United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/2-78-016
July 1978

Air

EPA

An Approach for the Preliminary Assessment of TSP Concentrations

EPA-450/2-78-016

An Approach for the Preliminary Assessment of TSP Concentrations

by

Thomas G. Pace

Air Management Technology Branch
Monitoring and Data Analysis Division

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

July 1978

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - in limited quantities - from the Library Services Office (MD-35), Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

Publication No. EPA-450/2-78-016

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This document describes the technical basis, uses and limitations of an approach for making a preliminary assessment of annual Total Suspended Particulate (TSP) data. The approach was developed using a statistical analysis of ambient data. It defines average values for TSP based on several siting, land use and industrial descriptors. It is hoped that this document will prove useful to agencies and others who are interested in understanding the sources of TSP.

Ambient levels of TSP reflect the combined impact of many sources and source types which collectively contribute to TSP levels. These levels are above the National Ambient Air Quality Standard for TSP in many areas of the country. As an aid in identifying these sources and their relative contributions to annual average TSP levels, a data base of 142 sites in 13 urban areas was compiled. Each site was visited and information on monitor placement and the surrounding neighborhoods was obtained. The sites represented a mix of undeveloped, residential, commercial and industrial land use. The 14 urban areas visited represented a variety of industrial and non-industrial urban centers and spanned the country geographically.

Five components were identified as a result of the site visits and preliminary analysis as comprising most if not all of the ambient TSP concentration. Four of the components (primary non-urban background, urban sulfates and nitrates, local sources and urban activity) are generally associated with sources other than industrial primary stack emissions. These four components collectively are referred to

as non-industrial components. They were found to contribute significantly to observed TSP levels in all cities and at all site types (except undeveloped) in varying ratios. The impact of the fifth component, industrial primary stack emissions (called industrial component) was found to be restricted primarily to industrial site types except when major steel making facilities were near residential or commercial areas. Using statistical analysis, this document estimates average contributions to observed annual TSP concentrations attributable to each of these five components.

Of the five components, primary non-urban background and urban sulfates and nitrates are estimated directly from measurements taken in non-urban areas and chemical analysis of sulfate and nitrate. The average contribution of local source and urban activity components was estimated empirically from the data base gathered in the non-industrial cities. Using these average values as a guide and referring to information for each of the 142 sites in the data base, an estimate was made of the total non-industrial component. A multiple linear regression technique was next used to estimate the average contribution of the industrial component to TSP levels.

Thus, this document describes the derivation of average values for each of the five components comprising TSP annual averages. These average values were used to compose estimates of total annual TSP levels for sites in two test cities. These estimates were compared with actual observations and were found to be a reasonably accurate approximation of the observed levels. The fraction of variance in the observed data which is explained by the regression equation (R2) was .70 and .79 for the two test cities.

The empirically derived relationships between observed annual TSP and the five previously described components of TSP can be used to estimate TSP levels. This estimate can be useful in several ways:

1) The estimate can be compared with the actual concentration at a site to identify those situations which differ substantially from the norm. Thus, such an estimate becomes a screening technique for identifying abnormal influences. It can also be used as a screening technique for areas without monitors.

2) The estimate can be further broken down using data from previous analyses to provide a preliminary estimate of source categories contributing to TSP levels. This preliminary estimate can be refined through more extensive analysis or used in those situations where a more refined estimate (by atmospheric diffusion models or from measurements such as filter analysis or special sampling) is precluded by time or resource constraints.

3) The estimate can be useful in interpreting monitoring data and in identifying possible siting anomalies.

4) Comparing the estimate with dispersion model predictions may help identify the causes of discrepancies between predictions obtained with dispersion models and observations, such as certain improper emission factors or use of a different grid size.

ACKNOWLEDGMENTS

This study was undertaken by the Air Management Technology Branch, Monitoring and Data Analysis Division. The primary author was Thompson G. Pace.

Many people were involved in the preparation and review of this document. Particularly, Warren P. Freas, Dr. Edwin L. Meyer and Dr. Elsayed Afify provided detailed review and guidance. Others who participated in the study are Edward J. Lillis, Dallas W. Safriet, James L. Dicke, Dr. David Marsland, Dr. James Woodburn and Carole Mask.

1 INTRODUCTION

Measurements of Total Suspended Particulate (TSP) ambient concentrations have been made routinely since the early 1950's using the high-volume sampler. This sampler draws air through a glass fiber filter and the concentration of TSP in the air is expressed as the ratio of the total weight of particulate collected on the filter, in micrograms, to the volume of air drawn through the filter, in cubic meters. Such data, taken for a 24-hour period regularly throughout the year, are summarized by an annual geometric mean concentration at each site.

The purpose herein is to describe the derivation and potential applications of a set of empirical relationships which identify five major components of ambient TSP concentrations and the relative contribution of each to TSP levels as measured on high volume samplers. These components are: 1) primary nonurban background particulates, 2) urban secondary particulates (sulfates and nitrates which are formed by the atmospheric reaction and transformation of gases, SO_x and NO_x), 3) particles arising from urban activity, 4) industrial influences and 5) particles arising from area sources in the immediate vicinity of the monitor (i.e., local sources). The five components of TSP are reviewed and empirical relationships are developed for their individual impacts on TSP levels. Potential applications for these empirical relationships in the preliminary assessment of TSP problems and explaining variations among the data are suggested.

2 DATA BASE

The data base used in the analysis leading to the development of empirical relationships was obtained for thirteen urban areas by visiting monitoring sites and documenting the local sources. All told, 142 monitors were visited. The visits were made by GCA Technology Division as a part of a particulate study conducted for the U.S. Environmental Protection Agency. Many of the thirteen urban areas visited during the study had monitoring networks extending over a large area. The entire network for each area could not be visited due to time constraints. Usually around ten sites from each urban area were visited. They were about equally divided among residential, commercial and industrial neighborhoods (in those areas with industry) and were considered representative of the entire network.[1]

Seven of these areas (Chattanooga, Miami, Oklahoma City, Providence, San Francisco, Seattle and Washington) were selected because they had relatively low emissions from industrial sources except in clearly defined industrial areas. Therefore, these emissions would not generally contribute greatly to measured concentrations outside of the industrial neighborhoods in which they are located. This argument is supported by a recent study of particulates in these areas.[2] These seven areas provide data at 50 sites which can be used for estimating the non-industrial components of TSP levels without the masking effect of major industrial influence.

The other six areas (Baltimore, Birmingham, Cincinnati, Cleveland, Philadelphia and St. Louis) provide data for 92 additional sites, which are a mix of residential, commercial, general industrial and heavy industrial influences. These data provide a perspective on the industrial influence on TSP levels.[3]

2.1 Site Visits

Photographs of the surrounding area and of the building or structure on which the monitor was located were taken during the site visits. Selected localized sources of particulate were often photographed, as well. At each site the following information was noted: 1) site classification (residential, commercial, industrial); 2) type and height of support structure for monitor; 3) description of neighborhood surroundings; and 4) major local sources. In addition, the typical non-urban levels of TSP and urban sulfate and nitrate concentrations were noted for each city.

2.2 Tabulation of Data

The data for these 142 sites are summarized in Appendix 7.1. These data provide insight into the nature and level of influence of the components of TSP. The 1974 annual geometric mean is used throughout, because this is the year in which the site visits were made and local and industrial sources were noted. It would be advisable to include other years of data in any further analysis if changes in local environs were known. Several years' worth of data would enable the consideration of variations in meteorology as a part of the technique.

2.3 Local Sources

Characterization of the immediate surroundings was made at each site, and local sources were identified as to type and approximate distance. As a general rule, only sources within .5 km (about 1/4 mile) were considered. It is recognized that different types of sources will affect TSP concentrations to varying degrees. Therefore, the local activity level near each site was classified as "high" or "low", with the information in Appendix 7.2 used as a guide. It must be emphasized that some flexibility and judgment was necessary in specifying the level of local activity, because there are many situations in the field which do not conform precisely to the cases in Appendix 7.2.

Appendix 7.3 summarizes the concentrations and activity levels for the 50 residential and commercial sites visited in the seven lightly industrialized areas. Industrial sites in these areas were also visited, but these are not tabulated here because it was suspected that the industrial influence might mask the impact of the non-industrial component. The data from these 50 sites are subsequently used to estimate the impact of the local sources and urban activity on ambient TSP levels.

3 DERIVATION AND DISCUSSION OF EMPIRICAL RELATIONSHIP

In analyzing the data base described in Section 2, the air quality concentrations reflect the combined effect of many sources of particulates. The five components of TSP, previously mentioned, each were hypothesized (or observed) to vary considerably between geographic areas, or site types or local siting differences. Each of these components and the methods used for estimating their "typical" or average contribution to TSP levels is presented in this section.

Four of the five components (primary non-urban background, sulfates and nitrates, local sources and urban activity) are generally associated with sources other than industrial stack emissions. These four have been grouped together in the following analysis and are referred to as non-industrial (NI) components. In the derivation of an empirical relationship, the NI component will be considered separately from the industrial component.

3.1 Estimating the Non-Industrial Components of TSP

The Primary Non-Urban Background (PNB), the Urban Sulfate, Nitrate component (USN), the Local Source component (LS) and the Urban Activity (UA) component are discussed below, along with the methods used to estimate their average contribution to TSP levels.

3.1.1 Primary Non-Urban Background (PNB) and Urban Sulfates, Nitrates (USN) Components

This portion of TSP is comprised of non-urban primary particulates which are homogeneously distributed over a scale of hundreds of kilometers (a part of the traditional background level) and urban sulfates and nitrates. It is assumed that sulfates and nitrates measured in urban areas represent the composite impact of rural and urban sources. These portions of the TSP may vary considerably from one urban area to another but are considered in this analysis to be generally constant and uniformly distributed across a given urban area.

