# PROJECTED $PM_{2.5}$ ATTAINMENT STATUS OF EACH COUNTY IN THE U.S AND STRATEGIES FOR DEALING WITH NONATTAINMENT DESIGNATIONS AND WITH THE PROPOSED INTERSTATE AIR QUALITY RULE

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## ABSTRACT

Air quality monitoring data collected by state and local government agencies between 1999 and 2002 for fine particulate matter ($PM_{2.5}$) at over 1,200 sites in the U.S. are indicating the prospect of widespread designations of nonattainment of the annual $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) of 15.0 $\mu g/m^3$. U.S. EPA required states to submit their proposed $PM_{2.5}$ attainment designations to the agency by February 2004 with the EPA intent on making all attainment designations by December 2004. EPA is also requiring states to submit their State Implementation Plans (SIPs) for attaining the $PM_{2.5}$ NAAQS by December 2007 with attainment dates of between 2009 and 2014.

In December 2003, EPA issued a notice with the proposed Intestate Air Quality Rule (IAQR) to address the $PM_{2.5}$ and ozone nonattainment problem and the regional haze problem. The proposed IAQR would require a 65% reduction from 2001 $SO_2$ Allowances for electric utility Affected Units in 29 states to a total of 2.7 million tons per year by 2015. It would also require a reduction in $NO_X$ Allowances for these same Affected Units to 1.3 million tons per year also by 2015. Interim emission reductions would be required by 2010.

The purpose of this paper is to project the $PM_{2.5}$ attainment status of each county in the U.S. based on the most recently available three years (2000-2002) of monitoring data and to discuss strategies for dealing with the expected widespread nonattainment designations including the proposed IAQR.

## 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 ($PM_{2.5}$)[1]. These standards consist of a 15 µg/$m^3$ annual average concentration based on a 3-year rolling average and a 65-µg/$m^3$ 24-hour concentration based on a 3-year average of the 98$^{th}$ percentile of the daily 24-hour concentrations. States were required to establish their $PM_{2.5}$ monitoring networks by December 1999. In total, over 1,200 $PM_{2.5}$ gravimetric samplers began operation in 1999. In addition, approximately 300 $PM_{2.5}$ speciation samplers were placed into operation throughout the U.S. to collect information on the chemical composition of $PM_{2.5}$ concentrations.

Table 1 summarizes EPA's current schedule for attaining the $PM_{2.5}$ NAAQS [2].

On December 17, 2003, EPA announced the proposed Interstate Air Quality Rule (IAQR), which was published in the Federal Register in January 2004 [3]. This proposed rule requires major reductions in $SO_2$ and $NO_x$ emissions from electric generating units covered under Title IV of the Clean Air Act (Affected Units) in 29 states in the eastern half of the U.S. These states are listed in Table 2.

In February 2004, states and tribes recommended proposed attainment and nonattainment designations for $PM_{2.5}$. EPA is planning to inform states/tribes of intended modifications to these proposed designations by July, 2004. EPA is planning to promulgate the $PM_{2.5}$ attainment and nonattainment designations in December 2004.

EPA plans to finalize the IAQR by January 2005. States and tribes will be required to submit State Implementation Plans (SIPs) for attaining the $PM_{2.5}$ NAAQS by December 2007 with plans for attainment of all $PM_{2.5}$ NAAQS by 2009 to 2014, depending on the area.

These developments will have a major impact on Affected Units in these 29 states, on other existing sources of $PM_{2.5}$ emissions and on future permitting of new facilities.

Under the proposed IAQR, existing Affected Units in the above 29 states will be subject to $SO_2$ emission reductions equal to 65% of the $SO_2$ Allowances of these Affected Units for 2001. Existing Affected Units will also be subject to $NO_x$ emission reductions equivalent to a resulting annual emission rate equal to an average of 0.125 lbs $NO_x$ per MMBTU times the maximum annual BTU consumption of the Affected Units in the 29 states over the period 1999-2002. These emission rate reductions must be achieved in two phases ending in 2015. Final emissions are proposed to be 2.7 million tons per year of $SO_2$ and 1.3 million tons per year for $NO_x$ for the Affected Units in these 29 states.

