control measures employed. Monitors within half a mile of construction may have annual geometric means 10 to 15 $\mu g/m^3$ higher than normal. Therefore, if 10 percent of the monitors in an urban area are near construction activity, the calculated citywide average TSP level would be 1 to 2 $\mu g/m^3$ higher than otherwise expected.

These measured impacts are much less than would be expected based on a simple interpretation of the emission levels developed for each county (see Appendix E). Obviously, the use of those emission levels must be restricted to input into modeling programs which adequately account for the fallout and deposition of particles. Development of new emission factors to reflect the type and degree of activity and any control measures would be more appropriate than the use of the existing factors.

National Assessment

While the above discussions have not covered all topics possible under the heading of nontraditional sources, they did center on those sources that have been identified as probable major influences. From these sources alone it is evident that there are contributions to the total TSP levels simply from man's activity and that the contributions are the highest in an urban area where man's activity is greatest. Similarly, the closer to the activity, the larger the impact. These variations have been addressed above for each of the sources, but an overall combined assessment is needed to indicate the extent of the total impact of nontraditional sources on TSP levels, and thereby on the problem of attaining standards.

Because of the range of TSP levels that may be contributed by the various nontraditional sources, it is not possible to identify at this stage either the exact impact at any monitoring site or even the average impact in any one city. Such a determination would require extensive data and modeling, most of which are not available. Rather, the intent is to provide a measure of the range of impacts that may reasonably be expected in most situations and an understanding of the relative importance of nontraditional sources for standards attainment on a national basis. Therefore, this conclusion should not be taken as sufficient to preclude detailed analysis in each city but as guidance to the development of national priorities for further planning measures.

The average and range of TSP levels attributed to tailpipe emissions and tire wear were given in the above analyses by site type. Recognizing that ranges of values varied in different cities, average contributions can still be calculated. Tailpipe emissions provided an average level of TSP in industrial and commercial areas of 4 to 5 $\mu g/m^3$ and approximately 3 $\mu g/m^3$ in residential areas. Tire wear added rubber concentrations of 6 $\mu g/m^3$ at industrial sites, 9 $\mu g/m^3$ at commercial sites, and 3 $\mu g/m^3$ at residential sites.

Construction activity is more difficult to present on an average basis because of the wide range of possibilities that may occur. Some cities have construction underway at individual, widely dispersed locations which are not close to monitoring sites, while others may have similar activity but close to one or more monitoring sites. Levels of TSP due to construction are expected to range between 0 and 15 $\mu g/m^3$; the closer the monitor, the greater the impact. If only one or two monitors out of a network of 20 are near construction activity, a citywide average will only be affected by 1 to 2 $\mu g/m^3$ annual geometric mean. However, in some cities major construction programs such as urban renewal and subways are going on in concentrated areas of the city. These activities are apparently causing higher-than-normal values at a large number of nearby monitors and will provide elevated average values in the commercial section of the city.

While construction is obviously a localized source, the reentrainment problem exists wherever there are roads and traffic. Since the level of reentrained matter could not be exactly determined through microscopy or elemental analyses, as with rubber and tailpipe emissions respectively, other measures were necessary. By calculating the excess levels at residential, commercial, and industrial sites that could not be explained after accounting for nonurban levels and traditional sources, the total nontraditional impact on the annual geometric mean TSP levels averaged around 20 to 25 $\mu g/m^3$ at residential sites and 30 to 35 $\mu g/m^3$ at commercial and industrial sites. By subtracting the above levels estimated to be due to tirewear, tailpipe emissions, and construction, the average reentrainment contribution was approximately 20 $\mu g/m^3$ at industrial monitors, 18 $\mu g/m^3$ at commercial monitors, and 14 $\mu g/m^3$ at residential monitors. (The higher levels at industrial monitros are likely the result of dirtier roads in the area.) These levels of TSP were compared with those calculated in specific studies in Miami and Providence, by using the distribution of monitor siting situations and the expected impact of reentrainment at each site, and also with projected reentrainment levels based on published reports of the ratio of tailpipe TSP to reentrainment TSP. The same order of magnitude was found in all cases.

Figure 11 indicates the quantitative impacts on TSP levels of each of the nontraditional sources considered above in various types of neighborhoods. As has been stressed throughout this discussion, these are only average values and a wide range of values can be expected when comparing particular situations.

MONITORING CONSIDERATIONS

The monitoring of ambient TSP levels is not a causative factor in the attainment of standards in the same sense as high nonurban levels or emissions from either traditional or nontraditional sources. However, network configuration and station siting do affect the extent to which measured levels are representative. These factors also affect the overall quality and usefulness of the data base needed for both air quality planning and verifying attainment.

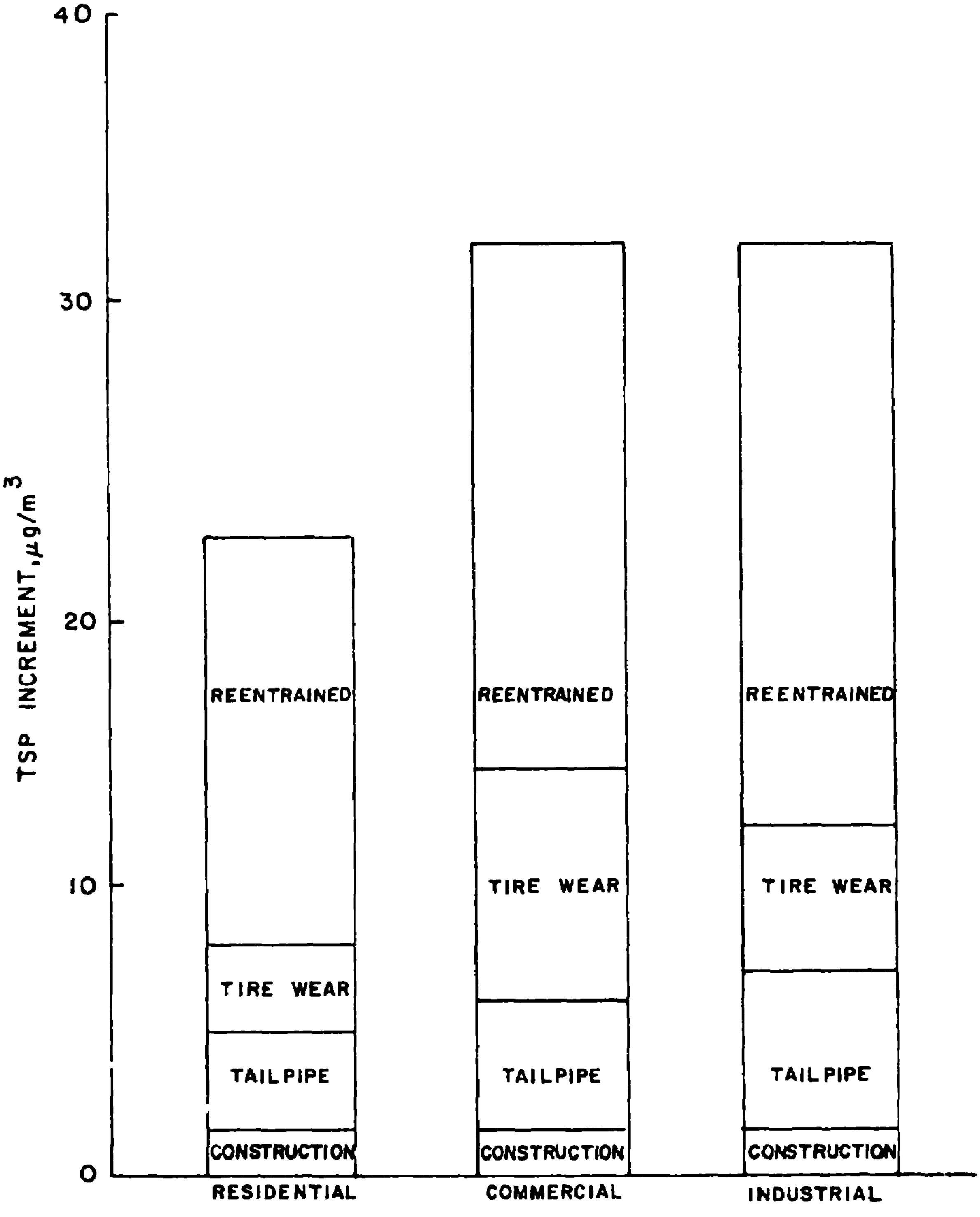


Figure 11. Nontraditional source increments at different site types

This section compares current EPA guidance on monitoring, as found in OAQPS Guideline No. 1.2-012, with the actual network configurations and siting practices found during visits to more than 150 monitoring sites. It contains an analysis of the effects of the variations in networks and siting on measured levels and thus on standards attainment, and an analysis of the impact of deviations from EPA guidelines.

Monitoring Objectives

Table 12 from the EPA monitoring guideline document lists the objectives that have been commonly used in designing current networks. Basically these are the outgrowth of the original NASN objective of surveying typical pollutant levels, with some recent additions in the areas of planning and enforcement. Conspicuously missing from the list, however, other than under the general rubric of research, is any concept of monitoring to determine the nature of the air pollution problem in a given area or the identity and location of sources having an impact in a particular situation.

Table 12. GENERAL MONITORING OBJECTIVES

- Provide data for research
- Provide data for air quality planning efforts
- Provide data for emergency episode prevention
- Monitor time trends and patterns
- Monitor source compliance with regulations
- Ascertain attainment and maintenance of NAAQS (population exposure)
- Determine impact of specific proposed or constructed facilities on ambient concentration
- Provide data to support enforcement actions

Monitoring Guidelines

The current EPA monitoring guidelines define a general structure for discussion and planning network monitoring objectives, emphasizing the need to design the network to meet well-defined objectives and data needs. They prescribe the general size of monitoring effort required, emphasizing that this must be adjusted to suit local conditions. More specifically concerning hi-vol placement, the guidelines recommend a horizontal clearance of at least 2 meters and a height range of 2 to 15 meters; this latter permits placement at any height from essentially ground level to about 50 feet.

Network Configuration

The concept of network configuration involves the number of monitoring sites and their geographic distribution over the area of concern. It includes both the concept of selecting patterns of sites and areas of cities over distances of several miles and the concept of selecting neighborhoods over distances of a few city blocks.

Configuration Problems - In general, the monitoring networks studied in the 14 cities did not have major problems with overall configuration. However, two problems of some concern in several of the cities do warrant further discussion. These problems were the general lack of stations to measure incoming air mass concentrations and the lack of clearly defined industrial area monitors in several cities.

The widespread lack of relatively remote stations is to some extent a matter of policy and agency jursidiction as well as a matter of network design. For only a very few of the urban areas studied was there an appropriate station to measure the TSP loadings of incoming air masses. Previously operated nonurban sites have been abandoned in two areas, while in many they never existed. When necessary for air quality planning, a TSP concentration in incoming air is typically just assumed, usually based on the NASN nonurban sites, which are frequently not appropriately near.

This lack of adequate nonurban data is not yet a serious problem in major industrialized urban areas, where ambient levels typically exceed the standards substantially, so that precise knowledge of incoming levels is not yet necessary. However, it will no doubt become increasingly problematic as ambient levels approach the standards, and as improvements in air quality require increasingly precise planning. In those study areas where levels are nearer the standards, particularly those areas where traditional sources are not dominant, there is already a planning problem resulting from the lack of precise knowledge of the transition in levels from remote through suburban into urban areas. This problem is of additional concern in regions of the country where we find significant levels of secondary pollutants of generally unknown origin.

