PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Developments in Continuous Fine Particle Mass Monitoring

PROJECT FOCUS

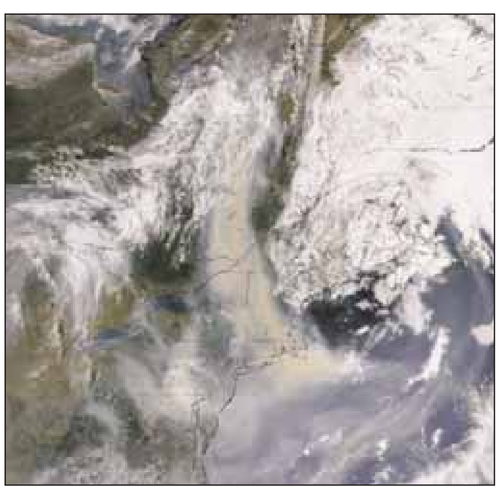
This project developed two products designed to improve the semi-continuous monitoring of fine particulate matter ($PM_{2.5}$) mass in ambient air. Both are based on an existing method for measuring particulate mass: Thermo's (formerly Rupprecht & Patashnick) standard Series 1400a Tapered Element Oscillating Microbalance (TEOM®) monitor. The goals of this study were:

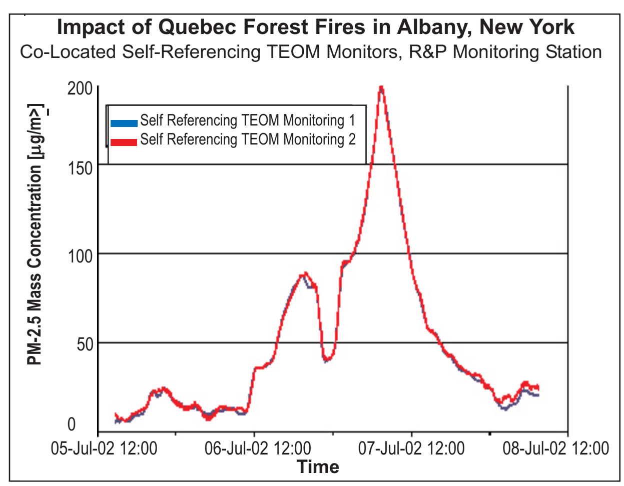
- To increase the consistency of measurements made using the TEOM to those made using the Federal Reference Method (FRM), which provides a 24-hour filter-based mass measurement. Studies have shown that when there is a significant semivolatile organic component, the TEOM monitor can underreport the particulate mass compared to the FRM. To address this problem, the "sample equilibration system" (SES) was designed, which allows the TEOM to operate at a reduced temperature of 30°C. At this lower temperature, the system retains more of the semivolatile components.
- To develop a monitoring system that better represents the mass of fine particles in ambient air than measurements made using FRM techniques. The Differential TEOM concept was developed to account for effects taking place on the filter (e.g., gas adsorption, desorption, or chemical reactions), thus providing greater certainty about particulate mass in ambient air.

CONTEXT

Combustion processes play a major role in the production of fine particulate matter ≤2.5 microns in diameter ($PM_{2.5}$). Important sources are fossil-fuel electricity-power generation, industrial processes, industrial boilers, incinerators, and car and truck engines. Constituents of the $PM_{2.5}$ "soup" include carbon, metals, nitrates, sulfates, and semivolatile organics. These particles can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases (secondary particles).

In July 1997, the National Ambient Air Quality Standards (NAAQS) were revised to include annual and 24-hour standards for $PM_{2.5}$ mass in ambient air. Bringing New York ambient $PM_{2.5}$ mass to levels that are compliant with the NAAQS will likely require new emissions regulations. The NAAQS are based on $PM_{2.5}$ measurements made with an FRM sampler. In this procedure, a filter at a defined temperature and humidity is weighed. Then, a sample is collected on the filter for 24 hours at ambient temperature and humidity. The filter is then reweighed under the original laboratory conditions. The difference in weight is used to derive the 24-hour average ambient $PM_{2.5}$ mass concentration. This method has several drawbacks, however, and ultimately provides an indication of the average $PM_{2.5}$ mass, rather than a precise representation of air as it is breathed under ambient conditions. The standard TEOM monitor is a significant advance in measuring ambient PM mass, allowing ambient PM mass concentrations to be monitored in near real time for extended periods, without the burden and costs of operator intervention.





Credit: Image provided by Orbital Imaging Corporation

Credit: Rupprecht and Patashnick

During July 2002, numerous forest fires were raging in Quebec Province, Canada. Weather patterns caused the smoke generated by the fires to blanket eastern New York and New England. Pollution monitors such as the R&P TEOM mass monitor are able to track the effects of such events in real time.

Principal Researcher

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Thermo Electron Corporation

Credit: Rupprecht and Patashnick

After the events of 11 September 2001, R&P TEOM monitors were used to monitor air quality at the World Trade Center site, gauging the effects of the events and the clean-up of the area on ambient air. The enclosures house standard TEOM monitors which are set up to measure $PM_{2.5}$.