EPA proposes to achieve these emission reductions by establishing required emission reductions by state and by giving states the option of satisfying these emission reduction requirements through a 29-state regional cap and trades program and/or through requiring other existing sources to participate in these emission reductions.

New major sources or major modifications to existing sources located in or near $PM_{2.5}$ nonattainment areas will also be affected by the $PM_{2.5}$ nonattainment designations. These sources will require emission offsets for $PM_{2.5}$ or its precursors that equal or exceed the proposed new emissions, the use of Lowest Achievable Emission Rate Control Technology and a demonstration that the proposed new source or modification will not adversely affect air quality as required under 40CFR Part 51.

The purpose of this study is to project the $PM_{2.5}$ attainment status of each county in the U.S. based on 2000-2002 $PM_{2.5}$ monitoring data and to identify strategies for dealing with the expected widespread nonattainment designations and the proposed Interstate Air Quality Rule.

## EXTENT AND MAGNITUDE OF THE PROJECTED $PM_{2.5}$ NONATTAINMENT DESIGNATIONS

### Methodology

Available $PM_{2.5}$ monitoring data clearly indicate that the annual 15 $\mu g/m^3$ standard is limiting. Accordingly, in this study we accessed the EPA Air Quality Management System (formerly AIRS) database and reviewed the $PM_{2.5}$ annual average concentrations in each U.S. county where monitoring was conducted from 2000 to 2002. We then calculated the 3-year annual average at each $PM_{2.5}$ sampler and selected for analysis the single sampler in each county with the highest measured 3-year annual average $PM_{2.5}$ concentration. If only two years of monitoring data were available at a site, we used the two-year average for the expected three-year average once three complete years of data are available.

An evaluation of the extent of $PM_{2.5}$ nonattainment in each state was made by determining the percent of counties with $PM_{2.5}$ 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 $PM_{2.5}$ concentration and the percent reduction needed to attain the NAAQS and 2) determining the *average* percent reduction in 3-year annual average $PM_{2.5}$ 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 are a total of 24 states plus the District of Columbia that have at least one $PM_{2.5}$ monitor that exceeded the annual $PM_{2.5}$ NAAQS for the period 2000-2002. This conclusion is subject to the qualification that some states had $PM_{2.5}$ samplers exceeding the annual NAAQS with only two years of valid monitoring data and others did not satisfy all the requirements for sufficient data collection to be treated as a valid year for making an attainment determination. Nevertheless, these results are indicative of what the monitoring results are expected to be in the next few rolling three-year periods when all monitors do collect three years of valid monitoring data.

These states are listed in Table 3 along with the percentage of counties with $PM_{2.5}$ samplers in each state projected to be nonattainment. Table 3 indicates that most of the states projected to have $PM_{2.5}$ nonattainment areas are concentrated in the eastern half of the country. Only Montana and California are not east of or bordering the Mississippi River. The percentage of counties with $PM_{2.5}$ samplers projected to be nonattainment ranges from 100% (District of Columbia) and 80% (Ohio) to 6% (Arkansas).

For comparison purposes, the proposed IAQR estimates that 19 states plus the District of Columbia are violating the $PM_{2.5}$ annual NAAQS based on monitoring data for the period 2000-2002 [3]. The additional states estimated to be nonattainment in our independent analyses of this monitoring data are Arkansas, Connecticut, Massachusetts, Missouri and Rhode Island.

Table 4 lists the maximum percent reduction required in annual $PM_{2.5}$ concentration for states with the highest measured concentrations. Pennsylvania heads this list with a maximum percent reduction of 56% in York County.

Table 5 summarizes the results of state maximum annual $PM_{2.5}$ concentration reductions needed to attain the NAAQS. This table shows that six states require a greater than 25% reduction, 15 states require reductions in the range of 10 to 25%, and four states require less than 10% reductions.