The second area in which there were some problems with network configuration is the matter of sites in industrial areas. In some of the heavily industrialized urban areas studied, there were clearly defined industrial sites, located either within the industrial area or along the margins between industrial and residential areas. At these sites, there was no real question about the air quality influence of the industrial areas and operations, and the trend or lack of trend in industrial emissions was clear. In other areas, however, the sites best described as industrial were not in fact located in or representative of the most uniformly dense industrial areas, but rather were often influenced primarily by one nearby industrial source. Consequently, the air quality impact of the city's industrial areas is not clearly monitored, and the effects of control efforts are not readily seen. The reason for these problems is primarily the nature of the industrial areas themselves. In the areas that are well monitored, the industrial activities are typically iron and steel mills and associated metallurgical operations, usually located in large, contiguous, readily identifiable areas. In contrast, the poorly monitored areas are in long, narrow riverside flood plains and contain much more heterogeneous industrial activity, with extensive warehousing, truck and rail terminals mixed in. Another somewhat similar problem is the matter of agency jurisdiction. Not accidentally, major industries are frequently located just beyond city boundaries, either in smaller satellite municipalities or in unincorporated areas, and hence tend to escape thorough coverage in a network focused upon the responsibilities of a city agency. This is clearly a difficulty occurring in Philadelphia, where a major heavy industrial area extends from the edge of the city along the riverfront in adjacent counties and into adjacent states.

Air Quality Patterns — Based on site visits, over 150 hi-vol sites were classified as nonurban, residential, commercial, or industrial on the basis of the principal impact on air quality, rather than strictly on location; that is, a site in a residential neighborhood that received a major impact from an adjoining industrial area was categorized as industrial rather than residential. A consistent pattern appeared when the sites were grouped by the four neighborhood types. In each urban area, the average air quality levels were lowest in the residential neighborhoods and highest at the industrial sites. Table 13 compares average concentrations by site type after those sites that are unduly affected by nearby sources (in addition to an areawide influence) were removed from the data base. Not surprisingly, industrial sites were systematically higher; traditional sources have long been recognized as a major source of air pollution. However, it is also important to note that commercial sites were similarly higher. This is because the potential for automotive-related pollutants (such as exhaust particles, rubber tire particles, and other types of reentrained street dust) is greater in commercial areas than in residential areas due to increased vehicle miles traveled (VMT).

Table 13. AVERAGE TSP CONCENTRATIONS BY NEIGHBORHOOD TYPE

Cities	No. of sites studied	Geometric mean TSP concentration above nonurban levels, μg/m³		
		Residential	Commercial	Industrial
Category I				
Cleveland	11	45	86	113
Birmingham	13	35	56	88
St. Louis	22	29	41	74
Average		36	61	92
Category II				
Philadelphia	10	26	48	58
Baltimore	9	30	40	71
Cincinnati	12	24	36	66
Average		27	41	65
Category III				
Chattanooga	8	20	42	54
Denver	6	48	81	96
Seattle	7	21	33	62
Providence	8	18	29	None
Average		27	46	71
w/o Denver		20	35	58
Category IV				
Washington, D.C.	9	17	30	None
Oklahoma City	14	26	49	None
Miami	13	24	36	None
San Francisco	11	24	31	None
Average		23	37	None

Because ambient air quality levels in different types of neighborhoods show such distinct differences, it is important to consider network configuration, especially the representation of industrial neighborhoods, in any comparison of air quality between cities. Failure to do so might very well result in faulty conclusions about the effectiveness of regulations, the relative contributions of source categories, or any other objective of the comparison.

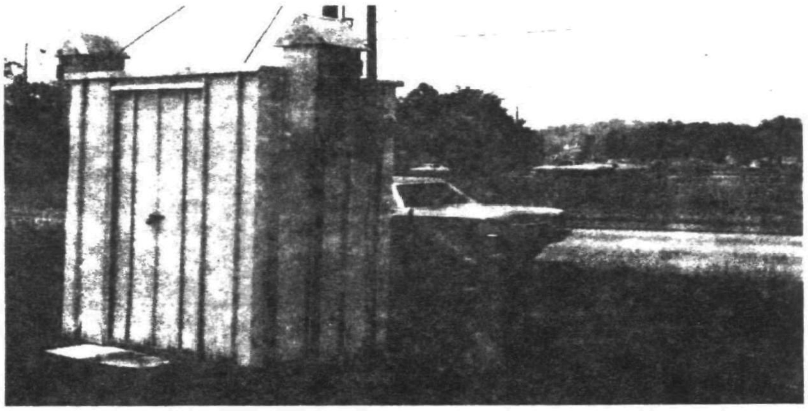
Station Siting

The selection of the actual site for placement of the hi-vol is a major consideration. As a matter of historical practice, siting decisions have usually been made on the basis of more practical matters, such as building access, security, power availability, and so on. However, the principal factors to consider on a technical basis are the effects of height and distance from the street, and any nearby sources of particulates.

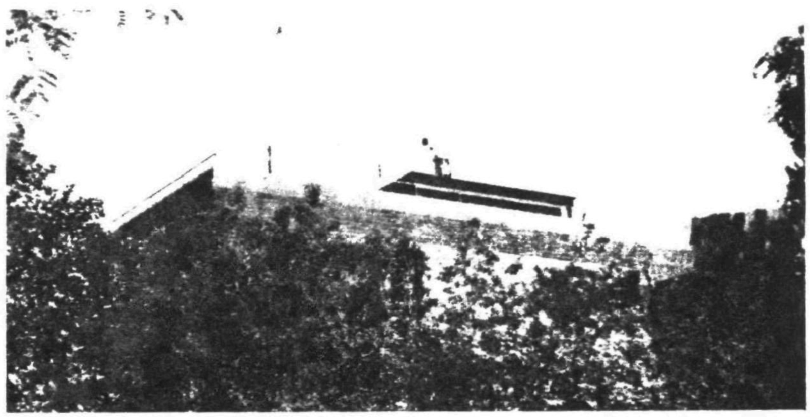
Height Effects - The primary problem with siting is the height of the hi-vol above the ground or street level. the height issue is difficult because the traditional practice is to put hi-vols on rooftops, while the more recent view of some is that the health-oriented spirit of the Clean Air Act should mandate placement near the breathing zone.

Typically, hi-vol heights range from ground level to the top of many-story buildings; Figure 12 illustrates three points on this range: a low-level (6 foot) site type routinely used in Birmingham; an unusually high site — the "Food Circus" building in Seattle at 70 feet; and a more typical site — a one-story fire station in Oklahoma City. In general, sites of all these varieties are present in each network, but on an overall basis there is a significant difference among cities in the average height of the hi-vols. Table 14 shows the variations in monitor height among the 14 cities. Clearly, variation is significant.

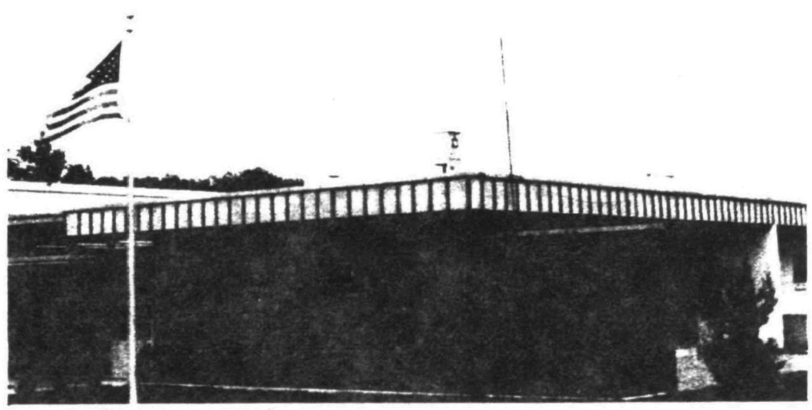
The distance of the hi-vol back from the nearest street is often related to the vertical height because of the relationship of general building size and neighborhood type. The typical central business district (CBD) site on a tall building will be both vertically higher and horizontally nearer to the street than a residential site, which may well be on a one-story building but is more likely to be set back from the street a significant distance. Distance back from the street is clearly a somewhat more flexible parameter than height, as the hi-vols can usually be



(a) Low-level site (Birmingham)



(b) Elevated site (Seattle)



(c) Sites of typical height (Oklahoma City)

Figure 12. Range of heights in typical hi-vol installations

moved about on a rooftop. The analyses of dust reentrainment from streets in Appendix E found that there was some evidence that TSP levels were more affected by variations in height than by distance back from the street.

Table 14. VARIATION IN MONITOR HEIGHT AMONG THE 14 CITIES

Cities	Height of monitors, feet	
	Mean	Median
Heavily industrialized		
Cleveland	37	25
Birmingham	10	6
Philadelphia	14	13
Baltimore	31	30
St. Louis	38	19
Moderately industrialized		
Cincinnati	29	25
Chattanooga	21	19
Denver	30	23
Seattle	34	20
Providence	56	49
Lightly industrialized		
Washington, D.C.	33	28
Oklahoma City	17	15
Miami	20	18
San Francisco	30	18

The original decision in favor of placing hi-vols on rooftops rather than at street level, first made in establishing the NASN in the early 1950s, considered the fact that such siting would minimize the measurement of particulate matter reentrained from the ground. (The other significant reasons were concern over vandalism and the fact that ground-level sites are hard to find in the CBD.) The fact that these original monitors were deliberately placed where measurement of reentrained particles would be minimized emphasizes the changing concept of the TSP problem. Today low-level, reentrainment-type emission sources are seen by many cities as the reason that they cannot meet the ambient standards, but in the 1950s they were considered by most as extraneous interferences, not pollution sources; the pollution sources were the heavy industries and the large fuel combustion operations. Consequently, appropriate siting of hi-vols is still an issue today, and the inconsistencies, both among sites within an urban area and among networks in different urban areas, continue to hamper not only careful data analysis but also problem definition.

Impact of Nearby Sources — The exact placement of a hi-vol with respect to other types of sources can also have a significant impact on the levels measured. This is particularly true at sites that are at all proximate to low-level dust entrainment sources, such as unpaved parking lots or roads, construction activity, sources of fugitive emissions, and industrial sources with much settleable particulate or low-level emission points. The sites visited in the study were classified as to whether any nearby source had an undue influence on the measured levels; Table 15 summarizes the number and type of sites with nearby sources. It is apparent from the table that a significant fraction of the hi-vols in most of the cities are influenced by nearby sources, and significant changes in concentrations at these sites are dependent on controlling the nearby source. In many cases, the source is nontraditional or is related to fugitive dust.

Only three residential sites had special local impacts, but in the commercial and industrial categories such influences were common. Ten of the 60 commercial sites had local impacts, even when a fairly stringent definition of undue influence was used. For example, since so many commercial sites had an obvious impact from traffic, such an influence was labeled an undue effect only if the monitor was either unusually low and close to the street (as in Figure 12(a)) or affected by a major street, as in the case of samplers adjacent to expressways. Construction, a cause of special local impacts at three sites in 1974, was identified only if it

Table 15. NUMBER OF SITES WITH AN ESTIMATED IMPACT OF LOCAL INFLUENCES, BY NEIGHBORHOOD CLASSIFICATION

	Residential	Commercial	Industrial	Undeveloped	Total
Total number of sites visited	39	60	41	14	154
Number with some apparent degree of local impact	10	36	24	0	70
Number with degree of impact judged major	3	10	21	0	34
Number with "undue" impact in context of neighborhood definition	3	10	0	0	13
Average TSP levels at sites without "undue" impact	60 $\mu g/m^3$	78 $\mu g/m^3$	110 $\mu g/m^3$	-	-
Typical increment at sites with "undue" impact	15 $\mu g/m^3$	25 $\mu g/m^3$	-	-	-

was immediately adjacent to the site (within one or two blocks) and if the impact on air quality levels was apparent.

The 41 industrial sites presented a different situation. As initially classified, essentially all the industrial sites had impacts from nearby unpaved roadways, parking areas, trucking terminals, and other fugitive dust sources. Consequently, it was deemed appropriate to include these impacts in the basic concept of an industrial neighborhood, and no industrial sites were classified as having undue impacts. Some sites in commercial neighborhoods, however, were so classified on the basis of undue impacts from isolated industrial sources.

