

# Introduction to the A&WMA 2006 Critical Review

## Health Effects of Fine Particulate Air Pollution: Lines that Connect



Judith C. Chow

Suspended particulate matter (PM) has adverse effects on visibility,<sup>1</sup> climate,<sup>2</sup> ecosystems,<sup>3,4</sup> and, along with other pollutants, human health.<sup>5-11</sup> Of these effects, human health is of greatest importance and has been addressed in previous critical reviews.<sup>5-11</sup> This topic is of special interest in 2006 because the U.S. Environmental Protection Agency (EPA) has proposed revisions

to the PM National Ambient Air Quality Standards (NAAQS).<sup>12</sup> These revisions would retain the annual average level for PM<sub>2.5</sub> (particles with aerodynamic diameters less than 2.5  $\mu\text{m}$ ) of 15  $\mu\text{g}/\text{m}^3$ , averaged over 3 yr,<sup>13</sup> but lower the 24-hr PM<sub>2.5</sub> level from 65  $\mu\text{g}/\text{m}^3$  to 35  $\mu\text{g}/\text{m}^3$  (98<sup>th</sup> percentile averaged over 3 yr). The PM<sub>10</sub> (particles with aerodynamic diameters less than 10  $\mu\text{m}$ ) standards of 50  $\mu\text{g}/\text{m}^3$  annual average and 150  $\mu\text{g}/\text{m}^3$  24-hr average<sup>14</sup> would be replaced by a coarse particle indicator (PM<sub>10-2.5</sub>, the difference between collocated PM<sub>10</sub> and PM<sub>2.5</sub> mass concentrations) applicable only in urban areas with populations exceeding 100,000. The proposal reasons that there is sufficient evidence to implicate resuspended urban paved road dust, construction dust, and industrial dust in adverse health effects, but there is insufficient evidence of adverse effects from other sources of PM<sub>10-2.5</sub>. The proposal explicitly excludes agricultural and mining contributions from emission reduction strategies. Twenty-four-hour average PM<sub>10-2.5</sub> would not be allowed to exceed 70  $\mu\text{g}/\text{m}^3$  (98<sup>th</sup> percentile averaged over 3 yr). PM<sub>10-2.5</sub> compliance monitoring would only be pursued in highly populated areas in relatively large cities.

EPA's proposal is at odds with EPA's Clean Air Science Advisory Committee's (CASAC) recommendation of a PM<sub>2.5</sub> annual average in the range of 13-14  $\mu\text{g}/\text{m}^3$  and PM<sub>10-2.5</sub> monitoring in both urban and rural communities.<sup>15</sup> This disagreement highlights the controversy that often accompanies air quality standards owing to uncertainties in measuring size-specific PM and its chemical components, PM toxicity, human exposure, dosage, and relevant health end points.

The 36<sup>th</sup> Annual A&WMA Critical Review<sup>16,17</sup> addresses the epidemiological evidence for the effects of PM

on human health indicators, specifically sickness (morbidity) and death (mortality). This review identifies and builds on previous and recent reviews, especially the EPA criteria document<sup>18</sup> and staff paper<sup>19</sup> used to justify NAAQS revisions. The review documents substantial progress since the 1997 critical review<sup>11</sup> in all areas of understanding, with notable advances in the areas of: 1) short-term exposure and mortality; 2) long-term exposure and mortality; 3) time-scales of exposure; 4) the shape of the concentration-response function; 5) cardiovascular disease; and 6) biological plausibility.

