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Analysis of Particulate Matter Data in New York Using Advanced Source Apportionment Methods

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Project Location

New York Metropolitan Area

USEPA Speciation Trends Network (STN) locations in NYC and northern NJ used in this study.

Keywords

- U.S. EPA Supersite program
- Factor analysis models
- Positive Matrix Factorization (PMF)
- $PM_{2.5}$
- Source apportionment
- Expanded Factor Analysis

PROJECT FOCUS

To improve our understanding of local and regional sources of ambient fine particulate pollution in New York State (NYS), this project combines the best features of advanced factor analysis models using Positive Matrix Factorization (PMF). The effectiveness of this improved methodology will be assessed using a wide set of available particulate matter (PM) data, with an emphasis on data from NYS. The project is supported by the Environmental Monitoring, Evaluation, and Protection (EMEP) program and the U.S. Environmental Protection Agency (EPA).

CONTEXT

Airborne PM is a broad class of materials, transported as solid particles or liquid droplets (aerosols). These particles are emitted from a variety of natural processes and human activities, including fossil-fuel combustion, forest fires, wind erosion, agricultural practices, industrial manufacturing, and construction. They can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases, such as sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds (secondary particles).

In July 1997, motivated by concerns about adverse health effects, the USEPA proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including daily maximum ($65\ \mu g/m^3$) and annual maximum ($15\ \mu g/m^3$) average concentrations. As is the case with ozone and its precursors, fine particles are generated and deposited locally but are also transported regionally. Improved methods, needed to identify important sources both in the state and in the region, will be essential to develop a State Implementation Plan (SIP) to attain federal standards.

Although the current NAAQS uses $PM_{2.5}$ mass concentrations to gauge air quality, some particles that contribute to PM mass are expected to be more toxic than others, depending on their composition. Thus, focusing on all particles that contribute to PM mass may lead to less efficient and effective control strategies than focusing specifically on particles that are implicated in adverse health effects. As the number of possible chemical species associated with the particle mass is large, it would potentially be more effective to consider airborne PM as a mixture of different combinations of particles arising from a variety of source categories. Each of the various source types, such as spark-ignition or diesel-powered vehicles; coal-, gas-, or oil-fired power plants; incinerators; and road dust, has characteristic chemical and/or physical patterns and signatures. These may be used in combination to match the composition of particles found in ambient air.

Recent studies suggest that PM health effects can vary by source category. A variety of source-apportionment methods, used to attribute PM components to different source categories, are currently being used to assess these effects. This study relies on "factor analysis" methods to identify sources of particulate matter in New York's airshed, which are used to examine data sets for patterns of intercorrelations between variables (or factors). With this statistical technique, the number of variables to be considered may be reduced.

METHODOLOGY

This project is developing an inventory of available $PM_{2.5}$ databases that includes analytes sampled, sampling duration and frequency, methods of analysis, and other information deemed relevant. To analyze available data, the project team will use enhanced PMF approaches developed through a companion EPA STAR project. One objective of this effort is to develop and test models that make the best possible use of data collected on different timescales. Such new approaches are critical in extracting the most information from available data.

Credit: Monica Mazurek
Elizabeth toll plaza on the New Jersey Turnpike - a STN sampling site.

These new methods will be tested using data accumulated at U.S. EPA Supersites; EMEP studies at Potsdam and Stockton, and Hunter College and Tuxedo; the U.S. EPA Speciation Trends Network (STN); and other New York studies. While NYC data will be the primary focus, all available information will be utilized. The analyses will include:

- Comparisons of source-apportionment results from different studies in the region, as well as comparisons of this project with other studies;
- Spatial analysis across NYS to identify sources common to all sites;
- Recommendations of analytes for sampling and sampling duration for ongoing research elsewhere in the state; and
- Development of an approach for better estimating overall uncertainties in the results.

Credit: Monica Mazurek
Tisch 2 channel fine particle sampler

PRELIMINARY FINDINGS

$PM_{2.5}$ mass: Data suggest that $PM_{2.5}$ mass at different NYC sites in large part originates from common sources and is secondary in nature. The widespread formation of secondary $PM_{2.5}$ coupled with the long lifetimes of components ensures some measure of uniformity in $PM_{2.5}$ composition across the metropolitan area. No obvious seasonal variations appear in the time series of $PM_{2.5}$ mass. Peak $PM_{2.5}$ mass concentrations, ~15 μgm^{-3} higher than the NAAQS standard of 65 μgm^{-3}, were measured on 7 July 2002, resulting from a large forest fire in northern Quebec, Canada. PMF results indicate that the common source for $PM_{2.5}$ is long-range transport, accounting for ~69%-82% of $PM_{2.5}$ mass concentrations. Local emissions contribute only ~18%-31% of observed levels.

Primary $PM_{2.5}$ Emissions: According to EPA's National Emission Inventories, fugitive dust is the major primary $PM_{2.5}$ source in the Bronx and Queens (NY), and Union and Morris counties (New Jersey), accounting for ~38%-57% of local emissions. Highway vehicles account for just ~6%-12% of local emissions.

Carbon concentrations: Both primary and secondary emissions influence carbon levels. The higher percentages of carbon at certain sites may show the effects of local sources. Elemental carbon (EC) concentrations showed some seasonal variations at several sites and were relatively high in winter and low in summer; for other sites there were no obvious seasonal variations. This suggests that EC levels measured at these sites may come from different sources. The impact of local source emissions on EC is important. Organic carbon (OC) levels measured at these five sites, however, may have common sources.

NH_4^+, NO_3^-, and SO_4^{2-}: Results indicate that long-distance transport accounts for 71%-86% of NH_4^+, 54%-65% of NO_3^-, and 93%-100% of SO_4^{2-} measured in metropolitan NYC. Concentrations measured at study sites are secondary in origin.

Al, Ca, Fe, K, Si, and Ti: These "crustal" elements do not show obvious seasonal variations. Trajectory analyses attribute their peak concentrations, measured on two separate occasions, to intercontinental dust events: a major dust storm observed in Asia and desert dust from the Sahara.

Source Apportionment with PMF Model
Source contributions to $PM_{2.5}$ from the PMF model are shown below.

	Bronx - NYBG	Bronx - IS52	Queens College II	Elizabeth, NJ	Chester, NJ
Secondary sulfate	5.77	7.2	4.87	6.67	6.43
Secondary nitrate	2.1	2.57	1.81	1.98	1.05
Soil dust	1.48	1.07	0.75	0.99	0.99
Aged sea salt	0.68	0.49	0.44	1.14	0.87
Oil combustion	0.52	1.36	1.25	0.85	
Spark Ignition	2.14	1.11	2.55	2.57	3.01
Highway vehicle				1.3	
Diesel	0.43	0.45		2.16	0.35

Average contributions of identified sources to $PM_{2.5}$ concentrations

PROJECT IMPLICATIONS

Accurate $PM_{2.5}$ source identification and apportionment are vital for developing effective control strategies, especially for areas that are not in attainment of the $PM_{2.5}$ standard. The information and methodologies that emerge from this research will prove useful in identifying the regional contribution of fine particles to New York's airshed and in assisting State policymakers to develop the New York $PM_{2.5}$ SIP, which is due in 2007. The improved $PM_{2.5}$ assessment methods will also benefit research efforts at the NYS Department of Environmental Conservation and Department of Health.