Air Quality Patterns — Approximate impacts of nearby sources of various types were estimated and are summarized in Appendix G. Also determined were the impacts of sources of fugitive emissions, generally identified as being in the immediate vicinity of the monitor; these impacts were discussed in the section on traditional sources.

The typical effect on air quality levels at sites with significant impact from nearby sources can easily be 20 to 25 $\mu g/m^3$. This represents an increase of at least 30 percent over the typical levels recorded at commercial neighborhood sites in the 14 study cities. Data at specific sites can vary substantially from these average values, depending on the proximity of the source to the site.

Comparison of Actual Siting to Guidelines - The general conclusion regarding siting of the monitors visited is that they are altogether too loosely placed with respect to both height and horizontal placement. However, they are generally within the height range specified in the EPA guidance material, which recommends sites less than 50 feet high, and provides only qualitative cautions concerning horizontal placement. Thus, it is concluded that more definitive guidance is needed, particularly on height and proximity to nearby sources, such as paved roads.

Operating Frequency and Schedule

Designing the frequency and scheduling aspects of TSP network operations is generally a matter of balancing the precision desired or required in the resultant annual mean with any necessary resource restraints. These decisions are not generally a major problem in designing a network and the matter of operating schedules was not found to be, in and of itself, a significant factor relative to standards attainment. Common practice in the networks studied was to sample on a systematic schedule every 6th day, following recommended EPA guidance; this is generally adequate to produce acceptable estimates of the annual mean and the frequency of violations of the 24-hour standard.

The only significant interaction between hi-vol operating frequency and the problems of standards attainment is a matter of having enough data to provide adequate knowledge of the air pollution problem to be dealt with. As an example, the analyses of meteorological parameters and TSP levels in Section III and Appendix F, conducted to investigate the impact of urban fugitive dust influences, were dependent on having essentially daily hi-vol data available; in other urban areas where similar detailed analyses would have been important for judging the cause of the TSP problem, data gathered on the standard every-6-days schedule proved to be completely inadequate for a proper analysis. This is believed to be a fairly common failing because the very nature of particulates from urban activity makes the problem closely interrelated with meteorology. Since the problems of fugitive dust emissions, resuspension of material from the roadway, etc., are increasingly being blamed for failure to attain the standards, increased sampling frequency should appropriately be a part of agencies' attempts to define this problem adequately for planning purposes.

Summary

The degree to which monitoring considerations influence the attainment of standards is philosophically difficult to assess. The matter of network configuration, or neighborhood selection, is difficult because there are no clear criteria for defining proper configuration; it would necessarily be a function of the purpose of the monitoring. The matter of individual site placement is philosophically difficult because it gets into the vague area of defining the dividing point between "ambient" air, where the standards should be met, and source-oriented monitoring sites.

Network Configuration — The selection of neighborhoods for monitoring reflects a difficult tradeoff between the various monitoring objectives. Selecting residential neighborhoods will provide better population-exposure coverage but will likely result in lower values than selecting commercial neighborhoods. Industrial sites, in turn, will have higher values than commercial sites, but will provide necessary information on the progress of traditional source control. One obvious conclusion relating to network configuration is that the latitude air pollution control agencies necessarily have in the design of their networks can easily affect the number of sites in the jurisdiction that attain the standards. However, this is a concern over the relative balance between residential, commercial and industrial sites in the network, which doesn't necessarily relate to the overall effect of the control program on the aggregate exposure of the population. One obvious approach to this, which is simple at least in theory, is to designate smaller subnetworks for various purposes, each of which might have a different balance of sites.

Hi-vol Siting - For certain specific sites, the difference between attaining and exceeding the standard is very clearly attributable to the special influence of some nearby source. Philosophically, this situation could be viewed either of two ways. It could be called a sampler siting anomaly, which should be resolved by moving the hi-vol or redesignating it a source-oriented research station. Alternatively, it could be viewed as a site receiving an impact from a pollution source which, though possibly temporary or of a fugitive dust nature, is still something that should be controlled. Which of these two interpretations is appropriate depends on the precise nature of the site in question. Since public access has been presumed by

EPA to be the criterion for defining ambient air, the key parameter is the extent to which the public has access to the site in question. The interpretation of public access may prove difficult, however. For instance, the Dyer Street site in Providence, which exceeds the standard because of the impact of an expressway, is located on a parcel of right-of-way land immediately adjacent to the expressway. While the public technically and legally has access to the parcel, as a practical matter the general public has no reason to go there, and in fact there appears to be no significant pedestrian volume.

In assessing the overall impact of undue influences from local sources, the important factor is the proportion of sites falling in each of these two categories. Based on the site visits and the above philosophy on interpretation of public access, the significant majority of cases appear to be situations where the source should be controlled, and the instances of true monitoring anomalies which should be corrected are a small minority.

In a position somewhat between these latter two situations is the group of sites that have significant but temporary local influences, usually construction. These are to a certain degree clearly controllable fugitive dust problems; because of their transitory nature, however, some portion of the impact must be written off as an anomaly.

Another obvious conclusion is that, because nearby sources do affect measured air quality considerably, the siting practices of the agency can significantly affect the number of sites indicating violations. Consideration of the siting practices of the agency is thus a necessary prerequisite to comparing air quality values between cities.

METEOROLOGY AND CLIMATOLOGY

General Considerations

In determining which AQCRs have met or are likely to meet the national particulate standards and which, if any, are not, it is important to keep in perspective the role of meteorology and climatology. As part of this goal, the following discussion summarizes the impact of certain meteorological variables and meteorological conditions on TSP levels in as quantitative a fashion as appears reasonable at the present time.

The principal effects to be considered are discussed at length in Appendix F where the range of conditions experienced by the 14 study cities is analyzed. A brief discussion of these findings follows.

Precipitation - The effect of precipitation is twofold: (1) it cleanses the atmosphere by capturing particles within the cloud (rainout) and by the washout of particles below the clouds; and (2) it suppresses fugitive dust. Precipitation is very effective in reducing TSP levels in areas with high concentrations which have resulted from either industrial or fugitive dust sources, and average concentrations decrease steadily with increasing 48-hour precipitation amounts in these areas. The effect of precipitation is greatest on the day it occurs and lasts an average of about 2 days. In the city case studies of high-concentration areas, concentrations measured during the last half of a 48-hour period with precipitation $\geq$ 0.25 inch averaged approximately half of concentrations measured during 48-hour periods with negligible precipitation. Concentrations at typical urban sites (excluding clean residential areas) on days with measurable precipitation were about 75 to 85 percent of average values for the site and time of year.

Figure 13 presents a graphical summary of the findings at two sites in one of the study cities when different levels of 24-hour precipitation are used to classify a day as one with precipitation. Under one analysis, any day with measurable precipitation (0.01 inch) was considered to have had precipitation; in a second analysis, only days with at least 0.25 inch of precipitation were considered as days with precipitation. Figure 13 shows that, on the average, TSP levels remain depressed the day after rain at North Birmingham; at Downtown Birmingham the levels return to near normal more quickly. The effect of rainfall of different intensities is shown by

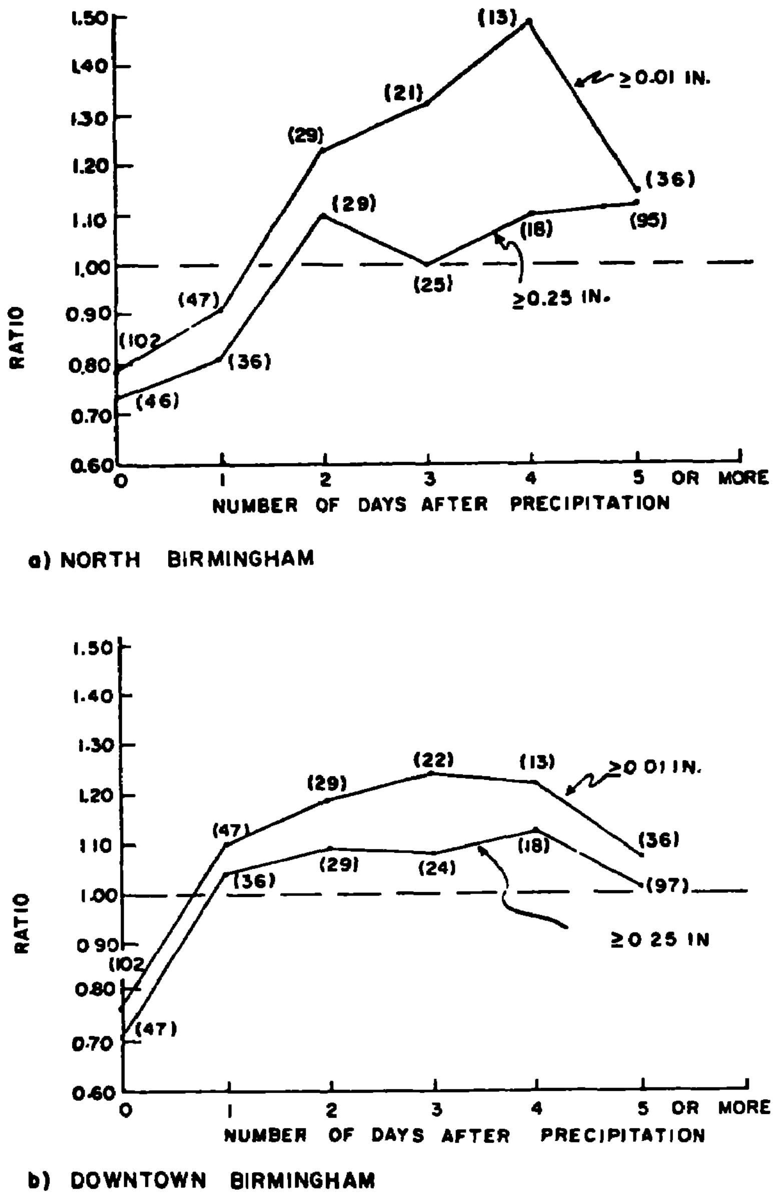


Figure 13. Duration of rainfall effectiveness in reducing TSP levels at two Birmingham sites

the difference between the two curves for each site. The occurrence of the peak average ratio at 4 days after precipitation at North Birmingham reflects a few very high ratios apparently associated with periods of dry, light-wind, poor-dispersion conditions lasting for several days.

Wind Speed — The effect of wind speed is also twofold. First, as the speed of the wind increases, the effective volume of air available for dilution increases. Thus, for constant source strengths, downwind concentrations are inversely proportional to wind speed. However, in the case of particulates, total emissions are not invariant with wind speed since the wind is the agent by which soil and dust particles are naturally entrained. The amount of fugitive dust entrained depends on the moisture content and nature of the soil (or dust) and the wind speed. At speeds below 10 to 15 miles per hour, however, the amount is basically negligible even under dry conditions. At greater average speeds, and particularly under gusty conditions, fugitive contributions can be substantial. Wind speed also indirectly contributes to fugitive emissions by increasing the rate of evaporation, and hence speeds the drying of the soil and dust particles.

Specific analyses on the effect of wind speed were conducted in four of the study cities using 24-hour average TSP concentrations and daily average airport wind speeds. One of these (Birmingham) is heavily industrialized, two (Chattanooga and Denver) are moderately industrialized, and one (Oklahoma City) is lightly industrialized. Birmingham and Chattanooga have above-average precipitation and low average wind speeds, Denver has little precipitation and below-average wind speeds, and Oklahoma City has nearly average amounts of precipitation and high average wind speeds.

