PROJECT UPDATE

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New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Monitoring Particle Size Distribution in Rochester

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Project Location

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Keywords

- Nucleation events
- $PM_{2.5}$
- Ultrafine particles (UFPs)
- UFP number concentration
- UFP size distribution

PROJECT FOCUS

This project monitored the concentrations and size distributions of ultrafine particles (UFPs) with near real-time resolution. The information, gathered at a site in Rochester, NY, is crucial for studies on the health effects of UFPs. The specific objectives of this project were to:

- Develop a database of ambient atmospheric measurements of size distributions for particles 0.010-0.50 µm (microns) in diameter;
- Examine variations in particle size and the occurrence of "nucleation events," whereby ultrafine particles are formed through the interaction of gases in the atmosphere, using these and additional data on particulate mass and composition; and
- Provide data to health studies on the potential implications of UFPs for human health.

CONTEXT

Airborne particulate matter (PM) comprises a broad class of materials, transported in the air 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. "Primary" particles are those emitted directly into the atmosphere, while "secondary" particles are formed in the atmosphere from precursor gases such as sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds. In July 1997, motivated by concerns about the adverse health effects of PM, the U.S. Environmental Protection Agency proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including maximum daily concentrations of 65 $\mu g/m^3$ and maximum annual average concentrations of 15 $\mu g/m^3$.

Ultrafine particles are an important component of $PM_{2.5}$. Extremely small particles of less than 0.1 µm in diameter, UFPs are primarily generated from combustion processes, including stationary fossil-fuel electric power generation, industrial processes, boilers, and car and truck engines. While UFPs, because of their very low mass, contribute little to $PM_{2.5}$ mass concentrations in ambient air, they have nevertheless been associated with a set of adverse health effects. Recent studies have indicated that the number of UFPs in ambient air, rather than their particulate mass contribution, is responsible for the observed health effects. Nucleation events are an important factor affecting the number concentrations of UFPs in ambient air. A reliable data record of UFP number concentrations and size distributions is vital for understanding these events, for studying the health effects of UFP exposure, and ultimately for assessing the effectiveness of PM control efforts in New York with regard to human health. Unfortunately, there are few locations for which such data are available.

UFPs are generated from combustion processes such as car and truck engines.

METHODOLOGY

Through this project year-round, real-time UFP data were collected near the New York State Department of Environmental Conservation (NYS DEC) National Atmospheric Monitoring Site (NAMS) in Rochester, NY. Researchers measured number and size distributions for particles 0.010-0.50 µm in diameter semi-continuously (at 5-6 minute intervals) over a 14-month period (January 2002-June 2003). These measurements were made using a Scanning Mobility Particle Sizer (SMPS), which was collocated with other ambient air quality monitoring equipment at the NYS DEC monitoring site. The instruments provided continuous and filter-based PM_{10} and $PM_{2.5}$ mass values, $PM_{2.5}$ composition data, as well as gaseous pollutant data (ozone [O_3], sulfur dioxide [SO_2], and carbon monoxide [CO]). Since both particulate mass and composition were previously being measured at this location, it was an ideal site for measuring particle size distributions in order to examine associations between these indicators of exposure levels and adverse health effects. These data will be provided to project collaborators at the U.S. Environmental Protection Agency's PM Health Center at the University of Rochester for evaluating potential health implications.

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Locations of sampling sites and major local stationary sources in Rochester, New York.

Project Status

- Initiated 2001
- Project completed

Since 1975, the New York State Energy Research and Development Authority (NYSERDA) has developed and implemented innovative products and processes to enhance the State's energy efficiency, economic growth, and environmental protection. One of NYSERDA's key efforts, the Environmental Monitoring, Evaluation Protection (EMEP) Program, supports energy-related environmental research. The EMEP Program is funded by a System Benefits Charge (SBC) collected by the State's investor-owned utilities. NYSERDA administers the SBC program under an agreement with the Public Service Commission.

PROJECT FINDINGS

Size Distribution of UFPs: Over 70% of the total UFP number concentration is associated with 0.011-0.050 µm particles, while ~20% is associated with 0.050-0.100 µm particles (see Figure below).

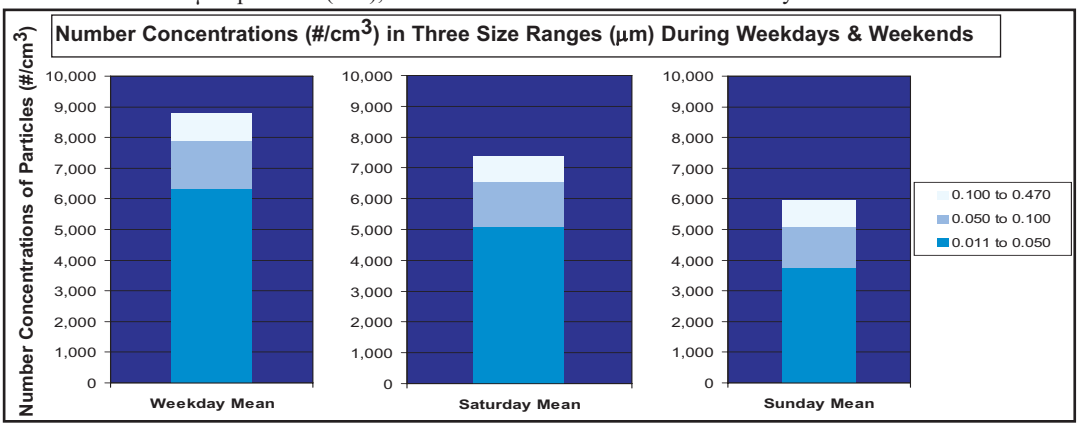
$PM_{2.5}$ Mass Concentrations: UFP number concentrations were poorly correlated with $PM_{2.5}$ mass concentrations, but are likely correlated with FP number concentrations.

Daily Variations: Two peaks in number concentrations were typically found for 0.011-0.050 µm particles as a function of time of day.

- Morning rush hour (~8 AM): During winter, these peaks were associated with increases in CO. Particles appeared to arise from direct emissions of motor vehicles during the morning rush hour.
- Noon - 6 PM: Number concentrations in this smaller size range often increased during the late afternoon rush hour, particularly in winter. This second peak was associated with nucleation events forming new UFPs. These events were more likely in the spring and summer.

Weekly Variations:

- The average number concentration of 0.011 - 0.050 µm particles (UFPs) was significantly higher during weekdays than on weekends, confirming suggestions that motor vehicles are one of the main sources of UFPs.
- For 0.100 - 0.470 µm particles (FPs), there was no difference between weekdays and weekends.



Seasonal Variations:

- Mean UFP number concentrations were higher during winter months than in the summer, likely owing to the cooling of motor-vehicle combustion exhaust and other factors.
- Strong UFP nucleation events were generally observed in the summer months.

Nucleation Events: These usually occurred from noon - 6 PM and were most active in April - September 2002.

- SO_2 peaks were observed during strong nucleation events, and were closely associated with peaks in UFP number concentrations, but $PM_{2.5}$ and CO showed no significant influence.
- It is hypothesized that these UFPs are sulfuric acid and water, formed from the oxidation of SO_2.
- Strong SO_2 peaks were observed when the wind came from the northwest, where three SO_2 sources are located.
- Events typically occurred when ambient temperature was high and relative humidity was ~60%.
- During weak nucleation events, the correlation between SO_2 and UFP number concentrations was poor.

PROJECT IMPLICATIONS

Bringing ambient $PM_{2.5}$ concentrations in New York State to levels compliant with the NAAQS may require new emissions regulations. In June 2004, the U.S. EPA identified 243 counties in the nation, including several in the New York City area, that do not meet federal standards for $PM_{2.5}$ pollution. Following EPA's final PM designations in December 2004, which listed 225 nonattainment counties across the country, states will be required to submit implementation plans to comply with the new standard. While attainment deadlines begin in 2010, the EPA is expected to release a proposed PM implementation rule early in 2005.

Recently, concerns have been raised that the existing mass-based standard for $PM_{2.5}$ will not be adequately protective of human health as it ignores UFPs. While contributing little to $PM_{2.5}$ mass even when present in large numbers, UFPs have been shown to have pronounced health effects. The data on UFP number concentrations and size distribution collected through this project address these concerns and represent the beginnings of a database that may be used in future studies of UFPs and their adverse health effects. With several years of such data, it may become possible to explore the relationship between particle number concentrations and adverse health effects such as mortality, emergency room visits, and hospitalizations.

Besides Atlanta, GA, Rochester is the only location in the United States for which sufficient data are being accumulated to allow an epidemiological study of UFP health effects. Thus far, project findings indicate that the inhabitants of Rochester, NY are regularly exposed to high UFP concentrations arising from motor vehicle emissions and nucleation events. The most common nucleation events are attributable to emissions from local sources and very likely related to emissions from the local coal-fired power plant.