NETWORK OPERATION OF THE PM$_{10-2.5}$ DIFFERENCE METHOD

An Independent Study Conducted by the Jefferson County Department of Health in Birmingham, Al During 2003 and 2004

by

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### 1.0 Introduction

During 2003 through 2005, the U.S. EPA’s Office of Research and Development conducted a series of comprehensive field studies to evaluate ambient samplers designed to measure the coarse fraction of PM$_{10}$ (i.e., PM$_{10-2.5}$). In order to determine the inherent performance of the samplers, these multi-site evaluations were conducted under very carefully controlled conditions using three primary initiatives. First, the samplers’ manufacturers were involved in all phases of the study to ensure that their respective samplers were functional; contained the latest software, hardware, and firmware revisions; and that collected sampler data was being properly downloaded, reduced, and interpreted. Second, strict operating protocols were developed for each sampler and the samplers were carefully calibrated immediately prior to each study. During the course of each 30-day field campaign, three performance audits were conducted to ensure that the samplers were holding their calibration settings within the required specifications. If a given sampler failed the performance audit, it was leak checked and recalibrated before additional tests were conducted. Third, experienced field and analytical personnel were involved in the study during all phases of the study. As a result of these initiatives, the sampler performance data obtained during these field campaigns might be viewed as “best case” and not necessarily representative of those which might be obtained by State, Local, or Tribal agencies under “real world” conditions where resources might be more limited.

In addition, the sampling sites selected for EPA’s field studies were intended to evaluate the samplers in areas of relatively high PM$_{10-2.5}$ concentrations to ensure that the samplers were capable of providing accurate measurements over a wide range of concentrations. Also, coarse mode particles tended to dominate the PM$_{10}$ aerosols at these sites thus producing relatively low PM$_{2.5}$/PM$_{10}$ ratios. In conjunction with the high PM$_{10-2.5}$ concentrations inherent to these sampling sites, the low PM$_{2.5}$/PM$_{10}$ ratios would tend to make it unlikely that zero or negative PM$_{10-2.5}$ measurements would occur. The ability of the difference method to consistently produce positive PM$_{10-2.5}$ concentration measurements, therefore, could not be adequately demonstrated during these studies. The large filter mass gains inherent to these field studies also made it difficult to assess the difference method’s precision at low PM$_{10-2.5}$ concentrations.

To address these issues, EPA contacted the Jefferson County Department of Health (JCDH) in 2002 and requested that PM$_{10-2.5}$ difference method samplers (i.e., collocated designated PM$_{2.5}$ and designated low-flow PM$_{10}$) be independently set up and operated as part of their normal operating network. In particular, JCDH was asked to document the frequency of any negative PM$_{10-2.5}$ concentrations and report the conditions under which they occurred. Within available resources, JCDH was also asked to operate multiple difference method pairs in order to determine the precision of the difference method under typical network operating conditions. In
response to this request, JCDH evaluated difference method samplers at 7 separate network sites during 2003 and 2004. During 2004, the precision of the difference method was evaluated every 6th day at the Leeds site located in eastern Jefferson County.

This report provides a brief summary of test results obtained by JCDH during these independent efforts.

2.0 Methods

Jefferson County is located in the Birmingham-Hoover metropolitan area and has a population of approximately 660,000. Figure 1 shows a map of Jefferson County along with the location of the 7 sites selected for the 2003 and 2004 evaluation of the PM$_{10-2.5}$ difference method. The North Birmingham and Wylam sites are classified as urban neighborhood sites and are heavily impacted by a variety of nearby industries as well as by nearby interstate traffic. Located south of Birmingham, the Hoover site is classified as a suburban site and is impacted primarily by mobile emissions from HW 31 and I65. The remaining 4 sites (Providence, McAdory, Pinson, and Corner) are located 15 to 25 miles away from Birmingham and are classified as rural background sites and are generally not impacted by nearby industrial sources.

