THE STEUBENVILLE COMPREHENSIVE AIR MONITORING PROGRAM (SCAMP):INITIAL AMBIENT AIR RESULTS

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ABSTRACT

The Steubenville Comprehensive Air Monitoring Program (SCAMP) is a comprehensive ambient air-monitoring program that was begun in the summer of 2000. CONSOL Energy R&D, the Harvard School of Public Health, Ohio University, Wheeling Jesuit University, Franciscan University of Steubenville, and St. Vincent College have formed a team to conduct the multi-year ambient air monitoring program that will clarify the uncertainties in the current understanding of fine particulate matter ($PM_{2.5}$) concentration and exposure.

An urban ambient air sampling "super site" is located in Steubenville, Ohio. Additional fine particle samples are collected at four sites surrounding Steubenville. Additionally, indoor concentrations and personal exposures to particles, NO_2, SO_2, and O_3, are measured for volunteer elderly and child subjects. The chemical constituents of the outdoor and indoor particles are being characterized.

SCAMP is funded by the U.S. Department of Energy, the Ohio Coal Development Office, the Electric Power Research Institute, the American Petroleum Institute, the National Mining Association, the American Iron and Steel Institute, Edison Electric Institute, and CONSOL Energy Inc.

INTRODUCTION

The Steubenville Comprehensive Air Monitoring Program (SCAMP) is a multi-year ambient air monitoring program focused on the study of fine particulate matter concentration, composition, and exposure. Fine particulate matter ($PM_{2.5}$) consists of airborne particles having aerodynamic diameters of 2.5 μm or less. It differs from coarse particulate matter, which includes particle diameters between 2.5 and 10 μm. PM_{10} includes both fine and coarse particulate matter. Particulate matter can be emitted directly into the atmosphere (primary sources) or formed in the atmosphere from the reaction of gaseous precursors (secondary sources).

Recent concerns about $PM_{2.5}$ have arisen from the findings of several epidemiological studies that discovered a relationship between increased $PM_{2.5}$ concentrations and adverse health effects. In response to these findings, the United States Environmental Protection Agency announced a new standard for ambient air $PM_{2.5}$ concentration in July 1997. The standard sets an annual limit of 15 $\mu g/m^3$ (averaged over three years) and a 24-hour limit of 65 $\mu g/m^3$ (98^{th} percentile, averaged over three years). However, prior to implementing the new EPA standard, further research is required to resolve several important uncertainties regarding $PM_{2.5}$. First, since the standard is based on data collected at a centrally located outdoor monitoring site, it is important to determine whether these data accurately indicate personal exposure to $PM_{2.5}$. In addition, there is uncertainty as to whether the observed health effects are caused by the total $PM_{2.5}$ concentration, which is regulated by the EPA standard, or rather by some particular chemical component of the $PM_{2.5}$ or even by a co-pollutant. Finally, the mechanisms responsible for causing elevated levels of $PM_{2.5}$ still are not fully understood.

SCAMP was launched in May 2000 to gather data that will help answer some of these questions. The program includes two major components. One involves sampling $PM_{2.5}$ and co-pollutants in the personal breathing space and homes of children and cardiovascular-diseased patients. The other involves sampling $PM_{2.5}$ and co-pollutants outside of the participants' homes, at a central urban site in Steubenville, Ohio, and at four remote outdoor sites located at the compass points about the central site. These data are being used to determine the relationships between indoor, outdoor, and personal $PM_{2.5}$ concentrations and compositions. Furthermore, the effects of location, time, co-pollutant concentration, and weather conditions on $PM_{2.5}$ concentration and composition are being studied. The overall objective of SCAMP is to provide a scientifically sound, comprehensive database for use in future epidemiological and transport studies and in the development of fine particle compliance programs.

A research team comprised of CONSOL Energy R&D, the Harvard School of Public Health, Franciscan University of Steubenville, Ohio University, Wheeling Jesuit University, and St. Vincent's College is conducting SCAMP. Funding for the program is provided by the U.S. Department of Energy, the Ohio Coal Development Office, the Electric Power Research Institute, the American Petroleum Institute, the American Iron and Steel Institute, the National Mining Association, the Edison Electric Institute, the National Institute of Environmental Health Services, the U.S. Environmental Protection Agency, and CONSOL Energy Inc.