The magnitude of the primary non-urban background (PNB) portion of TSP cannot be directly measured in an urban area. It is a generally accepted (although not precise) practice to use the measurements of TSP concentration in non-urban areas near the urban area being studied as an indicator of the total non-urban background. Such measurements typically range from 15 to 35 $\mu g/m^3$, depending upon the region of the country, with highest values in the East. This non-urban measurement includes both a primary non-urban portion and also a non-urban sulfate and nitrate portion. In order to estimate the primary non-urban portion of the non-urban measurement, the non-urban sulfate and nitrate portions are subtracted from the total non-urban measurement. It is assumed that all organics which have been formed by photochemical reaction are included in the primary non-urban estimate. The urban sulfate-nitrate (USN) portion of the TSP is estimated by measuring sulfate and nitrates in the urban area. Thus, USN includes the non-urban sulfate-nitrate as a subpart of that measured in the urban area. Together, the PNB and the USN comprise that portion of TSP which is commonly assumed to be (relatively) constant across a given urban area.

In this analysis, the National Air Surveillance Network (NASN) sites were used to estimate the primary non-urban and the sulfate-nitrate levels. The non-urban levels measured by NASN stations can be divided into sulfate, nitrate and a remainder which is mostly primary particulate (with a small amount of secondarily-formed organic particulate). This is commonly assumed to be the PNB value for the nearby urban area. The urban sulfate and nitrate can be estimated from the urban NASN data. Of course, if several non-urban stations and detailed meteorological data were available to estimate the non-urban TSP influx, it would be preferable to use such data.

Once the PNB and USN have been determined for an area, these levels must be subtracted for the measured TSP concentration of each site within the urban area. The "adjusted" value thus reports the concentration at the site due solely to the influence of sources within the urban area. Consequently, each annual average (reported in Appendix 7.3) was adjusted by subtracting from it the appropriate PNB and USN values given in Appendix 7.4. These adjusted values are used in the further analysis of the Local Source and Urban Activity components.

3.1.2 Analysis of Local Source (LS) Component

Review of the information available from the site visits provided an indication that the height of the monitor and the amount of local activity from traffic and parking near the monitors may be significant factors affecting the concentration measured at these sites. Residential sites appeared to be only occasionally influenced by this local activity because there was seldom any such activity, but commercial and industrial sites were nearly always near such influence. However, industrial sites experience a highly variable influence from industrial process and fugitive emissions which would mask the effect of local activity. Thus, it was decided to base the Local Source and Urban Activity analysis on residential and commercial sites in non-industrial or only slightly industrial urban areas to avoid this masking effect. A total of 50 sites in 7 cities are in this subset of the data base (see Appendix 7.3).

The data were plotted, and visual examinations were made to determine whether a height-concentration relationship was present for each activity level (see Appendix 7.2). Figures 3.1 and 3.2 show the results of the plot for low and high local activity. It is clear from Figure 3.1 that the adjusted concentration near "low" activity sites averages 20 $\mu g/m^3$ and there is no apparent relationship between height and concentration. Figure 3.2 for "high" activity, however, shows a distinct relationship of height and concentration. The height-concentration relationship is expected, based upon earlier studies which observed that the number concentration of a colloid in a gravitational field decreases exponentially with increasing height.[4] Such an exponential decrease would be more easily observed where ground-level activity predominates. The lack of an apparent height-concentration gradient at the "low" activity sites suggests that the local influence on concentration from this low level of activity must be very slight. Also, the apparent increase in concentration

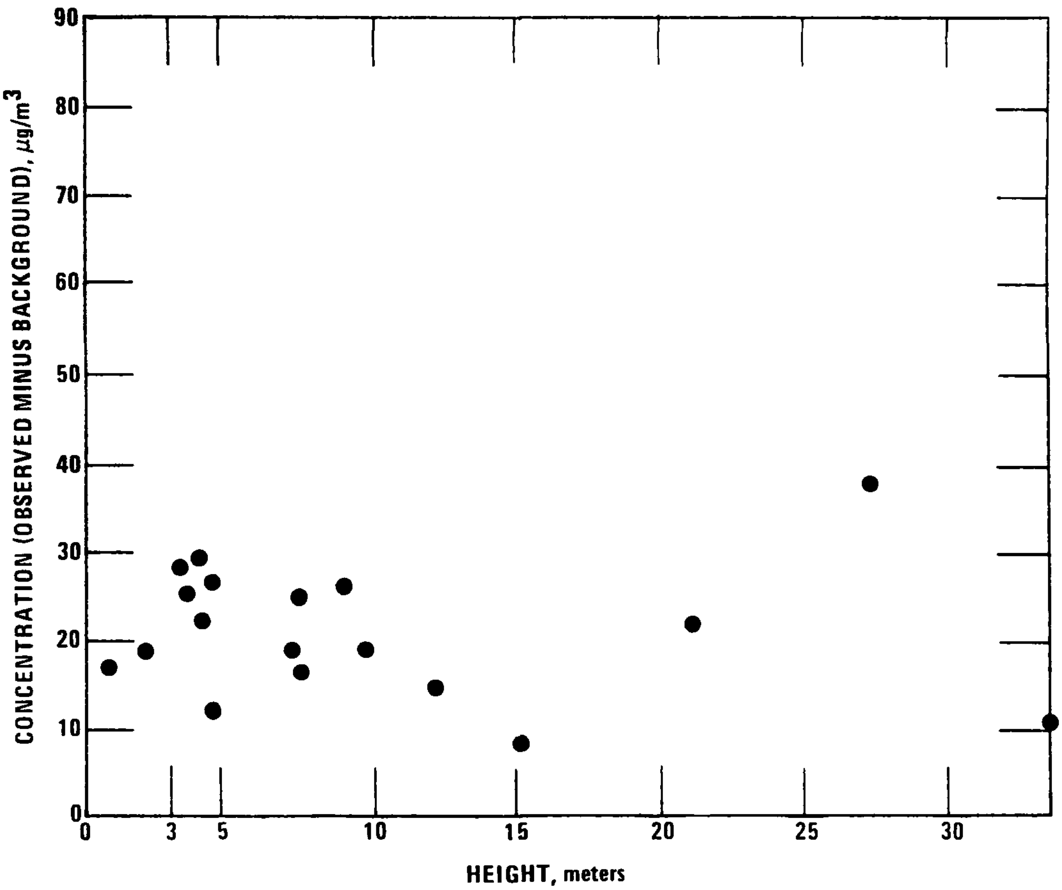

Figure 3.1 Constancy of adjusted concentration versus height for sites with "low" local activity

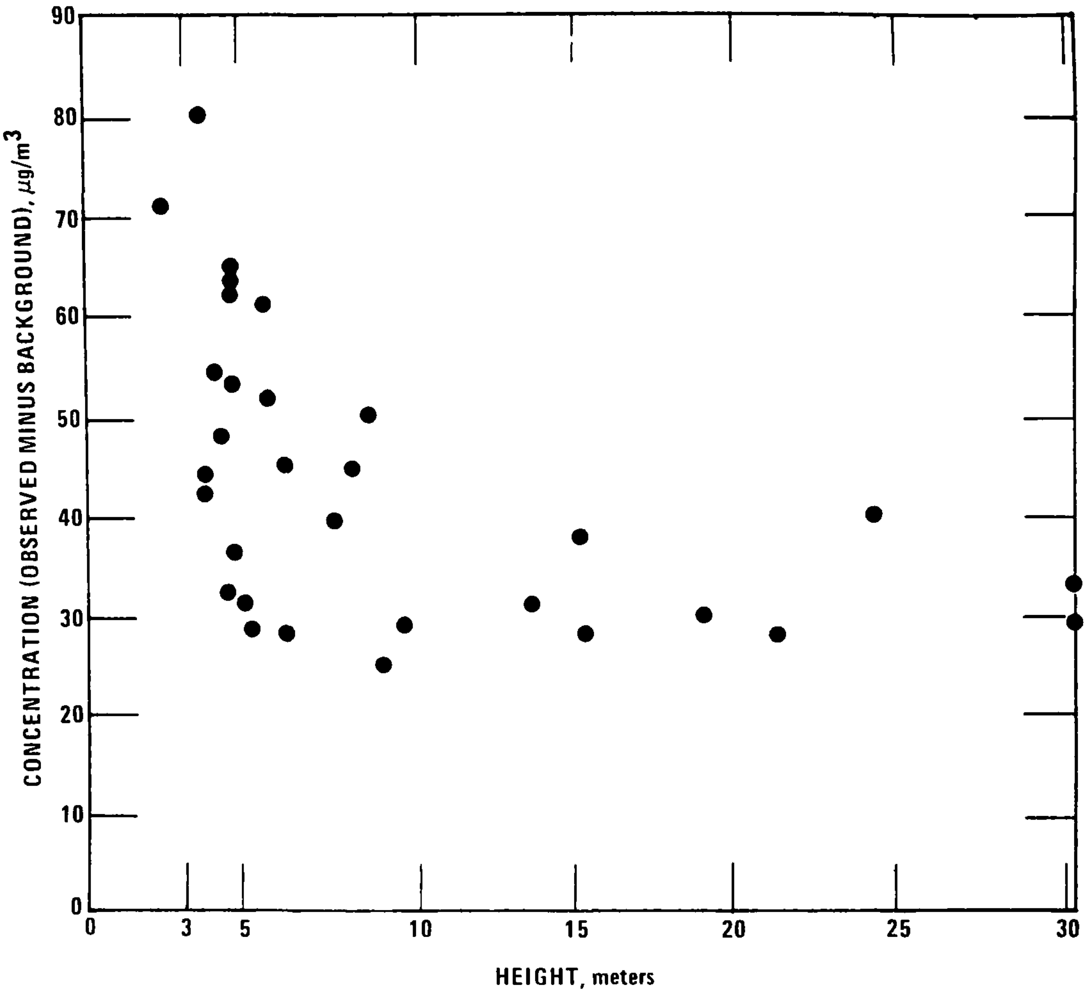

Figure 3.2 Decay of adjusted concentration versus height for sites with "high" local activity

between "low" and "high" activity sites suggests that local activity level is a significant determinant of measured concentrations. The activity relationship is understandable, if one assumes that TSP emissions are higher near sites with the high activity level.