The results of these studies showed that the dilution effect of wind speed was noticeable below speeds of about 10 miles per hour in industrial areas where major contributions were made from point sources. At higher wind speeds and in nonindustrial urban areas, average TSP levels did not appear to be related to wind speed. It was not possible to discover to what extent this invariance with wind speed resulted from an interplay between dilution and wind-induced fugitive dust contributions. However, the findings in Birmingham apparently indicate some reentrainment of particulates at high wind speeds. As shown in Figure 14, the average concentration decreases with increasing wind speed for speeds up to about 8 knots and then remains essentially constant. Furthermore, the decrease of average concentration with wind speed, as shown by the dashed line, is approximately linear from 2 to 8 knots, as would be expected if dilution were the controlling influence. The change in slope shown at 2.5 knots can be attributed to stagnation conditions at very low wind speeds. While the curve for North Birmingham reflects the same relationship as that for Downtown Birmingham, the average concentration at Mountain Brook appears to be invariant with wind speed. This difference may be explained by the availability of particles for reentrainment being very low in the residential areas. The industrial site, being in a dirtier area, has a larger amount of particulate that can be reentrained.

<u>Stability and Stagnation</u> — The stability of the air, as measured by the change of temperature with height, controls the rate of vertical turbulent diffusion and the mixing depth. It therefore is a measure of the dilution power of the atmosphere in the vertical. The diurnal variation of wind speed caused by the vertical transfer of momentum is closely related to the diurnal variation in stability. Stagnating air masses permit the accumulation of pollutants and the development of stable transport patterns.

While no special attempt was made during this study to isolate the effects of stability or stagnation periods on TSP levels, several general statements can be made. First, the highest 24-hour concentrations are observed during stagnating conditions since by definition these are periods with very low wind speeds and inversion conditions over at least a 24-hour period. Under these conditions, concentrations are typically about two or two and a half times the average values for the site and time of year, and the 24-hour standards are most likely to be exceeded. In the more polluted areas, levels may be increased 100 $\mu g/m^3$ or more. For that

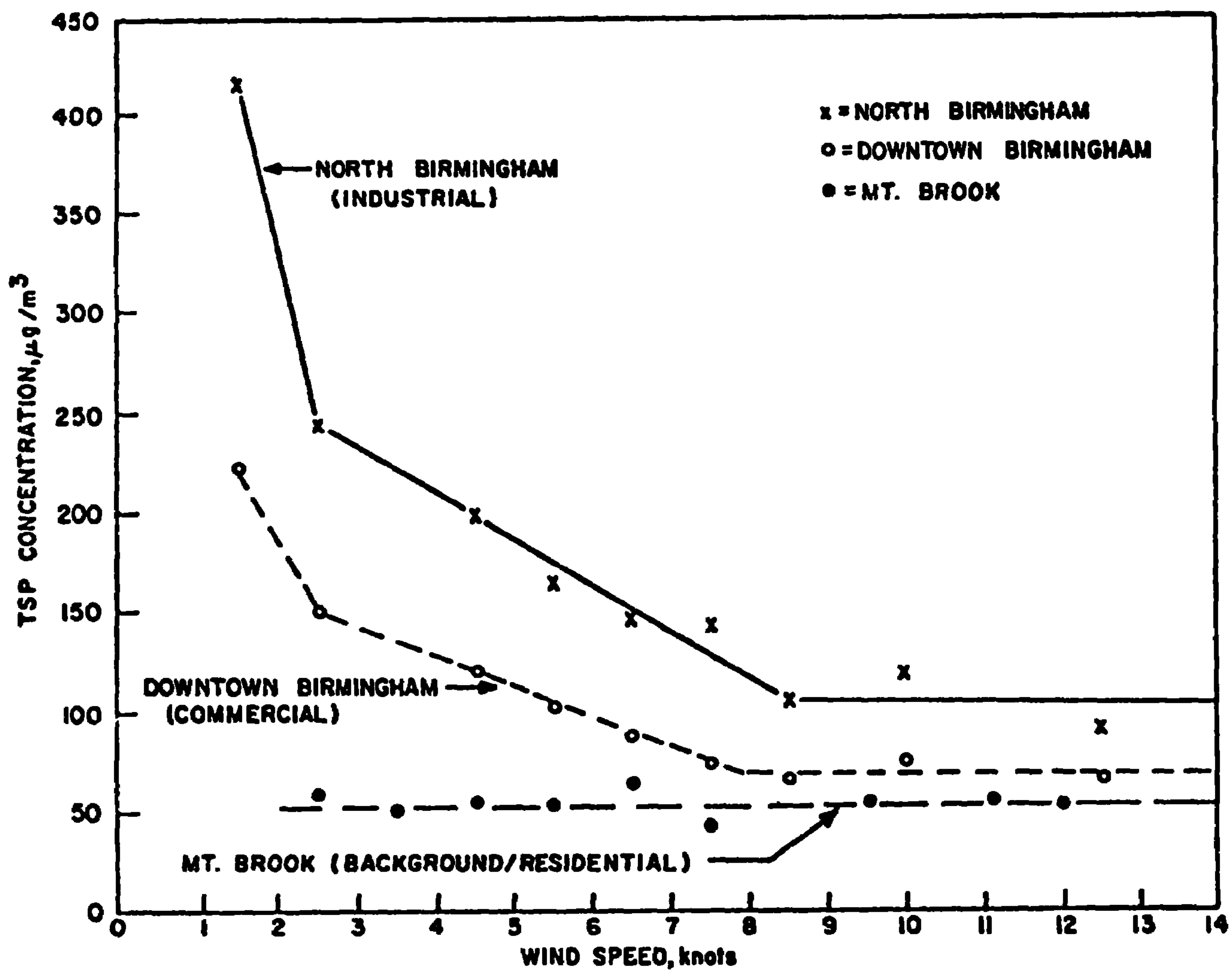


Figure 14. Relationship between TSP concentrations and wind speed at three selected sites in Birmingham on days with 48-hour precipitation amounts ≤ 0.02 inches

part of the country with the maximum number of stagnations (14), stagnations occur on an average of 3.8 percent of the days in a year. If on these days the average concentration is 2.3 times the annual mean, the increase in the annual mean due to the stagnation days is approximately 5 percent.

Temperature — Temperature, and seasonal temperature patterns, are the best single indicators of space heating requirements, and hence correlate with particulate emissions from these sources. Emissions from city to city for the same number of degree days will vary with the type of fuel burned. Temperature also plays a part in fugitive dust emissions by affecting the evaporation rate of water and by its influence on the growth of vegetation.

The impact of temperature (using heating and cooling degree days) was investigated in each city and the results are reported in the individual volume for the city. Comparisons among the various cities were made using a regression analysis, reported later in this section. (Also see Appendix F.)

Wind Direction — On a local scale, the wind direction determines the polar distribution of pollutants around their sources, and hence is requisite to the understanding of source-receptor relationships and the design of source-specific sampling networks. On a regional scale, the TSP concentration in the air mass entering an urban area is determined by the past history of the air mass, which is best estimated by trajectory calculations; wind direction roses can also be helpful. While wind direction-pollution roses were calculated and reported in many of the city volumes, trajectory analysis was done for only one case; that analysis is given in Appendix C.

Solar Radiation — In addition to being the driving energy source for weather systems, solar radiation relates to particulate emissions through temperature, evaporation, and plant growth. Solar radiation can also increase the ambient TSP levels by providing the requisite energy for the conversion of gases to secondary particulates.

Combined Impact of Meteorology

Multiple regression analysis was used to estimate the effects of annual variations in meteorological parameters over the 5-year period from 1970 to 1974 on the annual mean TSP levels in the study cities. The three meteorological parameters initially considered as independent variables were precipitation, temperature (heating degree days), and wind speed. After initial calculations, plus reflection on the apparent lack of short-term correlation between wind speed and TSP level except in industrial areas, it was decided to exclude wind speed from the analysis. Allowance for a linear trend was made by designating 1970 as year 1, 1971 as year 2, and so on.

In the analysis, each site type average in each city was treated as a separate observation. Dummy variables were used to permit different intercepts for the several cities and the three site types, while the meteorological effects were estimated based on data from all cities. This approach in effect assumes that the meteorological parameters operate in roughly the same manner throughout the country, which is clearly neither an obvious nor a trivial assumption. Previous analyses that permitted the meteorological effects to differ from city to city did indicate that the effects found in the various cities were quite similar in magnitude, and it is on this basis that the assumption was made.

The resulting equation was:

$$TSP = C - 2.9Y - 0.43P + 2.5T$$

where TSP = annual geometric mean concentration in $\mu g/m^3$

C = constant in $\mu g/m^3$

Y = year, 1 to 5

P = annual precipitation in inches

T = heating degree days in thousands.

The implication of the general regression equation is that within the study cities concentrations have been lowering at the rate of 2.9 $\mu g/m^3$ per year over the last 5 years, that an increase of 1 inch in annual precipitation decreases the mean concentration by 0.43 $\mu g/m^3$, and that an increase in heating degree days of 1000 increases the mean concentration by 2.5 $\mu g/m^3$.

This result can be used to get some feel for the magnitude of the effects of annual changes in precipitation and temperature on TSP levels. Examination of the variations in precipitation and temperature over the 5-year period in each of the 14 study cities showed that the smallest range in precipitation (6 inches) occurred in St. Louis while the greatest range (27 inches) occurred in both Chattanooga and Providence. The minimum range for heating degree days was 188 in Miami and the maximum range was 1189 in Cleveland. The implied differences in TSP levels resulting from these annual variations in precipitation range from 2.6 $\mu g/m^3$ in St. Louis to 11.6 $\mu g/m^3$ in Chattanooga and Providence, and the differences resulting from variations in heating requirements range from 0.5 $\mu g/m^3$ in Miami to 3.0 $\mu g/m^3$ in Cleveland.

Although conclusions based on this equation must be considered tentative, the relationship provides a ready means for comparing precipitation and heating demand effects throughout the country. For example, the results of applying the equation to the climatological precipitation pattern (Figure F-20) can be displayed as the relative effect of differences in total annual precipitation on the annual TSP level, as has been done in Figure 15. In this figure a precipitation rate of about 35 inches a year corresponds to the "0" relative effect isopleth. The maximum geographical difference in the annual mean shown by the figure is approximately 35 $\mu g/m^3$ (from -25 to +10 $\mu g/m^3$).

The use of the relationship between heating degree days and TSP level in conjunction with the geographical distribution of degree days shown in Figure F-27 suggests a maximum contribution to the annual mean from space

