Projected Attainment Status of Each County in the U.S. with the PM2.5 National Ambient Air Quality Standards Based on 1999-2001 Monitoring Data and Strategies for Dealing with Nonattainment Designations

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ABSTRACT

Air quality monitoring data collected by state and local government agencies between 1999 and 2001 for fine particulate matter (PM2.5) at over 1,000 sites in the U.S. are indicating the likelihood of widespread designations of nonattainment of the annual PM2.5 National Ambient Air Quality Standard (NAAQS) of 15.0 ug/m3. U.S. EPA is requiring states to use the first three years of PM2.5 monitoring data that meet certain data completeness criteria to make PM2.5 attainment designations. The purpose of this paper is to project the PM2.5 attainment status of each county in the U.S. based on 1999-2001 monitoring results and to discuss strategies for dealing with the expected widespread nonattainment designations. These strategies include evaluating the feasibility of a Primary-First control strategy for PM2.5 where reductions in primary emissions of PM2.5 from local sources are made first and where secondary emission reductions from distant sources especially including power generation are only used to complete the attainment demonstration. We discuss the potential cost-effectiveness of this Primary-First approach and ideas for providing an equitable sharing of the costs of a Primary-First control strategy.

INTRODUCTION

On July 18, 1997, U.S. EPA issued new National Ambient Air Quality Standards (NAAQS) for fine particulate matter with an aerodynamic diameter of 2.5 microns or less (PM2.5). These standards consist of a 15 ug/m^3 annual average concentration, based on a

3-year rolling average, and a 65-ug/m^3 concentration, based on a 3-year average of the 98th percentile of the daily 24-hour concentrations. States were required to establish a PM2.5 monitoring network by December 1999. In total, over 1,100 PM2.5 samplers began operation in 1999 nationwide.

Within one year after collection of three years of PM2.5 data, states are to make attainment and nonattainment designations, EPA must promulgate the final attainment and nonattainment designations for each state by the earlier of one year after state submittal of its proposed designations or no later than December 31, 2005. For any area designated as attainment or unclassifiable for such standard, State Implementation Plan (SIP) revisions must be submitted to EPA within one year after the agency's final designations. For areas designated as nonattainment, SIP revisions for attaining the NAAQS for PM2.5 must be submitted within a schedule established by EPA, but no later that three years after the agency's nonattainment designation. Finally, under Section 172 of the 1990 Clean Air Act Ammendments, EPA must promulgate the SIP revisions received by the states (if complete) within 12 months of receipt. These SIP revisions must achieve attainment of the PM2.5 NAAQS as expeditiously as practical, but not later than five years from the date of nonattainment designation by EPA.

These developments will have a major impact on future permitting of industrial sources. For new sources, or major modifications of existing major sources, located in PM2.5 attainment areas, SIP revisions will be in place between December 2005 and December 2007. For such facilities located in or near PM2.5 nonattainment areas, SIP revisions will be promulgated within the period December 2007 through December 2009. These SIP revisions will almost certainly include provisions to comply with the Emission Offset Interpretive Ruling, which requires major new sources and major modifications to existing sources to obtain emission reductions (offsets) from existing sources. Except for a shutdown or a reduction in the permitted maximum operating hours for an existing source, it will be difficult and costly to create these emission offsets, since the cost of particulate control increases exponentially as particle diameter decreases. Emission reductions of gaseous precursors to PM2.5 (SO_2, NO_x, and VOCs) are also under consideration for PM2.5 control.

PM2.5 monitoring data collected by state and local government agencies between 1999 and 2001 are indicating the likelihood of widespread designations of nonattainment of the annual PM2.5 standard. The purpose of this study is to project the PM2.5 attainment status of each county in the U.S. based on these monitoring results and to identify strategies for dealing with the expected widespread nonattainment designations. These strategies include evaluating the feasibility of a "Primary-First" control strategy for PM2.5 where reductions in primary emissions of PM2.5 from local sources are made first and where secondary emission reductions from distant sources especially including power generation are only used to complete the attainment demonstration.

