Distinguishing Local and Regional Impacts for PM$_{2.5}$ in Allegheny County, PA

MARAMA 2011 Data Analysis Workshop

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PM2.5 in Southwestern PA

Pittsburgh is *not* one of the highest cities in the U.S. for PM2.5

Liberty-Clairton is a Separate Nonattainment Area within Allegheny County
SW PA PM2.5 Nonattainment Areas

Pittsburgh – Beaver Valley Area: includes all of Allegheny, Beaver, Butler, Washington, and Westmoreland Counties, and parts of Armstrong Co. (Washington Twp., Plumcreek Twp., and Elderton Borough), Greene Co. (Monongahela Twp.), and Lawrence Co. (Taylor Twp. south of New Castle)

Liberty – Clairton Area: includes Glassport, Liberty, Lincoln and Port Vue Boroughs, and City of Clairton
Liberty-Clairton Area
Allegheny County PM2.5 Monitor Sites

- Lawrenceville (urban downwind, dense residential)
- South Fayette (rural background)
- Clairton (residential, industrial valley)
- Liberty (residential, industrial valley)
- North Braddock (dense residential, industrial valley)
- Harrison (residential, industrial valley)
- North Park (residential, rural downwind)
- Moon (residential, commercial)
- Liberty (residential, industrial valley)
Continuous PM2.5 Trends

Liberty and Lawrenceville Hourly PM2.5 Averages, Long-Term (2000-2008)

[Graph showing hourly PM2.5 concentrations for Liberty and Lawrenceville from 1 to 24 hours, with distinct lines for each location.]
Speciation Sites in SW PA

- Florence
- Lawrenceville
- Greensburg
- Liberty
Species Pie Charts, Lawrenceville & Liberty

Lawrenceville Average Major Species Pie Chart, 2005-2009
(Total PM2.5 = 15.6 μg/m³)

- Crustal component: 5%
- Elemental carbon: 5%
- Organic carbon: 26%
- Ammonium: 12%
- Sulfate: 28%
- Other: 13%
- Nitrate: 10%

Liberty Average Major Species Pie Chart, 2005-2009
(Total PM2.5 = 20.7 μg/m³)

- Crustal component: 4%
- Elemental carbon: 8%
- Ammonium: 13%
- Organic carbon: 24%
- Sulfate: 27%
- Other: 17%
- Nitrate: 7%
Primary sulfate was not present in earlier data (2000-2004 timeframe).

“Other” can be water, unknown compounds, or differences in analytical methods.
Crustal Time Series

ACHD Concurrent Crustal Component, 2005-2009

Concentration [μg/m³]

Date


LB Crustal component
LV Crustal component
Ammonium Time Series

ACHD Concurrent Ammonium, 2005-2009

Concentration (µg/m³)

Date

“Other” Time Series

ACHD Concurrent Other, 2005-2009

- LB Other
- LV Other

Concentration (µg/m³)

Date

Source Apportionment Analysis

Positive Matrix Factorization

EPA PMF
Version 3.0.2.2

The United States Environmental Protection Agency through its Office of Research and Development funded and collaborated in the research described here under Contract Numbers EP-D-05-004 and 68-W-04-005 to Sonoma Technology, Inc. This software is now being subjected to external peer-review and is for evaluation purposes only. Portions of the code are Copyright©2005-2008 ExoAnalytics Inc. and Copyright©2007-2008 Bytescout.
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<thead>
<tr>
<th>Factor</th>
<th>Species/Tracers</th>
<th>Possible Source(s)</th>
<th>Total</th>
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<td>1</td>
<td>Carbons, Sulfate, Pb, Zn</td>
<td>Primary Sulfate, Diesel Vehicles, Industrial Carbon</td>
<td>4.548</td>
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<td>2</td>
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<td>Burning/Cooking</td>
<td>2.141</td>
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<td>Elemental Carbon, Si</td>
<td>Coal/Coke Dust</td>
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<td>4</td>
<td>Fe, Mn, Zn</td>
<td>Blast Furnaces</td>
<td>0.100</td>
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<td>5</td>
<td>Organic Carbon, Cu</td>
<td>Gasoline Vehicles, Metal Processing</td>
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<td>6</td>
<td>Se</td>
<td>Coal Combustion, Glass Manufacturing</td>
<td>0.143</td>
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<td>Cl, Br, Elemental Carbon</td>
<td>Industrial Halides</td>
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<td>Al, Ca, Fe, Ti, Si</td>
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<td>Elemental Carbon, As</td>
<td>Coke Ovens, Diesel Vehicles</td>
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<td>Secondary Nitrate</td>
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<tr>
<td>12</td>
<td>Cr, Ni</td>
<td>Metal Processing</td>
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Conditional Probability Function (CPF)

CPF uses wind direction rather than trajectories to determine likely direction of sources. CPF compares these highest concentration days to the average transport pattern (i.e., the climatology).

\[ CPF = \frac{m_{\Delta \Theta}}{n_{\Delta \Theta}} \]

\( n_{\Delta \Theta} \) = number of times wind direction is from sector \( \Delta \Theta \).

\( m_{\Delta \Theta} \) = number of times source contributions are high while wind direction was from sector \( \Delta \Theta \).

CPF close to 1.0 for a given sector \( \Delta \Theta \) indicates a high probability that a source is located in that direction.

Example CPF plot for the highest 25% contribution from a PMF factor pointing the northwest of the site as a possible source region.

(Source: Kim et al., 2004)
CPF Results by Factor

- Primary Sulfates, Carbons
- Burning/Cooking
- Coal/Coke Dust
- Blast Furnaces
- Gasoline Vehicles, Cu
- Coal Combustion
CPF Results by Factor (cont.)

- Halides
- Crustal Component
- Secondary Sulfate
- Coke Ovens
- Secondary Nitrate
- Metal Processing
Monongahela Valley PM2.5 Sources

US Steel ET / Langenfelder / Braddock Recovery

20 km Background

Kinder Morgan

McKeesport / Liberty Sources

Liberty Site

US Steel Clairton

Koppers Mid-Continent Coal/Coke

Clairton Slag

Eastman/Sanyo

Guardian

RRI Energy Elrama (Wash. Co.)

Kelly Run
CPF Overlay – Coke Ovens
CPF Overlay – Blast Furnaces
Potential Source Contribution Function (PSCF)

PSCF uses HYSPLIT back trajectories to determine probable locations of emission sources.

$$PSCF = \frac{m_{ij}}{n_{ij}}$$

$n_{ij} =$ number of times trajectory passed through cell $(i,j)$.
$m_{ij} =$ number of times source contribution peaked while trajectory passed through cell $(i,j)$.

Top 10%-20% source contributions are used for $m_{ij}$.

In the example on the right, all 5-day back trajectories, for every 2 hours were applied to the corresponding 24-hr source contributions.

PSCF calculated for each cell sized $1^\circ \times 1^\circ$ and results displayed in the form of maps on which PSCF values ranging from 0 to 1 are displayed in a color scale.

Potential source contribution function plot for sulfate affecting Philadelphia. Higher probability is associated with area of high SO$_2$ emissions.

(Source: Begum et al., 2005)
Typical Transport
2009 Low Production - Liberty

Liberty Hourly PM2.5 Averages, Long-Term (2000-2008) and 2009
2009 Low Production - Lawrenceville

Lawrenceville Hourly PM2.5 Averages, Long-Term (2000-2008) and 2009
Liberty-Lawrenceville Differences

Hourly Average PM2.5 Difference, Liberty Minus Lawrenceville, Long-Term (2000-2008) and 2009, Shifted 12-Hour Periods

Concentration μg/m³

Hour
PM2.5 Local Source Modeling

• Liberty-Clairton, PA
• St. Louis, MO / East St. Louis, IL
• Birmingham, AL
• Atlanta, GA
• Detroit, MI
Local Area “Hybrid” Approaches

- **Liberty-Clairton**
  - CMAQ regional with CALPUFF local for primary carbons
  - Additive combination of impacts w/o double-counting

- **St. Louis**
  - CMAQ regional with AERMOD local for primary component
  - Additive combination by primary/secondary, with “zero-out” for local primary sources from regional

- **Detroit Study**
  - CMAQ and CAMx regional with AERMOD local
  - Multiplicative combination of impacts

- **Birmingham, Atlanta**
  - CMAQ regional + AERMOD local, additive combination of reductions
SW PA Modeling Domains

150 km

20 km

MM5 Met
Modeled Near-Field Percent Reductions

Additional reductions can be due to decreases in emissions from surrounding and background sources.

Reductions here due to shutdown of Mon Valley Transportation Center.

Reductions throughout downwind area primarily due to proposed future configuration at U. S. Steel Clairton Plant.

Controls used in SIP for 1997 Standards.