The average percent reductions required in annual $PM_{2.5}$ concentration for states with the highest concentrations are listed in Table 6. Only three states require average percentage reductions in their annual average $PM_{2.5}$ concentrations of more than 15%. They are California with 27%, Pennsylvania with 23% and Connecticut with 17%.

Table 7 summarizes the results for average percent reductions in annual average $PM_{2.5}$ concentrations needed to attain the NAAQS. This table shows that one state requires an average reduction of more than 25%, 14 states require average reductions of from 10% to 25% and ten states require average reductions of less than 10%.

**Table 1.** EPA Current Schedule for Attaining the $PM_{2.5}$ National Ambient Air Quality Standards.

| **Action** | **Date** |
|---|---|
| EPA proposed Interstate Air Quality Rule | December 2003 |
| States/Tribes recommend proposed attainment and nonattainment designations | February 2004 |
| EPA responds with letters describing intended modifications to the proposed designations | July 2004 |
| EPA finalizes implementation rule | Fall 2004 |
| EPA finalizes attainment and nonattainment designations | December 2004 |
| State/Tribal State Implementation Plans due | December 2007 |
| Attainment dates | 2009-2014 |

**Table 2.** States Requiring $SO_2$ and $NO_x$ Emission Reductions Under the Proposed Interstate Air Quality Rule.

| |
|---|
| Alabama |
| Arkansas |
| Connecticut |
| Delaware |
| Florida |
| Georgia |
| Illinois |
| Indiana |
| Iowa |
| Kansas |
| Kentucky |
| Louisiana |
| Maryland/District of Columbia |
| Massachusetts |
| Michigan |
| Minnesota |
| Mississippi |
| Missouri |
| New Jersey |
| New York |
| North Carolina |
| Ohio |
| Pennsylvania |
| South Carolina |
| Tennessee |
| Texas |
| Virginia |
| West Virginia |
| Wisconsin |

**Table 3.** Percent of counties with $PM_{2.5}$ samplers projected to be nonattainment based on 2000-2002 monitoring results.

| State | Percent | State | Percent |
|---|---|---|---|
| DC | 100 | IL | 26 |
| OH | 80 | NC | 26 |
| GA | 75 | NJ | 25 |
| WV | 69 | NY | 22 |
| IN | 63 | CT | 20 |
| TN | 53 | MA | 20 |
| KY | 53 | VA | 18 |
| PA | 52 | MO | 12 |
| AL | 44 | SC | 11 |
| MD | 43 | MI | 10 |
| CA | 36 | MT | 8 |
| DE | 33 | AR | 6 |
| RI | 33 | | |

**Table 4.** Maximum percent reduction required in annual $PM_{2.5}$ concentration for states with the highest concentrations.

| State | Percent |
|---|---|
| PA | 56 |
| CA | 54 |
| TN | 37 |
| OH | 34 |
| AL | 30 |
| NY | 30 |
| IL | 25 |
| MI | 24 |

**Table 5.** Summary of results on maximum percent reductions in $PM_{2.5}$ concentrations needed to attain the annual NAAQS.

| Needed Percent Reduction | Number of States |
|---|---|
| >25 | 6 |
| 10-25 | 15 |
| <10 | 4 |

**Table 6.** Average percent reduction required in annual $PM_{2.5}$ concentration for states with the highest concentrations.

| State | Percent |
|---|---|
| CA | 27 |
| PA | 23 |
| CT | 17 |
| MO | 14 |
| DC | 14 |
| OH | 13 |
| IL | 13 |
| MI | 13 |

**Table 7.** Summary of results on average percent reductions in $PM_{2.5}$ concentrations needed to attain the annual NAAQS.

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

## STRATEGIES FOR DEALING WITH $PM_{2.5}$ NONATTAINMENT DESIGNATIONS AND THE PROPOSED INTERSTATE AIR QUALITY RULE

### Background and Shortcomings of IAQR Approach

In a previous paper, we suggested a strategy of four steps for dealing with the impending $PM_{2.5}$ nonattainment designations [4]. These were: 1) evaluate the validity of the $PM_{2.5}$ monitoring data, 2) use spatial averaging for attainment designations, 3) focus on a Secondary-First $PM_{2.5}$ control strategy, and 4) focus on a Primary-First $PM_{2.5}$ control strategy.

