Final Technical Report

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Center Name: NYU-EPA PM Center: Health Risks of PM Components
Center Director: Morton Lippmann
Title: Physicochemical Parameters of Combustion Generated Atmospheres as Determinants of PM Toxicity
Investigator: L.C. Chen
Institution: New York University School of Medicine
EPA Project Officer: Stacey Katz/Gail Robarge
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RFA: Airborne Particulate Matter (PM) Centers (1999)
Research Category: Particulate Matter

Objective(s) of the Research Project: Combustion generated particles often make up a significant portion of ambient particulate matter (PM) in many regions. This study examines the hypothesis that the toxicological effects associated with combustion-generated PM depend upon specific physicochemical characteristics of the particles. PM effluents from high temperature processes, such as fossil fuel combustion and pyrometallurgical systems, consist of inorganic materials having a wide size range and chemical composition, including H_2SO_4 and unreacted SO_2. Such effluents have been shown to be toxicologically active. Freshly formed acidic fly ash atmospheres (containing SO_2 and ultrafine particles with transition metals on their surface) produce decrements in lung function (Amdur, et al., 1986; Chen, et al., 1990). Furthermore, sulfuric acid as a coating on particle surfaces has been shown to be 10 fold more potent in producing pulmonary effects than are pure acid droplets of the same H^+ concentration (Amdur and Chen, 1989). Epidemiological data have indicated increased daily mortality to be associated with particulate air pollution indices, and a significant contribution from SO_2 could not be ruled out. Since SO_2, by itself, has low toxicity, it is reasonable to speculate that a synergistic interaction between SO_2 and particles may have been responsible for these observed effects (Amdur and Chen, 1989; Amdur, et al., 1986).

Several human panel studies in the U.S. and the MONICA study in Europe (Gold, et al., 1998; Pope, et al., 1998; Shy, et al., 1998; Peters, et al., 1998), as well as animal studies (Watkinson, et al., 1998; Lovett, et al., 1998; Nadziejko, et al., 1997) have suggested an association between PM and changes in host homeostasis. In this study, cardiopulmonary effects are measured in healthy and compromised animals exposed by inhalation to laboratory-generated particle atmospheres having precisely defined physicochemical characteristics.

This study examined the hypothesis that the toxicological effects associated with combustion-generated PM depend upon specific physicochemical characteristics of the particles and determined the influence of physicochemical parameters of combustion generated PM on the time course, dose response, and persistence of particle-induced cardiopulmonary effects.

Summary of Findings:

Technical Aspects

This project was closely integrated with Project 4 (R827351C006; Nadziejko, PI) in the measurement of cardiopulmonary effects upon exposures to various PM atmospheres. The accomplishments of Project 4 are separately reported by Dr. Nadziejko.

We have developed two furnace systems to produce realistic combustion effluents, and have successfully produced a mixture of carbon, SO_2, and metal (iron or copper). This allows determination of specific components, especially metals, which may be responsible for adverse health effects, and an assessment of whether any effects could be nonspecific, i.e., they follow inhalation of any type of particle. For the work described herein, the electronics for temperature regulations of both furnace systems were updated. To produce Fe (or Cu), and S coated carbon particles, sucrose solutions containing varying concentrations of $Fe(NO_3)_3$ (or $Cu(NO_3)_2$) were produced by a nebulizer and burned in the furnace system previously used to produce coal fly ash. The mass median diameters (MMD, determined by a Mercer impactor) of particles produced by a Collison nebulizer (before combustion) using 10 sucrose solutions (each containing 1117 ppm Fe) were 0.9 μm. When a 10% sucrose solution containing 1117 ppm Fe (or Cu) was burned in the furnace at 750°C in the presence of 1 ppm SO_2, ultrafine particles with a median diameter of 32 ± 1.3 nm (34.0 ± 7.4 nm for Cu) and sg of 1.55 were produced. Number concentrations as high as 1.9×10^7 particles/cc were achieved. XRF was used to measure the concentrations of iron, copper, and sulfur in these particles. At this combustion condition, the particles produced from this furnace contained 35.1% and 3.6% by mass of iron and sulfur, respectively (30.6% copper and 6.9% sulfur when copper was used). It appeared that copper is almost twice as efficient (6.9% vs. 3.6%) in converting sulfur dioxide gas to particle-associated sulfur.

Sprague Dawley rats were exposed to furnace gas or 450 $\mu g/m^3$ of these particles for 3 hours and their lungs were lavaged 24 hr post exposure. A lead oxide diffusion denuder was used to remove SO_2 from the exposure atmospheres. None of the exposure atmospheres produce changes in LDH levels in the lavage fluid. However, those aerosols containing a mixture of iron, SO_2, and carbon produced a 6.8 fold increase over the furnace gas control for the total number of cells in the lavage, whereas particles containing copper, SO_2, and carbon did not produce any change in this parameter. The results are shown in Table 1.

Table 1. Effects of Ultrafine Particles in Rats

Exposure Atmospheres	Total Cell Counts (10^6)	LDH (BB unit)
Furnace Gas	0.70 ± 0.14	95.5 ± 10.2
SO_2 + carbon	1.52 ± 0.31	78.7 ± 6.3
Copper + SO_2 + carbon	1.52 ± 0.23	80.0 ± 13.5
Iron + SO_2 + carbon	4.77 ± 0.41*	113.7 ± 28.2

Values were mean ± SE, (n=4 to 7 per exposure group).
* significantly different than furnace gas control ($p < 0.0001$).

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Supplemental Keywords: NA

Relevant Web Sites: http://www.med.nyu.edu/environmental/
http://es.epa.gov/ncer/science/pm/centers.html