Sources of PM$_{2.5}$ in New York State

Philip K. Hopke
Center for Air Resources Engineering and Science
Clarkson University
Potsdam, NY
Introduction

- Areas of New York State have been determined to be in non-attainment of the National Ambient Air Quality Standard (NAAQS) for Particulate Matter.
Introduction

• As a result of these designations, it will be necessary to prepare state implementation plans (SIPs) that outline an air quality management strategy to bring the areas in question into attainment.

• New standards to be announced later this year are likely to put more areas of the state out of attainment if there are no changes in emissions across the region.
Introduction

• Even in areas that meet the National Ambient Air Quality Standard, there are regional haze problems that require planning to improve air quality, but on a much longer time scale.
Introduction

• To help inform the planning process, a number of studies of PM$_{2.5}$ have been made across New York State that have collected, analyzed the samples for chemical composition, and the data analyzed to investigate source/receptor relationships.
Prior Studies


Prior Studies

- The Sources of PM$_{2.5}$ in Metropolitan New York City, Y. Qin, E. Kim and P.K. Hopke, submitted to Atmospheric Environment (2005).
- Identifying and Quantifying Transported vs. Local Sources of New York City PM2.5 Fine Particulate Matter Air Pollution, R. Lall, G.D. Thurston, submitted to Atmospheric Environment (2005).
Measurement Sites
Particle Composition - Urban
Particle Composition - Rural
Particle Composition

[Maps showing distribution of sulfur dioxide (SO₂) and nitrogen oxide (NOₓ) concentrations across the United States.]
Combining back trajectory analyses from Underhill, VT and Brigantine, NJ permits triangulation of the source regions (Hopke et al, 2005) for sulfate that is attributed to coal-fired power plants and Ni and V-related particles assigned to residual oil combustion.
Examination of the emissions inventories for coal-fired power plants and residual oil combustion can be presented as contour plots of the average annual emissions.
Sulfate

Overlaying these two sets of maps shows the congruence between the areas that were identified as being important emissions regions from the data analysis and those that are known to be emissions areas from the emissions inventories.
Sulfate in NYC Area

- Several groups have estimated the relative influence of upwind sources on the amount of sulfate in NYC.
- Bari et al. (2003) suggest that on an annual basis 43% of sulfate, 14% of the sulfur dioxide, 30% of the PM2.5 mass, 27% of HCl, and 24% of HNO3 were attributed to upwind emissions, with the remaining amounts due to emissions in the metropolitan New York.
• Dutkiewicz et al. (2004) attribute 44–55% of the sulfate at Queens on an annual basis is transported into the region.

• Lall and Thurston (2005) conclude that nearly half of the total PM2.5 reported in NYC is attributable to transport into the city on annual basis, and more than half (nearly two-thirds) of the PM2.5 in the summertime. For sulfate, the transported percentage is much greater, reaching approximately 90% of all the sulfate impacting the site considered in downtown Manhattan.
Sulfate in NYC Area

• Qin et al. (2005) report that 63% of the sulfate is transported into the region (see related poster at this meeting)

• Although there are a variety of estimates of the extent of local versus regional sulfate, all of the studies suggest a very large fraction are not local in origin suggesting that a substantial contributor to the NYC PM$_{2.5}$ non-attainment is not under NYS control
Nitrate in NYC Area

• Qin et al. (2005) find secondary nitrate was a major component of PM$_{2.5}$. It contributes about 8-18% of concentration for PM$_{2.5}$.

• About 54 to 65% of the ammonium nitrate measured in metropolitan area of New York City is the result of transport based on the Chester concentrations.
NYC Sources

- Lall and Thurston (2005) have examined the PM$_{2.5}$ composition data from samples collected at Hunter College and Tuxedo in 2001. A World Trade Center aerosol was also identified after September 11.

<table>
<thead>
<tr>
<th></th>
<th>Sulfate</th>
<th>Traffic</th>
<th>Residual Oil</th>
<th>Soil &amp; Dust</th>
<th>Fe-Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average</td>
<td>8.3</td>
<td>6.8</td>
<td>3.6</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Winter</td>
<td>6.6</td>
<td>4.4</td>
<td>8.6</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Summer</td>
<td>12.9</td>
<td>9.1</td>
<td>0.9</td>
<td>0.6</td>
<td>0.4</td>
</tr>
</tbody>
</table>
NYC Sources

- Qin et al. (2005) analyzed the STN data from three STN sites in NYC (IS52, NY Botanical Gardens, and Brooklyn College).

Table 1. Average contributions of identified sources to PM$_{2.5}$ concentrations

<table>
<thead>
<tr>
<th>Source</th>
<th>NYBG</th>
<th>IS52</th>
<th>QCII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary sulfate</td>
<td>5.77±5.26</td>
<td>7.20±5.88</td>
<td>4.87±4.47</td>
</tr>
<tr>
<td>Secondary nitrate</td>
<td>2.10±2.45</td>
<td>2.57±2.44</td>
<td>1.81±2.55</td>
</tr>
<tr>
<td>Soil dust</td>
<td>1.48±1.06</td>
<td>1.07±0.76</td>
<td>0.75±0.64</td>
</tr>
<tr>
<td>Aged sea salt</td>
<td>0.68±0.69</td>
<td>0.49±0.61</td>
<td>0.44±0.61</td>
</tr>
<tr>
<td>Oil combustion</td>
<td>0.52±0.43</td>
<td>1.36±1.30</td>
<td>1.25±1.27</td>
</tr>
<tr>
<td>Traffic</td>
<td>2.14±1.65</td>
<td>1.11±0.91</td>
<td>2.55±2.09</td>
</tr>
<tr>
<td>Spark Ignition</td>
<td>2.14±1.65</td>
<td>1.11±0.91</td>
<td>2.55±2.09</td>
</tr>
<tr>
<td>Diesel</td>
<td>0.43±0.34</td>
<td>0.45±0.34</td>
<td>0.45±0.34</td>
</tr>
</tbody>
</table>
• Based on the results of Qin et al. (2005), soil dust contributes 6-11% of the PM$_{2.5}$ in the NYC area.

• According to EPA’s National Emission Inventories, fugitive dust is the most important primary PM$_{2.5}$ emission source in this area. It supposedly accounts about 38-57% of local emissions of PM2.5 in the Bronx and Queens.

• However, it does not appear that there is sufficient concentrations of the crustal elements (Al, Si, Ca, Ti, Fe) to support the emissions estimates.
• Oil combustion contributes about 4-11% of concentration for PM2.5 at these four sites. It is much higher than the EPA estimated contribution of oil burning to primary emission sources of PM$_{2.5}$.

• The source contributions of spark ignition vehicles are 8 to 22%. They are higher than EPA highway vehicle contribution to primary emission sources of PM$_{2.5}$.
Wood burning is listed by EPA as an import primary emission source for Queens supposedly accounting for 16.7% of primary PM2.5 emissions.

However, there does not seem to be sufficient measured potassium concentrations that such emissions would be expected to generate (Watson et al., 2001) and thus, wood burning could be identified at any of the sites.

These and the other results can then be used to refine the emissions estimates so that they can provide more accurate inputs into the models used for developing the SIP for the non-attainment areas.
Source Apportionment and Health Effects

- While the association between exposure to ambient fine particulate matter mass (PM2.5) and human mortality is well established, the most responsible particle types/sources are not yet certain.

- In May 2003, the U.S. Environmental Protection Agency’s Particulate Matter Centers Program along with NYSERDA sponsored the “Workshop on the Source Apportionment of PM Health Effects”.
The goal was to evaluate the consistency of the various source apportionment methods in assessing source contributions to daily PM2.5 mass-mortality associations. Seven research institutions, using varying methods, participated in the estimation of source apportionments of PM2.5 mass samples collected in Washington, DC and Phoenix, AZ.

Apportionments were evaluated for their respective associations with mortality using Poisson regressions, allowing a comparative assessment of the extent to which variations in the apportionments contributed to variability in the source-specific mortality results.

A poster describing this workshop is being presented at this meeting.
Conclusions

• Good tools are available to help with the source identification and apportionment
• Method development continues and better tools can be expected in the near future
• Apportionment can assist in SIP development, and
• Potentially can be used to assist in health effects epidemiology