Study has shown that the concentration-height relationship can be satisfactorily described by several mathematical forms.[5] This same study, however, did suggest the most desirable form. Using the nomenclature as summarized in Appendix 7.5, this form would be:

$$\hat{y} = a\, e^{-b\,H} + c \qquad \text{(Equation 3.1)}$$

where: $\hat{y}$ = predicted conc., μg/m³

H = height, meters

a, b, c = empirically derived constants

Thus, an empirical relationship of this form was fit by a least squares regression procedure.[6] The regression results for the combined data set are shown in Table 3.1, which indicates that the significance level is quite high; however, the standard error of 10 μg/m³ and the square of the correlation coefficient, R^2, of .41 indicate that factors other than height are also important, as mentioned. The resulting equation is:

$$\hat{y} = 45e^{-.2\,H} + 31$$

The distance of the source from the monitor and the variations in actual emission levels of the sources near the monitor account for much of the unexplained variance. A rough attempt was made to estimate the distance of the sources from the monitors and to consider

Table 3.1. Summary of Regression Coefficients and Statistics for Local Source Urban Activity at Sites With High Local Activity

Coefficients	For Equation 3.1, $\hat{y} = ae^{-bH}+c$ (Significance Level)
a	45 (.0002)
b	.2 N/A*
c	31 (.0001)
R-square	.41
Standard Error	10.1

* Not Available (value of coefficient determined by iteration)

this in the analysis. However, a review of the data base indicated that the distances from each monitor to nearby sources were not known precisely enough for inclusion in this analysis. The data base only included a general description of the surrounding area and not distances to specific sources such as streets.

In Equation 3.1, the first term, $a\ e^{-bH}$, represents that portion of the predicted concentration which varies with height. As "H" (height) becomes higher, this term decreases in value and approaches zero, and the predicted concentration approaches the constant "c". Thus, this model implies that monitors located higher than about 40-50 feet are not subject to appreciable height-concentration gradients attributable to high local activity. The constant "c" is presumed to represent urban activity influences on a sub-urban scale. As discussed in the following section on urban activity, this 31 $\mu g/m^3$ is assumed to represent a component of TSP which is related to emissions and activity over a larger geographical area than that which contributes to the local scale component. Thus, the local scale component includes only the exponential part of the equation.

There were no data points below about 3 meters elevation upon which to base the empirical relationship in Equation 3.1. Also, it is possible that there is a limit to the height-concentration relationship below which there is relatively uniform mixing due to ground level disturbances. Thus, Equation 3.1 should only be applied to sites higher than 3 meters, until additional data are gathered and further study made. Meanwhile, it is recommended that the assumption be made that there is a uniform mixing cell 3 meters high for ground level sources and that there is no concentration gradient in the first three meters. The relationship between height and concentration is plotted in Figure 3.3.

There are relatively few (50) data points used in the analysis and the sites were not selected by a strict random method (although no bias was intended). Thus, the data set was reviewed to determine whether there appeared to be a systematic bias which accounted for the height-concentration relationship. The adjusted concentration data were against height separately for each city. and the plots were examined for trends or patterns. It was found that the height-concentration pattern was evident in Providence, Washington, D.C., and Oklahoma City, whereas barely perceivable patterns appeared to exist in San Francisco and Chattanooga. No pattern is apparent in Miami. Seattle had only one data point. It was concluded that there is no systematic bias among cities in the data set which could account for the pattern in the combined data set. Also, it was evident that other factors beyond the scope of this investigation contributed to the weak or apparent lack of pattern in the data in some cities. For example, it has been shown in previous work by Record that the data set for Miami can be described by a parameterization including average daily traffic (ADT) and the slant distance, $\sqrt{\text{height}^2 + \text{distance}^2}$, of the site to nearby traffic.[7] Thus, any height effect among sites in specific cities may be masked by other variables such as ADT or distance of the monitor from the source.

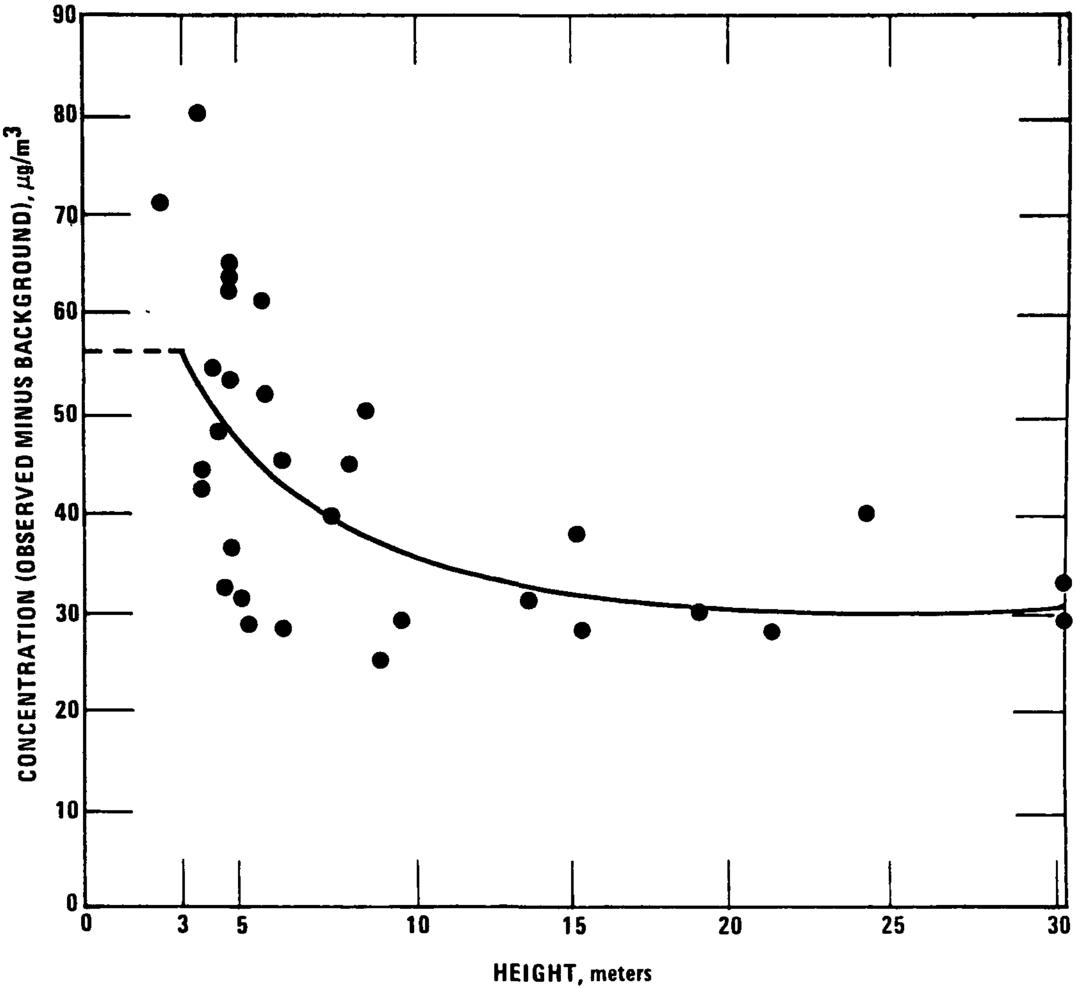

Figure 3.3 Plot of relationship between adjusted concentration and height of monitor

It is very important that further efforts attempt to define more clearly the relationships among height, distance and an estimate of source strength such as ADT.

To illustrate the height-concentration effect, a number of "pairs" of monitors have been located in various urban areas. These are either monitors located within a block or so of one another and at different heights (usually part of the local network) or located on a tower at the same location for a short-term experiment. These data are summarized in Table 3.2. It can be seen that the overall correlation between the values predicted by the empirical height relationship and observed differences in concentration is fairly good (R^2=.77). The several cases where the model severely underpredicted differences could be partly because the lower monitor was closer to the source laterally than the higher one.

3.1.3 Urban Activity (UA) Component

The activity in the area around the high-volume sampler but outside of the small radius which contributes to the local scale component, also contributes to TSP levels. This activity and its contribution to TSP levels is referred to as the Urban Activity (UA) component. The analysis in Section 3.1.2 estimates that the average urban activity component at sites with high local activity is about 31 $\mu g/m^3$. Since at least 90% of the sites which were reported to have a high activity level in Appendix 7.3 were commercial sites, it is assumed that most commercial sites would have an average 31 $\mu g/m^3$ influence from urban activity sources. Moreover, it was observed

Table 3.2 Tabulation of Measured and Predicted Difference in TSP Concentration For High-Volume Samplers Located Near Each Other But At Different Heights

Site Pair Location	Height, Meters		Measured Difference, $\mu g/m^3$	Difference Between Predicted Concentrations at "High" and "Low" Activity Sites Using Equation 3.1 $\mu g/m^3$
	High	Low		
Philadelphia, Broad St.	12	3	50	21
Philadelphia, Franklin Inst.	20	4	25	19
Kansas City	7	2	10	13
Austin, Texas	10	6	4	8
Austin, Texas	6	1	11	11
Cincinnati	7	2	7	13
Chicago	40	4	26	20
Pittsburgh	26	3	47	23

that the non-industrial activity in industrial neighborhoods was reasonably similar to that in commercial neighborhoods. Thus, until better data on which to base an estimate become available, it will be assumed that industrial sites have a similar average 31 $\mu g/m^3$ urban activity component. The data at sites with low activity (almost exclusively residential sites) indicate an average residential urban activity component of about 20 $\mu g/m^3$, as was shown in Figure 3.1. It is assumed that sites in undeveloped neighborhoods have no urban activity component because the primary non-urban background values would include any urban activity in these areas. Thus, the explicit "urban activity" term derived here would be zero for these areas.

