A REPORT ON THE *$PM_{2.5}$ SAMPLING AND ANALYSIS WORKSHOP*

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I. Introduction

A *$PM_{2.5}$ Sampling and Analysis Workshop* was held in Pittsburgh, Pennsylvania on Tuesday, September 30, 1997. The workshop was sponsored by the U.S. Department of Energy/Office of Fossil Energy's Federal Energy Technology Center (FETC) -- the Department's lead field office responsible for the research and development of technology for improving the efficiency and environmental performance of coal-based power systems. The *Workshop* presented an opportunity for a broad spectrum of interests to exchange ideas, concerns, and recommendations on a key environmental issue. Fifty-four people (see Attachment A for a list of attendees) participated in the one-day *Workshop,* representing a crosscut of stakeholders from the electric-utility and coal industries, Congressional staff, local, State, and Federal environmental protection agencies, environmental and energy research organizations, and academia. .

The primary motivation for the *Workshop* was the recent issuance of the fine particulate ($PM_{2.5}$) National Ambient Air Quality Standard (NAAQS). In support of the new standard, the U.S. Environmental Protection Agency plans to install a nationwide network of fine particulate monitoring sites. It is anticipated that as many as 1,500 sampling sites will be established over a three-to-four year period starting in mid-1998. The $PM_{2.5}$ data collected from these monitoring stations will be used to identify areas of the United States that are in compliance with the new standard and those that are not. In addition, selected sites will also collect samples for detailed characterization to help identify sources, both natural and anthropogenic, of fine-particulate emissions. The information gathered from the monitoring program will be used to address critical NAAQS-implementation decisions to be made in the 2005-2007 timeframe. This will include a determination of the need for additional control of primary and secondary-particulate precursor emissions from the man-made sources.

In Fiscal Year 1998, FETC will initiate research in the area of $PM_{2.5}$ monitoring and characterization as part of the Power and Environmental Systems Program. The goal of this effort will be to provide a better understanding of the relationship between emissions from coal-based power systems and ambient concentrations of fine particulates. To this end, the *Workshop* brought to light current $PM_{2.5}$ sampling and analysis issues, identified ongoing research activities, clarified key needs, and provided

recommendations for additional Federal investment in ambient fine particulate research. The results of the *Workshop* will help guide FETC in developing a collaborative fine particulate program that is well planned and coordinated, fully leverages available resources, and maximizes partnership opportunities.

II. Summary of Presentations

The Workshop agenda (see Attachment B) included seven presentations that were meant to set the stage for a discussion of $PM_{2.5}$ research needs and opportunities. A broad range of perspectives on the issue of fine particulate sampling and analysis were provided. The speakers included representatives from the electric-power and coal industry, various research organizations, and the U.S. Environmental Protection Agency. The following is a brief summary of each of the formal presentations. A hardcopy of the materials presented by each of the speakers can be found in Attachment C.

In addition to the scheduled speakers, a short presentation was made by Dexter Sutterfield on the proposed $PM_{2.5}$ research to be carried out as part of the Office of Fossil Energy's Oil and Gas Program (see Attachment C). A briefing was also made by Sylvia Edgerton of DOE's Office of Energy Research on the North American Research Strategy for Tropospheric Ozone (NARSTO). NARSTO is a public/private partnership with membership from government, utilities, industry and academia throughout the U.S., Canada, and Mexico. Research in $PM_{2.5}$ may be added to NARSTO's agenda in light of the relationship between ozone and the formation of fine particles.

Formal Presentations

Thomas Cahill, University of California-Davis - *Trends Analysis of Sulfates and Nitrates*

The focus of Dr. Cahill's presentation was on the question of whether or not current regulations under the 1990 Clean Air Act are working to address concerns about fine particulates. It was noted that there has been a measured increase in sulfate particulates at eastern U.S. national park sites during the period of 1982-1996, however, there has been a decrease in SO_2 emissions during the same period. The reason for this apparent contradiction is unclear, but could be the result of the effect of local sources on sulfate deposition. Dr. Cahill also presented data from the IMPROVE network, a national visibility and aerosol monitoring program to track spatial and temporal trends of visibility and visibility-inducing particles, and the Southeastern Aerosol and Visibility Study (SEAVS).