EXTENT AND MAGNITUDE OF THE PROJECTED PM2.5 NONATTAINMENT DESIGNATIONS

Methodology

Available PM2.5 monitoring data clearly indicate that the annual 15 ug/m^3 standard is limiting. Accordingly, in this study we accessed the EPA Aerometric Information Retrieval System (AIRS) database and reviewed the PM2.5 annual average concentrations in each U.S. county where monitoring was conducted from 1999 to 2001. We then calculated the 3-year annual average at each PM2.5 sampler and selected for analysis the single sampler in each county with the highest measured 3-year annual average PM2.5 concentration. An evaluation of the extent of PM2.5 nonattainment in each state was made by determining the percent of counties with PM2.5 samplers projected to be nonattainment. The magnitude of the nonattainment problem in each state was evaluated by 1) determining the *maximum* 3-year annual average PM2.5 concentration and the percent reduction needed to attain the NAAQS and 2) determining the *average* percent reduction in 3-year annual average PM2.5 concentration needed to attain the NAAQS averaging over the maximum percent reduction needed in each county which exceeded the standard. All results were sorted by state from highest to lowest percent reduction required.

Results

There were a total of 31 states plus the District of Columbia which had at least one PM2.5 monitor that exceeded the annual PM2.5 NAAQS. These states are listed in Table 1, along with the percentage of counties projected to be nonattainment. Table 1 indicates that most of the states projected to have PM2.5 nonattainment areas are concentrated in the eastern half of the country. The percentage of counties with PM2.5 samplers projected to be nonattainment ranges from 100% (District of Columbia) to 5% (Minnesota and Oklahoma).

Table 2 lists the maximum percent reduction required in annual PM2.5 concentration for states with the highest measured concentrations. California heads this list with a maximum percent reduction of 54%. Table 3 summarizes the results on maximum percent reductions, showing that nine states require a greater than 25% reduction, 17 states require reductions within 10-25%, and six states require less than 10% reductions.

The average percent reductions required in annual PM2.5 concentration for states with the highest concentrations are listed in Table 4 Again, California is the leader with a 26% reduction. Table 5 summarizes the results for average percent reductions, indicating that only one state requires a greater than 25% reduction, 15 states between 10-25% reduction, and 16 states less than 10% reduction in average annual PM2.5 concentration.

Table 1. Percent of counties with PM2.5 samplers projected to be nonattainment

State	Percent	State	Percent
DC	100	NJ	42
GA	90	AR	33
TN	87	RI	33
OH	79	SC	31
AL	76	CT	25
WV	71	MO	21
IN	68	MA	20
DE	67	NY	18
MS	56	MI	16
KY	55	NM	10
NC	50	MT	8
PA	50	TX	7
CA	48	LA	6
IL	45	WI	6
VA	44	MN	5
MD	43	OK	5

Table 2. Maximum percent reduction required in annual PM2.5 concentration for states with the highest concentrations

State	Percent
CA	54
MO	39
GA	38
AL	35
PA	34
NJ	33
OH	31
NY	29

Table 3. Summary of results on maximum percent reductions in PM2.5 concentrations needed to attain the annual NAAQS

Needed Percent Reduction	Number of States
>25	9
10-25	17
<10	6

Table 4. Average percent reduction required in annual PM2.5 concentration for states with the highest concentrations

State	Percent
CA	26
NY	19
NJ	19
DC	18
CT	18
GA	17
OH	16
DE	15

Table 5. Summary of results on average percent reductions in PM2.5 concentrations needed to attain the annual NAAQS

Needed Percent Reduction	Number of States
>25	1
10-25	15
<10	16

STRATEGIES FOR DEALING WITH NONATTAINMENT DESIGNATIONS

There are four strategies we recommend for dealing with nonattainment designations. These include:

1. Evaluate the validity of the monitoring data
2. Use spatial averaging for attainment designations
3. Focus on a Secondary-First PM2.5 control strategy
4. Focus on a Primary-First PM2.5 control strategy

These strategies are discussed below.

Strategy 1: Evaluate the Validity of the Monitoring Data

EPA has established a number of performance evaluation procedures for the PM2.5 monitoring program. These procedures include:

1. Sampler flow rate quarterly audits (State)
2. Precision checks via permanently collocated samplers at 25% of sites (State)
3. Performance evaluation with collocated samplers at 25% of sites per year (EPA)

4. Balance systems and performance audits (State)
5. Sampler performance audits (State)
6. Systems audit (EPA)
7. Systems audit (State)

PM2.5 monitoring network experience has indicated that potentially serious problems with flow measurement, sample handling, and laboratory QA/QC operations may result. Accordingly, we recommend, with state/local agency approval, independent, third party audits of network operations. These audits should include:

1. A review of results of EPA's performance evaluation with collocated samplers at 25% of sites per year
2. Independent performance audits of samplers with annual average concentrations exceeding 15 ug/m^3
3. Independent systems audit of samplers with annual average concentrations exceeding 15 ug/m^3

Strategy 2: Use Spatial Averaging for Attainment Designations

A state may propose a Community Monitoring Zone (CMZ) based on a spatial average of multiple PM2.5 samplers in making attainment designations if no individual sampler exceeds the spatial average by more than 20%. CMZs offer the potential for reducing the extent and magnitude of PM2.5 nonattainment designations and should be proposed to state/local agencies for consideration.