The data reviews and analyses supporting the proposed IAQR make it clear that some combination of primary and secondary emission reductions for $PM_{2.5}$ are needed to attain the NAAQS. Primary $PM_{2.5}$ emissions are defined as emissions directly emitted from sources in particulate form that do not go through a chemical transformation during transport and that typically are emitted locally. Secondary emissions are defined as $PM_{2.5}$ produced from atmospheric gas-to-particle conversion processes typically over long transport distances. Primary $PM_{2.5}$ consists mainly of black carbon, organic carbon and various metals. Secondary $PM_{2.5}$ consists mainly of sulfates, nitrates, organic carbon, and ammonium.

The major shortcoming of the IAQR approach is that the focus is exclusively on reductions in EGU emissions with their corresponding result of mainly reducing the sulfate fraction of $PM_{2.5}$ concentrations. However, the black and organic carbon fractions of $PM_{2.5}$ can constitute an

important portion of the total annual average concentrations. For example, Table 8 shows the black and organic carbon fractions of the $PM_{2.5}$ annual average concentrations at two $PM_{2.5}$ speciation sites near Pittsburgh, PA sponsored by EPA. These sites show that black plus organic carbon represent 31% of the total annual average $PM_{2.5}$ concentrations at each site for the period 2000-2002.

Table 5 shows that the maximum percent reduction in annual average $PM_{2.5}$ concentration needed to attain the NAAQS is 25% or less from current levels in 21 of the 24 states (plus the District of Columbia) currently projected to have counties that are nonattainment.

As a result, it is important to examine the potential for black carbon and organic carbon emission reductions together with sulfate reductions from EGUs as a starting point for attaining the $PM_{2.5}$ NAAQS. For example, improvements in federally mandated average fuel economy standards would reduce carbon emissions from motor vehicles significantly. Further reductions in VOC emissions from stationary sources to make progress towards attaining the 8-hour ozone standard would also reduce the carbon contributions to $PM_{2.5}$ concentrations in nonattainment counties.

Until and unless the federal government makes the above changes in its $PM_{2.5}$ attainment strategy, we focus on recommending an approach to attaining the $PM_{2.5}$ NAAQS that is consistent with current and the proposed federal air pollution regulations.

There are different fractions of primary versus secondary $PM_{2.5}$ concentrations at the site in each county with the highest measured annual average $PM_{2.5}$ concentration. In addition, the percent reduction in concentration needed to attain the NAAQS varies by county. As a result, the most cost effective combination of primary versus secondary $PM_{2.5}$ emission reductions needed to attain the NAAQS will vary by county in each state.

In its analyses supporting the proposed IAQR, EPA projected that in 2010 before any IAQR emission reductions, there will be 17 states plus the District of Columbia with a total of 71 counties nationwide designated as nonattainment for the $PM_{2.5}$ annual NAAQS. Only 55 of these counties are east of or bordering the Mississippi River. The other 16 counties are in California (15) and Montana (1).

Consequently, with only 55 counties to conduct a county-specific analyses for as described below, this type of approach should be both feasible and practical.

First, we review EPA's approach to developing the proposed IAQR. We then present our recommended approach for developing cost effective attainment demonstrations for the $PM_{2.5}$ annual NAAQS on a county-specific basis.