James Homolya, U.S. Environmental Protection Agency - *Going Beyond Regulatory-Based Sampling*

Mr. Homolya explained EPA's $PM_{2.5}$ sample collection and speciation program. The results of the program will be used to implement the new fine-particulate standard in terms of source attribution and tracking progress of control strategies. In addition, the data obtained will support ongoing health

studies and address visibility issues. A focus of the laboratory characterization will be the metallic constituents of fine particulates from a health-impact perspective. The EPA laboratory speciation effort will be based on samples from an initial 50 sites as part of NAMS, with approximately 250 additional sites to be added. The analytes will be similar to those of the IMPROVE sampling network. These target analytes include cations (particulate ammonium, ionic sodium, calcium, and magnesium), anions (particulate sulfate, nitrate, and chloride), organic and elemental carbon, trace elements, and semi-volatile organic particles. EPA will provide laboratory specifications, standard operation procedures, and QA documentation for the sample characterization program. The Agency will also be responsible for overall program management and QA audit support. It is anticipated the initial deployment of the chemical speciation monitors will begin in October 1998.

Judith Chow, Desert Research Institute - *$PM_{2.5}$ Measurement Methods and Implementation*

Dr. Chow discussed EPA's plans to include special purpose monitoring sites to evaluate source contributions to ambient fine particulates. Several non-Federal Reference Method samplers were identified, including sequential samplers, multi-filter samplers, and denuder samplers, as was ongoing research and development of continuous particle monitors. Dr. Chow also presented several concerns in fine particulate sampling that can bias results such as the loss of volatiles due to evaporation from the filter media, passive deposition of particulate matter when samplers are not in operation, and changes in flow rate and filter loading that can occur during sampling. As an example, the seasonal effects on nitrate volatilization from a 1990 study the San Joaquin Valley were discussed. In addition, recent and on-going $PM_{2.5}$ sampling activities were discussed, with a focus on additional fine particulate collection and analysis research needed to be carried out.

Pradeep Saxena, Electric Power Research Institute - *Real & Simulated Particle Concentrations: Problems & Prospects for Public-Private Sector Collaboration 1998-2002"*

The relationship between fine-particulate matter and ozone were discussed in terms of human-health effects, visibility concerns, and agricultural impacts. Several examples of the significant "unknown" component of fine particulate samples collected in the western and eastern U.S. were presented, as was the need for better definition of the organic-carbon composition of $PM_{2.5}$. As an example, analyses of a fine particulate sample taken in Los Angeles in 1992 identified were able to identify only about 10 percent of the organic carbon species present on the filter. Mr. Saxena also discussed results of global radiation balance studies that investigated total aerosol composition and physical properties. In addition, EPRI has also conducted research to quantify the lose of fine-particulate matter from single filter-based sampling methods and has plans to initiate a long-term $PM_{2.5}$ experiment starting with seven sites in the Southeast. Several ideas were offered for collaborative research including: 1) design and deployment of "in-situ" particulate matter sampling methods; 2) creating a standard suite of ozone and fine particulate measurements; 3) better coordination of model development and testing efforts; and 4) synchronization of fine particulate and ozone measurements.

John Watson, Desert Research Institute - *Source Apportionment and Network Design*

An overview of the design and implementation of a fine particulate monitoring network was provided by Dr. Watson, with an emphasis on spatial-scale considerations and impacts on data interpretation. The location of existing particulate monitoring sites was shown, pointing to the relatively limited number of sampling locations in the Northeast and upper Midwest. Dr. Watson also provided a summary of current source-apportionment models and identified their respective strengths, weaknesses, and research opportunities. It was recommended that more emphasis be placed on the formulation of conceptual models, and less emphasis on the use of complex mathematical source-apportionment models. Related to improvements in $PM_{2.5}$ sample characterization, Dr. Watson proposed the development and application of high-time resolution particle chemistry measurement methods.

Fred Lipfert, Brookhaven National Laboratory - *PM Monitoring: Issues and Objectives*

Five key issues related to particulate matter monitoring were identified by Dr. Lipfert. These were: 1) precision - what is the lower limit of reliability; 2) accuracy - what biases may be present; 3) spatial density - are fine particles uniform in urban areas; 4) frequency - are daily data needed; and 5) personal versus outdoor ambient exposure. Dr. Lipfert suggested the need for more intensive local spatial and temporal characterization of ambient fine particulates. Ambient monitoring should also be coupled with longer-term indoor air quality characterization to better define the role of indoor exposure on human health. Regarding existing fine particulate data, archived filters could be analyzed to obtain information on possible tracers to improve source apportioning. In addition, correlations between meteorological and fine particle speciation data could be developed to further improve source identification. Dr. Lipfert also suggested that additional data needed to be collected for all ambient particulate matter, not just $PM_{2.5}$.