EXPERIMENTAL

There are two components to the program - an indoor and personal sampling program and an outdoor sampling program. In the indoor and personal air component, which is led by the Harvard School of Public Health, personal exposure to particulate matter and gaseous species is being measured and characterized for two groups identified by EPA as being at risk for health effects from fine particles. These groups are children and cardiovascular patients. While the personal air sampling is being performed, samples are taken of the air inside of the participants' homes and immediately outside of their homes; the latter comprises a component of the outdoor sampling program.

In the remainder of the outdoor air component, which is led by CONSOL R&D, the ambient outdoor air in the area of these homes is being characterized. This includes an urban central sampling site in Steubenville, Ohio, and four satellite sites surrounding Steubenville.

This paper reports on data collected at the Steubenville central site and at the four remote satellite sites between May 13 and December 31, 2000. Twenty-four-hour average $PM_{2.5}$ and PM_{10} concentrations were measured each day using Federal Reference Method (FRM) samplers to collect PM samples on Teflon filters. These samples were analyzed every fourth day to determine their ammonium, sulfate, nitrate, and chloride contents. In addition to the FRM samples, $PM_{2.5}$ concentration was measured continuously using a tapered element oscillating microbalance (TEOM). Gaseous co-pollutant (SO_2, $NO/NO_2/NO_x$, CO, O_3) concentrations were monitored continuously using Federal Reference Method or Federal Equivalent Method analyzers. Meteorological data were monitored continuously from a 10-meter weather tower. Pollen and mold spores were collected daily using a Burkard pollen and mold spore trap. At each of the four remote sites, which were located to the north near New Manchester, West Virginia, to the west in Hopedale, Ohio, to the south in Wheeling, West Virginia, and to the east in Latrobe, Pennsylvania, $PM_{2.5}$ concentration was measured daily using the federal reference method. The ammonium, sulfate, nitrate, and chloride composition of the remote site samples was determined every fourth day. The ammonium, sulfate, nitrate, and chloride composition was determined by leaching the PM collected on the Teflon filters using DI water and using ion chromatography to determine the percentage of ammonium, sulfate, nitrate, and chloride contents of the leachate.

RESULTS AND DISCUSSION

Daily average $PM_{2.5}$ concentrations at each of the five sites exhibited a high degree of day-to-day variability, with concentrations changing by 20 $\mu g/m^3$ or more from one day to the next in many instances (Figure 1). The average $PM_{2.5}$ concentration for May 13 to December 31, 2000, in Steubenville was 20.7 $\mu g/m^3$.

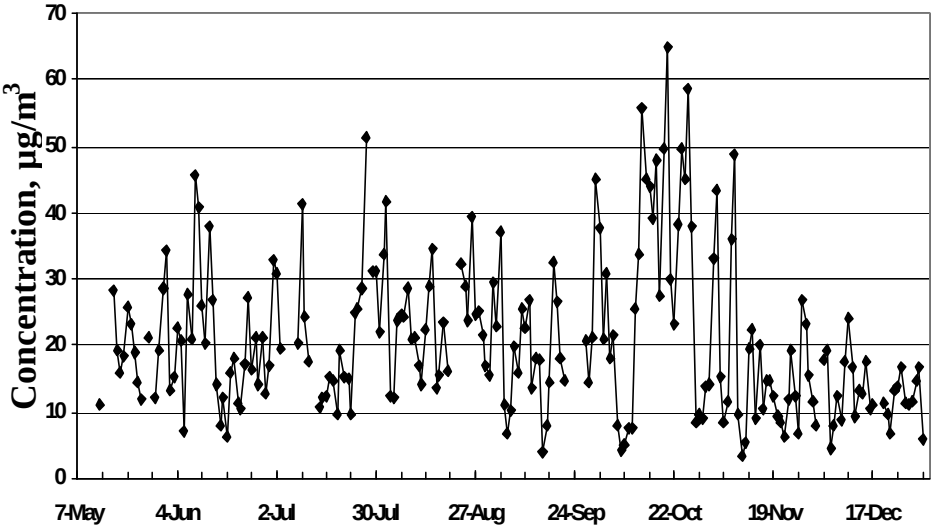

Figure 1. Steubenville $PM_{2.5}$ concentration, May 13 to December 31, 2000.

