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Procedures For Estimating Probability Of Nonattainment Of A PM_{10} NAAQS Using Total Suspended Particulate Or PM_{10} Data

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Technical Note

This document has been altered from the February 1984 version in order to reflect public comments received in response to proposed regulations for implementing revised particulate matter NAAQS (40 CFR Parts 50, 51, 52, 53, 58, 81) FR (April 2, 1985), as well as the results of more recent studies.

In order adequately to illustrate the procedure described in this report, it was necessary to assume a cutpoint and values for the annual and 24-hour NAAQS. The decision concerning the appropriate values for the NAAQS has not yet been published. We have arbitrarily chosen to illustrate the procedure, assuming the following NAAQS: 150 μg/m^3 24-hour average not expected to be exceeded more than once per year, and 50 μg/m^3 annual arithmetic mean. Should the NAAQS differ from those assumed in this report, several of the curves (i.e., Figures A, B, 1, and 2) may have to be revised using Tables 1 and 2 as shown in this report. The procedure described herein would be identical.

EPA -450/4-86-017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The proposed primary National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) specify ambient concentrations for particles smaller than 10 micrometers (μm) aerodynamic diameter (PM_{10}). If measured PM_{10} ambient concentrations are not available, ambient measurements of other PM size fractions, such as total suspended particulate (TSP), may have to be used to provide estimates of PM_{10} concentrations. In this document, emphasis is placed on a methodology for using available TSP measurements to estimate whether or not the annual and/or 24-hour NAAQS for PM_{10} are likely to be violated (probability of nonattainment). The probability of nonattainment will be one of the criteria which may be used to specify action States are to take in developing PM_{10} monitoring requirements and State Implementation Plans (SIP's). The document also suggests appropriate methods for determining the spatial extent of the nonattainment situations.

The probability of nonattainment is defined by a series of calculations which are based on data from a nationwide network of collocated ambient TSP and PM_{10} samplers and applied to TSP data collected at current monitoring locations. The PM_{10} samplers were operated by or for the U.S. Environmental Protection Agency (EPA) during 1982-83 and the high volume samplers were operated by State or local agencies during the same time period. These data include TSP as measured by the high volume sampler and PM_{10}, as measured by the dichotomous sampler. The calculated probability represents the likelihood that either NAAQS for PM_{10} was violated at the sampling site.

The following hierarchy is defined for using available ambient measurements to determine attainment/nonattainment directly or to estimate the probability of PM_{10} nonattainment. The first preference is to use ambient PM_{10} data, providing a site has complete sampling. PM_{10} data should be used if sufficient [see Section 2.4 of Appendix K to 40 CFR, Part 50] data are available.* The second preference is to use less than complete PM_{10} data and Inhalable Particulate (IP) measurements obtained with the dichotomous sampler.** A third preference is to use PM_{10} data with less than complete sampling in conjunction with TSP data to draw inferences about PM_{10} nonattainment. As described in this document, both preferences two and three may use IP or TSP measurements together with a statistically defensible site specific probability distribution for 24-hour PM_{10}/IP (or PM_{10}/TSP) ratios to estimate likelihood of nonattainment, provided that sufficient IP (or TSP) data are available. The sample size of concurrent PM_{10} and IP data in the IP National Monitoring Network is insufficient for a default PM_{10}/IP distribution to be presented in the document. The fourth preference is to use TSP data alone to draw inferences about the probability of PM_{10} nonattainment. Such inferences are drawn on the basis of PM_{10} to TSP ratios observed at sites in the National IP Monitoring Network.

For the annual NAAQS, PM_{10}/TSP ratios have been computed from arithmetic mean concentrations of PM_{10} and TSP using only days in which both PM_{10} and TSP have been measured at collocated monitors. Frequency distributions of the resulting PM_{10}/TSP ratios have been plotted and used to derive figures such as Figure A. Using Figure A, the probability of nonattainment of the

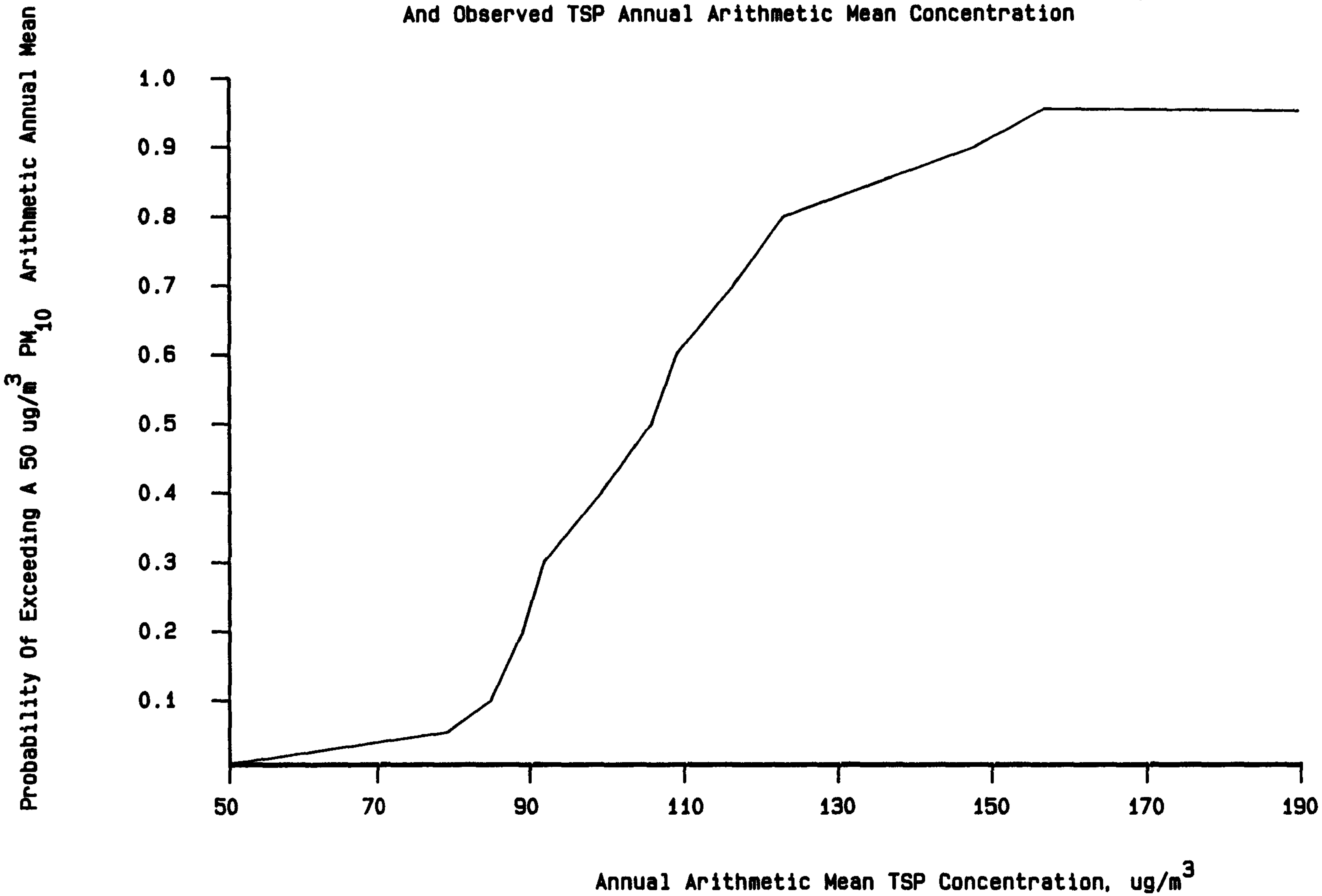
*In some instances, PM_{10} observations within 20% of the NAAQS would not be treated as exceedances. See Chapter 2 of the <u>PM_{10} SIP Development Guideline</u> for details.

**If size selective hi volume samples were collected on quartz fiber filters, these concentrations may be treated as dichotomous sampler measurements. Otherwise, the use of the term IP in this document refers to those particles collected by the dichotomous sampler with a 15 µm size discriminating inlet and teflon filters. It is anticipated that IP data will be used very infrequently in conjunction with this guideline.

Figure A.

Relationship Between The Probability Of Exceeding A 50 ug/m^3 Annual PM_{10} Concentration

And Observed TSP Annual Arithmetic Mean Concentration



annual PM_{10} NAAQS can be estimated directly from the average TSP concentration for the most recent three complete years of sampling. An example is presented in Section 4.0.

In the case of 24-hour data, this calculation depends on the number of exceedances allowed by the standard. Attainment of the 24-hour standard, expressed in terms of an expected number of exceedances, depends on the number of sampling days and an adjustment for missing data. This adjustment, however, is not made for the first observed exceedance, so that at least two exceedances are required for nonattainment.