Robert Statnick, CONSOL Inc. - *$PM_{2.5}$ Research Issues*

Dr. Statnick discussed several potential $PM_{2.5}$ sampling concerns, including the evaporation of volatile species, the adsorption of vapor species on filters, the effect of liquid water content on mass measurements, and the contamination of filters during manufacture and handling. To address these and other concerns, a number of research needs were identified. A key area of research concerned improved organic carbon sampling and characterization in order to elucidate precursor compounds and emission sources. It was also felt that an improved inventory of emissions of VOC and NH_3 was needed. The composition of fine particulate matter was discussed relative to uncertainties regarding the contribution of sulfate compounds and the relatively high "unknown" component. In addition, the importance of obtaining an ambient background $PM_{2.5}$ level so that the effectiveness of particulate control strategies can be determine

III. Research Needs and Recommendations

A major objective of the *Workshop* was to identify key research requirements related to the sampling and characterization of fine particulates in order to improve our understanding of the relationship between man-made emission sources and ambient fine particulates. This input would be used to help guide FETC in formulating a $PM_{2.5}$ research program. The following is a summary of the research needs and recommendations made by the *Workshop* participants. They are listed in no particular order of preference or priority.

Research Needs and Recommendations

1. Investigate the effect of relative humidity and temperature on the collection and subsequent analyses of nitrate and sulfate secondary fine particulates using current sampling technology and methods. Concern remains that sulfate/nitrates can be biased high or low if precautions are not taken to prevent condensation of water vapor or gaseous precursor species or if secondary particulate matter volatilizes after collection.

2. Improve the collection and characterization of organic-carbon compounds. A significant fraction of collected organic carbon particulate matter can be of unknown origin.

3. Assess the impact of Low-NO_X Burners (LNB) for reducing NO_X emissions on the emissions of primary particulate matter. This concern stems from the potential increase in unburned carbon content of the fly ash that can result from the operation of LNB technology.

4. Increase emphasis on measuring particle-size distribution of collected fine particulates.

5. Improve overall planning, coordination, and integration of fine particulate and ozone monitoring programs.

6. Measure/track the atmospheric transport and conversion of SO_2 and NO_X to secondary sulfates/nitrates particulate matter and their subsequent deposition, including in-plume and in-cloud interactions of SO_2 and NO_X with volatile organic carbons, ozone, and primary particulates. Develop better understanding of conversion rate of gaseous precursors to secondary particulates. Assess the current "rule-of-thumb" that 10% of the SO_2 and 5% of the NO_X emitted from anthropogenic sources is eventually converted to a sulfate or nitrate fine particulate.

7. Apply non-destructive analytical techniques to characterize particulate matter.

8. Establish a $PM_{2.5}$ "super site" to test and evaluate new equipment, collection methods, sample preparation and storage procedures, filter media, etc. The site would be equipped with several different samplers designed to collect specific fine particulate components.

9. Assess the impact of the burning western coal (e.g., Powder River Basin) in power plants

located in the East and Midwest on primary particulate emissions and ambient fine particulate concentrations.

10. Better characterization of fine particulate emissions from anthropogenic sources and laboratory simulation of in-plume/in-cloud fine particulate formation and behavior. Also improve VOC and ammonia emission inventories.

11. Evaluate $sulfur^{32}/sulfur^{34}$ isotopes as tracers for fine particulate emissions from coal-fired boilers. Develop other tracer techniques.

12. Develop improved primary and secondary fine particulate control emission factors for anthropogenic sources.

13. Assess the impact of NO_X control technology such as selective and non-selective catalytic reduction on the emission of NH_3 from coal-fired utility boilers.

14. Ensure that Federal support for $PM_{2.5}$ research be coordinated and leveraged with other public- and private-sector funding to maximize return on investment.

15. Identify and include in any source apportionment studies those fine particulate constituents that are suspected of having human-health impacts.

16. Establish and maintain a wind profiling network in concert with other $PM_{2.5}$ monitoring networks/sites in order to develop more accurate and detailed wind fields for improved source apportioning. Collaborate where possible with the National Weather Service.

17. Coordinate $PM_{2.5}$ and ozone monitoring.

18. Increase sampling frequency at fine particulate monitoring sites.

19. Develop/improve accuracy of continuous particulate emission monitors for application at emissions sources and receptor sites.

20. Develop/improve source emission "fingerprints" that could be used to identify sources contributing to fine particulate matter collected at a receptor site.

21. Establish additional receptor monitoring sites, particularly near key emission sources to better understand local (short-range) transport and deposition phenomena.

22. Develop and apply uniform QA/AC procedures for all fine particulate source and receptor sampling and analytical methods.

