Southern Fine Particulate Monitoring Project

Second Quarterly Progress Report

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U.S. DEPARTMENT OF ENERGY
National Energy Technology Laboratory
P. O. Box 10940
626 Cochran's Mill Road
Pittsburgh, PA 15236-0940

Attn: William Aljoe

Prepared by

SOUTHERN RESEARCH INSTITUTE
2000 Ninth Avenue South
P. O. Box 55305
Birmingham, AL 35255-5305

Principal Investigator: Ashley D. Williamson, (205) 581-2445

This is the second quarterly progress report of the “Southern Fine Particulate Monitoring Project”, funded by the U.S. Department of Energy’s National Energy Technology Laboratory under DOE Cooperative Agreement No. DE-FC26-00NT40770 to Southern Research Institute (SRI). In this two year project SRI will conduct detailed studies of ambient fine particulate matter in the Birmingham, AL metropolitan area. Project objectives include:

- \$ Augment existing measurements of primary and secondary aerosols at an established urban southeastern monitoring site
- \$ Make a detailed database of near-continuous measurements of the time variation of fine particulate mass, composition, and key properties (including particle size distribution)
- \$ Apply the measurements to source attribution, time/transport properties of fine PM, and implications for management strategies for PM_{2.5}
- \$ Validate and compare key measurement methods used in this study for applicability within other PM_{2.5} research by DOE-FE, EPA, NARSTO, and others.

Summary of Technical Progress

During the second project quarter, installation of a partial set of instruments at the monitoring station was accomplished and monitoring was initiated. Details include:

- \$ Installation of TEOM, particle sizing package at site in SEARCH shelter
- \$ Start of onsite monitoring in February, 2001
- \$ Specifications developed for additional shelter for monitoring station for order in April
- \$ Licensing arrangements completed for particulate sulfate monitor of Harvard design
- \$ Coordination with Eastern Supersite program for July measurement intensive

Plans for Next Quarter

- \$ Continue onsite monitoring with continuous monitoring instruments
- \$ Continue analysis of initial continuous particulate data
- \$ Installation of new shelter at monitoring station and relocation of instruments from SEARCH shelter (June, 2001)
- \$ Assembly and checkout of particulate sulfate monitor of Harvard design; comparative measurements with R&P 8400S
- \$ Preparation for July measurement intensive with Eastern Supersite program

Problems and Assessment for Future Progress

As reported last quarter, two logistical problems have caused schedule delays and potential data loss. First, additional shelter space not anticipated in initial planning was needed to accommodate all anticipated instruments for the project. In order to minimize data loss, initial instruments were installed in the SEARCH shelter while an additional shelter is acquired and installed to accommodate the full instrument package for this project. Specifications for this new shelter were developed, and the order was initiated pending final approvals. Anticipated delivery will be early June, allowing instruments to be redistributed from the SEARCH shelter. Second, some delays had occurred in availability of the new R&P 8400S continuous sulfate analyzer. Current estimated delivery in early May, 2001. In order to assure this key measurement, we have made arrangements to construct a sulfate monitor on the design of Allen (Harvard School of

Public Health), which may have superior time resolution.

As described previously, the impact of these delays appears to be limited to loss of some of the anticipated measurements for one to three months. Some revision of equipment items was necessary, but will not result in overall added cost to the project.

Detailed Progress Narrative

During the second project quarter, a partial set of instruments was installed at the monitoring station and monitoring was initiated, while preparations continued for acquisition of expanded shelter space and installation of additional instruments. These activities will be described in detail below.

Shelter deployment arrangements

As reported last quarter, it became evident after project initiation that additional shelter space not anticipated in initial planning was needed to accommodate all anticipated instruments for the project. In order to minimize data loss, the following plan was discussed at the kickoff meeting and agreed to by all parties. First, initial instruments in the SRI project package would be installed in the EPRI SEARCH shelter while an additional shelter is acquired and installed to accommodate the full instrument package for the project. These initial instruments were to include the PM_{2.5} TEOM, the particle sizing monitors (TSI Models 3320 APS and 3934 SMPS), and possibly the nephelometer (Radiance Research Model 903). As described below, all but the nephelometer were installed in the SEARCH shelter in mid February, 2001. In the interim, plans for a new shelter were developed and submitted to the county for review. Following County and DOE approval, the shelter was ordered. After this new shelter is installed, instruments will be redistributed from the SEARCH shelter. Certain coordinated measurements of the two projects may be housed in the same shelter. Infrastructure changes (power, phone lines, changes to platform and fencing) will be coordinated with Health Department and use subcontractors approved for the site. Anticipated delivery will be early June, allowing instruments to be in place for the July intensive measurement program.