The average $PM_{2.5}$ concentrations for the same time period at the north, south, east, and west satellite sites were 14.9, 18.9, 16.9, and 14.4 $\mu g/m^3$, respectively. $PM_{2.5}$ concentrations at each of the four satellite sites were positively correlated with the $PM_{2.5}$ concentration at Steubenville, with R^2 values ranging from 0.31 for the eastern site to 0.67 for the west site. Parity plots for the satellite site $PM_{2.5}$ concentrations vs. the Steubenville $PM_{2.5}$ concentrations are shown in Figure 2.

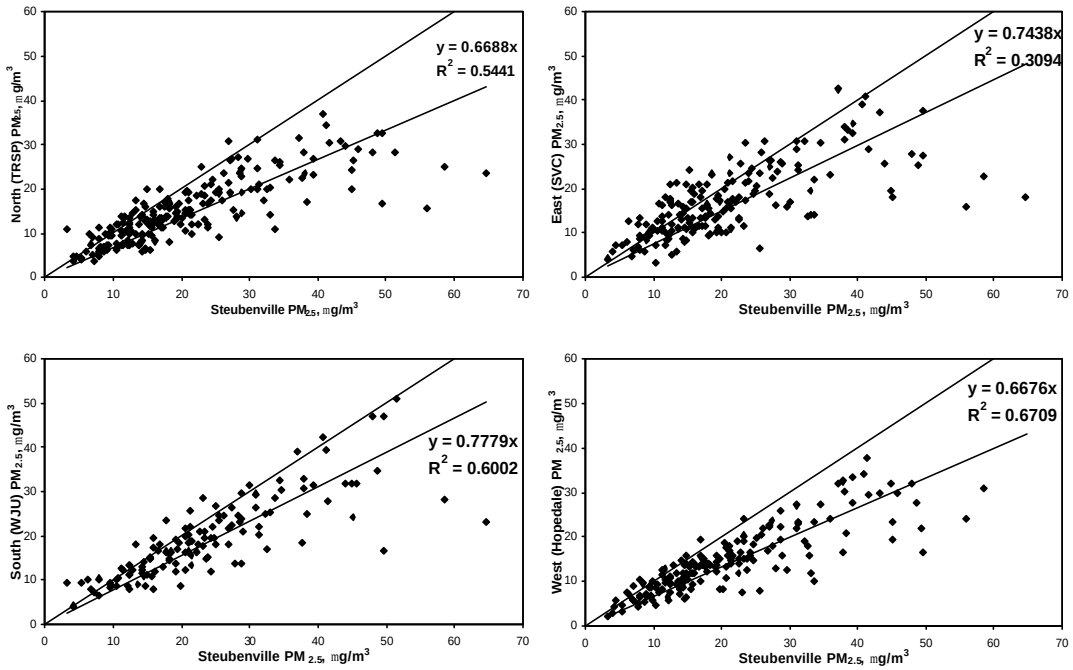

Figure 2. Parity plots showing the $PM_{2.5}$ concentration at the satellite sites vs. the $PM_{2.5}$ concentration at Steubenville, May 13 to December 31, 2000.

On average, the $PM_{2.5}$ mass at the central site was composed of 29% (w/w) sulfate, 12% ammonium, less than 10% nitrate, and less than 1% chloride. The remaining 50% by difference was likely comprised of elemental and organic carbon and crustal material. Additional analyses will be performed to determine the contributions of these components to the $PM_{2.5}$ mass. The average compositions at the four remote sites are listed in Table 1.

Table 1. Average composition (wt %) of $PM_{2.5}$ samples collected May 13 to December 31, 2000.