At each of the 7 sites, designated PM$_{2.5}$ samplers (BGI PQ200) were operated concurrently with designated low-flow PM$_{10}$ samplers (BGI PQ200 with their PM$_{2.5}$ fractionators replaced by a downtube). All samplers involved in the study were operated for 24 hours on a midnight to midnight schedule. The 47 mm Teflon filters used for the designated PM$_{2.5}$ and PM$_{10}$ samplers were conditioned and weighed at the JCDH’s weighing facility in Birmingham. For each sampling event, the PM$_{10-2.5}$ concentration was calculated as the numerical difference between the measured PM$_{10}$ concentration and the measured PM$_{2.5}$ concentration.

The difference method evaluation began at the 7 sites on January 1, 2003 and was operated on a one in 6 day schedule (with the exception of the first test of each month when field blank tests were performed) during 2003 and 2004. To assess the precision of the PM$_{10-2.5}$ difference method at low PM$_{10-2.5}$ concentrations, a collocated pair of difference method samplers began operating at the Leeds site (see Figure 1) on January 4, 2004 using the same operating and analysis procedures as those of the other 7 sites.

3.0 Results

3.1 Year 2003

Table 1 summarizes the mean PM$_{2.5}$, PM$_{10-2.5}$, and PM$_{10}$ concentrations measured at the
7 sites during 2003. As a measure of the aerosol size distribution, the mean PM$_{2.5}$/PM$_{10}$ ratio was also calculated for each site.

As expected, due to their proximity to major industrial sources of air pollution, the North Birmingham and Wylam sites had the highest mean PM$_{2.5}$ and PM$_{10}$ concentrations. The North Birmingham site was also characterized by a mean PM$_{2.5}$/PM$_{10}$ ratio of 0.48 indicating that, on average, coarse mode particles slightly dominated the PM$_{10}$ mass concentration. As a result, the North Birmingham site also experienced the highest mean PM$_{10-2.5}$ concentrations.

As indicated in the table, both PM$_{10}$ concentrations and PM$_{10-2.5}$ concentrations decreased with increasing distance from the center of Birmingham. For the Pinson, Corner, and Providence sites, the mean PM$_{2.5}$ concentration was approximately one-third of the mean PM$_{10-2.5}$ measured at the North Birmingham site. For these same sites, however, PM$_{2.5}$ concentrations were approximately 80% of the mean PM$_{2.5}$ concentration measured at the North Birmingham site. These values show that PM$_{2.5}$ aerosols are generally regionally distributed in the Jefferson County area but that high coarse mode particles concentrations are confined primarily to the areas in which they are generated. These test results, therefore, emphasize the importance of collocating PM$_{2.5}$ and PM$_{10}$ monitors when conducting difference method calculations.

Figure 2 shows the 2003 timeline of PM$_{10}$ and PM$_{10-2.5}$ concentrations at the site of lowest mean PM$_{2.5}$ and PM$_{10}$ concentrations, the Providence site. In addition to having the lowest mean PM$_{10-2.5}$ concentrations, the Providence site is also of interest because its PM$_{2.5}$/PM$_{10}$ ratio is approximately the same mean ratio of sampling sites in the continental United States. As indicated in the timeline, very low PM$_{10-2.5}$ concentrations were occasionally observed at the Providence site in 2003. In fact, 24 of the 60 PM$_{10-2.5}$ concentrations (i.e., 40%) were less than 5 µg/m$^3$, with the lowest concentration being 0.6 µg/m$^3$. Despite these relatively low concentrations, no zero or negative PM$_{10-2.5}$ concentrations were measured at the Providence site during the 60 sampling events in 2003.

