The Case for a Stronger Ozone Air Quality Standard

The U.S. Environmental Protection Agency (EPA) is in the midst of its periodic review of the National Ambient Air Quality Standards (NAAQS) for ozone. EPA last reviewed the air quality standards for ozone in 1997, when the Agency set a new 8-hour average standard of 0.08 ppm. Due to a "rounding loophole," the current standard is effectively 0.085 ppm. On or about January 31, 2007, EPA will issue a final Staff Paper outlining the EPA staff scientists' recommendations for revisions to the ozone NAAQS.

A number of independent reviews of the air quality standards by the World Health Organization, the California Air Resources Board, EPA's Clean Air Scientific Advisory Committee and others have recommended that the ozone standards be lowered to protect public health.

- **EPA's Outside Science Advisors Urge Stricter Standards**

The Clean Air Scientific Advisory Committee (CASAC) is an independent committee chartered under the Clean Air Act to review the scientific adequacy of EPA scientific documents prepared as part of the standards review. After reviewing the 2,000 page Criteria Document summarizing scientific research on the health effects of ozone, and the extensive analysis in the second draft Staff Paper, the 23-member CASAC panel unanimously concluded:

- There is no scientific justification for retention of the current primary standard;
- The rounding loophole must be eliminated; and
- The 8-hour ozone standard should be set in the range of 0.060 to 0.070 ppm.[1]

- **World Health Organization Recommends Lower Ozone Standards**

In October 2006, the World Health Organization (WHO) revised their international air quality guidelines for ozone.[2] The pre-existing guideline for 8-hour average ozone concentrations of 120 $\mu g/m^3$ (0.061 ppm) was reduced to 100 $\mu g/m^3$ (0.051 ppm). This is substantially lower than the current U.S. air quality standard of 0.085 ppm.

The basis for the revised guidelines is twofold. First, new epidemiological studies show convincing evidence of associations between daily mortality and ozone levels, independent of the effects of particulate matter. Similar associations have been observed in both North America and Europe. These time-series studies have shown effects at ozone concentrations below the previous guideline, without clear evidence of a threshold. Second, evidence from both chamber and field studies also indicate that there is considerable individual variation in response to ozone.

---

[1] Letter from Dr. Rogene Henderson, Chair, Clean Air Scientific Advisory Committee to Stephen L. Johnson, Administrator, U.S. Environmental Protection Agency, re Clean Air Scientific Advisory Committee's (CASAC) Peer Review of the Agency's 2nd Draft Ozone Staff Paper, EPA-CASAC-07-001, October 24, 2006.

[2] World Health Organization. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment. Available at: http://www.who.int/phe/air/aqg2006execsum.pdf

The WHO report specifically indicates that an 8-hour average concentration of 82 ppb, does not provide adequate protection of public health. The report notes that 1) this is the lower level of 6.6-hour chamber exposures of healthy exercising young adults where physiological and inflammatory lung effects have been observed; 2) this is the ambient level at various summer camp studies showing effects on health of children; and 3) this level is associated with an estimated 3-5% increase in daily mortality, based on the findings of daily time-series studies.[3]

- **California Sets New 8-Hour Ozone Standard**

California completed a review of its state ozone air quality standards in April 2005, under the Children's Environmental Health Protection Act. The California Air Resources Board unanimously approved establishment of a new 8-hour standard for ozone of 0.070 ppm not to be exceeded. This standard supplements the pre-existing 1-hour state standard of 0.09 ppm.

The California standard is based on numerous controlled human exposure studies of healthy individuals which demonstrate reduced lung function, increased respiratory and ventilatory symptoms, increased airway hyperreactivity, and increased airway inflammation following 6.6 to 8-hour exposures to 0.08 ppm ozone.