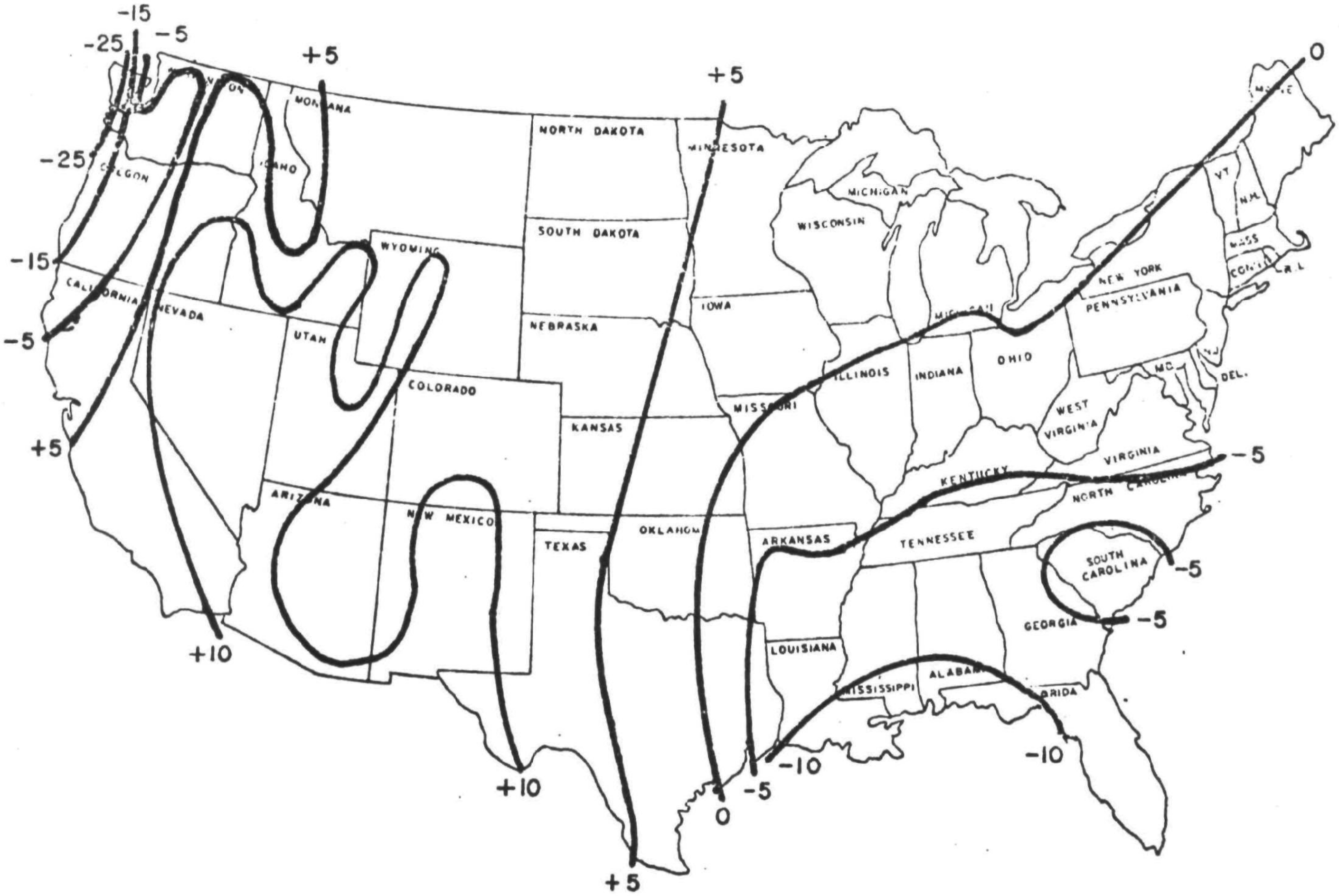


Figure 15. **Relative effect of annual precipitation on annual TSP level in a hypothetical urban area. (Estimated from regression equation, p. 99)**

heating of 25 $\mu g/m^3$. The spatial variation in degree days found in the western United States has been drastically smoothed out in Figure F-27, so attention should really be focused on the area east of the Rockies. The effect of space heating on TSP levels ranges from about 5 $\mu g/m^3$ in the southern tier of states to 22 $\mu g/m^3$ in the most norther states. Again, this is an attempt to generalize the effect of space heating using data from a mix of cities with widely different fuel usage characteristics, and the results therefore are not necessarily appropriate for any specific city.

Conclusions

Low TSP levels are to be expected in a "standard" urban area if it is located in a generally flat, well-exposed topographical setting where:

- Entering air is clean (i.e., nonurban levels are low).
- Annual precipitation is high and distributed throughout all months of the year. (Moderate amounts of precipitation roughly every third day are very effective in cleansing the atmosphere and in suppressing fugitive dust.)
- Wind speeds are not extreme. (Light winds minimize dilution, and strong gusty winds generate fugitive dust under dry conditions).
- Daytime mixing depths are high and the frequency of low-level inversions is low. (This combination maximizes periods of good vertical daytime dispersion and minimizes periods of poor nighttime dispersion.)
- Space heating demands are minimal. (With a standard mix of fuels, space heating emissions are proportional to degree days.)
- High-pressure weather systems do not stagnate. (Stagnant anticyclones with accompanying light winds, a persistent subsidence inversion, and nocturnal surface-based inversions lead to accumulated high TSP concentrations and violations of the 24-hour standards.)
- The frequency and character of winter precipitation is such that street sanding is rarely, if ever, required. (On the other hand, snow cover is highly effective in eliminating fugitive dust.)

Conversely, high TSP concentrations are to be expected in a "standard" urban area if air entering the city already contains a substantial particulate loading, and if the location is sheltered with resulting poor ventilation, has a cold, dry climate, and experiences frequent stagnant high-pressure systems.

Because of complex interrelationships among meteorological parameters and the generation, transport, dispersion, and depletion of airborne particulates, however, it must be recognized that a single parameter may bring about opposing effects and, further, that certain meteorological parameters tend to be linked by the nature of typical weather systems: fast moving air dilutes and transports pollutants readily but also increases evaporation, thus hastening the drying of soil and settled particulates, and as a consequence the air stream may entrain particulates from the dried surfaces; high temperatures increase evaporation, but also encourage the growth of vegetation and eliminate the need for space heating; snow and ice eliminate fugitive dust emissions from most surfaces, but may result in the need for extensive street sanding and hence ultimately be responsible for an increase in urban fugitive dust emissions.

While it is possible to make certain judgments based on what are believed to be the major effects of precipitation, heating degree days, and stagnation periods as done above, only a rigorous statistical analysis can properly assess the effects of meteorological and climatological parameters on nationwide urban TSP levels. Such a study was beyond the scope of the present effort, and any serious attempt to assign a TSP pollution potential rating to individual AQCRs should await the completion of such an analysis.

RELATIVE CONTRIBUTIONS OF VARIOUS FACTORS

By way of summary, the following discussion considers the overall average ambient TSP level and divides it into portions considered representative of the influences of the various major factors discussed in this section.

Such an analysis is essentially a mnemonic device, averaging over many important variables. Consequently, it should not be interpreted quantitatively with respect to any particular site or urban area; a discussion concerning how these results may be particularized to specific conditions is presented in Appendix G.

The contributions to the overall particulate level at any point have been classified as coming from three major categories — emissions from traditional sources, emissions from nontraditional sources, and nonurban particulates. In addition, two major categories of modifying influences were identified - metecrological factors and monitoring considerations. The rough qualitative impact of these factors was suggested in the sketch in Figure 2 in Section II. The following quantification of those factors is built around Figure 16.

Nonurban Levels — The most basic contribution to the total is roughly 30 $\mu g/m^3$ of natural and transported particulates. As discussed above, and as seen in the small bar chart to the side in Figu ɜ 16, this level varies significantly among various regions of the continent. The low west coast level of about 15 $\mu g/m^3$ represents the favorable situation of being located on the ocean and receiving air with essentially globally averaged natural TSP levels. The mid-continent level of about 25 $\mu g/m^3$ includes a 10 $\mu g/m^3$ increments, representing a slight increase in secondary particulates (1 to 2 $\mu g/m^3$) and a major contribution from the natural particulates accumulated as the air mass passes over the broad, relatively dry, western portion of the continent.

The northeastern nonurban levels then contain a further 10 $\mu g/m^3$ increment, which consists of two major pieces. A significant increase in transported secondary particulates, the precise source of which is not thoroughly proven, is a large share of the increment. The other share is attributed to transported primary particulates from the major urban concentrations of the midwest and northeast.

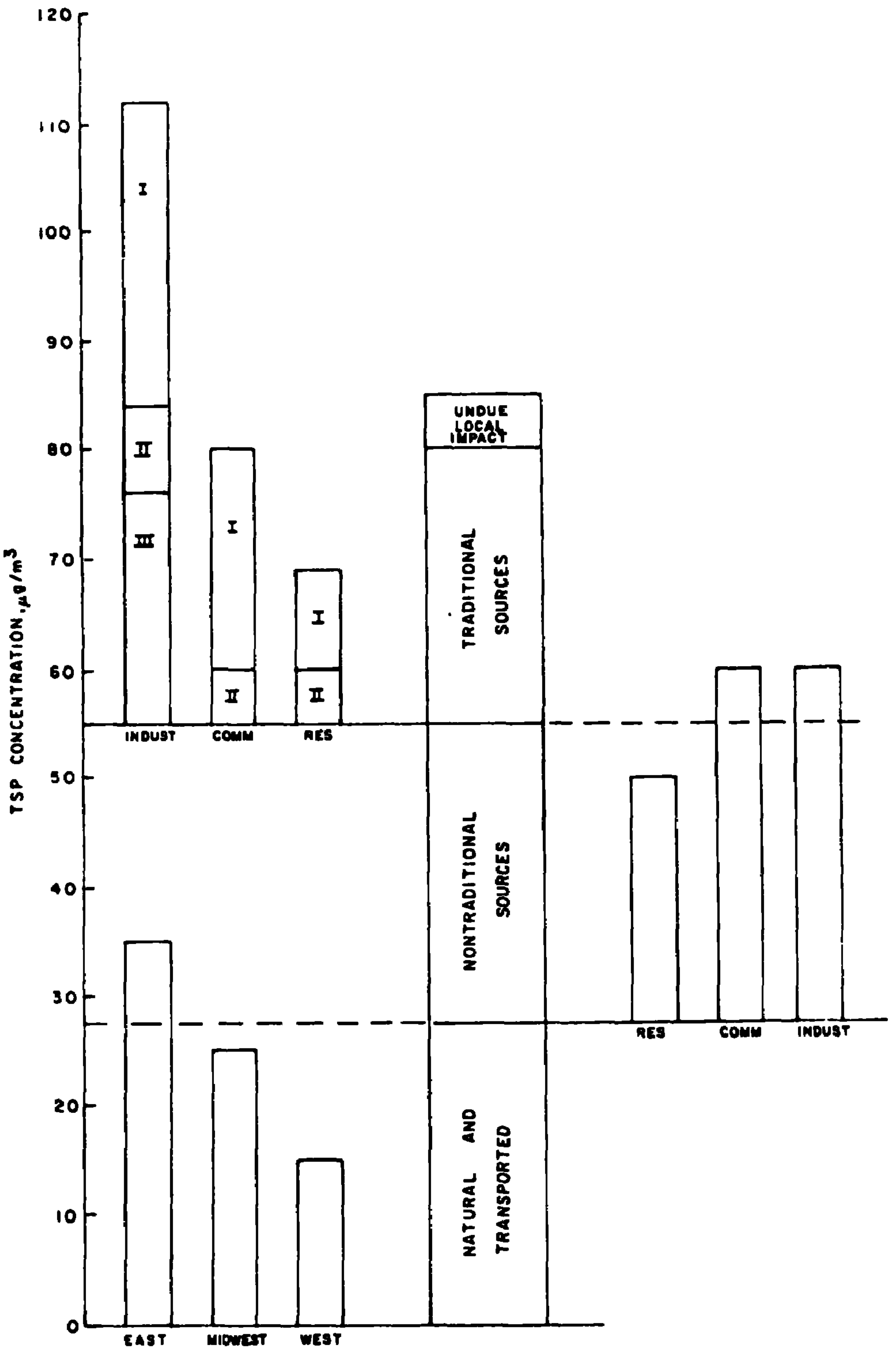


Figure 16. Summary of average impact of major contributors to TSP levels

Emissions From Nontraditional Sources - The general types of nontraditional sources identified as important are essentially the substance of human activity in urban areas. They occur in every urban area and hence are seen as more basic than the traditional sources, which are of only minor concern in at least some urban areas. The overall contribution from such sources, however, differs significantly among different neighborhoods within a single urban area, as seen in the small bar chart in Figure 16. This contribution, which consists primarily of the effects of tailpipe emissions, tire wear, and road dust reentrainment, is about 20 $\mu g/m^3$ in residential areas and about 30 $\mu g/m^3$ in commercial and industrial areas, the difference being the greater level of traffic. The proportion of residential versus other sites considered in averaging over the other two categories is a matter of abstract philosophy; an average of roughly 25 $\mu g/m^3$ has been selected for use in the figure.

Emissions From Traditional Sources - The third major contributor to ambient levels— traditional sources— varies dramatically not only with neighborhood type but also with the general industrial nature of the city. As was seen in Figure 8, the impact of traditional sources can range up to about 10 $\mu g/m^3$ and 30 $\mu g/m^3$ at residential and commercial sites respectively, and up to 50 $\mu g/m^3$ at industrial sites. This latter figure reflects the inclusion of fugitive emissions from industrial sources, but the contribution of truck traffic and similar industry-related emissions has been included with nontraditional sources. Roughly averaging over various neighborhood types and over the spectrum of non-industrial to heavily industrial cities, a value of 25 $\mu g/m^3$ has been included in Figure 16.