Assembly of instrumentation and Data collection

Near the end of the first quarter the initial instrument package (the PM_{2.5} TEOM, the APS and SMPS) was assembled and underwent operational checkout on the SRI campus. On February 12-13, 2001, the package of instruments was installed at the North Birmingham site. The instrument package ran continuously for the duration of the quarter. Data completeness for the second project quarter for the PM_{2.5} TEOM, APS, and SMPS was respectively 82%, 80%, and 65% of post-installation time due to several planned and unanticipated data gaps. A power outage at the site resulted in lost data for the entire instrument package the weekend of February 16 through February 18. The PM_{2.5} TEOM zero baseline was tested at the North Birmingham site using an inlet filter from February 26 to March 2. The SMPS was brought to SRI from March 29 through April 5 for routine calibration, cleaning, and refurbishment. The APS lost data early in the quarter due to computer failure. A new computer was installed at the site on March 20 to resolve the computer malfunctions.

Acquisition and installation of other instruments has continued during the current quarter. The

Radiance Research Nephelometer arrived at SRI on March 5, 2001 and underwent operational checkout. The Nephelometer was deployed at the North Birmingham site on April 13, shortly after the end of the second project quarter. As mentioned in the first quarterly report, some delays had occurred in availability of the new R&P 8400S continuous sulfate analyzer. Current estimated delivery is quoted to be early May, 2001. In order to assure this key measurement, we made arrangements during the quarter to construct a sulfate monitor on the design of Allen (Harvard School of Public Health), which uses a reactor to reduce particulate sulfate followed by a commercial SO₂ monitor. This system may have some advantages over the 8400S design if efficiency and interference levels are acceptable; one key factor is the probability of superior time resolution.

Results/ Data analysis

Continuous particulate measurements during the quarter sampling period are indicated in Figures 1 - 3. The figures contain the PM_{2.5} mass concentrations measured by the TEOM, and integrated size fractions measured by the particle sizing devices. Included are total (submicron) mass concentration as derived from the SMPS measurements, and integrated mass concentrations in the 1 - 2.5 and 2.5 - 10 µm size ranges from the APS measurement data. Figures 1 - 3 display the same four variables over three sequential time periods ranging from February 13 through March 31. The simplified and shorter time spans for each figure allows the trends of the data to be more visible. Each measurement is presented on its own sample schedule, which varied among instruments: The SMPS scans were repeated over 5 minute intervals; the APS samples accumulated at one minute intervals after February 26. TEOM data are reported on one minute intervals, though the averaging time of the instrument is approximately 5 minutes. For more meaningful comparison of the size-specific concentration data, hourly averages of each measurement were computed and presented on Figures 4 -6. In addition, hourly average PM₁₀ concentration data were obtained from the Jefferson County Health Department as measured by the county TEOM monitor at the site.

General features of the data in Figures 1 - 6 are typical of data from other urban monitoring sites. The concentrations follow broad daily time patterns interrupted by short-term "spikes" which are probably attributable to traffic patterns and plumes of local emission sources. The size-specific measurements indicate that the measured PM_{2.5} consists primarily of particles in the submicron size range, with a smaller component in 1-2.5 range. PM_{2.5} at this site is roughly 50% of PM₁₀, indicating that the coarse fraction mass is on average comparable to the PM_{2.5} fraction.

Figure 7 compares PM_{2.5} as measured by the TEOM and as calculated from integrated size fraction data over entire measurement period. The calculated PM_{2.5} values consist of the sums of the SMPS and APS components shown. It is clear that, while the ratio of the submicron and 1-2.5 fractions may vary somewhat, their sum correlates well with and is generally quite close to the TEOM values. This is more apparent from pairwise comparison and regression of these hourly average time points, as shown in Figure 8. There is a generally linear relationship and good correspondence of calculated and measured PM_{2.5} values at both high and low concentrations. The integrated submicron mass concentration containing roughly 75% of the total, also correlates well with the TEOM values. The minor fraction above 1 µm aerodynamic diameter is somewhat more variable, suggesting that the source of this size fraction is at least in part independent of the source of submicron particles.

Figure 1: Continuous fine particle data from the North Birmingham site during the period February 13-28, 2001

Figure 2: Continuous fine particle data from the North Birmingham site during the period March 1-14, 2001

Figure 3: Continuous fine particle data from the North Birmingham site during the period March 15-31, 2001

Figure 4: Hourly average concentrations for size fractions shown in Figure 1. Also included are PM₁₀ concentrations reported by Jefferson County.

Figure 5: Hourly average concentrations for size fractions shown in Figure 2. Also included are PM₁₀ TEOM concentrations reported by Jefferson County.

Figure 6: Hourly average concentrations for size fractions shown in Figure 3. Also included are PM₁₀ TEOM concentrations reported by Jefferson County.

Figure 7: TEOM PM_{2.5} concentrations and size fractions measured by APS and SMPS during quarter

Figure 8: Comparison of TEOM PM_{2.5} concentrations and size fractions measured by APS and SMPS during quarter

A similar comparison may be performed for the coarse particle fraction, represented by the difference of the PM_{10} and $PM_{2.5}$ TEOM measurements. Figure 9 shows calculated PM coarse and the comparable integrated APS 2.5-10 size fraction over the available sampling period. As can be seen from Figure 9 and the pairwise comparison plot in Figure 10, the two measures of the coarse PM fraction are generally correlated, but the APS accounts for only about 25% of the mass indicated by the two TEOM measurements. This difference is at least in part attributable to size dependent losses of larger particles in the current APS sampling inlet lines.