A recent study of TSP by Record can be used to estimate the composition of the urban activity component.[8] It appears that motor vehicle exhaust and tire wear account for 10% to 15% each of the urban activity influence. Construction and demolition account for another 5% to 10%, unless major urban renewal projects in the area increase this component. Space heating, usually from oil-fired boilers and furnaces, can account for from zero to 40%, and small industry and power generation can account for from zero to 20+%, depending upon degree of control, type of fuel burned and climate conditions. The remainder (around 30-50%) appears to be due to dust from paved roads and unpaved roads and parking lots, which is suspended by both the wind and man's activity. These estimates may be used to provide a rough indication of the sources of TSP comprising the urban activity component.

3.2 Estimating the Industrial Components of TSP

In order to estimate the industrial influence at residential, commercial and industrial sites, it was necessary to include all the 142 sites described in Appendix 7.1. This gives a data base covering a variety of industrial and non-industrial areas and sites. A regression analysis was performed on these data. To do this, the non-industrial (NI) influence (computed as the sum of PNB, SN, UA, LS) was estimated for each site. Each site was described mathematically by a series of binary variables to identify sites near industrial influence and a multiple linear regression was performed to estimate the coefficients of the NI and Industrial terms. This procedure is described in more detail in the following sections.

3.2.1 Estimating Values for NI at Each Site

The variable NI (Non-Industrial) is an estimate of the combined impact of primary non-urban background, urban sulfates and nitrates, the urban activity component and the local source component previously developed. The method used to estimate NI is discussed below.

1) The secondary (urban sulfate, nitrate) and primary non-urban TSP levels were estimated for each urban area listed in Appendix A. As mentioned, the values assigned to the sites in each area are summarized in Appendix 7.4.

2) To this was added the appropriate urban activity value, based on site type. A value of 0, 20 or 31 $\mu g/m^3$ was assigned to each site, depending on its classification as undeveloped, residential or commercial/industrial.

3) Finally, a local scale component was added at each commercial and industrial site. It was assumed that since the vast majority of commercial or industrial sites are subject to high local ground-level activity, they have a local source influence.

3.2.2 Classification of Industrial Influence

It was observed by reviewing the data that industrial sites generally had higher concentrations if the monitors were near general industry, a steel mill or related operations. Also, residential-commercial site values were elevated in concentration near steel mills, though not as markedly. Thus, a procedure using binary classification variables (sometimes called "dummy variables") was developed to identify variations in industrial influence.

At this point, it is appropriate to explain the binary classification variables and why this method was selected for describing the industrial influence and incorporating it into an empirical relationship. First, it was decided that a multi-variable regression procedure would be used to estimate the industrial influence. Since data was not readily available to estimate the emissions of the industrial sources near each monitor, a method was needed to "classify" the industry as to its type or nature. Binary descriptors were used to identify whether a specific site met certain conditions of industrial influence (say, being within 2 km of a steel mill). If the site were near a steel mill, a "1" would be assigned as the classification variable for that site. Conversely, if the site were not near a mill, the "0" classification variable would be used. In the multi-variable regression, a coefficient would then be calculated which would be the estimate using the regression of the impact of the steel mill(s) on the site's measured concentration. It should be noted that these variables were selected based on a preliminary review of the data so that the regression could be used to evaluate any differences in concentration for these classifications.

In this analysis, all sites were assigned a series of three binary classification variables. The first variable (SMIND) was assigned a "1" if the site was considered industrial and there was a partially controlled or uncontrolled steel mill or coking operation within less than 2 km range. A value of "0" was assigned to all other sites.

The second classification variable (SMRC) was assigned a "1" if a partially controlled or uncontrolled steel mill or coking operation was within the range of 2-10 km. (These sites were designated as residential or commercial). Other sites were assigned a "0" value.

The third classification variable (GENIND) was assigned a "1" if it was near an industrial influence (1-2 km) and not near (less than 10 km) one or more steel mills or coke ovens. All other sites were assigned a "0".

The three classification variables are summarized below.

SMIND $\binom{0}{1}$ - The presence nearby of partially or uncontrolled steel mill and/or coking operations on industrial sites (less than 2 km).

SMRC $\binom{0}{1}$ - The presence nearby of partially or uncontrolled steel mill and/or coking operations at residential or commercial sites (within the range of 2-10 km).

GENIND $\binom{0}{1}$ - The presence nearby of general industry at industrial sites (less than 2 km away).

The regression model is given by Equation 3.2:

$$OBS_i = B_1\ NI_i + B_2\ GENIND_i + B_3\ SMRC_i + B_4\ SMIND_i + B_5, \quad \mu g/m^3$$

where:

NI = Total estimated non-industrial influence, $\mu g/m^3$ includes:

- Primary Nonurban Component
- Sulfates, nitrate levels in urban area
- Urban Activity Component (0, 20 or 31 $\mu g/m^3$ at undeveloped, residential and commercial/industrial sites, respectively).
- Local Source Component calculated by:

$$\text{zero or } 45\ e^{-.2\ (H_i)} \qquad \text{(Equation 3.1)}$$

where H_i is height of monitor, "i", meters

GENIND $\binom{0}{1}$ = The presence of general industry near (less than 2 km) industrial site.

SMIND $\binom{0}{1}$ = The presence of uncontrolled steel mill or coking operation near (less than 2 km) industrial site.

SMRC $\binom{0}{1}$ = The presence of uncontrolled steel mill or coking operation near (2-10 km) residential or commercial site.

B_1 thru B_4 = Coefficients to be derived from the Regression Procedure

B_5 = Regression constant

It is important to note that only one of the above variables can be assigned a binary classifier of "1" at a particular site. This would be the one that best describes the site. The other two must be assigned a "0".

3.3 Regression Analysis of Non-Industrial and Industrial Sources

A multiple regression was performed on the observed concentration (OBS) compared to the NI, SMIND, SMRC, and GENIND variables.[6]

Table 3.3 summarizes the number of observations for each variable and Table 3.4 summarizes the results of the regression. It is shown that the variables predict the observations with a standard error of 16 $\mu g/m^3$. For an average observation of 79 $\mu g/m^3$, this represents a coefficient of variation of $\pm$ 20%. The equation explained 71% of the variance (R-square) among the observations. As can be seen from the tabulation, all coefficients are significant at the 99% confidence level except the regression constant term (unexplained portion), which is significant at the 95% level. The coefficient of the non-industrial portion (.88) indicates that it was a reasonable predictor of the non-industrial component of this data set. The regression constant represents that portion of the observation that was not explained by any of the factors considered in the regression.

Table 3.3 Summary of Sites in Data Base

SITE TYPE	NUMBER
Undeveloped	9
Residential	35
Commercial	52
Industrial (GEN)	21
Industrial (SM)	13
Res/Com (SMRC)	12
Total	142

Table 3.4 Summary of Regression Analysis of Data for 142 Urban Sites in 13 Urban Areas

Results of Regression

	Coefficients	Significance Level	Standard Error
NI	.88	(.0001)	.10
GENIND	15.0	(.0010)	4.3
SMRC	22.9	(.0010)	4.9
SMIND	52.0	(.0010)	5.1
CONSTANT K	13.3	(.0371)	6.4

R-SQUARE .71

STANDARD ERROR 16.0

3.4 Example Calculation

The application of the empirical relationship for estimating TSP concentrations using the previously derived relationship (Equation 3.2) is relatively straight-forward. Data were obtained in Charlotte (Mecklenburg County), North Carolina to estimate TSP levels. Table 3.5 describes the sites, and Table 3.6 summarizes activity levels assigned to each site and the results of the calculations. As an example, TSP concentrations arising from each of the previously identified five major components of TSP are calculated at the Community Hospital site in Charlotte, North Carolina.

3.4.1 Primary Non-Urban Background and Urban Sulfate-Nitrate Components

Available NASN data were used to estimate PNB and USN levels. The non- urban NASN station near Charlotte averaged 30 $\mu g/m^3$. This includes approximately 9 $\mu g/m^3$ of nonurban sulfate (as ammonium sulfate) and nitrate, leaving a primary component of 21 $\mu g/m^3$. Urban sulfate and nitrate levels measured at the urban Charlotte NASN station totaled 12 $\mu g/m^3$.

3.4.2 Urban Activity Influence

The neighborhood around the Community Hospital monitor was primarily commercial for 1-2 km in each direction. Thus a value of 31 $\mu g/m^3$ is added as urban activity influence.

