



STATEMENT

Synopsis of Research Report 121

HEALTH
EFFECTS
INSTITUTE

Evaluation of Iron Nanofilm Detectors for Measuring Acidic Particles in Indoor and Outdoor Air

Over the last several decades, evidence has accumulated suggesting that exposure to airborne particulate matter (PM), which includes particles of varying composition and sizes (coarse, fine, and ultrafine), may affect the human cardiovascular and respiratory systems. Although ultrafine particles constitute a small percentage of the total PM mass in the size category regulated by the EPA through the National Ambient Air Quality Standards (PM < 2.5 μm in aerodynamic diameter), they are present in high number concentrations.

Much research has been conducted to learn how each component of PM contributes to its health effects in order to help inform decisions on ambient PM standards and pollution control strategies. Such research, especially in population studies, has been hampered by the lack of portable instruments that can measure the personal exposure levels of specific PM components. In 1998, HEI issued RFA 98-1, "Characterization of Exposure to and Health Effects of Particulate Matter," seeking studies to improve characterization of personal exposure to PM and to evaluate attributes of particles that may cause toxicity. In response to this RFA, Dr Beverly Cohen and colleagues at New York University Medical Center proposed to test a new iron-coated nanofilm for collecting and measuring ambient concentrations of acidic ultrafine PM. Cohen and colleagues hypothesized that because small particles are more likely than larger particles to deposit in the lower respiratory tract, and particle acidity is known to damage lung tissues, acidic ultrafine particles may be especially toxic. Until this study, none of the existing sampling methods could provide a measure of these particles.

APPROACH

The iron nanofilm detector is a thin iron-coated silicon chip (5 mm \times 5 mm \times 0.6 mm). The investigators

assumed that, upon impact, each acidic particle would react with the iron, creating an elevated site, or bump, on the film surface. They visualized the reaction sites by scanning the surface of the film using an atomic force microscope. As shown in this report and in previous work by Cohen and colleagues, laboratory-generated acidic particles generally form reaction sites surrounded by a ring. Therefore, elevated sites with rings on iron nanofilms exposed to ambient aerosol were assumed to reflect acidic particles. Sites without rings were assumed to represent nonacidic particles. Particle number concentration was calculated from the number of impact sites counted on the scanned areas with corrections to account for the collection efficiency and other parameters specific to each sampler.

The authors tested the performance of iron nanofilms preexposed to laboratory-generated sulfuric acid particles of different sizes under a variety of storage conditions (temperature and humidity). They used two types of air samplers for ambient monitoring. One was a combined system in which an electrostatic aerosol sampler (EAS) was preceded by a microorifice impactor (MOI) that removed particles larger than 100 nm from the air samples. The other was an ultrafine diffusion monitor (UDM), which did not have specific size selectivity. Field monitoring sessions (lasting 1 or 2 weeks) were conducted during each of the four seasons in a rural area (Tuxedo NY) between July 1999 and May 2000 and during the winter of 2000 in an urban area (New York City). For these tests, the MOI-EAS and the UDM were collocated. The UDM was also deployed in two indoor environments.

Cohen and colleagues made a number of comparisons of the data obtained. They compared the number concentrations of acidic particles and of total ultrafine particles between the MOI-EAS and

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the UDM; the number of acidic ultrafine particles measured using MOI-EAS with the acid content of particles of comparable size collected on MOI filters; and the total ultrafine particle concentrations (of acidic and nonacidic particles) determined using the MOI-EAS and the UDM with those determined using a commercially available particle counter, the scanning mobility particle sizer (SMPS).

RESULTS AND INTERPRETATION

Laboratory experiments showed that the surfaces of both blank nanofilms and nanofilms preexposed to sulfuric acid particles were generally stable for a period of 3 months, at average ambient temperature (22°C) and high humidity (92%), and were not affected substantially by exposure to particle-free ambient air. However, the surface appeared to deteriorate at high temperature (39°C, 88% humidity). Both ambient-temperature and high-temperature storage may have caused enlargement of some reaction sites, but the fact that the same areas of the detectors were not reexamined over time made it difficult to evaluate the temporal changes on the nanofilms.

The results of the monitoring studies showed limited agreement between the MOI-EAS and UDM measurements. There was no trend in the relation of acidic particle numbers measured by the two instruments. For the total particle number concentrations, however, the MOI-EAS consistently yielded lower values than those obtained with the UDM. The poor agreement between the two types of samplers can be attributed to differences in their size selectivity and efficiency of collection (with the UDM having a much lower efficiency than the EAS). In addition, the magnitude of error in the determination of deposition efficiency is not known.

The number concentrations obtained from the MOI-EAS nanofilms were lower than those derived from the comparison instrument, the SMPS, while those obtained from the UDM nanofilms were more similar to the corresponding SMPS measures for some sampling periods. Results of indoor measurements using the UDM were not compared with SMPS measurements.

The authors found no correlation between the number concentrations of acidic ultrafine particles (determined with the MOI-EAS) and the acid content of ultrafine particles (determined by measuring the pH of particles less than 100 nm in diameter collected on a filter placed in parallel with the EAS after the last stage of the MOI). This finding is intriguing and, if confirmed by further testing, suggests that conclusions about the association between health effects and exposure to acidic particles might be different if the number of acidic particles, rather than particle acidity, were evaluated.

Although the iron nanofilm is promising for acidic particle analysis, uncertainties remain to be better understood: the rate of the reaction of acidic and nonacidic particles with the nanofilm, the relation between particle acidity and the shape of the reaction site, the collection efficiency of the samplers (especially the UDM), and the error in counting the reaction sites.

Finally, it would be useful to evaluate how the nanofilms perform in locations with higher levels of particles and gases (especially ozone, which is the gas most likely to react chemically with the iron nanofilm). In the absence of other methods for measuring the number of acidic particles, iron nanofilms housed in an EAS may be used to approximate the ambient levels of acidic particles, although further improvements of the system are needed.