In order to estimate the probability of not attaining the 24-hour standard, observed daily PM_{10}/TSP ratios have been used to derive a frequency distribution of ratios. The appropriate distribution is used in conjunction with TSP data to estimate the likelihood of not attaining a 24-hour NAAQS for PM_{10}. For example, at sites sampling TSP less frequently than once every 3 days, these estimates are made using Figure B and equations (a) - (d).

$$P_0 = \prod_{i=1}^{n} q_i \qquad \text{(a)}$$

where

P_0 = probability of observing <u>no</u> PM_{10} concentrations greater than the level of the 24-hr. PM_{10} NAAQS

p_i = the probability that an observed TSP value (TSP_i) will correspond to a PM_{10} level greater than the PM_{10} 24-hr. NAAQS

q_i = $(1-p_i)$ = the probability that an observed TSP value, TSP_i, does <u>not</u> correspond with a PM_{10} value greater than the level of the 24 hour PM_{10} NAAQS

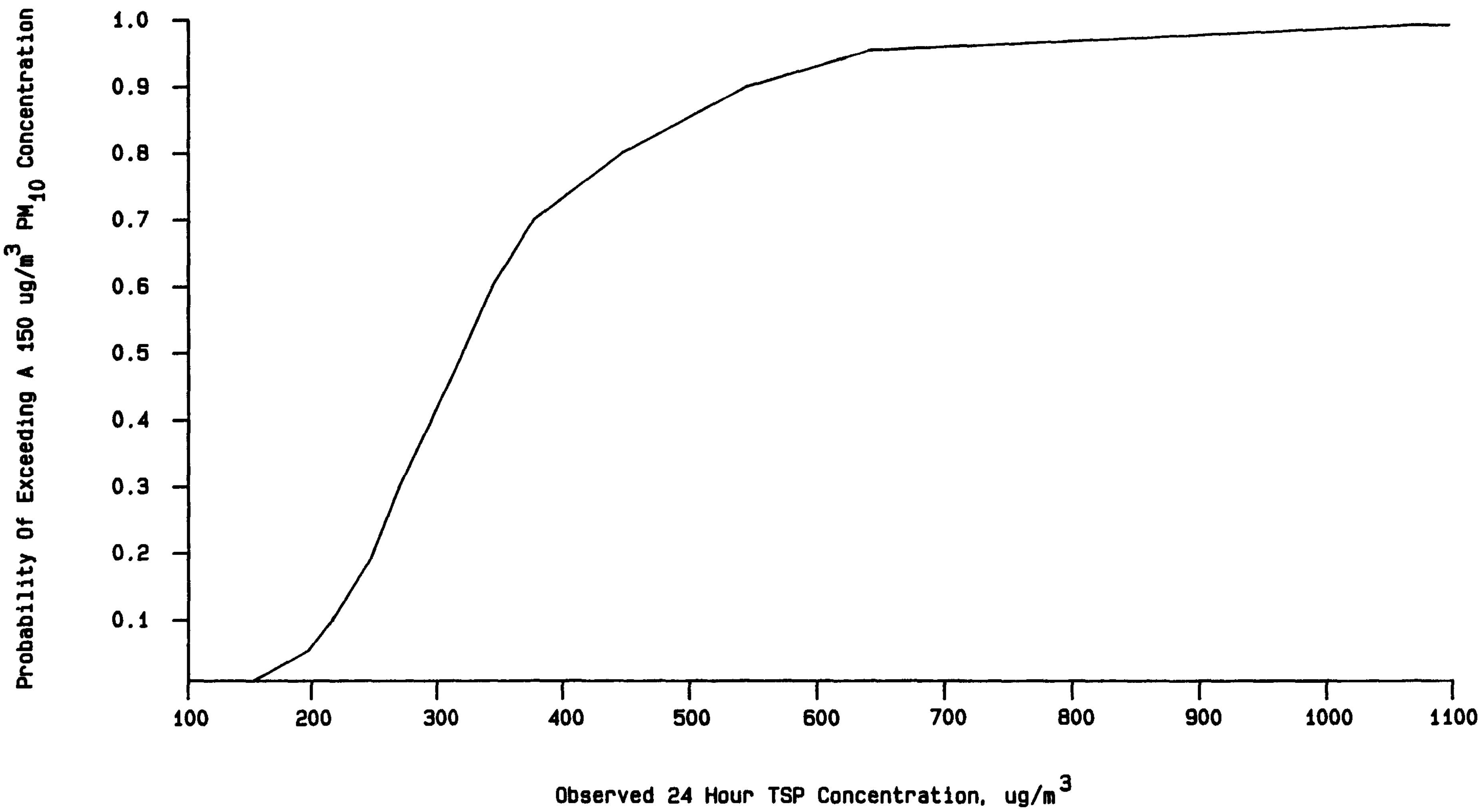
n = the number of TSP values greater than the level of the 24 hour PM_{10} NAAQS

$\prod$ = multiplication symbol such that $\prod_{i=1}^{3} q_i = (q_1)(q_2)(q_3)$

Figure B.

Relationship Between The Probability Of Exceeding A 150 ug/m^3 24 Hour PM_{10} Concentration

And Observed TSP 24 Hour Concentration



and

$$P_1 = P_0 C_1 \qquad \text{(b)}$$

$$C_1 = \sum_{i=1}^{n} \frac{p_i}{q_i} \qquad \text{(c)}$$

$$P_F\ (1) = 1 - (P_0 + P_1) \qquad \text{(d)}$$

As equation (a) suggests, for each 24-hour TSP concentration greater than 150 $\mu g/m^3$ there is an associated probability, p_i, that the corresponding PM_{10} concentration is also greater than the level of the NAAQS (i.e., 150 $\mu g/m^3$). This probability, p_i, is determined for each high TSP value by using Figure B. For example, if a site has three 24-hour TSP concentrations greater than 150 $\mu g/m^3$, Figure B is used three times to estimate the probabilities associated with each of the three high TSP values. The p_i determined from Figure B are then used in equation (a) to estimate the probability of observing no PM_{10} concentrations greater than the level of the PM_{10} NAAQS and in equation (b) to estimate the probability of observing one PM_{10} concentration greater than the level of the PM_{10} NAAQS. For sites sampling less frequently than once every 3 days over a 3-year period or less, there can be one observed PM_{10} concentration greater than the level of the PM_{10} NAAQS according to the proposed standard. Hence, the probability of violating the PM_{10} NAAQS at a site is simply the probability of observing two or more PM_{10} concentrations greater than 150 $\mu g/m^3$ (i.e., the level of the NAAQS) at the site. This is simply the complement of observing ≤ 1 PM_{10} value above 150 $\mu g/m^3$, and is computed using equation (d). This is illustrated by Example 5 in the text.

If samples are collected at a site at least as frequently as once every 2 days over a 3-year period, the NAAQS does allow two or more PM_{10} concentrations greater than the level of the NAAQS to be observed. For example, if sampling occurred every day over a 3-year period and produced 900 observations, two observed exceedances would be allowed during the 3-year period. In this case, the probability that a site is not in attainment with the NAAQS is the probability of observing <u>three</u> or more PM_{10} concentrations greater than the level of the NAAQS.

The 24-hour procedure is simplified somewhat if sufficient ambient PM_{10} data exist. In this case, the estimated number of exceedances in a given year, E_i, is calculated by equation (e).

$$E_i = e_i \, (N)/n_i \qquad \text{(e)}$$

where

E_i = the estimated number of exceedances for year i

e_i = the observed number of exeedances for year i

n_i = the number of data values observed for year i

N = total number of possible values in a year (e.g., 365)

The estimated number of exceedances over a 3-year period would be based on the average of the E_i for each of the 3 years, as shown in Examples 1 and 2 in the text. Based on the provision for the first observed exceedance,

$$E_i = 1, \text{ if } e_i = 1, \text{ or} \qquad \text{(f)}$$

$$E_i = 1 + (e_i - 1) \times N/ni, \text{ if } e_i > 1 \qquad \text{(g)}$$

(provided that the first exceedance occurred in year i).

If statistically defensible site-specific or representative geographic region-specific frequency distributions of PM_{10} to TSP ratios can be developed, either may be used in conjunction with the 24-hour NAAQS determination.

Similarly, site or area specific mean ratios may be used in conjunction with the annual NAAQS. Otherwise, the national distribution should be used for the years with TSP data. For both annual and 24-hour data, a site specific relationship can be based on a nearby, similar site. To do this, it must be demonstrated that the two sites are similar and that the ratio or distribution would be more applicable than the national distribution. Similar rules apply with regard to the derivation and use of "site specific" distributions for PM_{10}/IP ratios. Table A summarizes the use of national and more locally specific frequency distributions.

A computer program has been developed to automate the calculations necessary for estimating the probability of exceedance of both the annual and 24-hour NAAQS.

Determining the spatial extent of a nonattainment area requires subjective judgment. Three procedures are identified in Section 6.0 as useful in helping to arrive at this estimate. These are:

(1) a qualitative analysis of the area of representativeness of the monitoring site, together with consideration of terrain, meteorology and sources of emissions;

(2) spatial interpolation of air quality monitoring data;

(3) air quality simulation by dispersion modeling.

Choice of which procedure or combination of procedures to use depends on the available information and the complexity of the PM_{10} problem area.

TABLE A

A SUMMARY OF METHODS FOR USING AVAILABLE PM_{10}, IP OR TSP DATA TO ASSESS PM_{10} NAAQS ATTAINMENT/NONATTAINMENT STATUS

		Procedure	
Ambient Monitoring Data Available[a]	Type of Assessment	Annual NAAQS	24-hour
1. PM_{10} data meeting Appendix K sampling completeness requirement	Yes/No Determination	Compare average annual arithmetic mean PM_{10} directly to annual NAAQS	(a) Multiply number of observed exceedances in a given year by the ratio of 365 to the number of data values in that year to estimate the number of exceedances in that year, and (b) calculate average number of estimated exceedances per year from the most recent 3 years of data.[b]
2. PM_{10} data with less than complete sampling and IP[c] data available	Estimation of probability of nonattainment	(a) If sufficient PM_{10} data are available at a site or for a similar, nearby site(s), use to derive site-specific PM_{10}/IP mean ratio for site of interest (See Section 4.0) (b) Use mean ratio derived in (a) to estimate arithmetic mean PM_{10} for the most recent 3 years (c) Calculate average arithmetic mean PM_{10} and compare to the annual NAAQS	Use observed PM_{10} exceedances to estimate a revised number of allowed exceedances. If the revised number of allowed exceedances is less than 0, the site is in nonattainment. Otherwise use IP data for remaining years and a statistically defensible distribution for 24-hour PM_{10}/IP ratios using equations analagous to (6), (10), and (11), in the text and figures comparable to Figure 2 in the text. (See Section 5.4)

TABLE A (Continued)

Ambient Monitoring Data Available[a]	Type of Assessment	Procedure: Annual NAAQS	Procedure: 24-hour
3. PM_{10} data with less than complete sampling and TSP data available	Estimation of probability of nonattainment	Same as #2, only substitute "TSP" for "IP". If data are insufficient to derive a site-specific distribution, use the national default distribution.	Same as #2, only substitute "TSP" for "IP". If data are insufficient to derive a site-specific distribution, use the national default distribution.
4. TSP data only	Estimation of probability of nonattainment	Calculate the average arithmetic mean TSP level using the most recent 3 years of data; and estimate the probability of nonattainment using the above average and the relationship between the probability of exceeding the annual PM_{10} NAAQS level and observed annual arithmetic mean TSP concentration (based on the national distribution of annual arithmetic mean PM_{10}/TSP ratios).	Estimate the probability of individual observed 24-hour TSP concentration data to exceed the 24-hour PM_{10} standard level using observed 24-hour TSP data and the relationship between the probability of exceeding the 24-hour TSP concentration (based on the national distribution of 24-hour PM_{10}/TSP ratios), and use the equations (6), (10), or (11) in the text to estimate the probability of failing the attainment test.