This addition of 25 $\mu g/m^3$ is the same as the contribution from nontraditional sources; thus on a nationwide basis, the two categories are roughly equivalent. However, it must be kept in mind that the differences among cities affects this balance significantly.

Modifying Factors - The two major categories of modifying factors are not so readily represented graphically. Meteorological and climatological factors primarily can increase or decrease the average levels depending on the various regions of the country. Quantitatively, the effect is fairly commonly about 5 $\mu g/m^3$, and in some areas 10 $\mu g/m^3$.

The influence of monitoring considerations comes primarily in distorting comparisons of measured levels among neighborhoods and cities. However, the aggregate nationwide average of undue influence from nearby sources can add a very few $\mu g/m^3$ to the total, as indicated in Figure 16.

SECTION IV

SUMMARY

This section summarizes the findings of the study, including the study approach to general problem assessment, the attainment factors identified, the assessment of these factors, the control options available, and their applicability and priority for control.

PROBLEM ASSESSMENT

This study approached the national particulate problem with many of the same tools an individual air quality planner would use to approach an assessment of the problem in a particular urban area. It utilized air quality data analysis, emissions data and modeling, and analytical particle identification; these, along with special monitoring studies, are the techniques with which a TSP problem at any level is studied. However, the results of this study are intended to provide general information on a national scale rather than urban-scale planning information for the 14 study cities or any others. While the individual air quality planner will hopefully find the results useful, they are not intended to solve any specific problems in specific urban areas. Rather, the results provide an additional component of technical information which will need to be integrated and assessed in conjunction with local knowledge.

ATTAINMENT FACTORS IDENTIFIED IN CITY STUDIES

The purpose of the city case studies was to identify and study the various factors, problems, and issues concerned with attaining the TSP standards as they were experienced in each city. Since the 14 cities cover a broad range of city characteristics and hence represent a variety of situations with respect to TSP air quality and its determinants, analyses of the factors in the various cities can be drawn together for an overall assessment of the TSP attainment situation in the study cities and, by extrapolation, throughout the nation.

Following the analyses of the study cities, a number of factors were identified as significant for standards attainment. Many of these had been first identified in the preliminary literature review and were then followed up in the city studies; a few others were identified in the course of one or more of the city studies. These issues are listed below, grouped into categories that provide a framework for discussions.

Traditional Factors

Air pollution programs have traditionally been oriented toward the control of fuel combustion, process emissions and incineration. Such control programs have resulted in substantial reductions in emissions and corresponding improvements in air quality in many of the 14 study cities.

While all of the cities studied have ongoing control programs for traditional sources, there were differences both in the amount of traditional source influence and in the success of the program:

- Three cities still have significant problems with traditional sources. Citywide air quality averages are typically 30 $\mu g/m^3$ higher than they are in similar cities with light emissions from industry and fuel combustion.
- Three cities have had heavy industrial sources and problems, but have made major improvements in air quality. They still, however, have citywide averages typically 10 to 15 $\mu g/m^3$ higher than similar cities with light emissions. There is some potential for improvement in air quality in these cities by further reduction of traditional sources.
- Four cities have had moderate emissions problems and have them well under control. These cities must control nontraditional sources to make further, substantial improvements in air quality.

- Four cities never had problems with traditional sources, except fuel combustion for heating and power generation. Further improvements must come from control of nontraditional sources.

The major sources still presenting problems with attainment of standards are in the primary metals and minerals industries. Of primary concern are the fugitive emissions which are not confined and do not come from a stack or vent. These emissions have substantial impact on air quality; sites which were influenced by fugitive emissions averaged 25 $\mu g/m^3$ higher than industrial sites affected by stack emissions only. This is partly due to the typically low level emission point and poor potential for dispersion. Another problem is that of area source fuel combustion; fuel oil is estimated to contribute on the order of 5 $\mu g/m^3$ to citywide averages in some cities. A similar order of impact is realized from the many small (minor) sources if these sources are generally controlled.

Major program considerations which were determined to be a factor in traditional source impact are the assurance of compliance with existing regulations and, in some cases, the stringency of those regulations. This will be discussed further under control alternatives.

Nontraditional Factors

While many cities have realized substantial improvements in air quality, few cities have all sites below the primary standard and fewer still have all sites below the secondary standard. This is due to the impact of factors which have not been traditionally addressed by the air pollution programs, such as reentrained dust, tire wear particles, dust from construction, and automotive exhaust emissions. The impact of all such general urban activity varies from a typical impact of 20 to 25 $\mu g/m^3$ in residential areas to a typical impact of 30 to 35 $\mu g/m^3$ in commercial and industrial areas; the citywide contribution is about 30 $\mu g/m^3$. The components of this contribution are discussed below.

- Reentrained dust— The impact was found to vary with the traffic flow and inversely to the height and distance of the monitor from the street. The average impact on residential monitors is estimated at 10 to 15 $\mu g/m^3$ and 15 to 20 $\mu g/m^3$ at commercial and industrial sites respectively. The composition of this component is mostly mineral matter.

- Tire rubber particles— This component of nontraditional particulates is even more variable with neighborhoods. Typical impacts of 2 to 5, 5 to 10 and 3 to 7 $\mu g/m^3$ were found at residential, commercial and industrial sites, respectively. Sites located particularly near heavy traffic averaged twice the levels at other sites.

- Construction — Impacts of 15 $\mu g/m^3$ are common only if the construction is close to the monitoring site. Cities with typical levels of construction have citywide impacts on the order of 1 to 3 $\mu g/m^3$.

- Automotive exhaust — This varies somewhat with neighborhoods, with concentrations of 3 $\mu g/m^3$ in residential and 4 to 5 $\mu g/m^3$ in commercial and industrial areas. This estimate is for the primary particulate only and is generally about 20 to 25 percent lead.

Large Scale Factors

Large scale factors are the combined influences of particulate matter that dominate an area much larger than the urban areas being studied. They include natural particulates and transported primary and secondary particulates. These factors, in affecting the TSP levels in an urban area, can cause significant differences in the controllability of the TSP problem. Their effect on urban levels is generally estimated by measuring air quality in nonurban areas. The average nonurban particulate level for the 14 study cities is between 25 and 30 $\mu g/m^3$; however, values ranged from less than 15 $\mu g/m^3$ on the west coast to over 35 $\mu g/m^3$ in the densely metropolitan east.

Transported secondary particulates make up a significant portion of nonurban levels. Nonurban sulfate and nitrate levels range from very low in the midwest and west to around 10 $\mu g/m^3$ in the northeast. Total urban secondary levels vary up to around 15 $\mu g/m^3$ in the north and east.

Other Related Factors

In addition to the above factors, which are to varying degrees related to sources of emissions, other factors were found to affect the real or apparent TSP problem. As discussed in the selection of the cities, the meteorology and climatology of a region can help to aggravate or ameliorate the TSP problem; the dispersion characteristics and precipitation levels are the most prominent influences. The design of the monitoring network and the actual placement of monitors is also important in conceptualizing what the TSP situation is. The general findings from the city studies for these factors are summarized below.

- Monitoring considerations — The siting practice of the control agency has considerable impact on the air quality levels and number of violations recorded. For example, 10 of the 60 commercial sites visited had local impacts fro… nearby sources. With one exception, all these sites violated the primary annual standard. Also, since industrial neighborhoods were shown to have substantially higher TSP levels, the proximity of monitors to industrial neighborhoods is an important variable. A specific relationship was found in the study between average daily traffic (ADT) at a site, the slant distance of the monitor from the street, and air quality levels. For example, based on approximate calculations, a monitor 100 feet (slant distance) from a busy street (10,000 ADT) might be influenced by the reentrained dust, tire wear and exhaust by 10 $\mu g/m^3$. This same relationship shows an impact of 40 to 45 $\mu g/m^3$ if the monitor is only 25 feet from the street.

- Meteorology — The study found precipitation to be an extremely important variable; a yearly increase in rainfall of 1 inch can cause decreases in citywide annual averages of 0.4 $\mu g/m^3$. It also concluded that average windspeeds above 10 miles per hour could cause some resuspension of dust. The effect on air quality would depend upon the gustiness of the wind and the condition of the soil.

CONTROL STRATEGY OPTIONS

The development of a control strategy for the attainment and maintenance of the ambient particulate standards must depend on accurate identification of the sources responsible for the particulate problem. Once this identification has been established, the available control measures can be defined, evaluated, and combined into an aggregate control strategy which is appropriate and effective. The major single conclusion of the study is that the control measures traditionally directed at pollution sources are not going to be adequate in many cases, and that other, more novel control measures directed at nontraditional sources and sources contributing to nonurban levels must also be considered.

Proposing detailed control strategies or priorities for specific situations is beyond the scope of this study. Such a process must necessarily involve the addition of significant quantities of local knowledge. Nonetheless, two points should be mentioned briefly. The first involves the relative emphasis on the three main contributions to urban TSP. If traditional sources still contribute the major share of TSP in an area, they are clearly the most appropriate segment to attack. Potential overall reductions in emissions of 75 percent or more may be expected in those cases where sources are not yet stringently controlled. In every city, industrial or otherwise, the nontraditional sources present a more difficult target, with reductions of 50 percent or less probable even from truly extensive control efforts. The nonurban contributions, which are a major influence in at least the nonindustrial cities, are the worst in the sense of being essentially intractable at a state and local scale. The priorities for control must consider these general differences. The second point to remember when selecting among strategies is that there are a number of considerations other than simply mass particulate reduction. For instance, under the Clean Air Act mandate to protect public health, strategies that attack smaller particles or toxic materials are preferable to those that attack inert windblown dust; similarly, strategies that impact the more populated regions of a city should take priority over those that would affect fewer people. When evaluating control alternatives, economic factors, social disruption, and enforceability must also be considered.

Keeping in mind the need for individual consideration in each area violating the TSP standards, the following discussion lists the types of control measures generally considered appropriate for each of the various sources of particulates included in the three major categories previously outlined.

Control Measures Directed at Traditional Sources

The general pattern of control technology applicable to traditional sources is well established; the open questions are primarily those of application. In this sense, it is appropriate to subdivide the category of traditional sources into four subcategories:

- Major point sources
- Smaller point sources
- Fugitive emission sources
- Fuel combustion area sources.

Stack Emissions - With some differences in emphasis, the control measures available for both major and smaller point sources are similar.

- Obtain compliance with regulations - existing efforts to bring sources into compliance must continue, and must be extended in those areas where current efforts are incomplete.

- Tighten compliance determination and surveillance procedures - one area of significant difference by size of source; major sources should be stack tested at least annually, smaller sources inspected frequently under a tight surveillance system.

- Tighten regulation stringency - after considering carefully the local need for tighter traditional source control:

- Upgrade regulations for selected major sources and smaller sources to at least require the best control technology reasonably available (not necessarily RACT as currently promulgated).
- Incineration can be completely banned in favor of landfilling or shredding for power generation.
- Process losses covered under a general process weight regulation can be further restricted by adopting regulations specific to individual problem industries.

Fugitive Emissions - Aside from the major concerns of improved surveillance and enforcement, specific measures for reducing fugitive emissions from traditional sources include special regulations beyond simple nuisance or "reasonable precaution" regulations:

- Quantitative or visible emission standards at property lines
- Operating and maintenance standards for specific processes
  - Covering storage piles
  - Enclosing materials handling equipment
  - Paving roadways and loading and parking areas

Area Source Fuel Combustion - Though difficult to effectively control because of their large numbers, there is a real possibility of reducing emissions from such sources, if the need warrants, through measures such as the following:

- Design standards for new boilers
- Maintenance of oil boilers
- Prohibition of coal use
- Inspection and maintenance of small oil burners

Control Measures Directed at Nontraditional Sources

After agencies have taken the appropriate steps to controlling traditional sources, and in areas where traditional sources have never been the major problem, control strategies for the attainment of the TSP standards may have to consider control of those nontraditional sources discussed in Section III. Implicit in the very label "nontraditional" is the concept that these sources have not had control measures directed at them. However, control of these sources is not so much a matter that is beyond reach technically as it is a matter of using measures that are costly or hard to justify or, in many cases, simply measures that are not normally seen as pollution control measures. Examples of these types of measures are listed below for the three major categories of such sources:

- Motor vehicle exhaust
- Fugitive dust from construction and demolition operations
- Reentrainment of particles from roadway surfaces.