3.4.3 Local Source Influence

Table 3.5 indicates that there is an unpaved parking lot 100 feet away. There is a major arterial nearby and the surrounding

Table 3.5 Description of Sites in Charlotte, North Carolina

Site Name	Site Type	Height, Feet	Description
McAlpine Sewage Treatment Plant	Rural	10	Very clean looking area. All roads and parking paved. No bare land. No urbanization nearby. Nearest thru road is 2 lane light traffic 1/2 mile away.
Mint Hill	Small Town	8	Behind telephone Co. Bldg. Unpaved greenhouse area next door appeared to have very little traffic. Monitor was 75 feet from 2 lane road. No major activity within 1/4 mile. Not enough to produce a height effect.
Fire Station 14	Residential	16	Residential area surrounding two commercial strips - Randolph Road and Sharon Amity Road. Both are 4 lane and are 125 and 75 feet respectively from monitor. No unpaved areas.
Mecklenburg Health	Commercial	10	Monitor well removed from local traffic. East Blvd. is 1/8 mile away but is screened from monitor by trees. No unpaved areas.
Fire Station 10	Commercial	16	Approximately 100 feet from Wilkerson Blvd. (4 lane) and 50 feet from light traffic side street. Entire area very commercialized.
Beatties Ford	Commercial	8	Located in dirt parking lot which is used twice a day by around a hundred cars. Located 15 feet from Oaklawn Avenue-moderately traveled 2 lane and 75 feet from Beatties Ford Road- 4 lane. Expressway 500 feet under construction in 1973
Carpenter Airport	Rural	3	Very remote area of county. No traffic or activity nearby.
Community Hospital	Commercial	25	Generally active area. Four lane arterial 100 feet away and very active unpaved parking lot around 100 ft.
Fire Station 11	Commercial	15	Generally quiet area. Arterial within 1/4 mile but nothing within 100 feet. A fair amount of commercial activity within 1/4 mile.
Davidson Filter	Small Town	20	Not much activity here-typical small town. Not really enough urban activity to produce a height effect.
North 29 Patrol Station	Light Commercial	8	US 29 4 lane 200 feet away. Lightly commercialized but not in city limits. Rest of area is sparsely populated.
Davidson Pump	Rural	3	On lake, no activity, very remote

Table 3.6 Example Calculation of Empirical Prediction for Charlotte, North Carolina, Sites

Sites	Neighborhood	Activity Level	Height, Ft.	Estimated Concentrations μg/m³					Empirical Predicted μg/m³	1974 Observed μg/m³	Residual μg/m³
				Primary Nonurban Background μg/m³	Sulfate, Nitrate μg/m³	Urban Activity Influence μg/m³	Local Influence μg/m³	Industrial Influence μg/m³			
Fire Station 10	Commercial	High	16	21	12	31	15	0	83	66	+ 17
Fire Station 11	Commercial	High	15	21	12	31	16	0	84	62	+ 22
Fire Station 14	Residential	High	16	21	12	20	15	0	73	48	+ 25
Community Hosp.	Commercial	High	25	21	12	31	9	0	77	74	+ 2
Davidson Filter Plant	Rural	Low	20	21	12	0	-	0	42	46	- 4
Mecklenburg Health Dept.	Commercial	Low	10	21	12	31	-	0	65	55	+ 7
Beatties Ford Water	Commercial	High	8	21	12	31	23	0	89	101	- 12
Mint Hill	Rural	Low	8	21	12	0	-	0	42	39	+ 3
N. 29 Patrol	Commercial	Low	8	21	12	31	-	0	70	54	+ 16
McAlpine Sewage	Rural	Low	10	21	12	0	-	0	42	36	+ 6
Carpenter Airport	Rural	Low	3	21	12	0	-	0	42	30	+ 12

Statistical Data: Coefficient of Variance: $R^2 = .70$

Line of best fit: $y = .89x - 1$ μg/m³

area is commercial. This constitutes a high local activity level. Thus, the equation:

$$\hat{Y}_{LS} = 45\ e^{-.2H} \qquad \text{(Equation 3.1)}$$

is used where:

$\hat{Y}_{LS}$ = predicted local source concentration, μg/m³

H = height, 8 meters

therefore:

$$\hat{Y}_{LS} = 45\ e^{-.2\ (8)}$$

$$\hat{Y}_{LS} = 9\ \mu g/m^3$$

3.4.4 Industrial Influence

There is no specific industrial influence at the Charlotte, North Carolina, sites. Some minor industrial influence is probably reflected in the empirical value of Urban Activity Influence. Also included are the impact of fuel oil and coal space heating.

3.4.5 Calculation in Regression Equation

The regression model (Equation 3.2) is as follows:

$$\hat{y} = B_1\ NI + B_2\ GENIND + B_3\ SMRC + B_4\ SMIND + B_5\ \mu g/m^3$$

therefore:

$$\hat{y} = B_1(PNB + SN + UA + LS) + B_2\ SMIND + B_3\ SMRC + B_4\ GENIND + B_5$$

Substituting,

$$\hat{y} = .88\ (21 + 12 + 31 + 9) + 0 + 0 + 0 + 13.3$$
$$= 77\ \mu g/m^3$$

3.4.6 Comparison of Predicted and Observed Concentrations

Predictions of concentration were similarly performed for all sites. The predicted and observed values were analyzed by linear regression to determine the line of best fit. The resulting correlation was $R^2 = .70$. The equation of the line of best fit had a slope of .89 (times predicted concentration) and an intercept of -1.0 $\mu g/m^3$ which indicates excellent agreement between predicted and observed concentrations.

3.5 Additional Validation of the Empirical Relationship

The Mecklenburg County calculation serves as an independent check of the regression equation. In addition, a similar calculation was made for Allegheny County, Pennsylvania. Table 3.7 indicates the results of that calculation. The R-square was .79, the slope was .76 and the intercept was 21.6 $\mu g/m^3$ for a calculation of the line of best fit between the predicted and observed data. This is also quite good agreement for a model in a heavily industrialized area. The estimate for Allegheny County was made from a site description without actual site visits or prior knowledge the concentration at each site.

Table 3.7 Example Calculation of Empirical Prediction for Allegheny County, Pennsylvania

Sites	Neighborhood	Activity Level	Height, Ft.	Primary Nonurban Background μg/m³	Sulfate, Nitrate μg/m³	Urban Activity μg/m³	Local Influence μg/m³	Industrial Influence μg/m³	Model Predicted μg/m³	Average Observed 1974-76 μg/m³	Residual μg/m³
Baden	Industrial	High	18	23	22	31	13	52	144	135	+ 9
Beaver Falls	Commercial	High	6	23	22	31	23	0	100	80	+ 20
Koppel	Industrial	High	30	23	22	31	6	52	137	105	+ 32
Brighton Township	Rural	Low	3	23	22	0	0	23	76	- 80	- 4
Midland	Industrial	High	30	23	22	31	6	52	137	140	- 3
Elco	Rural	Low	-	23	22	0	0	0	53	75	- 22
Downtown	Commercial	High	30	23	22	31	6	23	108	95	+ 13
Central Lab	Commercial	High	45	23	22	31	2	23	105	110	- 5
Hazelwood	Industrial	High	45	23	22	31	2	52	133	100	+ 33
North Braddock	Industrial	High	15	23	22	31	16	52	144	135	+ 10
Duquesne II	Industrial	High	15	23	22	31	16	52	144	150	- 6
Liberty Boro	Industrial	High	30	23	22	31	6	52	137	140	- 3
Clairton	Industrial	High	30	23	22	31	6	52	137	120	+ 17
Airport	Commercial	High	60	23	22	31	1	0	80	84	- 4
South Fayette	Rural	Low	30	23	22	0	0	0	53	58	- 5

<u>Statistical Data</u>: Coefficient of Variance: $R^2 = .79$

Line of best fit: $y = .76x + 21.6$ μg/m³

3.6 Discussion

In the preceding analysis, two empirical relationships were developed which can be used to help explain variations in particulate concentrations. In the first relationship, height of the high-volume sampler above the ground was the independent variable and the coefficients of the proposed relationship were obtained by multiple regression. The significance levels of these coefficients suggest that the probability that the coefficients are not equal to zero is very high. The coefficient associated with monitor height was estimated by iterating the linear regression solution of the transformation $x' = e^{-bx}$ for various values of "b" to maximize the square of the correlation coefficient and minimize the standard deviation. Thus, no confidence level for this coefficient could be readily obtained. In fact, a coefficient of zero (on which a null hypothesis would be based) would not be very meaningful since $e^0 = 1$ and $\hat{y}$ = constant. A regression analysis was made where "b" = 1 and thus resulted in a very poor fit of the data. Since the regression statistics were relatively insensitive to small changes in "b" near the value of "b" = .2, the coefficient was only estimated to one significant figure. The resulting relationship is meaningful in that monitor height has been shown to vary greatly among sites. If, as was shown here, large variations in TSP concentration can be attributed to monitor height, then much more attention should be directed to monitor placement in the monitor siting and network design process.

The second regression estimated coefficients of both the non-industrial and industrial components of TSP. In selecting the terms for the regression, special attention was given to terms that would prove meaningful in control strategy development and in understanding the sources of TSP. The non-industrial component was estimated for each site using measurements and predictions from the first empirical relationship. Thus, the coefficient of this term in the regression would be expected to be close to 1.0 if the estimates for the non-industrial component were generally accurate. The resulting coefficient of .88 was considered satisfactory evidence that the non-industrial component estimates were acceptable. As in the first regression, the confidence that the null hypothesis can be rejected is very high. The coefficients of the industrial terms suggest strongly that industrial sources, particularly steel mills, are a major influence on TSP levels. The entire equation provides perspective on the relative impact of non-industrial sources and indicates that even at industrial sites non-industrial sources are a significant part of the total measurement. This is very significant in directing future particulate investigations.

4 POTENTIAL APPLICATIONS OF THE EMPIRICAL EQUATION

While it is certainly expected that the use of Equation 3.2 will provide a further understanding of general factors affecting TSP, there are other more specific uses of the empirical equation which should be of added benefit in particulate planning and analysis. Such applications include screening of sites to determine which sites might not fit the "typical" pattern (the value predicted by the equation), and thus might be candidates for further, more intensive analysis. It would serve as a non-data and resource-intensive tool which could be used to provide a preliminary analysis until data or resources for a more intensive analysis of TSP data and problems were available. Interpretation of monitoring data and dispersion model results are other potential applications.

4.1 Example Application

In this example application, Philadelphia, Pennsylvania (one of the urban areas in the data base), was analyzed. Using the same procedure as with Charlotte, Table 4.1 indicates the site characterization and concentration predictions for Philadelphia. In this instance, the model estimates compare fairly well with the observed values, explaining 68% of the variance. It must be pointed out that the primary use of the model is not to estimate concentrations but to help explain the observed data. Several examples of this follow.

