PROJECT facts

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SAMPLING, ANALYSIS, AND PROPERTIES OF PRIMARY $PM_{2.5}$: APPLICATION TO COAL FIRED BOILERS

DOE Supports Development of Dilution Sampler to Characterize Emissions

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Background

New requirements for airborne particulate matter with an aerodynamic diameter of less than 2.5 microns ($PM_{2.5}$) were announced in 1997 by the United States Environmental Protection Agency (EPA) under the National Ambient Air Quality Standards (NAAQS). Various cardiovascular and respiratory health problems have been linked to elevated concentrations of $PM_{2.5}$, presumably due to its ability to penetrate and accumulate deep within the human lung. Another adverse effect of airborne $PM_{2.5}$ is that of reduced visibility in our nation's urban centers, rural areas, and national parks. Procedures for addressing these effects are set forth under EPA's 1999 Regional Haze Rule. In order to develop regulatory guidelines to meet the NAAQS and Regional Haze standards, a further understanding of $PM_{2.5}$ and its possible sources is necessary.

It is important to note that, in many cases, only a minor percentage of $PM_{2.5}$ in ambient air is emitted in the form of solid, or "primary" particles. For example, primary $PM_{2.5}$ emissions from coal-fired utility boilers are generally viewed as less problematic than emissions of gases such as SO_2 and NOx, which react in the atmosphere (primarily with ammonia) to form "secondary" particles of ammonium sulfate and ammonium nitrate. Volatile and semi-volatile organic species emitted by natural and man-made sources can also react in the atmosphere to form secondary $PM_{2.5}$. These $PM_{2.5}$ formation and transport processes are not completely understood, so further research in this area is required.

Objectives

The main objectives of this project are to characterize the emissions of primary $PM_{2.5}$ from coal-fired utility boilers, study the formation of fine organic aerosols from these sources, and quantify sampling artifacts due to water and vaporization/condensation of semivolatile compounds. A state of the art dilution sampler is being developed to simulate the dilution and cooling processes that coal combustion products undergo in the atmosphere. Unlike traditional exhaust stack sampling methods, the dilution sampler allows the investigation of processes such as nucleation, condensation, and coagulation, which affect the size distribution and composition of the emissions.

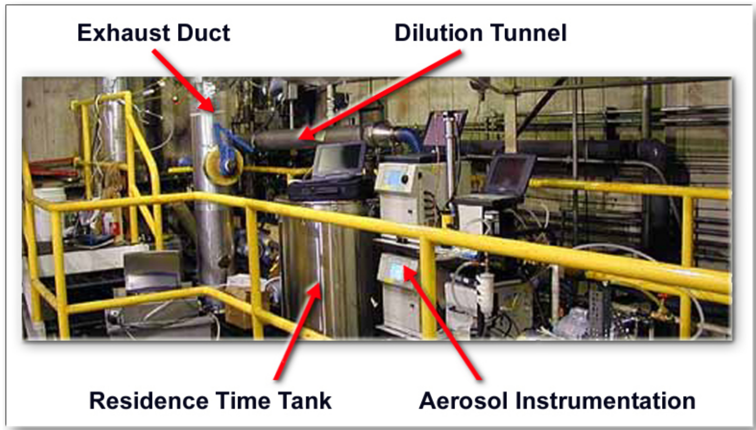
This characterization will theoretically allow $PM_{2.5}$ emissions to be tracked from their sources — in this case, coal-fired boilers — to their eventual destinations at ambient air monitoring sites.

Sampling, Analysis, and Properties of Primary $PM_{2.5}$: Application to Coal Fired Boilers

DOE Supports Development of Dilution Sampler to Characterize Emissions

Description

The dilution sampler developed under this project is being tested at NETL's Combustion and Environmental Research Facility (CERF). Flue gases from the CERF experimental furnace are sampled through a cyclone with a 2.5 microns cut point to prevent larger particles from depositing downstream in the dilution system. Next, the combustion products flow though a heated sampling probe, past a flow meter, and into the dilution tunnel. In the dilution tunnel, the sample is mixed under turbulent conditions with clean air that has been treated by activated carbon and HEPA filters to remove all contaminants. Temperature and humidity are controlled by passing the dilution air through a chiller and humidification system prior to mixing. The sampler is designed to operate at variable dilution ratios of up to 200:1.



The dilution sampler at NETL's Combustion and Environmental Research Facility

A fraction of the diluted sample is then pulled from the dilution chamber and stored in a residence time tank. This chamber provides up to several minutes of residence time, allowing condensation and nucleation to occur, thus enabling a study of the formation of semivolatile aerosols from coal combustion products. Diluted source particulate matter is then captured by a variety of aerosol classification equipment to determine the particle composition, size distribution and other pertinent information about the aerosol. Experiments are being conducted to determine the rates of $PM_{2.5}$ emission as a function of dilution rate, temperature, and relative humidity. The dilution sampler is intended to be fully portable to allow for transportation to individual power plants for emissions characterization experiments.

Results

Using the dilution sampler, size distributions were measured for various dilution ratios and residence tank times. Thus far, concentration data, normalized on a unit volume basis, show higher concentrations of particles of less than 0.01 microns when the dilution ratio is increased. These concentrations were found to decrease with longer sample residence times, due to increased coagulation.

Under this project, additional tests will be conducted with the dilution sampler at the CERF to further investigate the effects of coagulation, as well as the differences between dilution sampling and direct-stack sampling on concentrations of trace species. After the effects of the various sampling parameters have been investigated at the CERF, it is envisioned that the dilution sampler will be used to perform detailed sampling on full-scale coal boilers and other major industrial point sources.