Inspection of all other 2003 site data in Table 1 revealed that low PM$_{10-2.5}$ concentrations were a fairly frequent occurrence. For all 7 sites, 116 of the 417 sampling events (i.e., 28%) resulted in a calculated PM$_{10-2.5}$ concentrations less than 5 µg/m$^3$. Only one negative PM$_{10-2.5}$ concentration was recorded at any of the 7 sampling sites during the 417 sampling events. This occurred on December 14, 2003 at the Hoover site where measured PM$_{10}$ and PM$_{2.5}$ concentrations for this event were 9.16 µg/m$^3$ and 9.28 µg/m$^3$, respectively. The calculated PM$_{10-2.5}$ for this sampling event, therefore, was only -0.13 µg/m$^3$, and is certainly less than the detection limit of the measurement technique.
3.2 Year 2004

Table 2 summarizes the measurement results obtained at the 7 sampling sites during 2004. A comparison of Table 2 versus that of Table 1 reveals that all mean PM$_{2.5}$, PM$_{10-2.5}$, and PM$_{10}$ concentrations at all sites were less in 2004 than during 2003. Inspection of the site PM$_{2.5}$/PM$_{10}$ ratios reveals that the fine fraction of PM$_{10}$ was slightly higher at all sites in 2004 than during the previous year.

Figure 3 provides a timeline of PM$_{10}$ and PM$_{10-2.5}$ concentrations at the Providence site for 2004. The timeline indicates that the majority of PM$_{10-2.5}$ concentrations were below 10 µg/m$^3$ (84%) and many were below 5 µg/m$^3$ (56%). As in the case of the 2003 data, however, no zero or negative PM$_{10-2.5}$ concentrations were measured at this rural sampling site. Inspection of all site data in Table 2 reveals that 147 of the 411 sampling events resulted in PM$_{10-2.5}$ concentrations less than 5 µg/m$^3$. Despite measured PM$_{10-2.5}$ concentrations as low as 0.3 µg/m$^3$, none of the 411 sampling events resulted in PM$_{10-2.5}$ concentrations which were less than or equal to 0 µg/m$^3$.

3.3 Precision Tests

To measure the precision of the PM$_{10-2.5}$ difference method samplers, collocated pairs of designated PM$_{2.5}$ and PM$_{10}$ samplers were installed and operated at the rural Leeds site from Jan. 4 through Dec. 29, 2004. With the exception of the first test of every month (when field blank tests are performed), the collocated samplers were operated on a one in 6 day schedule. During 2004, this schedule produced 48 valid PM$_{10-2.5}$ data points.

Figure 4 presents a timeline of PM$_{2.5}$ concentrations measured by the two collocated PM$_{2.5}$ samplers. As indicated by the mean coefficient of variation (CV) of 2.2% during these tests, excellent intra-sampler agreement was observed for the PM$_{2.5}$ measurements. CVs ranged from a minimum of 0.0% to a maximum of 7.8%. For the 48 valid sampling events performed in 2004, both PM$_{2.5}$ FRM samplers measured a mean concentration of 15.0 µg/m$^3$.

A timeline of PM$_{10}$ concentrations measured by the two collocated PM$_{10}$ samplers is presented in Figure 5. As in the case of the PM$_{2.5}$ measurements, excellent agreement was observed between the two collocated PM$_{10}$ samplers as evidenced by a mean CV of 2.0%. With the exception of sampling events 19 through 23, where CVs of 6% to 12% were observed, extremely close agreement was observed between the two collocated PM$_{10}$ during all sampling events. For the 48 sampling events, the mean PM$_{10}$ concentrations measured by Sampler 1 and Sampler 2 were 24.0 µg/m$^3$ and 24.4 µg/m$^3$, respectively.

Figure 6 presents a timeline of the PM$_{10-2.5}$ concentrations calculated for the two
difference method pairs (i.e., two sets of PM$_{2.5}$ and PM$_{10}$ FRM samplers). Except during Runs 19-23, where the higher PM$_{10}$ CVs naturally resulted in higher calculated PM$_{10-2.5}$ CV values, the level of agreement among the collocated difference method pairs was generally strong. Including the Run 19 through 23 data, the calculated CV for the PM$_{10-2.5}$ method was 8.1%. The mean PM$_{10-2.5}$ measured by Sampler Pair 1 and Sampler Pair 2 during 2004 were 9.2 µg/m$^3$ and 9.5 µg/m$^3$, respectively. As in the case for results obtained at the other 7 sampling sites during 2004, no zero or negative PM$_{10-2.5}$ concentrations were measured at the Leeds site.