IV. Ranking of Identified Research Needs and Recommendations

An attempt was made to get a sense of the relative priority of the twenty-two research needs and recommendations that were identified by the *Workshop* participants. That is, given existing funding limitations for fine-particulate research, it is important that any additional work address the most significant needs. This was accomplished by asking the participants to select what they considered to be the top three needs/recommendations. It should be noted that not all of the participants voted. The results of the ranking are summarized in Table 1. The number in the "Need" column relates to the twenty-two research needs/recommendations identified in Section III.

Table 1 - Relative Ranking of Identified Research Needs and Recommendations

Need	Rank	No. of Top 3 Votes	Need	Rank	No. of Top 3 Votes	Need	Rank	No. of Top 3 Votes
1.	8 (tie)	4	9.	9 (tie)	2	17.	5 (tie)	8
2.	4	9	10.	1	16	18.	9 (tie)	2
3.	6 (tie)	6	11.	10 (tie)	1	19.	10 (tie)	1
4.	8 (tie)	4	12.	8 (tie)	4	20.	10 (tie)	1
5.	6 (tie)	6	13.	10 (tie)	1	21.	10 (tie)	1
6.	3	10	14.	5 (tie)	8	22.	7	5
7.	6 (tie)	6	15.	10 (tie)	1			
8.	2	15	16.	10 (tie)	1			

V. Summary

The *$PM_{2.5}$ Sampling and Analysis Workshop* brought into focus potential research that could lead to further closure on the relationship between fine particulate matter and anthropogenic emission sources. Using Table 1 as a gauge of the relative importance of each of the identified research needs and recommendations, emphasis was placed on improving our understanding of the formation, transport, and deposition of primary and secondary fine particulates. This would include field study of in-plume and in-cloud chemistry, coupled with laboratory simulations of gaseous and particulate species interactions. Another critical research need concerned the measurement and characterization of the organic-carbon component of fine particulates. The *Workshop* participants also felt that establishing a $PM_{2.5}$ monitoring "super site" would provide an opportunity to develop, test, and

evaluate methods and procedures for collecting, handling, and analyzing (i.e., speciating) fine particulate samples. Further, a common theme throughout the discussions was that at any additional ambient fine particulate research must be well planned and coordinated among all stakeholders.

The results of the *$PM_{2.5}$ Sampling and Analysis Workshop* will serve to guide FETC in developing a research program to provide additional insight into the impact of coal-based power generation on ambient fine particulate concentrations. It is crucial this program be built upon close coordination and partnership with other public- and private-sector organizations involved in $PM_{2.5}$ research to ensure maximum leveraging of limited resources. It is anticipated that the results of such a coordinated effort will help to ensure that the "best possible science" will be brought to bear in any future regulatory debate concerning ambient fine particulates and emission sources.

Workshop Agenda

8:00 am - 8:30 am	**Registration**
8:30 am - 8:40 am	**Welcome** Dr. Ralph Carabetta Deputy Director, Federal Energy Technology Center
8:40 am - 9:00 am	**Workshop Agenda/Purpose** Mr. Thomas Feeley Federal Energy Technology Center
9:00 am - 9:30 am	***Trends in Sulfate and Nitrate Emissions in the Eastern U.S.*** Dr. Thomas Cahill University of California at Davis
9:30 am - 10:00 am	***Going Beyond Regulatory-Based Sampling*** Mr. James Homolya U.S. Environmental Protection Agency
10:00 am - 10:15 am	**Break**
10:15 am - 10:45 am	***$PM_{2.5}$ Measurement Methods and Implementation*** Dr. Judith Chow Desert Research Institute
10:45 am - 11:15 am	***EPRI Perspective on $PM_{2.5}$ Data Needs*** Dr. Pradeep Saxena Electric Power Research Institute
11:15 am - 11:45 am	***Source Apportionment and Network Design*** Dr. John Watson Desert Research Institute
11:45 am - 12:45 pm	**Lunch**
12:45 pm - 1:15 pm	***$PM_{2.5}$ Monitoring: Issues and Objectives*** Dr. Fred Lipfert Brookhaven National Laboratory
1:15 pm - 1:45 pm	***CONSOL s Perspective on $PM_{2.5}$ Monitoring*** Dr. Robert Statnick

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1:45 pm - 2:00 pm	**Break**
2:00 pm - 4:15 pm	**Open Discussion** Leader: Thomas Feeley, FETC Facilitator: Diane Manilla, FETC **Topic:** ***Research Needs and Opportunities: Defining a DOE/FETC Role in $PM_{2.5}$ Monitoring and Analysis***
4:15 pm - 4:30 pm	**Wrap-up**
4:30 pm	**Adjourn**