Introduction to the A&WMA 2005 Critical Review

Nanoparticles and the Environment

Judith C. Chow

Nanoparticles are loosely defined as particles with diameters in the range of ~1 nm to 50 or 100 nm (nanometers). Nanoparticles are bigger than air molecules (~0.3 nm), but are smaller than the upper limits regulated by ambient air quality standards. (U.S. National Ambient Air Quality Standards regulate the mass of particles with diameters less than 2500 and 10,000 nm, $PM_{2.5}$ and PM_{10}, respectively.) Although nanoparticles do not contribute large quantities to $PM_{2.5}$ or PM_{10} mass, they dominate the number concentration and most of its surface area. Nanoparticles are produced by condensation of hot vapors in fresh combustion emissions. They also form from natural and man-made gases as secondary aerosol by photochemical oxidation of gaseous compounds. Nanoparticles may contain transition metals, organic material, sulfuric acid, and free radicals. Owing to their small size and high mobility, they diffuse rapidly and may combine with each other, with larger particles, and with nearby deposition surfaces. Owing to their short lifetimes and low mass concentrations, nanoparticles are not conveniently measured in source emissions and ambient air. For similar reasons, they are not easily generated for exposure, inhalation, and toxicological studies to determine their potential adverse effects on human health.

Nanoparticles are often considered to be deleterious when they are inhaled or ingested into the human body.[1] They penetrate deeply into the lung,[2] where their large numbers overwhelm defensive mechanisms. Thereafter, they can transport through the bloodstream or lymphatic system to vital organs.[3] However, nanoparticles can also be lifesavers. The same inhalation and transport properties can rapidly deliver medicines through the lungs. Iron nanoparticles can be magnetically directed to specific locations without invasive procedures. Nanomonitors can increase the effectiveness of health and environmental monitoring to detect hazards within and outside the human body.

The 35th annual A&WMA Critical Review addresses the broad topic of nanoparticles and the environment. It complements recent treatments of this topic in other journals.[4] The review offers a broad overview of environmental origins, consequences, and applications for nanoparticles. It shows that nanoparticles are produced both unintentionally by pollution sources and intentionally for commercial applications. Both of these can result in adverse health effects in the ambient and workplace environments if they are not appropriately controlled. Control methods are more complex and cost more than those for larger particles. Nanoparticles also form naturally when gases oxidize to compounds with lower vapor pressures and spontaneously nucleate or condense on other small particles. These events have been observed in both polluted and clean areas throughout the world.[5]

The authors, Drs. Pratim Biswas and Chang-Yu Wu, conclude that nanoparticles are an emerging environmental research area. They observe that most of the scientific literature has been published since the early 1990s. These publications span a wide range of scientific disciplines and journals, presenting a challenge to the reviewer. Different disciplines use different terminologies that do not necessarily agree with each other. Even the definition of nanoparticle size ranges depends on the application. The authors paint a broad picture of nanoparticle applications to environmental issues, including substitution for hazardous materials; sensors for hazardous gases and particles; waste remediation; hydrogen production and storage as an alternative energy source; fuel cell fabrication; longer-life and lighter batteries; and coatings for self-cleaning tiles, glass, and light bulbs. They place special emphasis on the potential adverse health effects. They observe that although there are some indications of effects, the jury is still out on how serious a threat nanoparticles create in the atmospheric environment. The authors conclude that there are many exciting opportunities for future nanoparticle research and that their advantages far outweigh their potential adverse environmental consequences.

Drs. Biswas and Wu are well qualified to conduct this critical review. Dr. Biswas is the Stifel and Quinette Jens Professor and Director of the Environmental Engineering Science Program at Washington University in St. Louis, MO. He has more than 25 years of experience in aerosol research, having received his B. Tech. degree from the Indian Institute of Technology, his master's degree from the University of California at Los Angeles, and his Ph.D. from the California Institute of Technology in 1985. He has published more than 130 articles and book chapters on environmental and industrial aspects of fine particles.

The Environmental Engineering Science program that he directs is an integrated, multidisciplinary program that provides a scientific education for individuals interested in focusing on the improvement and management of the quality of the environment. The mission of the program is to educate future generations of engineers and scientists to tackle and solve the complex environmental issues we face today and in the future.

Dr. Wu is an Associate Professor in the University of Florida's Department of Environmental Engineering Sciences, where he teaches graduate and undergraduate engineers and performs aerosol and air pollution control research. Dr. Wu received his bachelor's of science degree from National Taiwan University, his master's degree from the University of Cincinnati, and his Ph.D. from the University of Cincinnati in 1996. He has published more than 30 articles on control of fine metallic aerosols and development of environmental nanotechnology.

A&WMA members and interested parties are invited to read, attend, and comment on the 35th annual Critical Review at the Annual Conference & Exhibition in Minneapolis, MN, on Wednesday, June 22, 2005, from 8:00 to 11:30 a.m. As always, the review presentation will be followed by comments from invited discussants: (1) Dr. Nora Savage, Environmental Engineer in the U.S. Environmental Protection Agency's Office of Research and Development, who is evaluating relationships between nanotechnology and environmental justice; (2) Dr. Jack Solomon, Director of Technology Assessment and External Relations of Praxair Inc., who heads a project to define nanomaterial R&D priorities for different sponsoring agencies; (3) Dr. Yung Sung Cheng, Director of the Inhalation Drug Delivery Center at Lovelace Respiratory Research Institute, who evaluates medical applications of nanoparticles; and (4) Dr. Peter McMurry, Department Head and Professor for the University of Minnesota's Mechanical Engineering Department, who has a long record of research in nanoparticle measurement, generation, and applications.

The discussants will provide different perspectives, agreeing or disagreeing with the conclusions and recommendations of Drs. Biswas and Wu and with each other. They will identify additional issues and offer new information. Comments also will be accepted from the floor and from written submissions to the Critical Review Committee Chair. The Chair will condense and summarize these points in the October issue of the *Journal*. Members are encouraged to suggest topics and authors for future critical reviews and to apply for membership on the Critical Review Committee to assist with the process.

Critical Review Committee Chair (2001–2006)
Judith C. Chow; e-mail: judy.chow@dri.edu

Critical Review Committee Members
Pratim Biswas
Delbert Eatough
Charles McDade
Peter Mueller
Thomas Overcamp
John Watson
Chang-Yu Wu

REFERENCES

1. Oberdörster, G.; Gelein, R.M.; Ferin, J.; Weiss, B. Association of Particulate Air Pollution and Acute Mortality: Involvement of Ultrafine Particles? *Inhal. Toxicol.* **1995**, *7*(1), 111–124.
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4. Zhang, W.X.; Karn, B. Nanoscale Environmental Science and Technology: Challenges and Opportunities; *Environ. Sci. Technol.* **2005**, *39*(5), 94A–95A.
5. Kulmala, M.; Vehkamäki, H.; Petaja, T.; Dal Maso, M.; Lauri, A.; Kerminen, V.M.; Birmili, W.; McMurry, P.H. Formation and Growth Rates of Ultrafine Atmospheric Particles: A Review of Observations; *J. Aerosol Sci.* **2004**, *35*, 143–176.

Attend the Critical Review Presentation

"Nanoparticles and the Environment"

by Drs. Pratim Biswas (Washington University in St. Louis)
and Chang-Yu Wu (University of Florida)

Wednesday, June 22, 2005
Minneapolis Convention Center
Room 101A-B
8:00 a.m.–11:30 a.m.