4.2 Data and Site Screening

An obvious application of the empirical equation is in the screening of data and sites to determine which sites might not fit

Table 4.1 Example of Application of Empirical Equation to Data in Philadelphia, Pennsylvania

Site Name	Activity Level	Neighborhood	Monitor Height, ft.	Primary Nonurban Background μg/m³	Sulfates, Nitrates μg/m³	Urban Activity Influence μg/m³	Local Scale Influence μg/m³	Industry Influence μg/m³	Model Predicted μg/m³	1974 Observed μg/m³	Residual μg/m³
Belmont Filter	Low	Residential	13	24	18	20	0	0	68	72	- 4
Roxboro Filter	Low	Residential	13	24	18	20	0	0	68	59	+ 9
N. E. Airport	Low	Residential	13	24	18	20	0	0	68	64	+ 4
AMS Lab	Low	Residential	17	24	18	20	0	0	68	78	- 10
Franklin Inst. (CAMP)	High	Commercial	11	24	18	31	22	0	97	119	- 22
S.Broad & Spruce	High	Commercial	13	24	18	31	19	0	94	115	- 21
500 S. Broad	High	Commercial	35	24	18	31	4	0	80	76	+ 4
Defense Supply	High	Industrial	13	24	18	31	19	15	109	105	+ 4
Allegheny River	High	Industrial	13	24	18	31	19	15	109	122	- 13
Int. Airport	High	Industrial	13	24	18	31	19	15	109	94	+ 15
Aramingo Fire St.	High	Industrial	35	24	18	31	4	15	95	116	21

Statistical Data: Coefficient of Variance: $R^2 = .68$

Line of best fit: $y = 1.06x - 1.0$ μg/m³ the "typical" site as indicated from the empirically predicted value. Such information would be valuable in highlighting those sites which would require further study because of concentrations anomalously higher or lower than the model predicts. In the example of Philadelphia in Table 4.1, the equation underpredicted the concentration at the Broad and Spruce site, indicating the presence of a very strong influence not adequately accounted for by the empirical estimates. Recent inspection of the site indicated that this was probably due to local traffic with the monitor being extremely close (35 feet) to the road and low to the ground as well. A more detailed study was deemed warranted at this site and is now in progress. Another station which was underpredicted is the CAMP station, which is within 100 feet of a major unpaved parking area. The close proximity of the parking lot is probably one reason that the prediction is low. The underprediction at the Aramingo Fire Station may indicate the extreme dominance at that site by an industrial source across the street. As a screening tool, then, this equation appears to highlight sites which are dominated or influenced by extreme or unusual conditions. The equation also gives a preliminary estimate of the influences at all the sites by local, urban activity, Industrial, PNB and SN components. These examples indicate that distance from the source is an important consideration, even though it could not be included in this procedure because of data base constraints.

4.3 Preliminary Assessment of TSP Problem

The empirical equation provides a framework for apportioning the air quality measurements among sources. Table 4.2 illustrates how such a preliminary apportionment might be accomplished using the empirical equation. The values suggested for apportioning the urban activity and local source influences are derived from Record.[8].

It is felt that such a preliminary assessment will give the control official a framework for further analysis of the problem and will help to place the various portions of the TSP problem in perspective.

This preliminary estimate may provide an adequate level of analysis in certain areas where the problem seems relatively straightforward and the time and resources for more extensive analysis are not available, nor is the time available to allow a more detailed study. In most cases, however, further study and refinement of the estimate are warranted and encouraged. Such study might take the form of a field experiment to gather new data, examination of filters to identify source types, analysis of new or existing data by a variety of statistical methods, and modeling of specific sources or the entire area using dispersion models, as recommended in EPA guidance.[9,10,11,12]. In some cases, the resolution of source contributors may be provided by a single technique, such as dispersion modeling. However, in many cases, a refined estimate of sources will involve the synthesis of several analytical methods using good engineering judgment.

Table 4.2 Example of Preliminary Source Characterization at a Hypothetical Site

	Preliminary Estimate $\mu g/m^3$
Primary Non-Urban Background	21
Urban Sulfates	18
Urban Nitrates	4
Urban Activity Influence	31
Tailpipe Exhaust and Diesel Exhaust ------------- 10-15%	
Tire Rubber ------------------ 10-15%	
Vehicle and Windblown Resuspension --------------- 30-50%	
Space Heating ---------------- 0-40%	
Power Plant and Small Industry ------------------- 0-20+%	
General Construction --------- 5-10%	
Local Source Influence (additional vehicle-related)	16
Tailpipe Exhaust	
Diesel	
Tire Rubber	
Vehicle Resuspension	
Subtotal Non-Industrial	90
Industrial Influence	15
Total Predicted Before Using Regression	105

4.4 Interpretation of Monitoring Data

One recent study has indicated that there is wide variation in the placement of monitors in urban areas.[13] Likewise, there is wide variation in measured concentration. This empirical equation serves as an estimate of the degree to which monitor placement is a critical factor in measuring concentrations. Obviously, the equation places strong emphasis on the urban activity surrounding the monitor, the height of the monitor and the proximity of high ground level activity. Identification and tabulation of these factors should contribute to an understanding of the variations in measured concentrations among monitors and changes in the site surroundings or height which resulted in changes in measured levels. Unfortunately, other important factors such as activity level and distance from the source to the monitor cannot be considered quantitatively at this time due to limitations of the data base used in this study.

4.5 Interpreting Dispersion Model Results

There is clearly no direct link between the empirical relationship and the dispersion model. However, there should be no exclusive consideration of either approach in the presence of additional information. Clearly Equation 3.2 is imprecise in the area where it is potentially most useful--the identification of industrial impact. Thus, dispersion models have been and remain important tools in control strategy development and in assessing TSP problems. In estimating source contributions through use of dispersion models, it is possible that discrepancies in the data base, emission factors or dispersion parameters may exist. In such cases, the empirical model results can be used as an aid in identifying the discrepancies and for suggesting areas needing refinement, such as certain emission factors or use of a different grid size. Recent improvements in the capability of dispersion models, by incorporating particle-size distributions and natural removal mechanisms are providing better results for control strategy demonstrations and other uses.

5 SUMMARY

A technique is suggested for estimating differences in annual TSP levels due to monitor siting and location differences. To accomplish this, a data base of 142 monitoring sites in 13 urban areas was assembled and analyzed.

The data base was analyzed by using a model to describe TSP levels at each site as a function of land use, monitor height, etc., and then using a multiple regression technique to estimate the coefficients of each term. The results are summarized in Table 5.1. In the regression, terms I-IV represent the non-industrial (NI) portion of urban aerosol, term V represents industrial contribution and the regression constant (13.3 $\mu g/m^3$) represents the unexplained portion.

The resulting empirical model can be used to estimate TSP levels. This estimate can be useful in several ways.

1) The estimate can be compared with the actual concentration at a site to identify those situations which differ substantially from the estimate. Thus, it becomes a screening technique for identifying abnormal influences. It can also be used as a screening technique for areas without monitors.

2) The estimate can be further broken down using data from previous analyses to provide a preliminary estimate of sources contributing to TSP levels. This preliminary estimate can be refined through more extensive analysis or used in those situations where a more refined estimate (by atmospheric diffusion models, or

Table 5.1 Summary of Empirical Estimate of Annual TSP Concentration

COMPONENTS	METHOD USED TO DESCRIBE COMPONENT	EMPIRICALLY DERIVED OR CALCULATED VALUE
I. Primary Non-Urban Background	Non-Urban TSP Minus Non Urban Sulfates, Nitrates	(measured)
II. Secondary Particulates	Urban Sulfates plus Nitrates	(measured)
III. Urban Activity Influence	Undeveloped Sites	0 $\mu g/m^3$
	Residential Sites	20 $\mu g/m^3$
	Commercial/Industrial Sites	31 $\mu g/m^3$
IV. Local Sources	H, monitor height, meters	calculated from equation $45e^{-.02 H}$
V. Industrial Sources	Industrial Sites	
	·Near General Industry (< 2 km)	15 $\mu g/m^3$
	·Near Uncontrolled Steel Mill (< 2 km)	52 $\mu g/m^3$
	Residential/Commercial Sites	
	·Near Uncontrolled Steel Mill (2-10 km)	23 $\mu g/m^3$
	·Other Residential/Commercial Sites	0 $\mu g/m^3$

Total Estimated Concentration = .88 (I+II+III+IV) + V + 13.3 $\mu g/m^3$

from measurements such as filter analysis or special sampling) is precluded by time or resource constraints.

3) The estimate can be useful in interpreting monitoring data by estimating possible siting effects.

4) Comparing the estimate with dispersion model predictions may help identify the causes of discrepancies between predictions obtained with dispersion models and observations, such as certain emission factors or use of a different grid size.

6 REFERENCES

1. Frank A. Record, Robert M. Bradway, Gordon L. Deane, Rebecca C. Galkiewicz and David A. Lynn, National Assessment of the Urban Particulate Problem, Volume I. EPA-450/3-73-024, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 1976.

2. Frank A. Record, Robert M. Bradway, Gordon L. Deane, Rebecca C. Galkiewicz and David A. Lynn, National Assessment of the Urban Particulate Problem, Volumes VII, VIII, IX, X, XIII, XIV, XVI. EPA-450/3-73-026e, f, g, h, k, l, n, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, July 1976.

3. Frank A. Record, Robert M. Bradway, Gordon L. Deane, Rebecca C. Galkiewiicz and David A. Lynn, National Assessment of the Urban Particulate Problem, Volumes IV, V, VI, XI, XII, XV. EPA-450/3-76-026b, c, d, i, j, m, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, July 1976.

4. F. W. Sears and M. W. Zemansky, University Physics: Part One Third edition, Addison Wesley Publishing Company, Reading, Mass., 1963, page 450.