Motor Vehicle Exhaust - In urban areas where tailpipe emissions are found to be contributing 5 to 10 $\mu g/m^3$ to the total suspended particulate loading, it may be necessary to consider their control. The available control measures for lowering tailpipe emissions are:

- Reduce lead in gasoline
- Reduce VMT totals in area
- Reduce emission per mile through inspection and maintenance.

Construction/Demolition and Other Fugitive Dust Sources - The control of dust from construction and demolition activities and similar activities is most often approached through the use of nuisance or reasonable precaution regulations much as is the case with fugitive emissions. More specific control measures that can be applied include:

- Watering construction site and demolition rubble
- Chemical soil stabilization
- Use of sequential blasting demolition.

Reentrained particulates - The majority of such particulates are street dust entrained by traffic; control measures include both preventive measures and street cleaning:

- Control of dust deposition - A viable approach to controlling reentrained particulates is reducing the amount of particulate matter available for reentrainment; control measures include:

  - Fallout - The fallout level will decrease automatically with control of traditional source emissions.

  - Carryout - Dirt and mud carryout from unpaved roads and parking lost can be reduced by requirements for paving or stabilization of these areas.

  - Spillage - The loading on streets due to spillage from trucks is easily regulated against, but enforcement may be a problem. Regulations that require specific equipment on trucks would probably be an improvement.

  - Tirewear Particulates - Reduction in the amount of rubber tire particles could be effected by VMT reduction or by designing and requiring tires with better wear characteristics.

  - Sanding - Because of the obvious hazard of slippery roads, sanding and salting operations will obviously continue. Analysis of the efficiency of sanding may result in procedures that apply less sand more effectively; however, systematic road cleaning after sanding operations would be more appropriate.

- Street cleaning to remove deposited material - Since it is not possible to prevent all deposition of particles on a paved surface, an alternative or auxiliary approach to control of particle reentrainment is to remove the particles from the surface. Control measures include:

  - Street cleaning

    - Rotating broom sweepers

    - Regenerative air blast sweepers

    - Vacuum street cleaners

  - Street flushing with water.

Control Measures Directed at Transported Primary and Secondary Particulates

A complicating factor in any standards attainment strategy development is the concentration of TSP in the incoming air mass. When such concentrations approach or exceed the standards, there is little if anything that an agency can do to meet the standards unless the controls are also pursued for this incoming (nonurban) TSP. Obviously, there are really no appropriate measures for the contribution of natural sources to these TSP levels; however, those particulates directly attributed to man's activities are, to varying degrees, controllable. In certain cases attention directed toward control of these sources may be more profitable than nontraditional control techniques.

Transported Primary Particulates - Those particulates that are emitted directly as primary particulates and are then transported from one area to another can be controlled through conventional traditional source regulations. The difficulty arises in the development of regionwide control strategies in which one area may need to limit its emissions more severely than necessary to simply meet the standards in that area because of the impact on a neighboring area. Such regionwide planning may be immediately possible on a statewide basis or may require interstate and inter-EPA region cooperation.

Secondary Particulates - Much the same thing can be said for secondary particulates except that many of the secondary particulates are formed in transport over much longer distances than would normally be of concern for primary particulates. Therefore, these control strategies must seek national direction rather than state or interstate cooperation. However, secondary particulates that are locally formed can presumably be locally controlled. As indicated in Section III, urban excess secondary particulates may add 5 $\mu g/m^3$ to levels in the city and these particulates could be controlled once the appropriate precursor relationships are known.

FRAMEWORK FOR CONTROL STRATEGY PRIORITIZATION

The institution of control measures must be preceded by the careful prioritization of available options. This section suggests a framework for evaluating control options as a function of the scale of the problem. There are significant differences in the general prevalence of the three major factors — traditional sources, nontraditional sources, and large-scale consideration — and thus the applicability of their associated control options, when dealing with problems of different geographical scales. Consequently, priorities for instituting control options are best made within this context of differing scales.

Concept of Scale

A general assessment of the relative scale of impact of the factors affecting attainment can be made. It is helpful to think of TSP problems as affecting either a relatively small area (neighborhood), and entire urban area or many urban areas in a general region (intercity). These are discussed below.

- Neighborhood scale - TSP problems over areas a few blocks in size occur even in the urban areas with relatively low citywide levels; typically measured by only one hi-vol, these problems are often caused by a relatively local source, frequently a small industry or fugitive dust source.

- Urban scale - In some urban areas, the TSP problem is to a large extent citywide (in addition to neighborhood hot spots), and is less likely to be due to a relatively few identifiable sources as on the neighborhood scale.

- Intercity scale - In some portions of the country, there is a general regional TSP problem that transcends any individual urban area or AQCR.

Within any particular area, it is very possible to have problems in all three of these scales simultaneously. Nonetheless, the overall control approach to each can be generally independent and in fact, problems of certain types typically occur primarily in one geographic scale. For example, nontraditional sources typically cause mostly neighborhood problems, while traditional sources may more likely cause urban-scale problems.

Priorities of Instituting Control Options

The previous sections have delineated various control measures that could be instituted by agencies and suggested the general scale of applicability of different factors affecting attainment and their associated control measures. This section suggests the specific categories of sources for which control measures could be applied to reduce particulate concentrations at each level or scale. The source categories into which the many types of air quality problems have been generalized are as follows:

- Traditional
  - Major sources
  - Small sources
  - Fugitive emissions
  - Area source fuel combustion
- Nontraditional
  - Resuspended dust from roadways
  - Fugitive dust from construction and demolition
  - Auto tailpipe emissions
- Large scale
  - Transported primary particulates
  - Transported secondary particulate
  - Urban secondary excess

The following matrix (Table 16) summarizes the priorities for adopting control measures for these categories of sources as a function of the scale of the problem.

Table 16. CONTROL PRIORITIES

Order of priority	Regional scale of problem			
	Neighborhood	Urban		Intercity
		Lightly industrialized	Heavily industrialized	
1	Fugitive emissions Reentrained dust Fugitive dust/ construction	Reentrainment dust Auto tailpipe Area source fuel combustion	Major sources Urban secondary Small excess sources Fugitive emissions	Major sources Transported primary Transported secondary
2	Small sources Area source fuel combustion Auto tailpipe	Urban secondary Small excess sources Fugitive dust/ construction	Reentrained dust Auto tailpipe	Small sources Area source fuel combustion
3	Urban secondary excess Major sources	Major sources	Area source fuel combustion Fugitive dust/ construction	Fugitive emissions Reentrained dust Fugitive dust Auto tailpipe

SECTION V

RECOMMENDATIONS

The broad scope of this study provided an opportunity for an evaluation of the control practices to date, an assessment of the controls that are needed in the future, and an understanding of the obstacles that are preventing the attainment and maintenance of the NAAQS for TSP. Based on these findings, numerous recommendations have been formulated. The recommendations cover a wide range of topics and are directed at various audiences both inside and outside of EPA. Some of these recommendations are readily apparent from this study and are, in fact, called out separately, as in Appendix G. Others are the result of integrating all the findings and analyses conducted over the course of the study.

The recommendations provided below run the full gamut of considerations. They are organized by first presenting specific recommendations for emission control efforts, then more general recommendations concerning the major upgrading of quantitative air quality management planning, and finally recommendations regarding the current review and further development of the NAAQS for TSP.

In general, all of these recommendations recognize the need to provide appropriate justification for any new major control approach that must be adopted. Equally important is the demonstration that proposed control programs will result in the necessary improvements in air quality.

RECOMMENDATIONS FOR EMISSION CONTROL EFFORTS

The following recommendations are grouped for convenience into three groups corresponding to the three major components of urban TSP levels as discussed previously— traditional particulate sources, nontraditional sources, and nonurban particulate levels.

Control of Traditional Sources

All urban areas do not require an equivalent degree of traditional source control. The first set of recommendations presents control efforts considered appropriate for major industrialized urban areas having an apparent TSP problem primarily associated with emissions from major fuel combustion, industrial process and solid waste operations. The second and third set of recommendations are directed at all urban areas, both those that are heavily industrialized and those that have only a moderate to light amount of industry and area-wide combustion of oil or coal. Such a breakdown presumes that most of the effective programs will already meet the first set of recommendations for local control planning. However, additional control may still be needed under large scale planning efforts as discussed later.

1. Control of Major Point Sources

   a. Limitations on emissions from fuel-burning installations of all sizes should be tightened considerably. There is a factor of at least 4 between the typical regulation and the most stringent, yet workable, regulation; while very stringent requirements are likely not required in many urban areas, in major industrial areas they are clearly needed.

   b. Emission limitations applicable to major oil-burning installations should be defined separately, and more stringently, than those applicable to coal combustion. A single, uniform combustion regulation that was designed to permit some coal combustion will unavoidably permit relatively poorly controlled residual oil combustion, simply because of the inherently different emissions potential of the two fuels. There is no need for this, nor for the attitude that coal-to-oil conversion should be seen as a total abatement of the source; oil-fired sources can and should be controlled.

c. All major combustion sources that have undergone coal-to-oil conversion should be tested. There are significant differences in effectiveness when control devices designed for coal fly ash are utilized on oil-fired units, yet it appears not uncommon for the original percent-efficiency figures to be utilized in calculating emissions levels.

d. Emissions from industrial process losses should be regulated on the basis of industry-specific restrictions. The present common practice of utilizing a general process-weight curve necessarily means that relatively-easy-to-control processes will only be required to meet such standards as are appropriate for the more difficult to control ones. Major processes in any given area should be regulated with a specific emission limitation economically and technologically tailored to that industry.

e. Compliance determination procedures in general should be significantly strengthened, primarily by increased use of source testing and source surveillance. In general, the degree of assurance of stated control efficiencies, etc., appears to be less rigorous than needed to provide good quantitative compliance knowledge. While it is *not* recommended that all sources be physically tested, it is believed that a much greater level of testing is needed than is now practiced. All large sources and all unique sources should be tested on compliance attainment and at intervals thereafter, either by agency personnel or by an approved independent testing organization. Reliance on routine engineering calculations should be permitted only for the simplest, most routine situations. Source tests should take care to include not only stack emissions but fugitive emissions from processes. Systematically and randomly scheduled visits should be made with schedules depending upon the source size, history of complaints and problems, and compliance status.

2. Control of Fugitive Emissions

a. EPA should develop and make available an accurate methodology for inventorying the emissions and estimating the air quality impact in the vicinity of isolated sources of fugitive emissions, such as quarries and rock-crushing operations. In order to include such emissions in air quality management planning, more adequate information must be developed.

b. In every heavily-industrialized area, the cognizant state and local agencies should conduct, and EPA should support, a major survey effort to identify and inventory fugitive emission sources. Such surveys should include field monitoring, extensive inspections of industrial premises, and the rough estimation of emission quantities. While fugitive emissions from generally-isolated industrial operations (such as quarries) are relatively easy to identify, if not quantify, it is not easy to define the degree to which fugitive emissions from dense heavy industrial areas are a problem. Consequently, a serious effort to define the nature and magnitude of the problem is required prior to dealing with it.

c. Regulations applicable to fugitive emissions from industrial property should be strengthened by the itemization of specific control measures where possible and by the institution of property-line air quality limitations where required by the complexity of the area or the industrial operations involved. It is anticipated that in cases of clear-cut, obvious sources it will be more expeditious for the control agency to identify and specify the required control measures. In contrast, in more complex situations such as a major iron and steel facility, it is anticipated that it will be more expeditious to require the source to conduct property-line monitoring and be responsible for the identification and implementation of control measures on their own property so long as the control measures required as a result of property line monitoring are no less stringent than otherwise would be required.

