PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Environmental and Water Resources

11/2006

# INDIVIDUAL PARTICLE-ANALYSIS OF AMBIENT $PM_{2.5}$ USING ADVANCED ELECTRON MICROSCOPY

## Background

Several epidemiological studies have shown associations between elevated ambient concentrations of fine particulate matter ($PM_{2.5}$, with a mean aerodynamic diameter less than 2.5 µm) and adverse health effects, including respiratory and cardiovascular diseases. Fossil fuel combustion is believed to be a primary source of atmospheric $PM_{2.5.}$

Current air quality measurement techniques commonly employ scanning electron microscopy to characterize $PM_{2.5}$ air emissions and identify the chemical signature associated with the primary source. The challenge in developing appropriate chemical signatures for fossil fuel combustion sources stems from the limitations of existing equipment, specifically aerosol particle size measurement and chemical composition methods. Freshly generated particles from fossil fuel combustion sources are mostly nano-scale particles (approximately 1,000 times smaller than $PM_{2.5}$ particles) that are well below the capabilities of typical scanning electron microscopes.

Advanced measurement and characterization techniques for nano-scale particles will help provide a better understanding of particle formation, transport, and deposition mechanisms as well as the impact of particles deposited in human respiratory systems.

## Primary Project Goal

The overall goal of this project is to demonstrate a combination of advanced electron microscopy techniques that can be effectively used to identify and characterize individual particles and their sources. Specific techniques include:

- High-Angle Annular Dark Field Scanning Transmission Electron Microscopy (HAADF-STEM)
- Scanning Transmission Electron Microscopy Energy Dispersive X-ray Spectrometry (STEM EDX)
- Energy-Filtered Transmission Electron Microscopy (EFTEM)

## Objectives

- Collect a series of ambient $PM_{2.5}$ samples in communities near southwestern Detroit, MI (close to multiple combustion sources including motor vehicle/diesel, incinerators, and oil and coal combustion sources) and Steubenville, OH (close to several coal-fired utility boilers).
- Utilize the advanced electron microscopy techniques of HAADF-STEM, EDX, and EFTEM to provide information on the size, morphology, structure, and elemental composition of individual particles collected in Detroit and Steubenville.

## CONTACTS

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## PARTNER

University of Michigan

## PERIOD OF PERFORMANCE

07/22/2005 to 12/31/2006

## COST

**Total Project Value**
$49,968

**DOE/Non-DOE Share**
$49,968 / $0

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- Characterize ambient conditions during collection of $PM_{2.5}$ samples: gaseous pollutant concentrations including ozone ($O_3$), sulfur dioxide ($SO_2$), nitrogen oxides ($NO_X$), and carbon monoxide (CO); and meteorological parameters including temperature, relative humidity, precipitation, wind speed and direction.

## Accomplishments

This project is still in its early stages; however, interim accomplishments include:

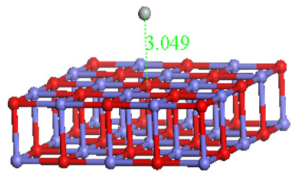
- Collecting $PM_{2.5}$ samples in several communities in southwestern Detroit, MI and Steubenville, OH continuously for seven days;
- Measuring gaseous air pollutants ($O_3$, $SO_2$, $NO_X$, CO) and meteorological parameters (temperature, relative humidity, precipitation, wind speed and direction) continuously to assess day-to-day variability in local transport pathways and emission source influences;
- Extracting and analyzing the samples for a suite of 29 trace elements using inductively coupled plasma-mass spectrometry (ICP-MS) to determine the bulk chemical composition;
- Applying the advanced electron microscopy techniques of HAADF-STEM, EDX, and EFTEM to obtain detailed information on the size, morphology, structure, and elemental composition of the individual particles collected; and
- Examining the nano-metal particles, including transition metals, detected in the Detroit, MI samples. High-resolution transmission electron microscope (HRTEM)-imaging was used in combination with the advanced electron microscopy techniques to map the elemental distributions at the nano-scale

## Benefits

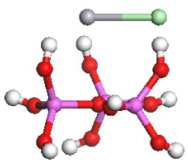
Characterization at the nano-scale is necessary to better understand the relationship between anthropogenic emission sources and ambient $PM_{2.5}$ from fossil fuel combustion and other sources. The testing and evaluation of HAADF-STEM, EDX, and EFTEM advanced analytical microscopy techniques will aid in the development of complementary analytical tools capable of providing detailed information on individual particles. This knowledge can then be used to help identify the primary emission sources and their relative contributions to the atmosphere.

## Planned Activities

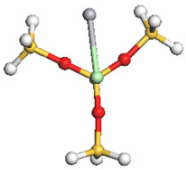
Individual particle analysis using the advanced electron microscope is on-going and the ambient $PM_{2.5}$ samples collected in Steubenville, OH will be examined next. Each sample will be analyzed by high-resolution ICP-MS and compared to the results obtained using the HAADF-STEM and EDX, and TEM. A detailed project report with recommendations will be prepared at the conclusion of the project.




*CaO 5x5x2 with optimized Hg-O surface bond interaction*



*HgCl adsorption on a $T_3$ $Al_2O_3$ model cluster*



*HgCl adsorption on a model $SiO_2$ cluster*

*"CaO, $Al_2O_3$, and $SiO_2$ are all constituents of PWDS that may contribute to mercury capture. These images show several of the possible interaction mechanisms."*