4.0 Summary

During 2003 and 2004, the JCDH conducted PM$_{10-2.5}$ difference method sampling at 7 sites using collocated, designated PM$_{2.5}$ and PM$_{10}$ reference method samplers. The sampling sites included two urban sites (North Birmingham and Wylam) close to industrial sources and the remaining five were designated as either suburban or rural sites. During both 2003 and 2004, PM$_{2.5}$ aerosols were more spatially distributed among the sampling sites than PM$_{10-2.5}$ aerosols. Mean PM$_{2.5}$/PM$_{10-2.5}$ ratios increased with increasing distance from the center of Birmingham. Temporally, mean concentrations of PM$_{2.5}$, PM$_{10-2.5}$, and PM$_{10}$ were less at all sampling sites during 2004 than during 2003.

At the Providence site, mean PM$_{10-2.5}$ during 2003 and 2004 were measured to be 6.0 µg/m$^3$ and 2.9 µg/m$^3$, respectively. Despite the low PM$_{10-2.5}$ concentrations characteristic of this rural site, no zero or negative PM$_{10-2.5}$ values were recorded during the 115 site measurements. For all 7 sites involved in the study, only one zero or negative PM$_{10-2.5}$ concentration (-0.13 µg/m$^3$) was observed during the total 828 measurements made during the two year period.

Collocated reference method pairs were operated at the Leeds site during 2004 in order to determine the precision of the difference method. The intra-sampler precision between the two sets of PM$_{2.5}$ and PM$_{10}$ samplers was excellent as indicated by CVs of 2.2% and 2.0%, respectively. The precision of the PM$_{10-2.5}$ difference method was determined to be 8.1% and mean PM$_{10-2.5}$ concentrations by the two difference method pairs during 48 sampling events was determined to be 9.2 µg/m$^3$ and 9.5%, respectively.

The concentration and size distribution of the ambient aerosol measured during the Birmingham tests would tend to increase the likelihood of the occurrence of negative PM$_{10-2.5}$ measurements using the difference method. Even during a routinely operating network, however, only one negative PM$_{10-2.5}$ was measured during the 1058 total measurements (including the Leeds data). In conjunction with the favorable PM$_{10-2.5}$ precision measured at the Leeds site, these test results indicate that the difference method can be successfully employed in a routine
monitoring network if proper sampling, handling, and analysis procedures are rigorously observed.

Jefferson County’s evaluation of the PM$_{10-2.5}$ difference method continues at each of the 8 sampling sites and data from the first 6 months of 2005 is currently being validated and reviewed. Procurement and installation of new PM$_{2.5}$ and PM$_{4.0}$ FRM samplers is underway and will enable PM$_{10-2.5}$ precision tests to be conducted at all 8 sites beginning Jan. 1, 2006.
Figure 1. Map of Jefferson County, Al showing the locations of the sampling sites involved in the evaluation of the PM$_{10-2.5}$ difference method samplers.
Table 1. Summary of the Mean Site Concentrations Obtained During 2003.

<table>
<thead>
<tr>
<th>Site</th>
<th>PM$_{2.5}$</th>
<th>PM$_{10}$</th>
<th>PM$_{10-2.5}$</th>
<th>PM$<em>{2.5}$/PM$</em>{10}$</th>
<th>Events (Total)</th>
<th>Events PM$_{10-2.5}$ ≤ 0 µg/m$^3$</th>
<th>Events PM$_{10-2.5}$ ≤ 5 µg/m$^3$</th>
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<tbody>
<tr>
<td>North Birmingham</td>
<td>17.3</td>
<td>36.1</td>
<td>18.7</td>
<td>0.48</td>
<td>60</td>
<td>3</td>
<td>0</td>
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<tr>
<td>Wylam</td>
<td>16.4</td>
<td>26.9</td>
<td>10.4</td>
<td>0.61</td>
<td>61</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Hoover</td>
<td>14.2</td>
<td>21.7</td>
<td>7.5</td>
<td>0.66</td>
<td>60</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>McAdory</td>
<td>14.2</td>
<td>23.6</td>
<td>9.3</td>
<td>0.60</td>
<td>60</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Pinson</td>
<td>14.0</td>
<td>21.0</td>
<td>7.0</td>
<td>0.67</td>
<td>57</td>
<td>24</td>
<td>0</td>
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<tr>
<td>Corner</td>
<td>14.4</td>
<td>21.5</td>
<td>7.1</td>
<td>0.67</td>
<td>59</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>Providence</td>
<td>12.6</td>
<td>18.6</td>
<td>6.0</td>
<td>0.67</td>
<td>60</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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<td><strong>116</strong></td>
<td></td>
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</table>
Figure 2. Timeline of PM$_{10}$ and PM$_{10-2.5}$ concentrations measured at the Jefferson County Providence site during 2003.
Table 2. Summary of the Mean Site Concentrations Obtained During 2004.

<table>
<thead>
<tr>
<th>Site</th>
<th>PM$_{2.5}$</th>
<th>PM$_{10}$</th>
<th>PM$_{10-2.5}$</th>
<th>PM$<em>{2.5}$/PM$</em>{10}$</th>
<th>Events (Total)</th>
<th>Events PM$_{10-2.5}$ $\leq$ 5 $\mu$g/m$^3$</th>
<th>Events PM$_{10-2.5}$ $\leq$ 0 $\mu$g/m$^3$</th>
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</thead>
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<tr>
<td>North Birmingham</td>
<td>16.2</td>
<td>30.7</td>
<td>14.5</td>
<td>0.53</td>
<td>58</td>
<td>6</td>
<td>0</td>
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<tr>
<td>Wylam</td>
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<td>20.0</td>
<td>7.6</td>
<td>0.62</td>
<td>61</td>
<td>14</td>
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<td>11.9</td>
<td>17.0</td>
<td>5.1</td>
<td>0.70</td>
<td>59</td>
<td>22</td>
<td>0</td>
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<tr>
<td>McAdory</td>
<td>10.6</td>
<td>15.4</td>
<td>4.7</td>
<td>0.69</td>
<td>59</td>
<td>16</td>
<td>0</td>
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<tr>
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<td>14.4</td>
<td>4.2</td>
<td>0.71</td>
<td>58</td>
<td>28</td>
<td>0</td>
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<tr>
<td>Corner</td>
<td>9.7</td>
<td>14.1</td>
<td>4.3</td>
<td>0.69</td>
<td>61</td>
<td>30</td>
<td>0</td>
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<tr>
<td>Providence</td>
<td>7.7</td>
<td>10.6</td>
<td>2.9</td>
<td>0.73</td>
<td>55</td>
<td>31</td>
<td>0</td>
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</table>

Total = 411, 147, 0
Figure 3. Timeline of PM_{10} and PM_{10-2.5} concentrations measured at the Jefferson County Providence site during 2004.
Figure 4. Timeline of PM$_{2.5}$ concentrations measured by the two collocated PM$_{2.5}$ FRM samplers at the Leeds site during 2004.
Timeline of PM$_{10}$ Concentrations at the Leeds Site  
(Jan. 4 - Dec. 29, 2004)

**Figure 5.** Timeline of PM$_{10}$ concentrations measured by the two collocated PM$_{10}$ FRM samplers at the Leeds site during 2004.
Figure 6. Timeline of calculated PM$_{10-2.5}$ concentrations measured by the two collocated PM$_{2.5}$ and PM$_{10}$ FRM sampler pairs at the Leeds site during 2004.