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Executive Summary

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Toxicity of Secondary Coal Combustion Emissions in Wisconsin

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EXECUTIVE SUMMARY

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Research Category: Program Interest Area A: Effect of air pollutants from coal-fired power plants on human health in Wisconsin

Project Period: September 1, 2002 – June 30, 2005

Background: Fine particulate matter ($PM_{2.5}$) is a complex mixture of materials from a number of emissions sources. Some PM is primary, emitted directly by traffic, industrial operations, and other sources, while some PM is secondary in nature, forming via complex reactions in the atmosphere. Some of these reactions involve organic compounds emitted from vegetation. Widespread implementation of PM control measures on power plants in the United States has resulted in low primary PM emissions. Therefore, the concern over power plant PM is largely focused on the secondary particles that form downwind of the plants from the oxidation of sulfur dioxide (SO_2) and nitrogen oxides (NOx).

However, despite the fact that primary power plant PM comprises a very small fraction of total ambient $PM_{2.5}$, most of the toxicology research on the health effects of power plant emissions has used coal fly ash or a pilot combustor, both of which represent the primary fraction. For example, some of the previous studies have involved exposing animals via lung instillation to fly ash collected from an electrostatic precipitator. No efforts to consider and account for secondary atmospheric chemistry have been made to date. This project is important because it evaluates secondary particles from coal-fired power plants. The project involves exposing laboratory rats via inhalation to realistic (atmospherically transformed) power plant and mobile source (traffic) emissions to help determine the relative toxicity of these PM sources. The research evaluates the regulatory assumption that all PM has an equal effect on human health, and does so using a novel and innovative experimental design.

Project Overview: Primary emissions are drawn from the power plant stack and converted to secondary particles by adding oxidants (hydroxyl radicals) and irradiating the mixture. This

process forms sulfate particles as they would form in the atmosphere, and represents an oxidized power plant plume, unneutralized by ammonia. In another experimental scenario, ammonia is added to simulate the neutralized, oxidized plume. We have also added a volatile organic compound, α-pinene, along with ozone to form secondary organic aerosol and simulate the mixing of the plume with biogenic emissions from vegetation. By evaluating all of these scenarios we are better able to understand the impact of different atmospheric conditions on particle formation as well as toxicity. After atmospheric processing, the emissions are characterized to determine concentrations of gas- and particle-phase components.

Laboratory rats are exposed to the different scenarios for 6 hours, and a wide variety of biological effects are evaluated, focusing on the pulmonary and cardiovascular systems. Specifically, lung function and breathing pattern are assessed, as changes in some parameters such as breathing frequency can indicate an irritant or asthma-like response. Oxidative stress, a type of reaction to certain toxicants, is evaluated in lung and heart tissue. Bronchoalveolar lavage fluid, blood, and lung tissue are collected and analyzed for evidence of inflammation and injury. All of these responses are commonly used in air pollution toxicology studies and together give us a good understanding of the biological effects, if any, of the exposures. Toxicological data for control animals (exposed to air only) and exposed animals are compared to determine if differences exist.

Objectives of Research: The primary objective of the project is to increase our understanding of the PM sources and components responsible for adverse health effects, specifically as these relate to coal combustion and mobile source emissions. Secondary objectives of the study are (1) to evaluate the relative toxicity of coal combustion emissions and mobile source emissions, their secondary products, and ambient particles; and (2) provide insight into the effects of atmospheric conditions on the formation and toxicity of secondary particles by simulating different atmospheric conditions.

Summary of Research/Accomplishments: This project was technically challenging by virtue of its novel design and requirement for the development of new techniques. Initially, a sampling system consisting of a venturi orifice and aspirator was assembled to draw emissions from the stack. However, after testing the equipment at the plant, it was suspected that primary particle losses may have been occurring in the sampler, and the sampling system was redesigned. The modified system resulted in no substantial increase in particle concentration in the emissions. This observation, coupled with stack sampling conducted according to standard EPA protocol, led us to the conclusion that the sampled emissions are representative of those exiting the stack into the atmosphere.

Two mobile laboratories were outfitted for the study: (1) a chemical laboratory in which the atmospheric aging was conducted and which housed the bulk of the analytical equipment; and (2) a toxicological laboratory, which contained animal caging and the exposure apparatus. Animal exposures were completed between May and November, 2004. Toxicological endpoints included (1) pulmonary function and breathing pattern; (2) bronchoalveolar lavage fluid cytological and biochemical analyses; (3) blood cytological analyses; (4) *in vivo* oxidative stress in heart and lung tissue; and (5) heart and lung

histopathology. These metrics were chosen because they are indicators of lung and heart abnormalities, both of which are linked with PM exposure. Exposure concentrations for the scenarios utilizing secondary particles (oxidized emissions) ranged from 70 - 256 $\mu g/m^3$, and some of the exposure scenarios contained high acidity levels (up to 49 $\mu g/m^3$ equivalent of sulfuric acid).

Toxicological results indicated no differences between exposed and control animals in any of the endpoints examined. In contrast, previous studies have reported lung and heart oxidative stress in animals exposed to concentrated ambient particles (CAPs) from Boston at comparable concentrations to those employed in this study, thereby demonstrating that urban PM can induce biological responses. The lack of response to secondary sulfate particles in the current study is consistent with the bulk of the toxicological literature reporting no adverse effects with sulfate exposure except at very high concentrations. However, caution must be used in generalizing the coal combustion results reported here to other power plants utilizing different coal types and with different plant configurations, as emissions may vary based on these factors.

Importance of Project to Wisconsin: These findings further our understanding of how coal-fired power plant emissions in Wisconsin might affect the health of the State's residents. We observed no adverse effects with exposure to multiple emissions scenarios at a Wisconsin power plant. These exposures were conduced at PM concentrations well above ambient levels. Based on the toxicological results, we would expect the impact of coal combustion emissions on public health to be low. Again, other plant configurations and coal types might lead to different results.

Future Directions/Activities: This project is part of a larger research effort, TERESA (Toxicological Evaluation of Realistic Emissions of Source Aerosols). TERESA includes fieldwork and assessment of health effects at three power plants: (1) the subject plant in this report, located in Wisconsin and burning Powder River Basin coal; (2) a plant in the Southeast burning low-to-medium sulfur eastern bituminous coal; and (3) a plant in the Midwest burning medium-to-high eastern sulfur bituminous coal, with a scrubber. Work at these latter two plants is being partially funded by the U.S. Department of Energy's National Energy Technology Laboratory. For additional information on this larger study, please visit http://www.netl.doe.gov/coal/E&WR/air_q/index.html.

The subject project also includes assessment of the toxicity of mobile source emissions (traffic emissions), being funded from other sources (Harvard-EPA Particulate Matter Research Center). This part of the project will be carried out by collecting emissions from a tunnel in Boston, introducing them into the mobile lab for atmospheric processing, and carrying out the same toxicological assessment as for the coal combustion work. Our plans are to conduct these experiments after completing the work at the three power plants. Thus, the mobile source work will be the last stage of the TERESA program. A comprehensive addendum to this report will be prepared after all field work has been completed and all the data have been analyzed. It is expected that the mobile source work will be completed by or before January 2010, and the addendum will be completed by June 2010.