Strategy 3: Focus on a Secondary-First PM2.5 Control Strategy

U.S. EPA's current preliminary draft strategy for development of SIPs for demonstrating attainment of the PM2.5 annual standard is a Secondary-First approach. This strategy involves regional air quality modeling at the PM2.5 monitors not attaining the standard to determine whether regional reductions in SO_2 and NO_x emissions that are precursors to secondary PM2.5 formation will reduce concentrations sufficiently to attain the standard. Secondary PM2.5 contributions to annual average PM2.5 concentrations are decreasing as the Phase II acid rain SO2 emission reductions took effect in the year 2000 and Clean Air Act Section 407 NO_x emission reductions from electric utility units take effect, thereby reducing the PM2.5 sulfate and nitrate contributions. These secondary contributions to PM2.5 concentrations will likely continue to decrease as states implement the NO_x reduction requirements in the NO_x SIP Call regulation. Under court order, all NO_x reductions under the SIP Call must take place by May 31, 2004. Secondary contributions are also expected to decline with the reduction of volatile organic compounds (VOCs) believed to be responsible for PM production as a result of the SIP provisions for making progress towards attaining the ozone NAAQS.

Strategy 4: Focus on a Primary-First PM2.5 Control Strategy

As defined earlier, a Primary-First PM2.5 control strategy first addresses emission reductions of primary particulate emissions. As a result of the aforementioned air pollution control programs, which focus attention on emissions which contribute to secondary PM2.5, primary PM2.5 emissions may become responsible for an increasingly significant portion of the total PM2.5 concentration at many of the PM2.5 monitors exceeding the 15.0 ug/m^3 annual NAAQS. Since available PM2.5 monitoring data indicate that many sites exceed the annual NAAQS by a relatively small margin (i.e., about 25% or less), as demonstrated in Table 5, there is significant potential for a Primary-First control strategy. With a Primary-First strategy, the major primary sources contributing to each PM2.5 monitor not attaining the air quality standard would be identified and particulate matter emission reductions would first be applied to these sources. Secondary emission reductions would be applied to any remaining violations of the NAAQS to demonstrate attainment.

Recent studies have shown that the most leverage in reducing annual average PM2.5 concentrations with primary PM2.5 controls is with primary organic carbon and, to a lesser extent, elemental carbon.[1] Cabada et al. has estimated that 65-90% of the total annual organic PM2.5 in the Pittsburgh, PA area is of primary origin.[1] Table 6 shows the chemical breakdown of the annual average PM2.5 concentration at the Cleveland, OH G.T. Craig Speciation site, assuming 90% of the organic carbon is primary. This table indicates that roughly one-half of the total PM2.5 concentration is primary particulate matter and that primary organic carbon and elemental carbon collectively contribute about two-thirds of the total estimated primary PM2.5.

Table 6. 2001 annual average PM2.5 concentration at the Cleveland, OH G.T. Craig speciation site assuming 90% of organic carbon is primary

Speciation Component	**Concentration (ug/m^3)**	**Percentage of Total Concentration**
Primary		
Elemental Carbon	1.05	4.9
Organic Carbon	6.09	28.2
Metals	3.35	15.5
Other	0.07	0.3
Total Primary	**10.56**	**48.8**
Secondary		
Sulfates	5.23	24.2
Nitrates	2.77	12.8
Ammonium	2.39	11.1
Organic Carbon	0.68	3.1
Total Secondary	**11.07**	**51.2**

The major local source categories of primary PM2.5 emissions can be identified through receptor modeling techniques using ambient PM2.5 speciation data and chemical source profiles of major emission sources. Cabada et al.[1] have developed an emission inventory of primary organic carbon and elemental carbon for the Pittsburgh, PA area. The

principal emission sources are listed in Table 7, which indicates that the major sources of primary organic carbon and elemental carbon include residential wood burning, heavy- and light-duty trucks, structural fires, steel works, and river vessels. The feasibility of a Primary-First PM2.5 control strategy may be assessed by an evaluation of the maximum economically and technologically feasible reductions in emissions from the major primary source categories contributing to the three-year annual average PM2.5 concentrations exceeding the NAAQS. The results of this evaluation will determine which primary emission controls should be implemented, to be followed by a determination of the extent of any remaining nonattainment in the state.