**Table 8.** Speciation of Annual Average $PM_{2.5}$ Concentrations at Two EPA-Sponsored Speciation Sites

| | **1999-2001 Measured Annual Average Concentration** | **Mass Fraction** |
|---|---|---|
| **AIRS Site 42-003-0064 (Allegheny County, PA) 1999-2001** | | |
| Total $PM_{2.5}$ | 21.02 | 1.00 |
| *Primary $PM_{2.5}$* | | |
| Black Carbon | **0.86** | **0.04** |
| Crustal | 1.16 | 0.06 |
| *Secondary $PM_{2.5}$* | | |
| Ammon. Sulfate | 10.07 | 0.48 |
| Ammon. Nitrate | 2.73 | 0.13 |
| ***Organic Carbon Primary & Secondary*** | **5.74** | **0.27** |
| *Unknown* | 0.46 | 0.02 |
| **AIRS Site 42-129-0008 (Westmoreland County, PA) 1999-2001** | | |
| Total $PM_{2.5}$ | 15.6 | 1.00 |
| *Primary $PM_{2.5}$* | | |
| Black Carbon | **0.6** | **.04** |
| Crustal | 0.71 | .05 |
| *Secondary $PM_{2.5}$* | | |
| Ammonium Sulfate | 7.69 | .49 |
| Ammonium Nitrate | 1.95 | .13 |
| ***Organic Carbon Primary & Secondary*** | **4.28** | **.27** |
| Unknown | 0.37 | .02 |

## EPA's Approach to Developing the IAQR

EPA's approach to developing the IAQR may be summarized in the following steps [(3)]:

1. Use the annual average speciated $PM_{2.5}$ concentrations at the approximately 300 speciation samplers collected in the 2001-2002 time period with an interpolation procedure to project the fraction of the annual average $PM_{2.5}$ concentration that is of each speciated compound at each of the approximately 1,200 $PM_{2.5}$ samplers.

2. Apply EPA's Regional Modeling System for Aerosols and Deposition (REMSAD)[6] to predict the reduction in $PM_{2.5}$ annual average concentration of each speciated compound in each county between the period 2000-2002 (represented by 2001) and the year 2010 after all existing and proposed federal air pollution regulations other than the IAQR have taken effect. Refer to these as the Relative Reduction Factors (RRFs). Repeat this analysis for the period between 2001 and 2015.

3. Based on control technology considerations and the cost per ton of various emission reductions, revise the $SO_2$ and $NO_x$ emissions of Affected Units down to the levels discussed under the IAQR.

4. Run the REMSAD Model for all 2010 nonattainment counties and 2015 nonattainment counties using the emission reductions for the Affected Units in Step 3.

5. Give states that contribute "significantly" ($\geq$ 0.15 $\mu g/m^3$ annual average $PM_{2.5}$ concentration) to a nonattainment county in a downwind state in 2010 the requirement to reduce $SO_2$ and $NO_x$ emissions by the reductions for Affected Units in the respective state proposed in the IAQR.

6. Allow states the options of achieving the specified emission reductions through a regional cap and trade program or by controlling sources in the state other than Affected Units.

7. Summarize the counties remaining in nonattainment and mandate that states develop their own additional air pollution control programs to further reduce concentrations to attain the NAAQS.

## Recommended Approach for Developing Cost Effective Attainment Demonstrations for the $PM_{2.5}$ Annual NAAQS

The following is our recommended approach for developing cost effective attainment demonstrations for the $PM_{2.5}$ annual NAAQS. The approach builds on the approach used by EPA in developing the proposed IAQR but with the goal of developing a more cost effective result by analyzing and determining the emission reduction requirements on a county by county basis using the most cost effective combination of primary and secondary emission controls.

This recommended approach consists of the following steps:

1. Use the projected speciated 2010 annual average $PM_{2.5}$ concentrations developed by EPA to divide the $PM_{2.5}$ concentrations into a secondary and a primary fraction for the monitor recording

the highest measured annual average concentration in each county for 2010. Procedures for dividing $PM_{2.5}$ concentrations into primary and secondary fractions are discussed in Dittenhoefer, et.al [4].

2. For each nonattainment county in 2010, determine the percent reduction in total 2010 annual average $PM_{2.5}$ concentration needed to attain the NAAQS and identify the percent reduction in primary concentration needed if there were no secondary concentration reduction.

3. Conduct receptor modeling using the Chemical Mass Balance Model Version 8 [5] or other appropriate receptor model to identify the contributions of each major source category to the total measured annual average concentration. This procedure is also discussed in Dittenhoefer et.al.