	Ammonium	Sulfate	Nitrate	Chloride	Other (by difference)
Steubenville	12	29	8.8	0.9	50
North (TRSP)	12	30	5.9	0.5	52
South (WJU)	14	37	2.0	0.4	47
East (SVC)	11	26	7.1	0.6	55
West (Hopedale)	12	31	8.2	0.6	48

The average PM_{10} concentration measured at Steubenville for May 13 to December 31, 2000, was 27.7 $\mu g/m^3$; these data also showed a high degree of day-to-day variability similar to that observed for the $PM_{2.5}$ data, with concentrations changing by 20 $\mu g/m^3$ or more from one day to the next in many instances. The daily PM_{10} and $PM_{2.5}$ concentrations at Steubenville were well correlated ($R^2 = 0.84$) (Figure 3).

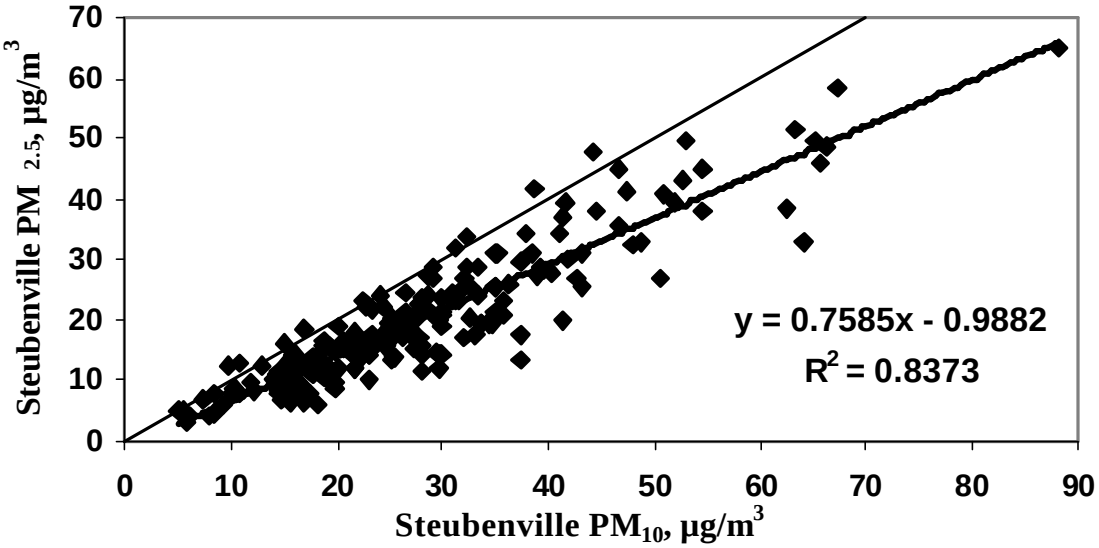

Figure 3. Steubenville $PM_{2.5}$ vs. PM_{10} concentrations, May 13 to December 31, 2000.

A single variate regression analysis of $PM_{2.5}$ concentration with the gaseous pollutant concentrations did not show a high degree of correlation; the R^2 values for CO, SO_2, NO, and O_3 were 0.21, 0.22, 0.30, and 0.01, respectively, for May 13 to December 31, 2000. Likewise, no significant correlations were found between the Steubenville daily average $PM_{2.5}$ concentration and daily average weather conditions, pollen, or mold spores for the period May 13 to December 31, 2000. Multivariate regression analyses are being performed for all of the measured variables with $PM_{2.5}$. Although not completed yet, the preliminary results indicate that the multivariate analysis will identify several statistically significant variables that correlate with the $PM_{2.5}$ concentrations.

CONCLUSIONS

- Daily FRM sampling reveals high day-to-day variability in $PM_{2.5}$ and PM_{10} concentrations
- For May through December 2000, 3 of the 5 sites averaged greater than 15 mg/m^3 for $PM_{2.5}$; in Steubenville the average was 20.7 mg/m^3
- The $PM_{2.5}$ concentrations at all five sites were correlated
- The $PM_{2.5}$ and PM_{10} concentrations in Steubenville were correlated

- For May through December 2000, single variate regression analysis revealed no strong correlation between $PM_{2.5}$ and gaseous pollutant concentrations, weather data, or pollen and mold spore concentrations

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