Table 7: Summary of major sources (>50 TPY) of primary organic carbon and elemental carbon
for the Pittsburgh area

Emission Source	**Emissions (TPY)**
Residential wood burning	588
Heavy-duty trucks	302
Structural fires	266
Steel works (coke burning)	228
Steel works	190
Light-duty trucks	171
River vessels	170
Paved road	140
Railroad	112
Meat cooking	106
Aircraft	84
Catalytic autos	67
Residential natural gas	55

Notes to Table 7:
(1) Based on the emission inventory developed by Cabada et al.[1]
(2) Total carbon emissions are estimated to be 1690 TPY (primary organic carbon) and 1040 TPY (elemental carbon), or 2730 TPY (total). The emission sources listed above represent over 90% of the total primary organic carbon plus elemental carbon inventory.

Since primary PM2.5 represents a significant portion, if not the majority in some cases, of the total PM2.5 concentrations at locations exceeding the annual PM2.5 NAAQS, there is the potential that a Primary-First control strategy may be more cost-effective than a Secondary-First strategy for attaining the NAAQS for two reasons.

First, consideration of a Primary-First strategy offers an additional choice for selecting a control strategy. If this approach proves less costly than a Secondary-First approach for attaining the NAAQS for PM2.5, then by definition it is more cost-effective.

Second, a Primary-First approach may attain the NAAQS at less cost than a Secondary-First approach for two reasons. The first reason for this is that the amount of PM2.5 concentration reduction per ton of emission reduction varies in some form of inverse relationship with source distance from the nonattainment area. Most of the emission reductions from secondary sources will occur from sources at large distances from the nonattainment area. Thus, much more secondary emission reductions are needed to achieve a 1 ug/m^3 PM2.5 concentration reduction in a given nonattainment area than would be required from nearby primary emission sources.

The second reason for this is that even if a Primary-First approach cannot totally attain the NAAQS, it reduces the amount of the more costly secondary emission reductions needed to attain the NAAQS.

But what about the equity of this Primary-First approach? With the Secondary-First approach, power generation and transmission/distribution companies and electricity users absorb all or almost all of the costs of this approach. With the Primary-First approach, these control costs are shared between the above groups and the industry and other contributors to the primary PM2.5 emissions.

We expect that government air pollution control officials would prefer to shift the cost of PM2.5 control more to the relatively small number of large power companies that are more easily regulated instead of imposing these costs on local industry and even local residents. However, one way to lessen the impact on local industry and residents of a Primary-First approach is to have the power companies subsidize a portion of the costs incurred by local industry and residents for the control of primary PM2.5 emissions. If the total cost to the power companies of doing this is less that complying with the Secondary-First control strategy, they may have interest in doing this on a voluntary basis.

Success in achieving this kind of equitable sharing of costs will require an unparalleled level of cooperation among EPA, state and local air pollution control agencies, the electric power industry and local industry. But if this cooperation can be achieved, it offers the possibility of attaining the PM2.5 annual NAAQS in a more cost-effective way than the current Secondary-First approach.

CONCLUSIONS

The results of this investigation have indicated the following:

1. There are projected to be widespread PM2.5 nonattainment designations in 31 states plus the District of Columbia.
2. Under a Secondary-First PM2.5 control strategy, these designations will result in potentially large costs to the electric power industry to comply with the SIPs states must develop and implement between five and seven years from now.

3. A Primary-First PM2.5 control strategy will reduce the level of secondary controls needed and, thereby, may offer the potential for more cost-effective ways to attain the PM2.5 NAAQS in many of the states to be designated nonattainment.

REFERENCES

1. Cabada, J.C.; Pandis, S.N.; Robinson, A.L. *J. Air & Waste Manage. Assoc.* **2002,** 52, 732-741.

KEY WORDS

PM2.5
particulate matter
nonattainment
primary emissions
secondary emissions