5. Thompson G. Pace, Warren P. Freas and Elsayed M. Afify, "Quantifications of Relationship Between Monitor Height and Measured Particulate Levels in 7 U.S. Urban Areas." APCA Paper 77-13.4, presented at the APCA Convention, Toronto, Canada, June 1977.

6. Jolayne Service, A User's Guide to the Statistical Analysis System. North Carolina State University Student Supply Store, Raleigh, North Carolina, August 1972.

7. Frank A. Record, Robert M. Bradway, Gordon L. Deane, Rebecca C. Galkiewicz and David A. Lynn, National Assessment of the Urban Particulate Problem, Volume XIV. EPA-450/3-76-026l, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, July 1976.

8. Frank A. Record, Robert M. Bradway, Gordon L. Deane, Rebecca C. Galkiewicz and David A. Lynn, National Assessment of the Urban Particulate Problem, Volume I. EPA-450/3-73-024, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 1976, pp. 213-264.

9. Guideline for Development of Control Strategies in Areas with Fugitive Dust Problems. OAQPS, No. 1.2-071, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, October 1977.

10. Control Strategy Preparation Manual for Particulate Matter. OAQPS 1.2-049, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, September 1977.

11. Interim Guideline on Air Quality Models. OAQPS 1.2-080, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, October 1977.

12. Users Guide for the EPA Industrial Source Complex Dispersion Model (Preliminary Report). H. E. Cramer Company, Inc., Salt Lake City, Utah, October 1977.

13. Frank A. Record, Robert M. Bradway, Gordon L. Deane, Rebecca C. Galkiewicz and David A. Lynn, National Assessment of the Urban Particulate Problem, Volume I. EPA-450/3-73-024, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 1976, pp 78-92.

7 APPENDIX

7.1 DATA BASE

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
BALTIMORE					
21 0120 001	Fire Dept. HQ	COMM	30	Near Expressway Construction	105
21 0120 006	NE Police Sta.	RES	20	---	53
21 0120 007	NW Police Sta.	RES	20	---	68
21 0120 008	SE Police Sta.	IND	20	---	105
21 0120 009	SW Police Sta.	RES	20	---	85
21 0120 023	Fort McHenry	IND	50	---	102
21 0120 024	Fire Co #22	IND	30	---	95

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
BIRMINGHAM					
01 0380 005	N. Birmingham	IND	6	Foundry Across St. w/ Controls By Passed	144
01 2140 003	Leeds	IND	6	Small Rural Town W/ Major Cement Pl.	143
01 3200 001	Tarrant City	IND	6	Gravel Quarry, Coke Ovens, Cupola	130
01 0380 019	E. Thomas	IND	6	On Road Downwind From Steel Mill 1/4 Mile	128
01 0340 001	Dessemer	COMM	6	General CBD And Some Unpaved Pdg.	98
01 0380 003	NASN	COMM	45	---	96
01 0380 012	Downtown	COMM	10	Near Well Swept Street	94
01 1880 002	Irondale	COMM	6	Small Town CBD Railroad Yards	90
01 1300 003	Fairfield	IND	10	Major Steel Works 6-10 Blocks	90
01 0380 011	West End	RES	6	---	88
01 0380 010	Woodlawn	RES	6	---	84
01 0570 001	Huffman	RES	6	---	51
01 2540 001	Mountain Brook	UNDEV	6	---	47

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
CHATTANOOGA					
44 0380 020	City Hall	COMM	50	---	80
44 0380 006	WDEF, W. Broad	IND	30	Foundry With Building Emissions	86
44 1280 003	Brainerd	RES	7	---	60
44 0380 017	Lookout Mtn.	UNDEV	3	---	38
44 0380 019	E. Chattanooga	COMM	25	Railway Street Traffic	81
44 0380 021	Silver Dale	UNDEV	30	---	38
44 0380 015	Shallowford Rd.	IND	10	Quarry and Unpaved Roads	101
44 0380 024	APC Bureau	COMM	12	Street Traffic	84

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
CINCINNATI					
36 1220 001	Public Library	COMM	80	---	75
36 1220 002	College Hill Fire Hse	RES	30	---	57
36 1220 011	Oakley Fire Hse	COMM	25	Train yard and Unpaved Parking	70
36 3540 001	Lockland	IND	20	---	100
36 1220 014	Carthage Fire Hse	IND	25	---	95
36 1220 013	Price Hill Fire Hse	RES	25	---	65
36 7700 001	Wyoming	RES	12	---	56
36 5880 001	St. Dernaro	IND	16	Truck Term., Train Yd., Material Transfer	130
36 1220 015	Corryville	RES	35	---	72
36 1220 016	Fairmont	IND	25	Foundry, Paved Rds. Railway	92
36 1220 020	Drake Hospital	RES	15	---	71
36 5880 002	St. B. St Clements	RES	45	---	76

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
<u>CLEVELAND</u>					
36 1300 013	APC Lab	IND	20	Unpaved Industrial Steel Mills, Trains	175
36 1300 024	Brooklyn YMCA	RES	50	---	76
36 1300 001	Health Museum	RES	24	---	90
36 1300 005	Pneumatic Tool	IND	59	---	88
36 1300 008	Fire St. #13	IND	23	---	147
36 1300 012	Fire St. #19	COMM	25	Unpaved Pkg. Gen. Commercial	124
36 1300 033	St. Vincents Hosp.	IND	4	---	149
36 1300 026	Harvard Yards	IND	60	Steel Mills, Etc. Unpaved Rds., Etc.	168
36 1300 006	JFK School	RES	60	---	50
36 1300 027	P. L. Dunbar School	RES	20	---	93
36 1300 029	Suppl. Ed. Center	COMM	65	Downtown Unpaved Parking	112

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
MIAMI					
10 3220 001	OPA Locka	COMM	18	Bare Area Extremely Dusty Area	86
10 0860 013	10001 NW 87th Avenue	COMM	13	Cement Trucks Spillage Resuspended	79
10 2700 006	6400 NW 27th Avenue	COMM	29	Unpaved Berms Sewer Construction	75
10 2700 003	3700 NW 7th Avenue	COMM	14	Near Major Expressways	73
10 0480 001	16770 NW 37th Avenue	COMM	20	Suburban Shopping Center Near Road	70
10 2760 001	Miami Springs	COMM	27	---	70
10 2700 002	864 NW 23rd Street	COMM	12	Near Unpaved Parking Lot	69
10 3040 001	19th Avenue Miami Beach	SPECIAL**	21	---	42
10 4740 001	West Miami	COMM	16	Near Unpaved Parking Lot	56
10 0860 003	600 SW 87th Avenue	RES	24	---	44
10 2720 007	Wash. Ave. Miami Beach	SPECIAL**	14	Hotel District Near Street	42
10 1766 001	Hialeah	RES	35	---	54
10 0220 002	Bay Harbor Island	RES	12	---	50

**Near Ocean

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
OKLAHOMA CITY					
37 2200 015	428 W. Calif.	COMM	15	On Fire Station Street, Urban Ren.	92
37 2200 001	200 N. Walker	COMM	70	On Courthouse Near Urb. Renewal	55
37 2200 002	SW 66th & Denning	UNDEV	14	---	41
37 2180 005	SW First & Main	UNDEV	14	---	39
37 1940 006	300 Mid America	RES	14	Unpaved Parking Near Fire Station	59
37 1940 010	NE 10th & Douglas	RES	14	---	49
37 0260 014	3919 N. Rockwell	RES	4	On Ground W/ Apt. House Const.	80
37 2200 018	2045 NW Tenth	COMM	8	Near Corner Traffic	98
37 2200 019	NW Hiway & Meridian	UNDEV	15	---	62
37 2200 020	Ranger Station	UNDEV	15	---	43
37 2200 021	SE 74 & Hiway	UNDEV	15	---	54
37 3300 022	SW Second & Robinson	COMM	12	Near On Ramp Traffic	101
37 0940 016	Edmund	RES	15	---	53
37 2200 017	NE 13th & Phillips	COMM	15	On Office Near Const. of Hospital	89

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
PHILADELPHIA					
39 7140 020	Belmont Filter	RES	13	---	72
39 7140 001	Roxboro Filter	RES	13	---	59
39 7140 024	N.E. Airport	RES	13	---	64
39 1400 004	AMS Lab	RES	17	---	78
39 7140 008	Franklin Inst (CAMP)	COMM	11	Street Traffic Unpaved Parking	119
39 7140 026	S. Broad & Spruce	COMM	13	Street Traffic	115
39 1400 003	500 S. Broad	COMM	35	---	76
39 7140 022	Defense Supply	IND	13	Railway	105
39 7140 019	Allegheny River	IND	13	Grain Handling Coal Storage	122
39 7140 021	Int. Airport	IND	13	Refineries General Dusty Area	94
---	Aramingo Fire St.	IND	35	Paint factory 50 yds.	116

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
PROVIDENCE					
41 0300 005	St. Office Bldg.	COMM	50	---	63
41 0300 006	Westminster St.	COMM	100	---	68
41 0300 007	Dyer Street	COMM	15	Traffic Island Near Expressway	88
41 0120 003	Tristam Burges Sch.	RES	30	---	61
41 0100 002	General Hospital	RES	50	---	43
41 0300 008	St. Josephs Hospital	RES	110	---	46
41 0100 001	Police Station	COMM	45	---	53
41 0120 001	Jr. High School	COMM	48	---	49