The authors, Drs. Arden Pope and Douglas Dockery, observe that more than 100 studies published over the past 10 yr, using many different study designs and data analysis methods, consistently show statistically significant associations between cardiopulmonary mortality and daily PM<sub>10</sub> or PM<sub>2.5</sub> concentrations. Long-term exposures show larger effects than short-term exposures across all of the studies. PM health effects appear to depend on both the concentrations and the length of exposure, with repeated exposures to high levels over many years being more serious than less frequent short-term exposures to higher concentrations. They note that setting a standard implies that there is a "threshold" below which no effects are observed, and that estimated concentration-response functions appear to be linear with no evidence of a lower limit at which no effects are observed. Whereas earlier research focused on the respiratory effects of PM exposure, the last decade has seen much progress on relationships with cardiovascular disease. There is now a definite link between the onset of heart attacks or heart irregularities and PM inhalation. Some of this may be due to excessive particle number or surface area (ultrafine particles) that are not well quantified by PM<sub>2.5</sub> mass monitors. They describe substantial progress in understanding the biological and chemical mechanisms that cause PM to adversely affect public health. Exacerbation of existing pulmonary disease, oxidative stress and inflammation, changes in cardiac autonomic functions, vasculature alterations, translocation of PM across internal biological barriers, reduced defense mechanisms, and lung damage have all been related to different levels of PM exposure, as well as to different particle sizes and compositions.

Despite this additional science, Drs. Pope and Dockery identify several knowledge gaps that need to be addressed in the future: (1) better defining susceptible populations, currently believed to be the young, the elderly, and people with existing respiratory and cardiovascular disease; (2) determining the relative effects of specific

compositions, physical properties, and sources of pollutants that cause specific effects; and (3) evaluating the importance of co-pollutants such as sulfur dioxide, nitrogen dioxide, and ozone.

Drs. Pope and Dockery are among the premier air pollution epidemiologists in the world and well qualified to prepare this critical review. Dr. Pope is a professor of economics at Brigham Young University in Provo, UT, where he has been employed since 1984. He received his Ph.D. in economics and statistics from Iowa State University in 1981. He has published more than 70 articles on epidemiology and public health in addition to more than 50 on environmental and agricultural economics. He was awarded a Fellowship at the Harvard School of Public Health in 1992–1993. Dr. Pope currently serves on the Board of Directors, American Lung Association of Utah, and the Executive Committee of the Thrasher Research Fund. Among other honors, Dr. Pope received the 2001 Thomas T. Mercer Joint Prize from the American Association for Aerosol Research and The International Society for Aerosols in Medicine in 2001 and the 2004 Utah Governor's Medal for Science & Technology. Dr. Dockery is a professor of environmental epidemiology in the Department of Environmental Health at the Harvard School of Public Health. He received his Sc.D. from Harvard in 1979 and joined the staff soon thereafter. He has published more than 100 articles on air pollution epidemiology and other topics, many of them in collaboration with Dr. Pope. His current research intends to more specifically identify the chemical and physical characteristics of particles responsible for the observed adverse health effects. Current studies also are attempting to understand the pathways of acute cardiovascular events associated with air pollution exposure and to link these epidemiologic finding with toxicologic studies of particle effects. In addition, the methods developed to assess air pollution health effects epidemiologically are being applied to other environmental hazards, including contamination of water supplies.

A&WMA members and interested parties are invited to read, attend, and comment on the 36<sup>th</sup> Annual Critical Review at the annual meeting in New Orleans, LA, on Wednesday, June 21, 2006, from 8:00 a.m. to 11:30 a.m. CDT. As always, the review presentation will be followed by comments from invited discussants: (1) Dr. Joseph L. Mauderly, Vice President and Senior Scientist at the Lovelace Respiratory Research Institute in Albuquerque, NM; (2) Dr. Daniel L. Costa, National Program Director for Air at EPA's Office of Research and Development in Research Triangle Park, NC; (3) Dr. Ronald E. Wyzga, Technical Executive and Program Manager for the Electric Power Research Institute (EPRI) in Palo Alto, CA; and (4) Dr. Sverre Vedal, Professor of Environmental and Occupational Health Sciences at the University of Washington in Seattle, WA.