[a]Listed in the order of preference.

TABLE A (Continued)

[b]Attainment/nonattainment estimates can also be made in terms of an allowable number of observed exceedances for a specific number of sample days:

Allowable Number of Observed Exceedances	Sample Size, Observations in 3 Years
1	$\leq$ 509
2	510-1018
3	1019-1096

[c]Obtained with a dichotomous sampler with a 15 μm size discriminating inlet and teflon filters. Samples obtained on quartz filters with a size selective hi-volume samplers may be treated as dichotomous sampler measurement.

1.0 INTRODUCTION

The promulgation of the National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) will require the revision of State Implementation Plans (SIPs) to account for the new standards. The revised standards include an annual and a 24-hour NAAQS specified in terms of PM nominally 10 micrometers and smaller in terms of aerodynamic diameter (PM_{10}).* Unfortunately, there are few measured data for this size fraction of PM. Other ambient data, primarily TSP [and also possibly inhalable particulate (IP)], which include PM_{10} but with larger particles as well, are available. The purpose of this document is to describe a methodology for using these data to estimate the probability of nonattainment of the annual and 24-hour NAAQS for PM_{10} at various sampling sites in the country. As described in the PM_{10} SIP Development Guideline, the probability estimates will be used prior to promulgation to help define where certain actions will be required.†

This document first discusses various measurement methods used to obtain the underlying rationale and methodologies for inferring ambient PM_{10} levels from available data. Methodologies for estimating the likelihood of not attaining PM_{10} NAAQS are presented, given ambient TSP data obtained with a high volume sampler. A procedure for estimating PM_{10} levels using IP data obtained with a dichotomous sampler** is also possible. Finally, limitations of the above methodologies are identified.

* A method of specifying particle diameter which considers both physical diameter and particle density.

† For use of probability estimates, see Chapter 2 of PM_{10} SIP Development Guideline, U.S. EPA, OAQPS.

** In this document, the term IP is used to denote particulate data collected with a dichotomous sampler that has a 50% collection efficiency of 15 μm particles. If size selective hi-volume samples were collected on quartz fiber filters, these concentrations may be treated as dichotomous sampler measurements.

2.0 AVAILABLE AMBIENT PARTICULATE MATTER DATA

The most desirable way to determine nonattainment of the proposed PM_{10} NAAQS is to measure PM_{10} directly. Several monitoring instruments have recently been developed and tested by the EPA. Unfortunately, sufficient data collected by these instruments are not yet available at many locations. Therefore, utilizing other particulate matter (PM) data as a means for estimating the likelihood that one or more PM_{10} NAAQS is not being attained would be useful. The principal data base measuring other PM is the total suspended particulate (TSP) data base. In the following paragraphs, attributes of TSP which are used in this report to derive relationships between PM_{10} and TSP are described.

2.1 Total Suspended Particulate (TSP)

The most common measurement of PM concentration available is TSP, as measured by the high volume sampler (hi-vol).(1) The hi-vol is generally considered to measure PM less than 100 μm aerodynamic diameter, but the collection efficiency (ability to capture) the very large particles is very poor. With average wind speeds, the sampler is about 50% efficient in collecting particles of 25-45 μm aerodynamic diameter. Thus, the sampler is said to have a D_{50} of 30 μm, where D_{50} is the particle diameter for 50% collection efficiency. For the purpose of this discussion, the hi-vol is considered to capture 100% or all particles smaller than 10 μm.

The hi-vol is generally considered to have several deficiencies which can cause problems in data interpretation. The D_{50} is dependent on windspeed and the orientation of the sampler. Also, the glass fiber filter has been shown to collect artifact sulfate of as much as 5 $\mu g/m^3$ or higher in high sulfate areas of the country.(2) Other artifact components such as nitrate and organic particulates may be significant in some areas. Another problem is the design of the hi-vol inlet which allows particles to be blown into the shelter and settle onto the filter during periods when the sampler is not operating.(3) Despite these problems, the hi-vol has been the standard reference method for TSP for many years and a vast data base is available for immediate use in screening potential nonattainment areas. Basing PM_{10} estimates on <u>empirically</u> derived relationships between PM_{10} and TSP lessens the degree to which these problems affect the validity of the final designations.

2.2 PM_{10}

PM_{10} data are collected by a dichotomous sampler whose inlet is designed to collect particles of 10 μm at 50% efficiency. The sampler separates the particles which pass through the inlet into two flowstreams (fine, <2.5 μm and coarse, 2.5-10 μm) and deposits them on two filters.

Potential problems which may bias reported results downward include internal wall losses (believed to be small) and the loss of particles from the coarse filter. This loss has been shown to occur on highly loaded filters during handling and shipment but is not believed to be a problem during routine network operation.(8)

The national IP network operated 39 sites equipped with dichotomous samplers measuring 10 μm. Because of the switch in hi-vol filter media manufacturers which occurred in 1981 and some dependence of PM_{10}/TSP relationships on TSP concentrations, the data base used to derive distributions of PM_{10}/TSP ratios is limited to 1982 and 1983 observations on days observing high ($\geq$100 $\mu g/m^3$) TSP concentrations or sites observing high annual mean TSP levels ($\geq$55 $\mu g/m^3$).(6) Further, all data used to derive the ratios are based on the same hi volume sampler filter media that is being used by State and local agencies at NAMS and SLAMS sites. These restrictions limit the size of the data base to 351 site-days and 35 site-years for the 24-hour and annual analyses respectively.

3.0 USE OF AVAILABLE DATA TO DRAW INFERENCES ABOUT PM_{10} LEVELS

The EPA Inhalable Particulate Network mentioned previously provides the available data base on TSP and PM_{10} at collocated sites.(9) The sites were located in urban and suburban locations to reflect maximum concentration and population exposure due to urban and industrial sources, and at nonurban sites to provide information on background levels. The data from these sites are used, to draw conclusions about relationships between PM_{10} and TSP.

The data used for investigation of the individual observations were collected from January 1982 - December 1983. These data from the IP network were screened and validated by the EPA's Environmental Monitoring Systems Laboratory (EMSL).

3.1 Ratio of PM_{10} and IP to TSP

The ratio of PM_{10}/TSP was examined at the sites comprising the data base in the hope that a simple ratio could be calculated which would permit the direct adjustment of TSP to PM_{10}. However, upon scrutinizing the data base, it is clear that a substantial degree of variability exists amongst individual ratios. (The IP/TSP ratios were also examined, only to establish that they confirmed the PM_{10}/TSP analyses.) This variability includes inter- as well as intra-site differences in the ratios. As described in Section 2.2, the PM_{10}/TSP ratio was also found to be somewhat sensitive to TSP concentrations.(6) This sensitivity is diminished by focusing on site-days observing TSP $\geq$ 100 $\mu g/m^3$ or, in the case of annual analyses, site-years with TSP $\geq$ 55 $\mu g/m^3$.

Several attempts have also been made to find an explanatory site descriptor which could account for the disparity in the ratios among sites (i.e., inter-site variability). In the first attempt, such site descriptors as urban versus suburban were compared; however, no statistically significant difference was found. Geographic area (East, Southwest, West Coast, etc.) and site type (industrial, commercial or residential) likewise revealed insignificant differences in the ratios.(10) In a more recent and more extensive investigation of geographic differences performed on the entire 1982 and 1983 data base, statistically significant differences were found among individual sites as well as among larger groupings of sites. However, the differences among larger groupings of sites are smaller and are difficult to explain on a physical basis. These investigations conclude that unless sufficient data to calculate a site specific PM_{10}/TSP ratio are available, the existing data base does not justify use of different distributions of ratios for different parts of the country.(6)

The previously described investigations of geographic, climatological, concentration range or site type classifiers were attempts to reduce or account for part of the variability in PM_{10} to TSP ratios. No doubt, a part of the overall variance in ratios results from intra-site variation in ratios arising from differences in the sources impacting the monitor site. Also, as discussed in Section 2.0, there are several issues associated with the precision of the TSP and PM_{10} measurements which affect intra-site variance. These factors include windspeed dependence, weighing problems, artifact formation and sampler wall losses. Thus, the inter-site variance can potentially be eliminated by the use of site specific data, but the intra-site variance can only be partially reduced by careful operating procedures.

The previously described variance among PM_{10}/TSP ratios suggests the need to examine the frequency distribution of ratios rather than relying on a single value for the ratio. The cumulative frequency distribution for PM_{10}/TSP is presented in Table 1 for site average (arithmetic mean) ratios. Table 2 contains a similar distribution for 24-hour ratios.

Another factor to consider is the development and use of site specific ratios or distributions for both annual and 24-hour cases. It seems logical that, if an area can justify a statistically different site or area specific distribution, its use should be encouraged. A site or area specific distribution of PM_{10}/TSP or of PM_{10}/IP may be developed if 1 year of PM_{10} and/or IP dichotomous sampler data is available. A distribution based on another site in the area may be used only if it is demonstrated on a physical basis and by an appropriate statistical procedure that the sites are similar and the specific distribution is a better representation of the data at that site than is the national distribution.

TABLE 1.

Cumulative Percentage of Ratios Greater Than a Given Value (Annual)

PM_{10}/TSP (annual)

Percentage	Ratio
97.1 (minimum)	0.28
95	0.32
90	0.34
80	0.40
70	0.43
60	0.46
50	0.47
40	0.51
30	0.54
20	0.56
10	0.59
5	0.63
2.9 (maximum)	0.66
Average	0.48
Standard deviation	0.09
Number of cases	35

TABLE 2.

Cumulative Percentage of Ratios Greater Than A Given Value (24-hour)

PM_{10}/TSP (24-hour)

Percentage	Ratio
99.7 (minimum)	0.029
99	0.140
95	0.223
90	0.275
80	0.334
70	0.396
60	0.433
50	0.472
40	0.507
30	0.547
20	0.597
10	0.687
5	0.754
1	0.950
0.3 (maximum)	1.181
Average	0.478
Standard deviation	0.165
Number of cases	351

Table 3 below is a summary of the appropriate use of the various methods available in descending order of preference. Sections 4 and 5 will provide additional explanation and examples of these methods and will establish procedures for combining the direct use of PM_{10} data with the frequency distribution or probability approach.

TABLE 3

A SUMMARY OF METHODS FOR USING AVAILABLE PM_{10}, IP OR TSP DATA TO ASSESS PM_{10} NAAQS ATTAINMENT/NONATTAINMENT STATUS

Ambient Monitoring Data Available[a]	Type of Assessment	Procedure: Annual NAAQS	Procedure: 24-hour
1. PM_{10} data meeting Appendix K sampling completeness requirement	Yes/No Determination	Compare average annual arithmetic mean PM_{10} directly to annual NAAQS	(a) Multiply number of observed exceedances in a given year by the ratio of 365 to the number of data values in that year to estimate the number of exceedances in that year, and (b) calculate average number of estimated exceedances per year from the most recent 3 years of data.[b]
2. PM_{10} data with less than complete sampling and IP[c] data available	Estimation of probability of nonattainment	(a) If sufficient PM_{10} data are available at a site or for a similar, nearby site(s), use to derive site-specific PM_{10}/IP mean ratio for site of interest (See Section 4.0) (b) Use mean ratio derived in (a) to estimate arithmetic mean PM_{10} for the most recent 3 years (c) Calculate average arithmetic mean PM_{10} and compare to the annual NAAQS	Use observed PM_{10} exceedances to estimate a revised number of allowed exceedances. If the revised number of allowed exceedances is less than 0, the site is in nonattainment. Otherwise use IP data for remaining years and a statistically defensible distribution for 24-hour PM_{10}/IP ratios using equations analagous to (6), (10), and (11), in the text and figures comparable to Figure 2 in the text. (See Section 5.4)

TABLE 3 (Continued)

Ambient Monitoring Data Available[a]	Type of Assessment	Procedure	
		Annual NAAOS	24-hour
3. PM_{10} data with less than complete sampling and TSP data available	Estimation of probability of nonattainment	Same as #2, only substitute "TSP" for "IP". If data are insufficient to derive a site-specific distribution, use the national default distribution.	Same as #2, only substitute "TSP" for "IP". If data are insufficient to derive a site-specific distribution, use the national default distribution.
4. TSP data only	Estimation of probability of nonattainment	Calculate the average arithmetic mean TSP level using the most recent 3 years of data; and estimate the probability of nonattainment using the above average and the relationship between the probability of exceeding the annual PM_{10} NAAOS level and observed annual arithmetic mean TSP concentration (based on the national distribution of annual arithmetic mean PM_{10}/TSP ratios).	Estimate the probability of individual observed 24-hour TSP concentration data to exceed the 24-hour PM_{10} standard level using observed 24-hour TSP data and the relationship between the probability of exceeding the 24-hour TSP concentration (based on the national distribution of 24-hour PM_{10}/TSP ratios), and use the equations (6), (10), or (11) in the text to estimate the probability of failing the attainment test.

[a]Listed in the order of preference.

TABLE 3 (Continued)

[b]Attainment/nonattainment estimates can also be made in terms of an allowable number of observed exceedances for a specific number of sample days:

Allowable Number of Observed Exceedances	Sample Size, Observations in 3 Years
1	$\leq$ 509
2	510-1018
3	1019-1096

[c]Obtained with a dichotomous sampler with a 15 μm size discriminating inlet and teflon filters. Samples obtained on quartz filters with a size selective hi-volume samplers may be treated as dichotomous sampler measurement.

4.0 METHODOLOGY FOR ESTIMATING THE PROBABILITY OF NONATTAINMENT FOR PM_{10} NAAQS - ANNUAL STANDARD

Concerning ambient levels of PM_{10} it is preferable to have sufficient measured ambient PM_{10} data so that ambient concentrations are determined directly. However, in the absence of complete PM_{10} data, the probability of nonattainment of one or both PM_{10} NAAQS can also be estimated for any location, given observed TSP data or observed IP data. The probability of not attaining the proposed annual standard, given annual arithmetic mean TSP data, is determined in a straightforward manner. A brief explanation and example are provided herein. Calculating the probability of not attaining the proposed 24-hour standard is more complicated. This requires a more detailed explanation, and will be discussed in Section 5.0.

It is possible to obtain an estimate of the probability of nonattainment of a 50 $\mu g/m^3$ level of the annual PM_{10} NAAQS by using annual arithmetic mean TSP data and the information in Table 1.* We can define TSP as:

$$TSP = \frac{PM_{10} \text{ concentration}}{PM_{10}/TSP}$$

For any fixed level of PM_{10}, such as a proposed NAAQS for PM_{10} of 50 $\mu g/m^3$, the value of TSP which would correspond to a given probability of exceedance can be calculated. For example, in Table 1 there is a 70% probability that the PM_{10}/TSP ratio will be greater than .43. Substituting into the above equation, a TSP concentration of 116 $\mu g/m^3$ is found (i.e.,

*It should be noted that the Tables and curves in this document depicting probability distribution or plotting exceedance probabilities as functions of TSP levels are not to be applied if one's hi-vol measurements for TSP were obtained with filters provided for local agency use prior to 1983. This is a consequence of the data used to derive the relationships in this document being based on this kind of a data base.

50/.43 = 116). This is the TSP value that, if measured, would correspond to a 70% probability that the proposed PM_{10} NAAQS of 50 μg/m^3 would be exceeded. A series of these calculations was made to develop the plot in Figure 1.

The relationship in Figure 1 can be used to estimate the probability of nonattainment at any site with annual arithmetic mean TSP data. To use Figure 1, the average annual arithmetic mean TSP concentration is calculated for the site. The figure is entered for that TSP value and a corresponding probability of nonattainment is read. For example, if the average annual mean TSP were 150 μg/m^3, the probability of nonattainment would be .92 or 92%.

For the purpose of estimating the probability of nonattainment at a specific site, the average of the annual arithmetic means of the most recent three year's data should be used, if available. For example,

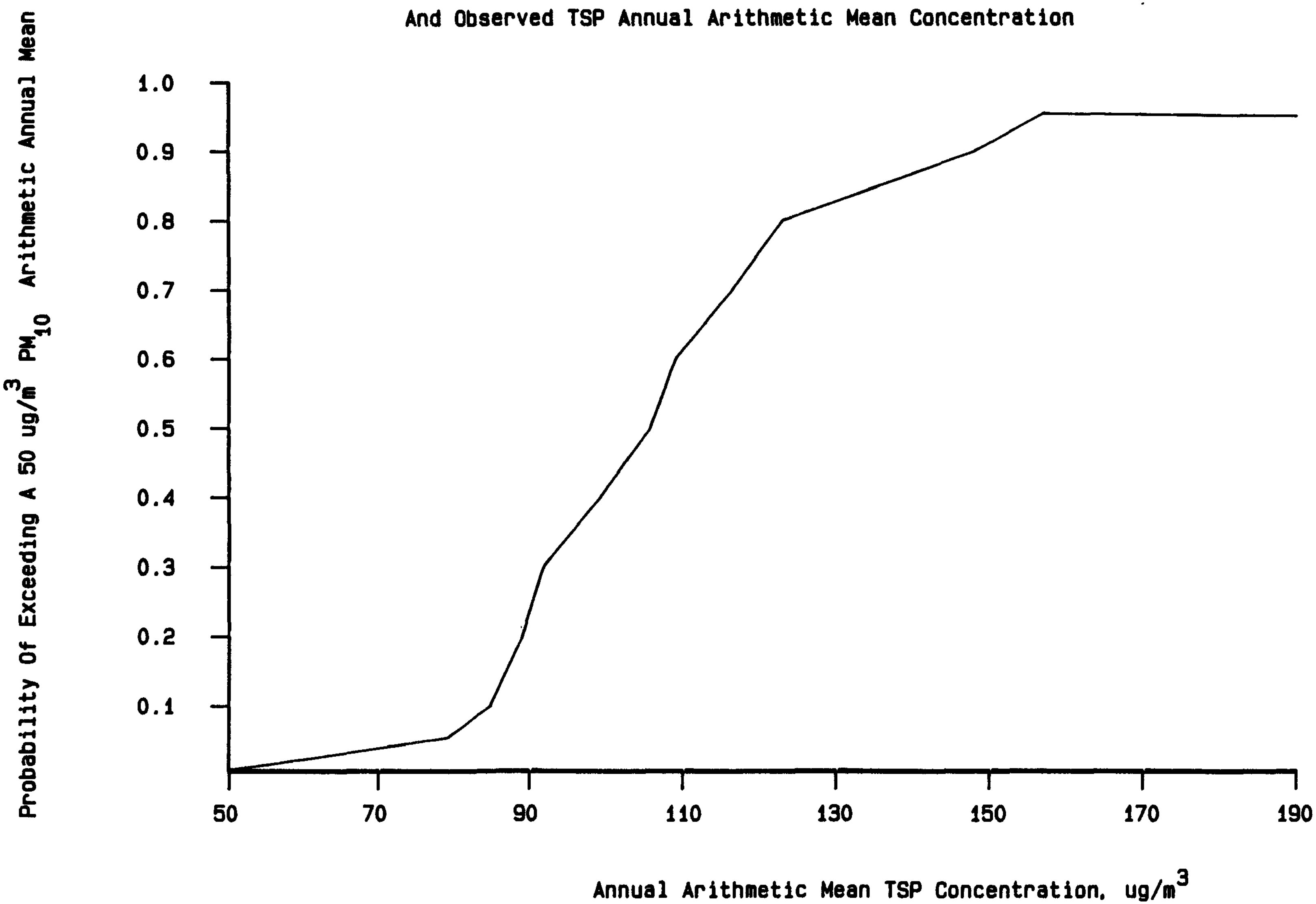
$$\overline{TSP} = \frac{(\overline{TSP})_{85} + (\overline{TSP})_{84} + (\overline{TSP})_{83}}{3} \qquad (1)$$

where $(\overline{TSP})_{85}$ is the <u>arithmetic</u> mean TSP concentration observed during 1985, μg/m^3, etc.

As an example, if the arithmetic mean TSP concentrations for the years 1983, 84 and 85 were 135, 142 and 158, the $\overline{TSP}$ would be (135 + 142 + 158)/3 = 145 μg/m^3. Figure 1 would indicate a 90% likelihood of exceeding an arithmetic mean PM_{10} NAAQS of 50 μg/m^3. This is quite different from a determination of the attainment status for the current annual TSP primary NAAQS. The current TSP NAAQS considers the <u>geometric</u> rather than <u>arithmetic</u>

Figure 1.

Relationship Between The Probability Of Exceeding A 50 ug/m^3 Annual PM_{10} Concentration And Observed TSP Annual Arithmetic Mean Concentration



mean. Further, no probability calculation is required since direct measurements of TSP are available.

If 3 years of valid data (i.e., at least 75% data capture per quarter) of PM_{10} is available, it may be used directly to determine whether the annual NAAQS is being attained. The annual arithmetic mean should be computed by taking the mean of the quarterly mean concentrations as described in Appendix K to Part 50, Code of Federal Regulations (CFR).

If at least 1 full year of PM_{10} data (having at least 75% data capture for each of 4 quarters and a full year of valid TSP data ($\geq$ 75% data capture) exist for a site for the same year, a site or region-specific mean PM_{10}/TSP ratio should be developed and used in the following procedure:

$$\overline{PM_{10i}} = \text{mean of full year of valid } PM_{10} \text{ data for year }_i \quad (2a)$$

$$\overline{PM_{10i-1}} = \overline{TSP_{i-1}} \times (\text{mean site specific 24-hour ratio})_i \quad (2b)$$

$$\overline{PM_{10i-2}} = \overline{TSP_{i-2}} \times (\text{mean site specific 24-hour ratio})_i \quad (2c)$$

where $\overline{PM_{10i-1}}$ = estimated annual arithmetic mean PM_{10} concentration in $year_{i-1}$

$\overline{PM_{10i-2}}$ = estimated annual arithmetic mean PM_{10} concentration in year $_{i-2}$

$\overline{TSP_{i-1}}$ = observed annual arithmetic mean TSP concentration in $year_{i-1}$

TSP_{i-2} = observed annual arithmetic mean TSP concentration in $year_{i-2}$

Thus, the PM_{10} for the 3 years' data would be

$$\overline{PM_{10}} = (PM_{10i} + PM_{10i-1} + PM_{10i-2})/3.$$

In effect, if $\overline{PM_{10}}$ is greater than the level of the proposed NAAQS, the probability of nonattainment is 1.0. Otherwise, the probability of nonattainment is 0.

Procedures similar to those described for estimating PM_{10} attainment status given TSP data can be used to estimate PM_{10} attainment given IP data, providing sufficient data exist to develop a site-specific PM_{10}/IP mean ratio (see data requirements for TSP above). This site specific distribution would be used to construct a figure analogous to Figure 1. This analogous figure would then be used as described above. Since few sites are likely to have 3 years of IP data, it is anticipated that IP data will be used very infrequently to estimate PM_{10} attainment status.

In summary, the annual PM_{10} NAAQS attainment status may be estimated directly using PM_{10} data or the probability of nonattainment may be estimated using TSP (or IP) data and the frequency distribution method described above.

The following steps apply in inferring PM_{10} levels at sites in which only TSP data are measured:

(1) calculate the average arithmetic mean TSP, as described in the proposed Appendix K to Part 50, Code of Federal Regulations;

(2) enter Figure 1 (for TSP) and read the corresponding probability of nonattainment of the annual arithmetic mean NAAQS for PM_{10}.

If PM_{10} data are available for fewer than 3 years, a statistically defensible site specific ratio for PM_{10}/TSP ratios may be developed. This mean ratio is used to convert mean TSP observations (in years with insufficient PM_{10} data) to equivalent mean PM_{10} values. Probability of nonattainment with the annual NAAOS is estimated by comparing the average of 3 yearly mean "PM_{10}" values with the level of the NAAQS.

5.0 METHODOLOGY FOR ESTIMATING THE PROBABILITY OF NONATTAINMENT FOR PM_{10} NAAQS - 24-HOUR STANDARD

The proposed 24-hour NAAQS for particulate matter (PM) specifies that the expected number of exceedances must be less than or equal to one per year. The proposed attainment test consists of using monitoring data to estimate the average number of exceedances expected with complete sampling over a 3-year time period. The test specifies that the average number of estimated exceedances be rounded to the nearest tenth (.05 rounds up). Thus, an estimated number of 1.05 (which becomes 1.1) exceedances per year would be required in order to fail the attainment test.

According to Appendix K to Part 50 and Part 58.13 of the proposed standards and the PM_{10} SIP Development Guideline, the first observed exceedance shall not be adjusted for incomplete sampling if everyday sampling is initiated thereafter. To be consistent with the intent of the proposed provisions of the standards, the procedures for estimating the probability of nonattainment of the proposed 24-hour standard include the provision that the first observed exceedance in the 3-year time period shall not be adjusted for incomplete sampling. Based on these considerations, the number of allowable exceedances as a function of data completeness is presented in Table 4. Use of the information in Table 4 is illustrated in Section 5.1.

Prior to the availability of 3 complete years of PM_{10} monitoring data, it may be useful to estimate the probability of not attaining the 24-hour PM_{10} NAAQS through use of TSP data. As PM_{10} monitoring continues, these data would also be incorporated into the nonattainment probability assessment. The following discussion addresses procedures for estimating attainment/nonattainment for three cases: (1) adequate PM_{10} data, (2) no PM_{10} data, and (3) some PM_{10} data.

5.1 Assessment Based on Adequate PM_{10} Data

If 3 years of valid PM_{10} data (i.e., at least 75% data capture per quarter) are available, the assessment of attainment/nonattainment is relatively straightforward. The approach is described in Appendix K to 40 CFR50, and consists of estimating the number of exceedances per year from the observed monitoring data and then averaging these estimates over a 3-year period. Thus, the probability of nonattainment is certainty (i.e., defined as 1.0) if the proposed attainment test is failed. Otherwise, the probability of nonattainment is zero.

For the purposes of this guideline, the adjustment for incomplete sampling shall be performed on an annual basis. The formula for estimation of exceedances, E_i from a year of PM_{10} monitoring data is as follows:

$$E_i = e_i \times N / n_i \qquad (2)$$

where

E_i = the estimated number of exceedances for year i, assuming complete sampling

e_i = the observed number of exceedances for year i

n_i = the number of data values observed in year i, and

N = the total number of possible values in year (e.g., 365)

Based on the provision for the first observed exceedance,

$$E_i = 1, \text{ if } e_i = 1, \text{ or} \qquad (2a)$$

$$E_i = 1 + (e_i - 1) \times N/n_i, \text{ if } e_i > 1 \qquad (2b)$$

(provided that the first exceedance occurred in year i).

Note that E_i is also called the estimated exceedance rate.

Example 1

The 3-year period 1983-1985 is being evaluated. In 1983, a hypothetical site measured 292 PM_{10} values with at least 75% data capture in each quarter. Two exceedances of the level of the NAAQS were observed. The recorded concentrations were 220 and 260 μg/m^3. Since more than one exceedance was observed in the first evaluation year, the estimated number of exceedances is calculated using equation (2b) as

$$E_{83} = 1 + \frac{1 \cdot 365}{292} = 2.25$$

Note that the concentration magnitudes of the observed exceedances were not considered. The magnitudes would be important, however, when the amount of required control is evaluated*.

The estimated exceedance rate over a 3-year period would be based on the average of the estimated number of exceedances for each year. If the numbers of estimated exceedances (E_i) for 1984 and 1985 were 0 and 2.5, respectively, then the average number of estimated exceedances, rounded to the nearest tenth, would be 1.6. Since 1.6 is greater than 1.0, this site would fail the attainment test.

Although attainment of the 24-hour expected exceedance NAAQS using PM_{10} data can be determined in terms of the average number of estimated exceedances (as in the above example), the procedure can also be done in terms of an allowable number of observed exceedances for a specific number of sampling days.

*In some instances, PM_{10} observations close to the level of the NAAQS would be subject to special interpretations, depending on the PM_{10} monitoring instrument used. See Chapter 2 of the PM_{10} SIP Development Guideline, U.S. EPA, OAQPS, for details.

The number of allowable observed exceedances over 3 years is shown as a function of sample size in Table 4. With the use of this table, it is assumed that the sampling rates are similar in each year. For the once in 6-day sampling rate historically applied to TSP and allowing for the first exceedance provision, one observed exceedance would be allowed. This follows because a site with a sample size as small as 183 (i.e., 3 x 61 samples/year) would fail the proposed attainment test only if it had 2 or more observations greater than the level of the NAAQS, according to Table 4.

Example 2

(a) As stated in Example 1, two exceedances were observed for a site in 1983 that sampled 292 PM_{10} values. Suppose that in the two subsequent years, 1 and 0 PM_{10} exceedances were observed and that the number of sampling days was 120 in both of these years. For the 3 years, there was a total sample size of 532 observations and from Table 4, we see that two exceedances are allowed at this sampling rate. Thus, the three observed exceedances cause a failure of the proposed attainment test.

(b) Suppose that PM_{10} data was not produced in 1983. In this case, over the 2-year period, 1984-1985, there was one observed exceedance. Results of the attainment test are now inconclusive. That is, the number of observed exceedances is consistent with the allowable number specified in Table 4. However, data from 2 years are insufficient to conclusively demonstrate attainment according to provisions in Appendix K. The situation described in part (b) of this example is addressed in Section 5.3.

TABLE 4. Allowable Observed Exceedances as a Function of Sample Size for a One Expected Exceedance Standard.

Allowable Number of Observed Exceedances	Sample Size, Observations in 3 Years
1	≤ 509
2	510-1018
3	1019-1096

5.2 Assessment Without PM_{10} Data

Unlike the 'yes-no' situation with actual PM_{10} monitoring data, the failure of the proposed PM_{10} attainment test using TSP data will be expressed as a probability. This probability will take into account the chance of a PM_{10} NAAQS exceedance on each TSP sampling day. The probability of nonattainment is defined in terms of the likelihood of observing more than the number of allowable PM_{10} NAAQS exceedances. The conditions specifying failure of the attainment test depend on TSP sampling frequency as outlined in Section 5.1 (see Table 4).

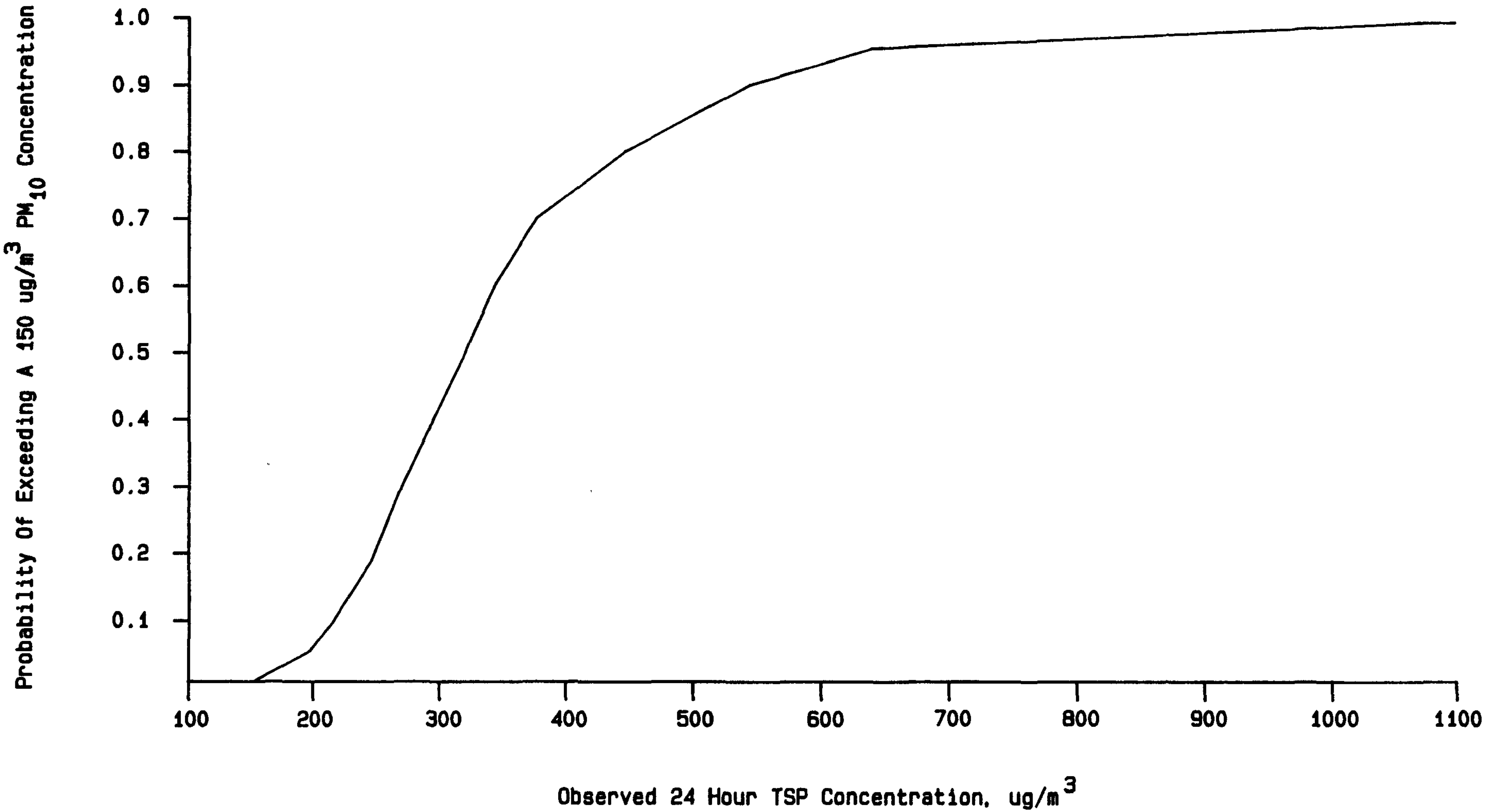
The chances of a PM_{10} NAAQS exceedance on each TSP sampling day is derived from the estimated probability distribution of the relative PM_{10} portion of TSP (Table 2). This distribution specifies the probability that the PM_{10} portion of the TSP would have exceeded a stated fraction. For a specific TSP concentration, these ratio probabilities translate into the probability that the concentration of the PM_{10} portion of the TSP would have exceeded a given PM_{10} concentration level. A curve of "exceedance" probabilities for a PM_{10} concentration $\geq$ 150 $\mu g/m^3$ is shown in Figure 2.

5.2.1 One Allowable Exceedance

Typically, TSP monitoring sites sample on a once in 6 day schedule and thus the number of TSP samples is usually less than 61 per year or 183 over a 3-year period. For these and other sites producing fewer than 510 observations in 3 years, one exceedance is allowed and thus the probability of failing the attainment test is the probability of observing at least two PM_{10} exceedances over the sampling time period (from Table 4). Stated another way, this is the probability of not observing zero or one exceedances as shown below in equations (3) - (6).

Figure 2.

Relationship Between The Probability Of Exceeding A 150 ug/m^3 24 Hour PM_{10} Concentration And Observed TSP 24 Hour Concentration



If p_i represents the PM_{10} exceedance probability for the ith TSP sample, then the probability, P_0, of observing zero allowable exceedances is

$$P_0 = \prod_{i=1}^{n} q_i \tag{3}$$

where $q_i = 1-p_i$ (the probability that an observed TSP value, TSP_i, does not correspond to a PM_{10} value greater than the level of the 24-hour PM_{10} standard), and

n = the number of TSP values greater than the level of the 24-hour PM_{10} standard.

Example 3

In this example, the level of the PM_{10} NAAQS is assumed to be 150 μg/m^3. TSP data greater than 150 μg/m^3 observed during the most recent 3 years are as follows:

Year	Sample Size	Observed TSP Concentrations Greater Than 150 μg/m^3
1983	60	250
1984	50	290,200
1985	50	400,280

Using Figure 2, the PM_{10} exceedance probabilities for each TSP value are as follow:

TSP	PM_{10} Exceedance Probability
400	.72
290	.38
280	.32
250	.20
200	.05

Based on equation (3), the probability of observing no exceedance is

$$P_0 = (1-0.72)(1-0.38)\cdots(1-0.05), \text{ or}$$

$$P_0 = .0897$$

The probability of observing exactly one exceedance is

$$P_1 = P_0 C_1 \tag{4}$$

where P_0 is defined in equation (3) and

$$C_1 = \sum_{i=1}^{n} \frac{p_i}{q_i} \tag{5}$$

Example 4

Suppose the data is the same as used in Example 3. Using equation (4) and (5), the probability of observing one exceedance, P_1, is

$$P_1 = P_0 \sum_{i=1}^{n} \frac{p_i}{q_i}$$, where P_0 is the same as derived in Example 3

$$\text{Thus, } P_1 = (.09)\left[\frac{.72}{.28} + \frac{.38}{.62} + \frac{.32}{.68} + \frac{.20}{.80} + \frac{.05}{.95}\right]$$

$$= (.09)\ (3.96)$$

$$= .36$$

As indicated earlier, the probability of failing the attainment test for sites producing fewer than 509 observations in 3 years is the probability of observing more than one PM_{10} exceedance over the sampling period. This probability is equivalent to the probability of not observing zero or one exceedance, or

$$P_F(1) = 1 - (P_0 + P_1) \qquad (6)$$

Example 5

Using the data and calculations performed in examples 3 and 4,

$$P_F(1) = 1 - (P_0 + P_1)$$
$$= 1 - (.09 + .36)$$
$$= .55$$

Thus, the probability of failing the attainment test is 0.55, i.e., 55% probability of nonattainment.

5.2.2 Two or More Allowable Exceedances

If the TSP data were sampled at least once in 2 days (or otherwise more than 509 days in 3 years), then two or more exceedances may be allowed by the standard over a 3-year period. For example, with 600 TSP samples over a 3-year period, Table 4 indicates that two observed exceedances are allowed by the standard. For this situation, the failure probability is defined as the probability of observing more than two exceedances.

With 3 years of TSP data (sampling every day), up to three exceedances may be allowed (Table 4). Depending on TSP sample size, the failure probability guide may be defined as the probability of observing more than two or three exceedances. These probability computations depend on the chance of observing exactly zero, one, two or three exceedances. The remainder of this section provides the equations for these calculations. Their use assumes that the annual TSP sampling rates are similar, as defined by the ranges in Table 4.

The formulas for the probability of exactly two exceedances, P_2, and exactly three exceedances, P_3, are

$$P_2 = \frac{1}{2} [P_1C_1 - P_0C_2], \text{ and} \quad (7)$$

$$P_3 = \frac{1}{3} [P_2C_1 - P_1C_2 + P_0C_3], \quad (8)$$

$$\text{where } C_r = \sum_{i=1}^{n} \left(\frac{p_i}{q_i}\right)^r, \; r = 1, 2 \text{ or } 3 \quad (9)$$

The probability of failing the attainment test for two or three allowable exceedances is

$$P_F\ (2) = 1 - (P_0 + P_1 + P_2) \quad (10)$$

$$P_F\ (3) = 1 - (P_0 + P_1 + P_2 + P_3) \quad (11)$$

The computational form of equations 4, 5, 7, 8, and 9 follows from the probability generating function of a Bernoulli process with variable probabilities and have been derived elsewhere.(13,14)

5.3 Assessment Based on TSP Data and One or More Years of PM_{10} Data

If three years of PM_{10} data do not exist (according to Section 5.1) to determine the probability of nonattainment directly, then available PM_{10} data shall be combined with prior TSP data to estimate the probability for the 3-year period. This procedure shall be discussed for two situations: first, when a partial year of PM_{10} data is available and second, when 1 or 2 years of PM_{10} data are available. In either case, minimum annual data completeness requirements for 3 years of data would be applicable.

When a partial year of PM_{10} data is available, then actual, PM_{10} concentrations, may be substituted for concurrent, collocated TSP measurements. If the PM_{10} value (rounded to the nearest 10 $\mu g/m^3$, as specified by Appendix K) is less than or equal the level of the standard, then the PM_{10}

exceedance probability would be 0.0, and is therefore not considered in equations (3)-(11). If any PM_{10} values are greater than the level of the standard, then the number of allowable exceedances, as per Table 4, are reduced by the number of observed exceedances.* The revised number of allowable exceedances is defined as

$$A' = A - E, \qquad (12)$$

where A is the allowable number of exceedances based on the total number of sampling days, and

E is the observed number of actual PM_{10} exceedances.*

The revised allowable number of exceedances can now be zero. When this is the case, the probability of nonattainment becomes

$$P_F\ (0) = 1 - P_0 \qquad (13)$$

When the number of observed exceedances exceed the allowable number (i.e., $A'<0$), the probability of nonattainment becomes 1.0. If this is not the case, then equations (3)-(13) are applied on the basis of the reduced number of allowable exceedances. In effect, the days when PM_{10} measurements were made would not be included in the computation. With this approach, the estimated PM_{10} exceedances derived from the actual PM_{10} data are viewed as being fixed, while the estimated PM_{10} exceedances derived from the TSP data are viewed as a random variable. Thus, the probability of failing the attainment test can be defined solely in terms of the additional PM_{10} exceedances estimated from the TSP data. This procedure is illustrated by the following example.

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*In some instances, PM_{10} observations close to the level of the NAAQS would be subject to special interpretations, depending on the PM_{10} monitoring instrument used. See Chapter 2 of the PM$_{10}$ SIP Development Guideline, U.S. EPA, OAQPS, for details.

Example 6

Following example 5, suppose that some PM_{10} data were collected in 1985 and that PM_{10} data were available for the days on which TSP concentrations of 400 $\mu g/m^3$ and 280 $\mu g/m^3$ were recorded. The day which recorded a value of 400 had a PM_{10} value of 180 $\mu g/m^3$, an exceedance of the 150 $\mu g/m^3$ standard level. This was the only PM_{10} exceedance recorded at this site. According to Table 4, one exceedance would have been allowed. Now, however, because of the single observed PM_{10} exceedance, no additional PM_{10} exceedances would be permitted (i.e. A '= 1-1 = 0).

Thus the probability of nonattainment is the probability of observing one or more additional exceedances, and there are only three TSP values (290 $\mu g/m^3$, 250 $\mu g/m^3$ and 200 $\mu g/m$) for which exceedance probabilities are needed.

Using equation (3), then

$$P_0 = (1-0.38)\ (1-0.20)\ (1-0.05), \text{ or}$$

$$= .4712$$

Using equation (13), the failure probability is

$$P_F(0) = 1-.4712 = .5233 \text{ or } .53$$

The development of the PM_{10} nonattainment probability using 1 or 2 years of PM_{10} data is based on a similar approach. For this situation, a site specific frequency distribution of ratios could be used to develop a revised Figure 2, providing that the site specific frequency distribution is statistically defensible. Otherwise, the national distribution is used. The distribution should be used to estimate the probabilities (i.e., the p_i) for use in equations (6), (10), (11), or (13).

When 1 or 2 years of PM_{10} data are available, and PM_{10} and TSP were sampled at the same frequency, then equations (3-12) will again be used to estimate the probability of failing the attainment test. An adjustment to the allowable number of exceedances using equation (13) would be required if any actual PM_{10} exceedances were observed, as discussed previously. The following example illustrates the calculations needed when PM_{10} and TSP have the same sampling rates.

Example 7

Suppose there are 180 PM_{10} samples in 1985 showing 2 NAAQS exceedances and 180 TSP samples collected annually during 1983-1984. Based on 540 PM_{10} plus TSP samples, the allowable number of exceedances, A, is equal to 2 (from Table 4, Section 5.2). Since two actual PM_{10} NAAQS exceedances were observed, the revised allowable number, A', is 2 - 2 = 0. Therefore for this case, failure of the attainment test is defined as the probability of observing 1 or more exceedances (equation 13).

When PM_{10} and TSP are sampled at different rates, the allowable number of exceedances, $\tilde{A}$, in Table 4 and equation (12) may not be used directly. First, intermediate calculations must be performed to produce adjusted allowable number of exceedances, $\tilde{A}$, and adjusted PM_{10} exceedances, $\tilde{E}$ according to the average TSP sampling rate. The total number of exceedances allowed in 3 years is 3.14. The first observed exceedance is not adjusted for incomplete sampling. If n_{TSP} and $n_{PM_{10}}$ represent the number of TSP and PM_{10} samples per year, respectively, then the total number of observed allowable exceedances is

$$\tilde{A} = 1 + \frac{2.14\ n_{TSP}}{365} \qquad (14)$$

and,

$$\tilde{E} = 1 + \frac{(E-1)n_{TSP}}{n_{PM_{10}}} * \qquad (15)$$

The revised number of allowable exceedances for the remaining years is defined as

$$\tilde{A}' = \tilde{A} - \tilde{E} \qquad (16)$$

The probability of nonattainment is the chance of observing more than $\tilde{A}'$ PM_{10} exceedances during the TSP sampling period. To be consistent with equations (3)-(13), the number of allowable exceedances are interpreted as the integer values of $\tilde{A}'$ (for example, the integer value of 1.7 is 1).

Note that with this approach, the number of allowable exceedances for the 1 or 2 years with TSP data cannot be more than what would be permitted for 3 years of TSP data at that same sampling rate (i.e. $\tilde{E}$ must be less than or equal to $\tilde{A}$). Depending on the PM_{10} sampling rate, however, 1-3 actual PM_{10} exceedances may be permitted for purposes of estimating nonattainment probabilities.

Example 8

In this example, assume TSP was sampled 60 times per year in 1982 and 1983. Suppose that PM_{10} was sampled 180 days in 1984 and showed two exceedances. What is the probability of PM_{10} nonattainment? First, we calculate $\tilde{A}$, on the basis of 3 years of data with 60 observations per year:

$$\tilde{A} = 1 + \frac{2.14(60)}{365} = 1.35$$

Next, we calculate the adjusted number of exceedances,

*Note that E is the actual number of observed exceedances, as defined in Equation 12.

$$\tilde{E} = 1 + \frac{(1) \times 60}{180} = 1.33$$

Therefore, $\tilde{A}' = 1.35 - 1.33 = 0.02$

The integer value of $\tilde{A}'$ equals zero, so no additional exceedances would have been permitted during the TSP sampling period (i.e. one additional exceedance would be sufficient for nonattainment). For this example, therefore, equations (3) and (13) would be used with 1982 and 1983 TSP data.

If three PM_{10} exceedances were observed in 1984, the site would automatically fail the attainment test and have a nonattainment probability of one. If the revised number of allowable exceedances, A', were estimated to be "1", however, Equations (3) - (6) would be used with 1983 and 1984 TSP data to estimate the probability of nonattainment.

5.4 Use of Site or Region-Specific Distributions

Section 4.0 made provision for the development of an annual site or region-specific ratio using at least 1 full year of concurrent PM_{10} and TSP data. Analogously, a site or region-specific frequency distribution of ratios should be developed (provided it is statistically defensible) and used in conjunction with the 24-hour NAAQS attainment determination. This distribution would then be used in place of the national distribution when PM_{10} data are available for partial years or not available at all as provided for in Section 5.3.

5.5 Use of IP Data

Similar procedures to those described in Sections 5.1 - 5.3 can be followed using IP and some PM_{10} data provided the data are sufficient to develop a site-specific PM_{10}/IP distribution. One would simply substitute the term "IP" for "TSP" in the preceding discussion. Since few sites would have current IP data, it is anticipated that this procedure would be used very infrequently.

5.6 Software Support

A computer program has been developed to automate the calculations necessary for estimating the probability of exceedance of both the annual and 24-hour NAAQS.(15)

6.0 ESTIMATING SPATIAL EXTENT OF NONATTAINMENT SITUATIONS

6.1 Introduction

As described in earlier sections, assessing attainment/nonattainment of the National Ambient Air Quality Standards (NAAQS) for PM_{10} requires the use of ambient monitoring data. If the data and the assessment procedures described earlier identify a nonattainment area and result in the requirement for control strategy development, the question remains as to what is the spatial extent of the nonattainment problem. Defining the spatial extent of the problem is not a simple, straightforward technical matter, as is evidenced by the differences in the size of boundaries for nonattainment areas for the other criteria pollutants and the original TSP NAAQS. For example, some nonattainment area boundaries are county or citywide, some include entire townships or parishes, while others encompass the central business district or an area bounded by designated streets.

Such differences occur because the size of the boundaries are influenced by a variety of technical factors such as the pollutant itself, its reactivity, type and density of emissions, meteorology, topography, etc. In addition to these technical considerations, final boundaries are also influenced by nontechnical factors such as the amount of time and resources available to effectively define their limits, as well as the jurisdictional borders of the areas surrounding the nonattainment monitoring site.

States have used several techniques, including dispersion modeling, isopleth analysis, source receptor models, and monitoring site scales of representativeness in defining nonattainment boundaries for other pollutants. These techniques are also used for other purposes and are fairly complex and detailed. Since they are not unique to nonattainment boundary definitions, and are adequately described and discussed elsewhere in the literature, they are not covered here in any great detail; rather, they are listed as techniques or approaches that are recommended for use as guidance in defining the extent of a nonattainment problem.

6.2 Use of Acceptable Air Quality Data

The use of acceptable air quality data is required in determining the attainment/nonattainment status of a monitoring site. In determining data acceptability, three items which need to be evaluated are: the type of sampler used, sampler location, and quality of the data.

6.2.1 Type of Sampler

When using TSP data for estimating the probability of nonattainment for PM_{10}, the TSP sampler must be a reference method, as defined in Appendix B to 40 CFR Part 50. For those situations where inhalable particulate (IP) data will be used for estimating the probability of nonattainment for PM_{10} or PM_{10} data will be used directly, the determination of the acceptability of the type of IP or PM_{10} sampler will have to be done on a case-by-case basis, as there is no existing designated reference method for IP or PM_{10}. Data collected from dichotomous samplers used in EPA's national sampling network for inhalable particulates are considered acceptable. As a general rule when using IP or PM_{10} data, the sampler should be similar to those used in the EPA IP network or EPA supplied PM_{10} samplers which are based on the principles of inertial separation and filtration. The Environmental Monitoring Systems Laboratory (EMSL), Research Triangle Park, North Carolina, will provide guidance to assist in making this determination.

6.2.2 Sampler Location

Appendices D and E of 40 CFR 58 included network design and siting criteria for TSP samplers and PM_{10} samplers, but not for IP. If TSP data are to be used in the assessment of attainment/nonattainment for PM_{10}, then these samplers must conform to the requirements of Appendices D and E.

6.2.3 Data Quality

The Agency's quality assurance policy is that all environmental data generated, processed, or used for implementing Clean Air Act requirements, will be of known precision and accuracy and, to the extent possible, be complete, comparable, and representative.

Consistent with this policy, TSP samplers must conform to the reference method requirements and the data must be collected in accordance with the quality assurance criteria contained in Appendix A of Part 58. For PM_{10} and IP data, the samplers must be similar to those used in the EPA national sampling network for inhalable particulates, except that size-selective hi-volume samples collected with glass fiber filters should not be used. Minimum quality assurance activities that should have been conducted during the PM_{10} or IP measurement process are quality control checks, data review and validation activities. The quality control activities include regularly scheduled flow calibrations where the flow measurement devices used to measure sampling rate were also calibrated. Data review and validation procedures should be similar to those established for the other criteria pollutants.

6.3 Determining the Boundaries of a Nonattainment Area

As noted in Section 6.1, several techniques have been used by States to define the spatial extent of NAAQS violations expressed as boundaries of nonattainment areas. Basically, the approaches used can be placed into three categories:

1. a qualitative analysis of the area of representativeness of the monitoring site, together with consideration of terrain, meteorology and sources of emissions;

2. spatial interpolation of air monitoring data;

3. air quality simulation by dispersion modeling.

In determining the extent of a PM_{10} nonattainment situation, the use of any one or a combination of the above categories would be considered acceptable to the EPA. The choice of which technique to use depends on the complexity of the PM_{10} problem area.

6.3.1 Qualitative Analysis

This approach, unlike the others discussed below, is not intended to define any single analytical procedure for defining the extent of a nonattainment problem. On the contrary, it is intended to recognize as acceptable various approaches that consider such factors as ambient monitoring data, the spatial scales of representativeness of the monitoring station, the number of areas in the community similar to that being measured by the monitoring station, the type of terrain, meteorology, and sources of PM_{10} emissions. Revisions to Appendix D of Part 58 describe the topic of spatial scales of repesentativeness for PM_{10} stations, as well as procedures for locating such stations. The predominant spatial scales for PM_{10} stations include micro, middle and neighborhood, with a fewer number of stations represented by the urban and regional scale. Properly located stations that are specifically classified according to their spatial scale could, in certain instances, be solely used to define the limits of the nonattainment area. Other situations obviously will require a more detailed review and analysis of sources, pollutant transport and receptor.

6.3.2 Spatial Interpolation of Air Monitoring Data

Although it would be desirable to ensure that the entire area of a designated nonattainment area is actually nonattainment, air monitoring costs are so high as to prohibit full coverage of a large nonattainment area. There are, however, two methods available to arrive at refined estimates of the spatial variation of air quality. One method is spatial interpolation of air monitoring data, the other which will be discussed in Section 6.3.3, is air quality simulation by dispersion modeling.

The use of spatial interpolation of air monitoring data is the method most appropriate for situations in which monitors are located at relatively close proximity to one another. Over the past years, most cities and urban areas have established fairly dense air monitoring networks which enabled the technique to become more widely applicable. A complete description of the method is described in the publication, "Guideline on Procedures for Constructing Air Pollution Isopleth Profiles and Population Exposure Analysis," U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711, EPA-450/2-77-024a, October 1977 (OAOPS No. 1.2-083).

The basic procedure involves the plotting of station locations and measured concentrations from these stations. For those areas of the map not covered by monitoring stations, a spatial interpolation scheme is used to estimate air quality concentrations. The technique can be done manually or through the use of computer mapping programs.

6.3.3 Air Quality Simulation by Dispersion Modeling

Determining the extent of the PM NAAQS nonattainment can also be accomplished by using dispersion models to simulate the spatial distribution of air quality under various conditions. Dispersion modeling is more appropriate than spatial interpolation of air monitoring data in areas where actual monitoring data are scarce. In order to use a dispersion model, source data, air quality data, and meteorological data are required. For dispersion modeling purposes, PM_{10} is treated as a nonreactive gas. The type of source (point, area, mobile, or stationary), type of standard (short term or annual), type of terrain (flat or rough), and the type of area (urban or rural) will of course affect the decision as to which model to use. The document, Guideline on Air Quality Models, (16), includes specific recommendations concerning air quality models, and also describes circumstances for which models, data and techniques other than those recommended in the guideline may be applied.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The proposed primary National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) specify ambient concentrations for particles smaller than 10 micrometers (μm) aerodynamic diameter (PM_{10}). This document describes a methodology for using available PM_{10} measurements in conjunction with TSP data to estimate whether or not the annual and/or 24-hour NAAQS for PM_{10} are likely to be violated (probability of nonattainment). The probability of nonattainment is one of the criteria which are used to specify action States are to take in developing PM_{10} monitoring requirements and State Implementation Plans (SIP's). The document also addresses appropriate methods for determining the spatial extent of the nonattainment situations. The following hierarchy is described in the document for using available ambient measurements to determine attainment/nonattainment directly or to estimate the probability of PM_{10} nonattainment: (1) use ambient PM_{10} data alone; (2) use less than complete PM_{10} data and Inhalable Particulate (IP) measurements obtained with the dichotomous sampler; (3) use PM_{10} data with less than complete sampling in conjunction with TSP data to draw inferences about PM_{10} nonattainment. Alternatively, IP or TSP measurements together with a statistically defensible site specific probability distribution for 24-hour PM_{10}/IP (or PM_{10}/TSP) ratios to estimate likelihood of nonattainment; (4) use **TSP data** to draw inferences about the probability of PM_{10} nonattainment. This document describes the above hierarchy and provides guidance for application.

17. KEY WORDS AND DOCUMENT ANALYSIS

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PM_{10} Particulate Matter Total Suspended Particulate Estimating Procedures Nonattainment National Ambient Air Quality Standards		

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