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
ST. LOUIS AREA					
26 0200 001	907 Chambers Road	COMM	25	---	78
26 0200 002	Rt 67 & I270	UNDEV	10	---	50
26 0260 001	Holman School	RES	4	---	59
26 1040 002	Clayton Health	COMM	55	---	64
26 2630 002	Lemay Mt. St. Rose	RES	4	---	71
26 2630 003	Lemay ACIC	IND	4	Coking and TiO_2 Production	128
26 4120 001	St. Ann	RES	9	Street Traffic	65
26 4300 003	Old Jamestown	UNDEV	4	---	40
26 4280 061	Shreve Rd. & I70	COMM	15	Street Traffic Railway	112
26 4280 066	River & Sulfur Ave.	IND	10	Unpaved Parking And Quarry	93
26 4280 006	Munic Courthouse	COMM	60		80
26 4280 007	8227 SDBWY	IND	35	---	126
14 0160 004	Alton	COMM	32	---	69
14 2120 006	City Hall	COMM	50	---	89
14 2120 008	Cahokie	COMM	15	Unpaved Parking Truck Terminals	109
14 2960 005	Granite City #1	COMM	15	---	117

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
ST. LOUIS AREA (Continued)					
14 8520 007	Wood River	IND	15	---	72
14 2960 008	Granite City #06	IND	25	---	85
14 2960 009	Granite City #07	IND	25	Unpaved Parking Near Steel Mill	158
14 2960 010	Granite City #08	IND	15	---	118
26 4280 010	Donovan Avenue	RES	30	---	61
26 4280 012	Munic. Arts	RES	35	---	59
26 4280 032	St. Louis Univ.	COMM	38		70

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annua Geometric Mean
<u>SAN FRANCISCO</u>					
05 5880 001	Pittsburg	COMM	20	Gravel Parking Lots	50
05 5300 004	Oakland NASN	COMM	62	Expressway 25 yds truck terminals	52
05 6860 001	San Francisco NASN	COMM	32	---	51
05 6860 003	San Francisco	COMM	15	---	53
05 8080 001	Sunnyvale	RES	33	---	41
05 6300 003	Richmond	COMM	17	Generally dusty area, dirt lot adjoining	50
05 6240 001	Redwood City	COMM	11	Street traffic truck terminals	50
05 4020 002	Livermore	COMM	18	Gravel pits unpaved parking, hghwy const.	74
05 0740 001	Berkeley NASN	RES	90		59
05 6980 004	San Jose	COMM	15	heavy traffic gravel parking lot	58

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
<u>SEATTLE</u>					
49 1840 058	McMicken Hts.	RES	15	---	35
--	Duwamish Fire Sta.	RES	25	---	48
49 1840 001	Public Safety	COMM	80	---	63
49 1840 013	Food Circus	COMM	70	---	45
49 1840 057	4500 Marginal Way	IND	20	Street, Railway, Gen Industry	68
49 1840 066	Harbor Island	IND	15	Grain Mill, Battery, Cement, Steel	77
49 1840 059	D.O.E. 6700 Marginal Way	IND	15	Street Traffic	105

SAROAD Code	Site Name	Neighborhood	Monitor Height (feet)	Neighborhood Description	1974 Annual Geometric Mean
WASHINGTON, DC					
09 0020 003	427 N. J. Avenue	COMM	15	Bldg. Const. Street Canyon	102
09 0020 001	Municipal Center	COMM	80	---	92
09 0020 015	Catholic Univ.	RES	50	University Near Cut and Cover Subway	70
09 0020 009	Amer. Chem. Soc.	COMM	100		67
09 0020 005	Brightwood Police	COMM	30	Commercial < 1 mi. to Cut and Cover Subway	63
09 0020 012	National Arboretum	UNDEV	3	---	59
09 0020 011	Cleve Pk. Library	COMM	25	---	54
09 0020 007	Nevel Thomas Sch.	RES	3	---	54
09 0020 008	General Hospital	RES	40	---	52

7.2 Description of Activity Levels

HIGH ACTIVITY

Presence of a network of several two and/or four lane roads which collectively contribute to a high level of urban activity. Examples of this would be commercial or industrial areas. Areas which are primarily residential except for perhaps a single moderately traveled street would not usually qualify. Likewise, the commercial activity in a small rural community would usually not be high activity. However, the presence of one or more of the following in a primarily residential or small community, and within 1/4 mile of the site, would suggest high activity:

- Expressways or major arterials carrying more than 25,000 ADT.
- Roads with moderate traffic (over 3,000 cars per day) and a noticeable accumulation of dirt in the traffic lanes.
- Construction activity with demolition, grading or mud carry-out of several months duration. Shorter or less intensive activities should not be counted.
- Active unpaved roads or parking areas. Activity of over 20 to 30 vehicles per day would be a general guideline but the length of travel and speed would be appropriate considerations that would modify this guide.
- Industrial plants with large and active unpaved areas within or around the plant.

LOW ACTIVITY

Low activity would be suggested by the following:

- Primarily residential, undeveloped or seldom used areas.
- Small rural communities.
- Sites with nearby activity screened by trees or buildings from the monitor.

7.3 Listing of Local Activity for Residential and Commercial Sites

City	Site	Height, Ft.	Annual Geometric Mean $\mu g/m^3$	Activity Level
Chattanooga	City Hall	50	80	High
"	E. Chattanooga	25	81	High
"	APC	12	84	High
"	Brainerd	7	60	Low
Seattle	Pub Safety	80	63	High
"	Food Circus	70	45	Low
"	McMicken Hts.	15	35	Low
"	Duwamish Fire Station	25	48	Low
Providence	State Office	50	63	High
"	Westminister	100	68	High
"	Police Station	45	66	High
"	Dyer St.	15	88	High
"	Tristam Burgess School	30	61	Low
"	General Hospital	50	43	Low
"	St. Joseph Hospital	110	46	Low
Wash. D.C.	ACS	100	67	High
"	Cleveland Park	25	54	Low
"	Brighton Police	30	63	High
"	Camp	15	102	High
"	Nevel Thomas School	3	54	Low
"	General Hospital	40	52	Low
Okla. City	West California	15	92	High
"	North Walker	70	55	High
"	NW 10th	8	98	High
"	2nd Robinson	12	107	High
"	13 and Phillip	15	89	High
"	Mid America	14	59	High
"	10th and Douglas	14	49	Low
"	Edmund	15	53	Low
San Francisco	SFR	32	51	High
"	SU	33	41	Low
"	PT	20	50	High
"	OK	62	52	High
"	RI	17	50	High
"	RC	11	50	Low
"	SJ	15	58	High
"	LI	18	74	High
"	BK	90	59	Low
Miami, Fla.	12-Westwood	27	70	High
"	20-NW 87	13	79	High
"	10-NW 27	29	75	High
"	8-NW 7	14	73	High
"	1-NW 23	12	69	High
"	16-SW 62	16	56	High
"	19-Ali Baba	18	86	High
"	600-SW 87	24	44	Low
"	Hialeah	14	54	Low
"	Bay Harbor Island	12	50	Low
"	28-NW 37	20	70	High

7.4 Tabulation of PNB and USN Data

Urban Area	Total Non-urban[a]	Non-urban S[b]	Non-urban N[b]	PNB	Urban US[c]	Urban UN[c]	(SUM) USN
Chattanooga	35	8	2	25	15	2	17
Miami	25	7	1	17	7	1	8
Okla. City	25	4	1	20	4	3	7
Providence	30	9	1	20	12	3	15
San Francisco	15	3	1	11	7	4	11
Seattle	15	4	0	11	9	3	12
Washington, DC	30	11	2	18	16	4	20
Cleveland	30	13	1	16	13	3	16
Birmingham	30	9	1	20	18	3	21
Philadelphia	35	13	1	21	18	4	22
Baltimore	35	10	1	24	13	3	16
St. Louis	25	8	1	16	15	3	18
Cincinnati	35	14	1	20	15	3	18

[a] From non-urban NASN network (PNB Total non-urban Non-urban Sulfates, Nitrates)

[b] Calculated as ammonium sulfate, nitrate

[c] From urban NASN network

7.5 Nomenclature and Abbreviations

TSP	Total Suspended Particulate
PNB	Primary Non-Urban Background
USN	Urban Sulfates-Nitrates
LS	Local Source
UA	Urban Activity
$\hat{y}$	Predicted concentration, $\mu g/m^3$
H	Height of monitor, meters
a	Empirically derived constant
b	Empirically derived constant
c	Empirically derived constant
e	Base of natural logarithm, 2.71828
R-square	The square of the correlation coefficient
ADT	Average Daily Traffic
B_1 thru B_4	Regression coefficients
B_5	Regression constant
x	Slope of Linear Regression Line

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

1. REPORT NO. EPA-450/2-78-016	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE "An Approach For The Preliminary Assessment of TSP Concentrations"		5. REPORT DATE July 1978
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Thompson G. Pace		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Monitoring and Data Analysis Division Research Triangle Park, N.C. 27711		10. PROGRAM ELEMENT NO. 2AA635
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Air quality data for Total Suspended Particulate (TSP) in 13 U.S. urban areas was examined. The data from 142 monitoring sites were grouped so that residential and commercial sites in non- or light-industrial urban areas could be examined. A relationship between height and concentration was noted at the sites with nearby ground-level activity due to traffic, parking, etc., such that the concentration decreased exponentially with increasing height of the monitor above ground. No such relationship was found at sites with no ground-level activity. Commercial and industrial sites were found to be near ground-level activity in 90 percent of the cases examined while residential sites were virtually never located near such activity.

The entire data base was then examined using a multiple regression procedure to estimate the relative impacts of non-industrial, general industrial and steel mill influences on TSP levels. Non-industrial influences were found to account for over half of the total concentration estimate in all cases.

Several potential applications of the linear regression technique are suggested. It can be used as a screening technique for examining TSP data to identify sites with unusual concentrations or to provide a preliminary estimate of sources of TSP. It can be used to interpret the variations in TSP data by estimating siting effects and it can help to identify the causes of discrepancies between predictions obtained with dispersion models and observations.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Measurement Particulates Model Monitor Siting Hi-volume Sampler Land Use Steel	Urban Activity Height Fugitive Dust Resuspension	

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 77
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE