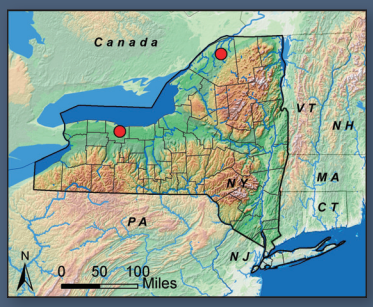
AIR QUALITY

PRINCIPAL RESEARCHERS
Philip Hopke
Clarkson University

PROJECT LOCATION
Potsdam and Rochester, New York.



Source: E&S Environmental Chemistry, Inc.

CONTACT INFORMATION
For more information on this project, go to:
www.nyserda.org/programs/environment/emep/
or contact Ellen Burkhard at:
egb@nyserda.org

PROJECT NUMBER 10604

KEYWORDS
- Air pollution
- Fine particles ($PM_{2.5}$)
- Free radicals
- Particulate matter (PM)
- Reactive oxygen species (ROS)
- Ultrafine particles (UFPs)

0912

New York Energy Smart℠ EMEP Environmental Monitoring, Evaluation, & Protection

NYSERDA New York State Energy Research and Development Authority

Atmospheric Species – Improved Monitoring, Characterization, and Understanding of Processes

PROJECT FOCUS

Reactive oxygen species (ROS), by-products of oxygen metabolism in the body, are highly reactive molecules that trigger inflammation in the lungs and also impair the heart and blood vessels. One type of ROS, known as free radicals, have been linked to DNA damage, hypertension, and increased levels of c-reactive protein, an inflammatory marker and predictor of heart attacks. ROS can reach unhealthy levels after inhalation of fine and ultrafine particles ($PM_{2.5}$ and UFPs), to which ROS adhere. The project team has developed an automated monitoring system to study particle-bound ROS, and will deploy the ROS monitor at the New York State Department of Environmental Conservation (NYSDEC) facility in Rochester, New York. Data gathered from this monitor are expected to add to knowledge about the mechanisms of particle-bound ROS formation, its chemical constituents and its precursors.

CONTEXT

Scientists once thought ROS formed in the body after inhalation of $PM_{2.5}$ and UFPs, but new findings indicate that ROS also exist in the atmosphere and can attach to particles prior to inhalation. Because of their small size (less than one-seventh the average width of a human hair), $PM_{2.5}$ and UPFs can be breathed deeply into the lungs and enter the bloodstream, where they reduce coronary blood flow and pumping of the heart, often resulting in arrhythmias. In laboratory tests, UFPs have been shown to induce oxidative stress and inflammation.

Epidemiological studies have linked airborne pollutants with respiratory outcomes such as asthma, chronic bronchitis, chronic rhinitis, and chronic obstructive pulmonary disease. Exposure to $PM_{2.5}$ and UFPs has also been linked to cardiovascular diseases such as arrhythmia, shortness of breath, hypertension, heart rate variability, congestive heart failure, and ischemic heart disease.

A primary source of $PM_{2.5}$ is combustion, including wood burning, residential fuel combustion, power plants, and motor vehicles. Other sources are wildfires, volcanoes, factories, industrial activities such as metal processing, and small engine use. Sources of UFPs include tailpipe emissions from motor vehicles, aircraft, and marine vessels. Particles emitted near the ground can remain at low elevations, or can be swept up into the atmosphere, where they are subject to complex chemical reactions.

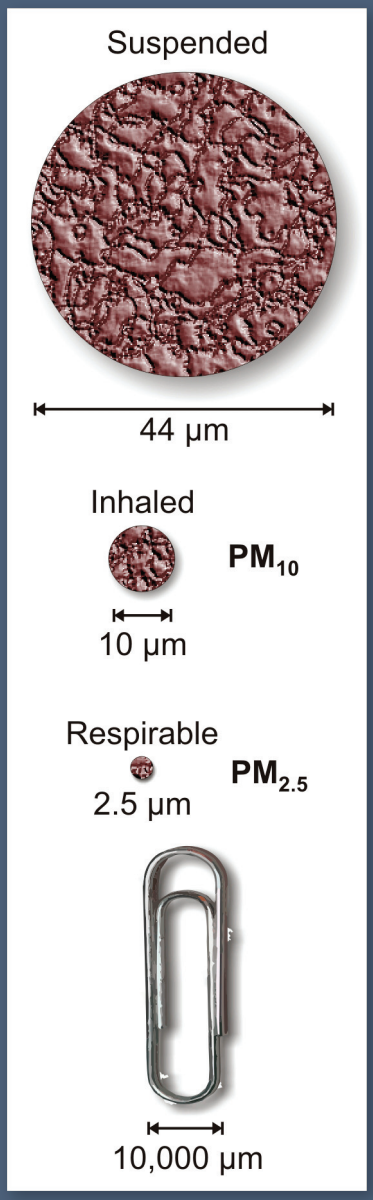
The data generated by this project may ultimately help to answer many questions raised about the health effects of particulate matter (PM), including:

- What are the adverse health outcomes associated with $PM_{2.5}$ and UFPs?
- What levels of exposure increase the probability of adverse health outcomes, and in which populations?
- How relevant are the chemical composition and atmospheric interactions associated with these pollutants?

PROJECT IMPLICATIONS

$PM_{2.5}$ and UFPs have come into prominence as a recognized health hazard, primarily because of the chemicals that can attach to their surfaces and be delivered to the gas exchange regions of the lungs. Each year in the U.S., an estimated 500,000 deaths annually are due to PM from all sources combined, and the Environmental Protection Agency states that one in three Americans is at increased risk for adverse health effects arising from exposure to $PM_{2.5}$. The EPA regulates PM as one of the criteria pollutants under the Clean Air Act; however, there is some disagreement among policymakers as to how stringent PM exposure standards should be. Major improvements in air sampling methods, such as the one described in this project, can have a significant impact on regulatory decision-making.

PROJECT STATUS
Ongoing



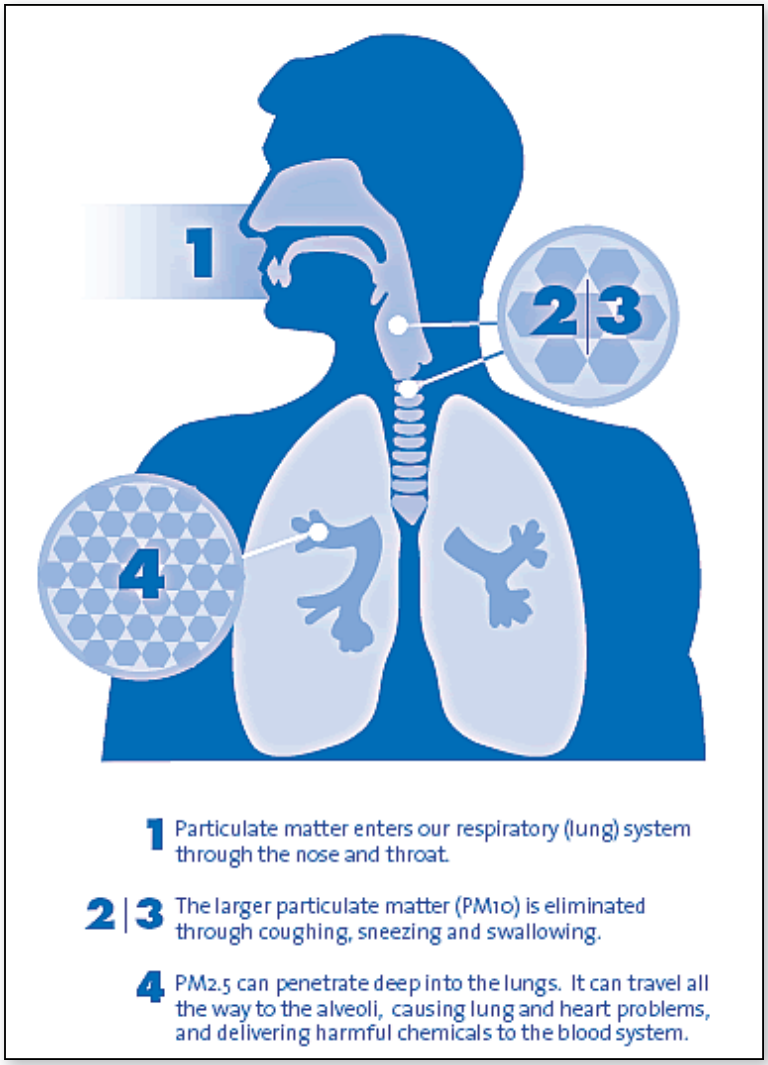
Particulate matter size comparison. Source: E&S Environmental Chemistry, Inc.

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, and 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

Clarkson University has developed an automated, mobile, continuous monitor of particle-bound ROS, for the purpose of assessing the ability of $PM_{2.5}$ to deliver a dose of ROS. This project marks the first field deployment of the new monitor, which was based on a laboratory monitor previously developed at Clarkson. It is being operated in conjunction with the laboratory unit and other systems to provide highly time-resolved particle species measurements and size distributions, and better identification of particle sources and formation processes.



A diagram detailing how particulate matter enters the respiratory system. Source: British Columbia Air Quality

Monitoring of ROS, organic carbon, elemental carbon, and sulfate is being performed for at least one month in each quarter; monitoring of particle size distributions, black carbon, carbon monoxide, carbon dioxide, nitrogen oxides, and ozone is being performed for one week in each quarter. Monitoring is expected to continue for one year. Data analyses will combine the particle size distribution data, all continuous species data, Speciation Trends Network data and molecular marker data to permit more detailed source apportionment. The project team will also coordinate with the University of Rochester Medical Center for use of air quality data from the Cardiac Rehabilitation Center. Special equipment is being used to distinguish wood smoke from other sources of carbon $PM_{2.5}$.

Analysis of the data is expected to provide geographical, spatial, and temporal maps of UFP distributions in the Rochester area over time, and to show variability in traffic and other emission sources.

FINDINGS

To adapt the laboratory version of a continuous monitor of particle-bound ROS for use in the field, it was necessary to address reagent stability and system optimization. Methods were developed to stabilize volatile, highly reactive species sufficiently for analysis. The use of "spin trapping" compounds resulted in the identification of several new peroxide species. In the fabrication phase, separate monitors for organic carbon, elemental carbon, sulfate, ROS, and gas were fitted into a seven-foot relay rack. A special instrument called a scanning mobility particle sizer was adapted to measure particle size distributions continuously.

The project investigators expect to estimate the levels of particle-bound ROS from both man-made and natural sources, to determine their oxidative capacity, and to develop strategies to target these specific causal agents for air quality management. The findings will determine which engineering controls can be applied or developed to reduce toxicologically relevant components of $PM_{2.5}$ and UFPs.