3. Control of Small Point Sources and Areawide Fuel Combustion

a. State and local agencies should reassess their point source cutoff to ensure that a major percentage of their traditional source inventory is receiving individual attention. Arbitrary cutoff points of 25, 50, 100 tons/year are often used to define point and area sources. Commonly, those cities that have significantly reduced the emissions from major point sources have used a high cutoff point. As the emissions have been reduced, smaller sources are now of concern and should be considered individually for modeling, compliance, and enforcement purposes.

b. Regulations governing the allowable emissions from small combustion units should be promulgated or, if already promulgated, reviewed to reflect current fuel usage, fuel availability, and control technology. Many jurisdictions do not control small combustion units or allow emissions higher than necessary for a well-maintained unit.

c. Small incinerators should be banned or should have permits required to ensure proper control and burning under favorable meteorological conditions.

Control of Nontraditional Sources

In contrast to the control of more conventional sources, which is primarily a problem in industrialized areas, the management of particulates arising from urban activity is likely to be required in essentially all urban areas of any size. However, nontraditional sources are not such a well-defined problem as to permit immediate and detailed control strategy planning. Rather, no major national attack on such particulate sources is considered appropriate for implementation until a variety of preparatory steps have been taken. Consequently, the following recommendations concern preparation for, rather than actual implementation of, the control of urban activity sources.

Control of Urban Activity Sources

a. EPA should develop appropriate methodologies for inventorying emissions from nontraditonal sources in urban areas and support their proper utilization by state and local agencies. To the extent possible these inventories will take into account particle size and spatial and temporal emission rates.

b. EPA should develop and provide to the states a diffusion model which adequately takes into account particle size, small scale diffusion, and the deposition characteristics of the inventoried emissions. Both short-term (24-hour) and long-term (annual) averaging models are needed which allow for variations in parameters including precipitation, ground cover, particulate loadings on roads (fluctuating with street cleaning, precipitation, sanding operations), wind speed, etc.

c. EPA should develop and implement a major effort aimed at providing, in 1 to 2 years' time, information on the costs and effectiveness of control measures potentially applicable to urban reentrainment. The effectiveness, and to some extent the cost, should be considered in light of the potential for public acceptance and ease of implementation. Cross-media environmental impacts should also be addressed; e.g., street flushing for reentrainment control.

d. EPA should develop and implement a public education effort aimed at developing recognition, on the part of appropriate bodies of public opinion and appropriate government agencies, that such nontraditional sources are of significance with respect to air quality and are a legitimate subject of environmental concern.

Control of Large Scale Influences - Additional reductions in TSP levels can be expected if precursors of secondary particulates are controlled, not only within an urban area, but also "upwind" of cities. Other contributions from "upwind" sources can arrive directly via transport. Planning measures to control these contributions require national direction for implementation, but will result in a more equitable distribution of the stringency of control measures.

1. Control of Secondary Particulates

a. EPA should continue efforts to develop and document the mechanisms of formation and models for the prediction of secondary particulate levels, especially sulfates and organics, on both the meso- and macroscale. The effects of precipitation on scavenging of precursors, stagnating air conditions, insolation, thermal radiation, etc., should be adequately considered.

b. State and local agencies should take into account the formation of secondary particulates in their formulation of control strategies for TSP. The urban excess of secondary particulates must be either consciously included in the TSP level that is considered uncontrollable, thereby requiring further restrictions on traditional sources, or should be addressed through the control of the emission of precursor pollutants.

c. EPA should not permit the use of supplementary control strategies or tall stacks to satisfy immediately local air quality needs since the result may be to increase levels of secondary particulates at sites remote from the source. Because of the continental scale and variability of meteorology, it is not likely that such controls techniques would be permitted anywhere in the country. In fact, additional SO_x controls may be needed at some sites to help solve the TSP problem elsewhere.

2. Transport and Primary Particulates

a. States should require air quality planning to be done on as large a regional scale as is necessary to reach into an area not impacted by transport. Where an autonomous local agency has control over only a small part of a problem area they should have their authority extended, through a contract with the state, a regional compact, or some other arrangement.

b. EPA should support research efforts directed at the better understanding of short- and long-range transported particulates. Long-range transport under specific meteorological conditions that contribute to excessive TSP levels and cause violations of the 24-hour standards could become predictable so that appropriate measures could be taken. Short-range transport needs better documentation and analysis so that the intercity contributions to high TSP levels, leading primarily to violations of the annual standard, can be considered for air quality planning. Comprehensive inter-EPA regional planning may be necessary for TSP control.

RECOMMENDATIONS CONCERNING AIR QUALITY MANAGEMENT PLANNING

The second broad area of recommendations concerns improving the states' ability to accurately and quantitatively develop plans for the attainment and subsequent maintenance of the ambient standards. As has been noted, the general failure of the SIPs to attain the standards despite significant emission reductions is in part due to inadequate data bases and, to a less extent, to inadequate planning methodologies. This area is thus very fruitful for action, particularly short-term EPA action.

1. Development of Improved Data Bases

a. EPA should support data gathering efforts and computerized systems by state/locals which are compatible with NEDS and SAROAD. A number of major changes and expansions in NEDS and SAROAD are currently underway, and it is essential that these receive continued support. The fundamental concept of a joint federal/state/local pollution control system depends on consistent, accurate, up-to-date bases readily available to all.

b. EPA should provide a greatly expanded nonurban ambient TSP data base, either through their own monitoring efforts or by encouraging and utilizing such monitors run by the states. There is a need for a clear understanding of the variation in ambient levels as one moves from remote nonurban areas through more proximate areas into suburban areas, as well as a need for more detailed data on the differences in levels between various portions of the continent. Current networks need to be reviewed for appropriateness, completeness, and possible local influences as discussed below.

c. EPA should conduct a study, based on existing nonurban sites, concerning the effect of height and distance on measured levels at such sites. Because of the long history of many of these sites, dating back to the earliest years of the NASN, they have apparently never been studied carefully from a siting viewpoint, and in fact many are apparently placed very close to the ground. Since they must of necessity provide data to be extrapolated over scales of hundreds of miles, it should be well-determined to what extent they reflect air masses on that large scale, and to what extent very local impacts may be important. The evaluation of the current network should be conducted with the point of establishing consistently sited monitors (height and neighborhood) and any changes in the siting should be documented through concurrent sampling for a period of time.

d. EPA should provide improved, more specific, network design and monitor siting guidelines for TSP monitoring in urban areas. Although the study cities visited were all major cities with active control programs and were all meeting the minimum monitoring requirements, an unfortunate number of circumstances arose where the data from these networks was inadequate to meet relatively simple analysis needs. Emphases in the recommended effort should include the minimization of local effects at sites, the development of inter-urban site standardization, and the encouragement of increased monitoring frequency for problem diagnosis purposes. The number of sites required for an area should not be based on an arbitrary formula but should be determined by the need to understand the full complexities of the TSP problem.

2. Development of Improved Planning Tools

a. EPA should promote increased use by state and local agencies of special studies as planning tools. These studies would be directed at providing analytical procedures and control development tailored to the particular TSP situation and topographical, meteorological, industrial, and social-economic characteristics of a region through coordination with other environmental and regional planning efforts.

b. State and local agencies responsible for emission inventory maintenance should reevaluate previous years' emission inventories to make them compatible with those inventories currently being used. A basic understanding of how the emissions situation has changed in the past and the resulting impact on air quality provides the soundest basis for future planning.

c. EPA should support the development of the microscale dispersion models that are required to adequately cope with the potential need to control vehicular traffic in urban settings as a TSP control measure. At the present, the quantitative consideration of such matters is limited to the type of empirical data analysis performed herein. While essential for many purposes, this type of treatment does not allow for the consideration of hypothetical alternatives, as is necessary for control strategy formulation.

d. EPA should develop both the conceptual framework and the requisite computer software needed to utilize long-distance air mass trajectory modeling as an air quality management tool available to the stages. As increasing refinement of control strategies is necessary, concern with background transport, regional-scale secondary particulates, and other large-scale considerations will become increasingly important.

e. EPA should develop and promulgate at least informally guidelines for the use of particulate analysis by microscopy and other analytical methods. The need to identify sources of particulate matter will very likely result in an increase in this work, and a mechanism is needed to assemble and make available experience with the various approaches.

f. EPA should assess and provide information to states on hardware available for and design of special field studies.

ISSUES CONCERNING NAAQS REVIEW

The nature of the control measures mentioned above with respect especially to many of the "nontraditional" sources of particulates and large-scale problems will significantly modify the nature of many pollution control programs. Implementation of some of the control measures will necessarily extend the scope of control programs into areas of municipal services that have not traditionally been involved in pollution control, and which will necessarily be costly. Consequently, they will no doubt require extended discussion and justification, not only in the eyes of public opinion, elected officials, and municipal executives, but also in the eyes of many personnel within the air pollution control community itself.

An important element in future planning concerns the actual standards themselves. The NAAQS are currently being reviewed by the National Academy of Sciences for appropriateness and completeness. While the purpose of this TSP attainment study did not involve addressing the need for standards review or the ongoing review by the NAS, five specific issues became apparent in the course of this study. These are listed below with the hope that they will be considered in the review of the standards for TSP.

1. Particle Size - At present, the particulate standard is based on the total mass of particulate matter suspended in the air; there is no concern with particle size, save that the particles be small enough to remain suspended. (Or actually, just to remain suspended long enough to reach the hi-vol, the proximity of which thus becomes crucial.) Because the health effects of particles of various sizes differ significantly, and because the size distribution of particles from various source types differs significantly, any standard, whether an emission standard or especially an ambient air standard, that fails to recognize such differences is unavoidably seen as oversimplified.

2. Particle Toxicity - Differential toxicity among particles of various chemical nature is an issue very like that of particle size. Known, obvious differences, such as the distinction between inorganic soil materials and organic coal tar derivatives, are not included in the basis for the present ambient standard, except implicitly through the selection of epidemiological evidence to support the standard. This unavoidably contributes to the general impression that the standard is oversimplified in letting important factors "average out." The composition of the total particulates is already coming under review due to recent concerns about toxic pollutants.

3. Monitoring Specifications - At present, neither the NAAQS themselves nor the specified Federal Reference Method address the question of how hi-vol monitors should be placed relative to the sources of the particulate matter. While "common sense" has probably been adequate in distinguishing between ambient and source-oriented situations in the case of major point sources, it is clearly not so in the case of such low-level dispersed sources as street dust reentrainment. In order to be seen as appropriately precise in this area, the standards should at least take note of the effects of height and distance from a source such as a street by specifying a reference point where the standard applies and defining relationships by which data from other points could be adjusted.

4. Time Scale of Standards - At present, the necessary recognition of differing averaging times is handled by having standards for both short-term and long-term (annual) averages, and this is generally considered adequate. However, there are some phenomena that operate on a longer-time period and tend to indicate a desirability in considering longer-term values as well, such as perhaps 5-year running averages. Such an approach would offer one way of resolving the difficulties in handling such features as meteorologically good and bad years in air quality planning. It would also help in rationalizing the situation caused by several-year temporary phenomena, such as major construction, which presently are viewed as anomalies, causing standards' violations that can be ignored because they are temporary.

5. Spatial Averaging - Similar to the problem of monitoring specifications is the concern over the Clean Air Act requirement that each and every area of a city meet the air quality standards. It can generally be assumed that every city has at least one corner which can not meet the standards even though the current monitoring network indicates no violations. In the same manner, monitors may be placed so as to ignore the problem. Average TSP levels within a certain area up to a set height may be more appropriate.