The discussants will provide different perspectives, agree or disagree with the conclusions and recommendations of Drs. Pope and Dockery, 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 (2001–2007)

Judith C. Chow; e-mail: judy.chow@dri.edu

### Critical Review Committee Members

Pratim Biswas  
Delbert Eatough  
Charles McDade  
Peter Mueller  
Tom Overcamp  
John Watson  
Chang-Yu Wu

### REFERENCES

1. Watson, J.G. Visibility: Science and Regulation. *J. Air & Waste Manage. Assoc.* **2002**, *52*, 628-713.
2. Firor, J.; Jacobsen, J.E. Critical Review: Global Climate Change and Sustainable Development. *J. Air & Waste Manage. Assoc.* **1993**, *43*, 707-722.
3. Hidy, G.M. Critical Review: Source-Receptor Relationships for Acid Deposition: Pure and Simple? *J. Air Poll. Control Assoc.* **1984**, *34*, 518-531.
4. McLaughlin, S.B. Critical Review: Effects of Air Pollution on Forests. *J. Air Poll. Control Assoc.* **1985**, *35*, 512-534.
5. Biswas, P.; Wu, C.Y. Critical Review: Nanoparticles and the Environment. *J. Air & Waste Manage. Assoc.* **2005**, *55*, 708-746.
6. Chow, J.C. Critical Review: Measurement Methods to Determine Compliance with Ambient Air Quality Standards for Suspended Particles. *J. Air & Waste Manage. Assoc.* **1995**, *45*, 320-382.
7. Ferris, B.G., Jr. Critical Review: Health Effects of Exposure to Low Levels of Regulated Air Pollutants: A Critical Review. *J. Air Poll. Control Assoc.* **1978**, *28*, 482-497.
8. Lighty, J.S.; Veranth, J.M.; Sarofim, A.F. Critical Review: Combustion Aerosols: Factors Governing Their Size and Composition and Implications to Human Health. *J. Air & Waste Manage. Assoc.* **2000**, *50*, 1565-1618.
9. Lippmann, M. Critical Review: Health Significance of Pulmonary Function Responses to Airborne Irritants. *J. Air Poll. Control Assoc.* **1988**, *38*, 881-887.
10. Molina, M.J.; Molina, L.T. Critical Review: Megacities and Atmospheric Pollution. *J. Air & Waste Manage. Assoc.* **2004**, *54*, 644-680.
11. Vedal, S. Critical Review—Ambient Particles and Health: Lines that Divide. *J. Air & Waste Manage. Assoc.* **1997**, *47*, 551-581.
12. U.S. Environmental Protection Agency. National Ambient Air Quality Standards for Particulate Matter: Proposed Rule. *Federal Register* **2006**, *71*, 2620-2708.
13. U.S. Environmental Protection Agency. National Ambient Air Quality Standards for Particulate Matter: Final Rule. *Federal Register* **1997**, *62*, 38651-38760.
14. U.S. Environmental Protection Agency. Ambient Air Quality Standards for Particulate Matter; Final Rule. *Federal Register* **1987**, *52*, 24634-24669.
15. Henderson, R.; Cowling, E.B.; Crapo, J.D.; Miller, F.J.; Poirot, R.L.; Speizer, F.E.; Zielinska, B. Clean Air Scientific Advisory Committee Recommendations Concerning the Proposed National Ambient Air Quality Standards for Particulate Matter: Letter to Stephen L. Johnson. U.S. Environmental Protection Agency. Environment Protection Agency (EPA)-CASAC-LTR-06-002, March 21, 2006, Washington, DC: EPA Clean Air Scientific Advisory Committee, **2006**.
16. Pope, A.C., III; Dockery, D.W. Critical Review: Health Effects of Fine Particulate Air Pollution: Lines that Connect. *J. Air & Waste Manage. Assoc.* **2006**, *56*, 709-742.
17. Pope, A.C., III; Dockery, D.W. Summary of 2006 Critical Review: Health Effects of Fine Particulate Air Pollution: Lines that Connect. *EM*, June, **2006**, pp 30-35.
18. U.S. Environmental Protection Agency. Air Quality Criteria for Particulate Matter, Vol. 1 and 2. EPA/600/P-99/002aF. US EPA, National Center for Environmental Assessment, Office of Research & Development: Research Triangle Park, NC, 2004.
19. U.S. Environmental Protection Agency. Review of the national ambient air quality standards for particulate matter: Policy assessment of scientific and technical information, OAQPS staff paper. EPA-452/R-05-005; U.S. Environmental Protection Agency: Research Triangle Park, NC, 2005.