M. Constantini
Health Effects Institute
Cambridge / USA

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Consideration on characterizing particles from emissions

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Maria Costantini, Health Effects Institute[1]

Several epidemiologic studies have shown that increases in the level of particulate air pollution are associated with increased mortality and morbidity. However, the mechanisms by which particles might cause such effects and the characteristics of particles that may be toxicologically important have just begun to be investigated. Efforts are also ongoing to better characterize particles in the ambient air and from their sources. Because both emission and ambient standards are based on the particle mass, particle measurements have focused primarily on determining their mass concentration. However, recently it has become apparent that mass alone is not sufficient to characterize particles and that other parameters such as number, shape, and surface area may be equally or more important indicators. Scientists characterizing particles in emissions or in the ambient air would like to know which characteristics of particles should be measured and, if appropriate, controlled. The health effects scientists, especially those who are designing studies to simulate exposure to real-world particles in the laboratory setting, would like to know the characteristics and composition of the particles from various sources and in the air in order to generate suitable particles for testing. At this time, there is no clear answer as to which parameters are more closely associated with health effects, but information emerging form the health effects research is pointing in certain directions.

This paper is not meant to provide a comprehensive review of the literature on particles and their health effects, but only to summarize some of the leading hypotheses regarding which particle characteristics may be associated with health effects. These are a) metal content, b) particle size, c) particles as carrier of other toxic compounds (peroxides, biological agents such as endotoxin, spores, pollen, etc.).

Role of metals. Transition metals (such as Fe, Cu, Ni, Co, Mn, etc.) have been hypothesized to be associated with effects because they can cause production of hydroxyl radicals, which are considered products toxic to the cells (Pritchard et al 1996). Scientists have shown that the ionizable concentration of total particulate metals was associated with indices of lung injury Pritchard et al. 1996) and that certain metal constituents of particles cause induction of inflammatory mediator genes similar to those induced by metal-rich particles such as residual coal fly ash (Kodavanti et al. 1997). The chemical form of the metal also appears to be important. In vitro studies conducted by Ann Aust (Utah State University) have shown that Fe

[1]955 Massachusetts Avenue
Cambridge, MA 0
Tel: 617-876-6700; Fax : 617-876-6709
e-mail: mcostantini@healtheffects.org

that can be solubilized by citrate (which is considered to be bioavailable) does not correlate with the total Fe content in coal fly ash (Aust et al. 1998). This researcher is now trying to determine the relationship between total Fe, available Fe, and biological endpoints.

Role of size. Another hypothesis is that ultrafine particles are more toxic than fine particles because they deposit in the alveolar region with greater efficiency and are cleared more slowly (Oberdörster et al. 1995; Ferin et al. 1992), but little information has been obtained so far showing that exposure to ultrafine particles is associated with acute mortality or morbidity. Dr. Oberdörster (University of Rochester) recently published initial results showing that ultrafine particles of carbon and platinum cause a slight increase in pulmonary inflammation in aged rats with compromised respiratory system, but not in young healthy animals (Oberdörster et al. 1998).

Particles as carrier. Scientists have hypothesized that atmospheric particles carry reactive chemical species (Friedlander and Yeh 1998). However, there are no data available yet showing that particles interact with gas-phase compounds or absorb biological molecules and carry them to the lung. Some studies to test specific hypotheses involving particles as carriers are currently in the planning phase.

There is a great deal of research under way to understand more about the attributes of particles are most important in causing health effect and more information will be available over the next couple of years. While most of the ongoing research is focusing on insoluble particles, there is still interest in the effects of soluble particles. The studies with acid aerosols have not provided consistent evidence for causal association with the effects studied (asthma, increased mortality, hospital admissions, reduction in lung function). Some epidemiologic studies conducted in several locations differing in particle composition and sources may shed some light on the role of different types of particles.

One factor that has delayed obtaining dose-response information in toxicologic studies has been the need to develop animal models of disease relevant to human diseases. Some of these models have now been tested with various types of particles, but the results of these studies have not yet appeared in the peer-reviewed literature. Additional studies are using those animals models with both concentrated ambient particles or laboratory-generated model particles to test specific hypotheses about mechanisms of particle toxicity and about particle composition (such as transition metals, biological contaminants), and to test the effects of interactions between different types of particles or between particles and gases.

Scientists who are characterizing particles in emissions should obtain as complete as possible a picture of which particles (in terms of size distribution, mass, particle number, surface area, and composition - organic compounds, elemental carbon, metals, sulfates, nitrates) and gases are present in emissions. These particles should be collected in ways that best approximate the dilution conditions of real world situations. As more information is obtained about what particles people are exposed to and the health effects of particles, a picture might emerge

pointing to certain types of particles or certain constituents as being the most toxicologically relevant. If one knows the characteristics of particles present in emissions and how these change as a result of engine modifications or fuel changes, then the regulators and the industry can make informed decisions as to what and how to control those emissions. Given the uncertainties about the contribution of various particle parameters to health effects, it would be a mistake at this time to limit the measurements to one type, or class, of particles.

In December 1995, HEI held a workshop on *Particle Formation and Characterization* (Health Effects Institute 1996) with the purpose of bringing together engineers who are measuring particles and health effects researchers. The workshop participants identified the following research needs for particle characterization in emissions.

"Data on the size distribution, the chemical and physical properties related to the size of the particles, and particle sources are needed to: a) assess the impact of emission controls and new technologies, b) help in apportioning ambient particles to emission sources, and c) assess the potential adverse health effects of primary particles. Instrumentation and other techniques designed to follow mobile source particle emissions under driving conditions (particularly under driving conditions that include hard acceleration and speed changes, when most particles are formed) are needed to aid in developing control strategies."

" The variety of techniques and instrumentation currently used for collecting particles, and determining size distributions and the chemical and physical properties need to be assessed for cross-correlations, precision, and sensitivity to sample conditioning and collection methods. The differences between methods that measure particle number and mass, and the appropriate conversion from one measurement to another need to be carefully described. Sample conditioning, collection, or in situ analyses, which mimic real-world conditions and avoid sampling artifacts, need to be developed."

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