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A significant benefit of particle size data is the potential to separate the impacts of different sources of particulate matter with high time resolution. Two examples of this are shown in Figures 11-14. Figure 11 is an expanded plot of TEOM and APS data taken on the morning of March 30, 2001. During this period, moderate concentrations ($5-20 \mu\text{g}/\text{m}^3$) of $PM_{2.5}$ were observed; except for two elevated hourly readings, the PM_{10} TEOM results were comparable during the period. For most of the period the APS concentrations were lower, indicating the submicron portion of the $PM_{2.5}$ to be dominant as is generally the case; but several brief excursions of both APS size fractions are evident. The 1 minute time resolution of the APS data allows these excursions to be resolved and size distributions of the added particulate contribution to be separated from the underlying background. For example, the figure shows two events (actually each is a doublet) at 3:06-3:17 and 6:50-7:01. The particle size distributions for these two periods is clearly larger than the underlying background. To extract the event size distributions, the averages of the eleven one minute APS data periods corresponding to each event were calculated, along with corresponding time periods immediately before and after each event. The net event size distribution was computed as the difference between the peak period and the average of the two periods before and after the event. The results of these calculations are shown in Figure 12. The particle size distributions of the two events are clearly different from one another and from that of the underlying background. The first event, with a mode centered near $3 \mu\text{m}$, appears to involve mainly coarse particles with no significant submicron contribution; the second size distribution is broader and clearly extends below $1 \mu\text{m}$. Reducing the averaging period to three minutes, the two peaks comprising event 1 can be resolved, and appear to have measurably different size distributions as well.

Figures 13 and 14 provide an example covering a longer and more complex period. Figure 13 depicts data collected on February 25-6. During a 12 hour period from about noon on February 25, hourly PM_{10} concentrations from the Jefferson County TEOM remained over $125 \mu\text{g}/\text{m}^3$, with two broad peaks at 2 and 10 PM near $180 \mu\text{g}/\text{m}^3$. During this event the particle size showed considerable evolution, as indicated by the measurements in the figure. The predominant coarse fraction, as indicated by the APS coarse size fraction shown, peaks at the beginning of the event and declines slowly through the day. The submicron fraction detected by the SMPS shows the reverse trend, increasing during the event. The intermediate APS fraction remains roughly

Figure 9: Coarse ($\text{PM}_{10} - \text{PM}_{2.5}$) particle concentrations calculated from TEOMs and the corresponding APS size fraction measured during quarter.

Figure 10: Comparison of coarse ($\text{PM}_{10} - \text{PM}_{2.5}$) particle concentrations calculated from TEOMs and the corresponding APS size fraction measured during quarter.

Figure 11: TEOM PM2.5 (1 minute), TEOM PM10 (Jefferson County, 1 hour), and two APS size fractions (1 minute) data for March 30, 2001. Two events signified by peaks in mass concentrations are identified around 3:00 and 7:00 AM, respectively. The relative magnitudes of the APS size fractions changed from event 1 to event 2.

Figure 12: APS Size distributions (differential mass concentrations, $dM/d\text{Log}D$) from 11-minute averages associated with events designated in Figure 11. Particle size of event 2 was significantly smaller than that of event 1.

Figure 13: TEOM PM2.5 (1 minute), SMPS (5 minute), and two APS size fractions (5 minute) data for February 25-26, 2001. The relative magnitudes of these size fractions varied substantially. Five time periods selected for inspection (in Figure 14) of size distributions are designated.

Figure 14: Combined SMPS/APS Size distributions (differential mass concentrations, $dM/d \log D$) averaged over time periods indicated in Figure 13.

constant. Five periods during the event are noted on the figure and selected for further size analysis. Period 1 (3-5 PM) corresponds to the initial period of low submicron concentration. Period 2 (6:30-8:30 PM) falls after the first abrupt rise in the submicron concentration around 6PM. Period 3 (9:30-10:00 PM) captures the peak of the second abrupt rise in the submicron concentration, and periods 4 and 5 (11:30PM -12:30 AM and 1-2 AM) cover the remaining period before the abrupt drop in all size ranges after 2:15 AM on February 26. Figure 14 indicates average size distributions measured by the two instruments during the five periods described above. The APS data indicate a single major coarse mode centered near 3 μm , varying less than 20% in concentration over the five periods. The SMPS relative size spectrum also changes very little during the sampling period even though the submicron concentration increases almost an order of magnitude as the period progresses. The SMPS size spectrum is quite broad over the 0.1 - 1 μm region, with the mean size increasing slowly through the period. Only during the peak Period 3 is there a significant change in the size spectrum, with the addition of a strong submicron mode above 0.5 μm . The particle size information can allow study of the separate evolution of the coarse and fine portions of the size spectrum.