4. Develop a program of feasible primary emission reductions that are cost effective. This may include installing additional particulate control devices on smaller combustion and process sources, restricting or further restricting open burning, adopting more stringent fugitive particulate emission controls and/or stationary sources of volatile organic compound emissions. Calculate the reduction in primary emissions and with the receptor modeling results the reduction in 2010 highest annual average $PM_{2.5}$ concentration as a result of implementing these feasible and cost effective emission controls for each nonattainment county in 2010.

5. Calculate the remaining secondary concentration reductions needed to attain the NAAQS for each nonattainment county in 2010. Assemble a statistical summary of the percent reduction in secondary concentration needed to attain the $PM_{2.5}$ annual NAAQS by nonattainment county in 2010.

6. Based on a review of this statistical summary, decide what percent reduction in secondary concentrations to target as a goal.

7. Assemble the same input data to the REMSAD Model as used by EPA in its proposed IAQR analyses except start with the 2010 emissions level of Affected Units before any reductions under the IAQR.

8. Run the REMSAD Model for various reductions in $SO_2$ and $NO_x$ emissions from Affected Units (e.g. 25%, 30%, 35%, etc. reductions in current $SO_2$ Allowances in 2010) to determine the reduction in secondary $PM_{2.5}$ concentrations at the monitors with the highest concentration in each nonattainment county.

9. For each county, review the feasible primary emissions and concentration reductions in conjunction with the results of the prior step to decide on the most cost effective combination of primary and secondary $PM_{2.5}$ emission controls needed to attain the $PM_{2.5}$ annual NAAQS in each nonattainment county in 2010.

## CONCLUSIONS

There are projected to be widespread $PM_{2.5}$ nonattainment designations in 24 states plus the District of Columbia based on an analysis of the $PM_{2.5}$ air quality monitoring data collected for the period 2000-2002 at over 1,200 monitor sites.

Existing and planned Federal regulations other than the proposed Interstate Air Quality Rule will by 2010 reduce the number of counties designated as nonattainment and the magnitude of the further concentration reductions needed to attain the NAAQS. However, some combination of secondary $PM_{2.5}$ emission controls and primary $PM_{2.5}$ emission will be still needed to attain the $PM_{2.5}$ NAAQS.

We examine how government agencies can determine the most cost effective combination of secondary (precursor) emissions control versus primary emissions control needed to attain the $PM_{2.5}$ NAAQS.

The major shortcomings of the IAQR approach are that the focus is exclusively on reductions in EGU emissions with their corresponding result of mainly reducing the sulfate fraction of $PM_{2.5}$ concentrations. However, the black and organic carbon fractions of $PM_{2.5}$ can constitute an important portion of the total annual average concentrations.

It is important to examine the potential for black carbon and organic carbon emission reductions together with sulfate reductions from EGUs as a starting point for attaining the $PM_{2.5}$ NAAQS. For example, improvements in federally mandated average fuel economy standards would reduce carbon emissions from motor vehicles significantly. Further reductions in VOC emissions from stationary sources to make progress towards attaining the 8-hour ozone standard would also reduce the carbon contributions to $PM_{2.5}$ concentrations in nonattainment counties.

Until and unless EPA makes the above changes in its $PM_{2.5}$ attainment strategy, we focus on recommending an approach to attaining the $PM_{2.5}$ NAAQS that is consistent with current and the proposed federal air pollution regulations.

We propose a county-specific approach for the 55 counties projected to be nonattainment for the $PM_{2.5}$ annual NAAQS in 2010 in the eastern half of the U.S. This approach combines various combinations of secondary emission reductions from electric power generation Affected Units and local primary emission reductions based on the basic analysis tools used by EPA to develop the proposed Interstate Air Quality Rule.

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## KEY WORDS

Interstate Air Quality Rule
$PM_{2.5}$
Particulate Matter
Primary emissions
Secondary emissions
Attainment
Nonattainment
REMSAD