Contact Information

For more information on this project see:

http://www.nyserda.org/programs/environment/emep

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Keywords

- Federal Reference Method (FRM)
- Particulate mass monitoring
- $PM_{2.5}$
- Semivolatile organics
- TEOM method

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Credit: Rupprecht and Patashnick

A R&P 1400 TEOM monitor, set up for PM_{10} sampling, installed on a busy street in Hong Kong to monitor PM levels.

Project Status

- Initiated 1999
- Completed 2003

New York Energy Smart
PUBLIC SERVICE COMMISSION NYSERDA

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.

METHODOLOGY

SES-TEOM: To increase correlation between the TEOM and FRM methods, a "sample equilibration system" (SES), designed as an upgrade to the standard TEOM monitors, was developed. The SES reduces moisture in the ambient air being sampled. As a result, the temperature of the TEOM filter can be reduced from 50°C to 30°C, bringing it closer to the method-defined laboratory temperature of the FRM. The lower temperature reduces the loss of the semivolatile components of $PM_{2.5}$ mass. Performance of the SES-TEOM was assessed by the Atmospheric Sciences Research Center (ASRC) of the State University of New York at Albany. Laboratory tests compared SES-TEOM measurements (at 30°C) with those of a standard TEOM (at 50°C). Field tests at Queens College in New York City and at Pinnacle State Park, NY compared measurements collected using three methods: (1) FRM, (2) standard TEOM, and (3) SES-TEOM.

Differential TEOM: To improve the measurement of ambient particulate matter, the project team designed the Differential TEOM Mass Monitoring System (Differential TEOM). Differential TEOM is based on the direct mass reading and real-time capabilities of TEOM, but with the addition of an electrostatic precipitator (ESP), inserted between the inlet (through which the air sample enters) and the TEOM mass sensor. When the ESP is switched off, the TEOM mass sensor measures particulate mass like a conventional TEOM: particles are collected on the filter mass sensor. When the ESP is switched on, particles are instead removed from the air stream and captured by the ESP before reaching the filter's mass sensor. Mass measurements made with the ESP on are subtracted from those made with the ESP off, thereby indicating any gain or loss of semivolatile materials on the filter. As a result, the measurement can provide a more detailed record of the PM mass over time. This self-correcting system removes from the final reported value the filter effects that pose a problem with the FRM. The performance of the Differential TEOM was assessed at several research institutions and in field studies in New York and California. During testing as part of an EPA-sponsored PM Supersite Program, results from two Differential TEOM monitors were compared with those from the (1) FRM, (2) standard TEOM, (3) SES-TEOM.

PROJECT FINDINGS

SES-TEOM Tests: SES-TEOM 24-hour average mass concentrations were more closely correlated with the FRM results than with the standard TEOM monitor results.

- *Humidity*: Under low humidity, the SES-TEOM monitor and the standard TEOM monitor measurements were consistent. With changes in the humidity level in the sample chamber, the standard TEOM monitor showed an effect, while the SES-TEOM monitor was unaffected.
- *Temperature*: During warm weather, TEOM sample temperatures were much closer to ambient temperatures (the collection temperature of the FRM). In these conditions, SES-TEOM and standard TEOM results were both closely correlated with the FRM. In cold weather, the difference in sample temperatures was greater for the standard TEOM, and SES-TEOM results were better correlated with the FRM than those of the standard TEOM.

Differential TEOM Tests: Tests have proven that the Differential TEOM monitor resolves issues related to adsorption and evaporation in the collected sample.

- *Nonvolatile aerosols*: Under conditions with very little semivolatile material in the atmosphere, the different methods reported similar results, as expected. For example, when sampling a nonvolatile aerosol (sodium chloride), the Differential TEOM monitor and the SES-TEOM monitor collected similar amounts and reported similar mass concentrations.
- *Semivolatile aerosols*: With ammonium nitrate aerosol, the SES-TEOM monitor reported lower mass concentrations of ammonium nitrate than did the Differential TEOM, as expected. With the ESP turned off, the Differential TEOM reported a mass concentration similar to that of the SES-TEOM. However, with the ESP on, the Differential TEOM showed that ammonium nitrate was evaporating from the filter. The mass concentration measured during the "ESP-on" periods indicated the evaporation rate of the ammonium nitrate. The data were corrected accordingly, yielding a final overall mass concentration that was significantly greater than that reported by the SES-TEOM.

Filter Dynamics Measurement System (FDMS). As a follow up to the Differential TEOM project, a simpler filter-based system of the monitor, the Filter Dynamics Measurement System (FDMS) was developed. The Series 8500 FDMS is designed for agencies that need a monitor as part of a routine monitoring network. The FDMS provides results similar to the ESP-equipped Differential TEOM, but with the same ease of use as the standard TEOM monitor. Since its release, the FDMS has been widely accepted by the industry and received approval from the Air Resources Board of California for both PM_{10} and $PM_{2.5}$ sampling.

PROJECT IMPLICATIONS

This NYSERDA-supported project has resulted in two major advances in the near real-time monitoring of fine particles with the TEOM instrument. One advance is the reduction of the moisture content of the sampled ambient air by lowering the temperature of the device to 30°C. The second is the innovative approach to account for the loss or gain of semivolatile materials on the filter surface. By reducing monitoring costs and providing accurate real-time data on $PM_{2.5}$ mass, the devices make an important contribution to $PM_{2.5}$ research efforts ranging from health-effects studies to analyses of the effectiveness of air pollution policy.