Additionally, evidence from epidemiological studies of several health endpoints including premature death, hospitalization, respiratory symptoms, and restrictions in activity and lung functions indicate that concentrations below the current federal standard cause adverse health effects. For instance, evidence from studies of emergency room visits for asthma suggests a possible threshold concentration between 0.070 and 0.10 ppm based on an 8-hour averaging time.[4]

- **American Academy of Pediatrics Recommends Stricter Ozone Standards**

In late 2004, the American Academy of Pediatrics (AAP) published a major review of ambient air pollution and health hazards to children. The review concluded that the 1997 NAAQS for ozone may not adequately protect the health of infants and children. The paper cites studies show showing declines in lung function, hospitalizations for respiratory tract illness in young children, emergency department visits for asthma, and asthma exacerbations at levels at or below the current standards. In addition, cumulative childhood exposure to ozone may affect lung function when exposed children reach young adulthood. The AAP review suggests that ozone may be toxic to children at concentrations lower than the current standard of 0.08 ppm.[5]

Recent Studies Show Harm

Breathing ozone can cause adverse health effects including reduction in lung function, inflammation of the airways, and a variety of respiratory symptoms such as coughing, throat irritation, chest tightness, wheezing, and shortness of breath. Ozone exposures can also trigger emergency room visits and hospital admissions for respiratory problems and can increase the risk

---

[3] World Health Organization. WHO air quality guidelines global update 2005. Report of a Working Group meeting, Bonn, Germany, 18-20 October 2006.
[4] ARB. Evidence on the Health Effects of Ozone Provided from Hundreds of Studies. Presentation available at: http://arb.ca.gov/research/aaqs/ozone-rs/aqac/pres/staff-1.pdf
[5] Kim JJ, American Academy of Pediatrics Committee on Environmental Health. Ambient Air Pollution: Health Hazards to Children. *Pediatrics* 2004;114:1699-1707.

of premature death. Children, the elderly, people who work or exercise outdoors, people with lung disease such as asthma, and otherwise healthy people who are especially sensitive to ozone are at greatest risk.

- **Ozone Reduces Lung Function**

A number of clinical chamber studies in the early 1990's demonstrated that a host of adverse health effects -- decrements in pulmonary function, increased respiratory symptoms such as cough and shortness of breath, heightened airway responsiveness, and inflammation of the airways -- were evident in certain individuals following 6.6- to 8-hour exposures to 0.08 ppm ozone. These effects were evident in healthy young adults participating in the experimental studies. For ethical reasons, children and those with serious lung disease are not tested. This implies that standards must be set below this level to protect sensitive populations with a margin of safety.

The findings of the earlier human exposure studies are reinforced by a recent meta-analysis of 21 human chamber studies where airway responses were assessed using bronchosopy-based lavage. Linear relationships were observed between ozone dose, airway inflammation, and protein leak into the airways over the early- and late-acute response time periods. Researchers found that exposure to ozone concentrations at 8-hour concentration s of 0.08 ppm at moderate ventilation rates would be sufficient to trigger acute airway inflammation. The researchers noted that since chamber studies use only healthy subjects, individuals with lung disease or other risk factors will experience responses at even lower levels.[6]

A recent study reported acute lung function decline in mail carriers exposed to ozone concentrations below the current ambient air quality standard.[7]

- **Low Levels of Ozone Trigger Respiratory Symptoms in Infants**

A study examined respiratory effects of ozone in 700 infants living in nonsmoking households in southwestern Virginia. The authors concluded: "At levels of ozone exposure near or below the current U.S. EPA standards, infants are at increased risk of respiratory symptoms, particularly infants whose mothers have physician-diagnosed asthma." In this study there were no days when the 1-hour standard was exceeded, and only two days when the 8-hour ozone standard was exceeded.[8]

- **Ozone Changes the Structure of the Lungs**

Significant lung development occurs after birth. A study in infant rhesus monkeys tested whether repeated cycles of injury and repair caused by ozone exposure lead to chronic airway disease and decreased lung function by altering normal lung maturation. Monkeys were used because their airway structure and postnatal lung development is similar to those of humans. One month old monkeys were exposed to 0.5 ppm ozone episodically over a five month period. Compared with control monkeys, the ozone exposed animals had major differences in airway structure and

---

[6] Mudway IS, Kelly FJ. An Investigation of Inhaled Ozone Dose and the Magnitude of Airway Inflammation in Healthy Adults. *Am J Respir Crit Care Med* 2004; 169:1089-1095.
[7] Chan C-C, Wu T-H. Effects of Ambient Ozone Exposure on Mail Carriers' Peak Expiratory Flow Rates. *Environ Health Perspect* 2005;113:735-738.
[8] Triche EW, Gent JF, Holford TR, Belanger K, Bracken MB, Beckett WS, Naeher L, McSharrry J-E, Leaderer BP. Low-Level Ozone Exposure and Respiratory Symptoms in Infants. *Environ Health Perspec* 2006;114:911-916.

morphology: four fewer nonalveolarized airway generations, hyperplasic bronchiolar epithelium, and altered smooth muscle bundle orientation in terminal and respiratory bronchioles.[9]

- **Large Populations Especially Sensitive to Ozone Exposure**

Large differences in the sensitivity of individuals to ozone have been well documented. Those that are particularly sensitive are known as "responders." A recent study sought to establish the prevalence of "responders" in four different population subgroups: children, asthmatics, the elderly, and athletes, by assessing symptoms and measuring respiratory function. The study found higher rates of ozone responders in asthmatics (21%) and children (18%), as compared to the elderly and athletes (both 5%). This means that children and asthmatics have a higher risk of being ozone sensitive and experiencing more acute lung function decrements than these other population groups.[10]

- **Ozone Exacerbates Asthma and May Trigger Asthma Development**

Yale University researchers studied a group of 271 asthmatic children under age 12, living in Connecticut and Springfield, Massachusetts involved in a prospective study of asthma severity. The children's mothers tracked their asthma symptoms such as wheeze, persistent cough, chest tightness, and shortness of breath, and their medication use, on a daily basis. The study reported that a 50 ppb increase in 1-hour ozone concentrations dramatically increased the likelihood of wheeze (by 35%) and chest tightness (by 47%). The study found that asthmatic children using maintenance medication were particularly vulnerable to ozone even after controlling for co-exposure to fine particles, and even at pollution levels below EPA's current air quality standards for ozone. The highest levels of ozone on a 1-hour and 8-hour average basis were associated with increased shortness of breath and rescue medication use.[11]

Asthmatic children born prematurely or with low birth weight have the greatest response to ozone. Scientists sought to ascertain which subgroups in a cohort of 846 inner-city asthmatic children aged 4-9 years old were most susceptible to the effects of summertime ozone. Children were recruited from emergency departments and primary care clinics eight U.S. cities. The study reported that "children of low birth weight or of premature birth are at greater risk for respiratory problems, and appear to be substantially more susceptible to the effects of summer air pollution than children of normal birth weight or full-term gestation." [12]

A prospective cohort study of over 3,000 adults in the nonsmoking Seventh Day Adventist community sought to examine the whether long-term exposure to ozone air pollution can contribute to the prevalence of asthma. The study found that 8-hour average ambient ozone concentration averaged over a 20-year period was associated with doctor diagnoses of adult-onset asthma in nonsmoking males.[13]

---

[9] Fanucchi MV, Plopper CG, Evans MJ, Hyde DM, Van Winkle LS, Gershwin LJ, Schelegle ES. Cyclic Exposure to Ozone Alters Distal Airway Development in Infant Rhesus Monkeys. *Am J Physiol Lung Cell Mol Physiol* 2006; 291:644-650.

[10] Höppe P, Peters A, Rabe G, Praml G, Lindner J, Jakobi G, Fruhmann G, Nowak D. Environmental Ozone Effects in Different Population Subgroups. *Int J Hyg Environ Health* 2003;206: 505-516.

[11] Gent JF, Triche EW, Holford TR, Belanger K, Bracken MB, Beckett WS, Leaderer BP. Association of Low-Level Ozone and Fine Particles with Respiratory Symptoms in Children with Asthma. *JAMA* 2003;290:1859-1867.

[12] Mortimer KM, Tager IB, Dockery DW, Neas LM, Redline S. The Effect of Ozone on Inner-City Children with Asthma: Identification of Susceptible Subgroups. *Am J Respir Crit Care Med* 2000;162:1838-1845.

[13] McDonnell WF, Abbey DE, Nishino N, and Lebowitz MD. Long-Term Ambient Ozone Concentration

An analysis from the California Children's Health Study points to ozone as a cause in the development of asthma in young people who did not previously have the disease. The study compared new asthma cases in 3,535 children who were followed over five years in 12 Southern California communities to determine the potential health damage caused by growing up in polluted air. Six of the communities had higher than average ozone concentrations while six had lower than average concentrations. The study found that children in the high ozone communities who played three or more sports developed asthma at a rate three times higher than those in the low ozone communities. Because participation in some sports can result in a child drawing up to 17 times the "normal" amount of air into the lungs, the study indicates that young athletes may be more likely to develop asthma.[14]

- **Ozone Sends Kids to Hospital Emergency Rooms**

A time-series study of respiratory emergency department visits in Atlanta reported an association between ozone and upper respiratory infection visits, specific to infants and children. The association with ozone persisted in multipollutant models. During warm months a 25 ppb increase in ozone was associated with a 2.6% increase in pediatric asthma visits to the emergency room.[15] Similary, a study in Portland, Maine reported that ozone increases were correlated with emergency room visits for asthma.[16]

- **Hospital Admissions Go Up with Rise in Ozone**

A very large case-crossover study of Medicare recipients in of 36 U.S. cities evaluated the effect of ozone and PM_{10} on respiratory hospital admissions in the elderly over a 13-year period. The study found that the risk of daily hospital admissions for chronic obstructive pulmonary disease (COPD) and pneumonia increased with short-term increases in ozone concentrations during the warm season, but not during the cold season.[17]

Australian researchers investigated the effects of ambient air pollution on 13,000 hospital admissions in Brisbane. Ozone was consistently associated with admissions for asthma and respiratory disease-with little evidence of a threshold. In two-pollutant models, the ozone effect was relatively unaffected by the control for high levels of other pollutants. [18]

- **Short-term Ozone Exposure Increases the Risk of Premature Death**

---

and the Incidence of Asthma in Nonsmoking Adults: The Ashmog Study. *Environ Res* 1999;80:110 -121

[14] McConnell R, Berhane K, Gilliland FD, London SJ, Islam T, Gauderman WJ, Avol E, Margolis HG, Peters JM. Asthma in Exercising Children Exposed to Ozone. *The Lancet* 2002;359:386 -391.

[15] Peel JL, Tobert PE, Klein M, Metzger KB, Flanders WD, Todd K, Mulholland JA, Ryan PB and Frumkin H. Ambient Air Pollution and Respiratory Emergency Department Visits. *Epidemiology* 2005;16;164 -174.

[16] Wilson AM, Wake CP, Kelly T, Salloway JC. Air Pollution, Weather, and Respiratory Emergency Room Visits in Two Northern New England Cities: an Ecological Time-Series Study. *Environ Res* 2005;97:312 -321.

[17] Medina-Ramón M, Zanobetti A, Schwartz J. The Effect of Ozone and PM10 on Hospital Admissions for Pneumonia and Chronic Obstructive Pulmonary Disease: A National Multicity Study. *American Journal of Epidemiology 2006*; 163:579-588.

[18] Petroeschevsky A, Simpson RW, Thalib L, Rutherford S. Associations between outdoor air pollution and hospital admissions in Brisbane, Australia. *Arch Environ Health* 2001 Jan-Feb;56:37-52.

A growing number of epidemiological studies have reported an association between short-term exposures to ozone and premature mortality. Short-term increases in ozone were found to increase total non-accidental mortality and deaths from cardiovascular and respiratory causes in a large 14-year study of residents of 95 U.S. cities. The relationship between mortality and ozone was evident even on days when pollution levels were below the EPA 8-hour standard of 0.08 ppm. The ozone and mortality results did not appear to be confounded by temperature or PM_{10}.[19] Similarly, a large multi-city European study reported a positive association between one- and eight-hour concentrations of ozone air pollution and daily mortality, especially respiratory mortality, during the warm season.[20]

A recent case-crossover study of 14 U.S. cities was designed to control for the effect of temperature on daily deaths attributable to ozone. The study concluded that the association between ozone and mortality risk reported in the multi-city studies is unlikely to be due to confounding by temperature. [21]

Another multicity study applied several statistical models to data on air pollution, weather, and mortality for 98 U.S. urban communities for the period 1987-2000 to estimate the exposure-response curve for ozone and risk of mortality and to evaluate whether a threshold exists below which there is no effect. The results show that any threshold would exist at very low concentrations, far below current U.S. standards. The authors concluded: "our nationwide study provides strong and consistent evidence that daily changes in ambient O_3 exposure are linked to premature mortality, even at very low pollution levels, including an idealized scenario of complete adherence to current O_3 regulations."[22]

The U.S. Environmental Protection Agency commissioned 3 meta-analyses of studies of ozone and mortality. Three separate research groups from Johns Hopkins University, Harvard University, and New York University were asked to conduct a meta-analysis, using their own methods and study selection criteria. All three meta-analyses report a small but substantial association between daily ozone levels and total mortality.[23,24,25]

---

[19] Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Ozone and short-term mortality in 95 US urban communities, 1987-2000. *JAMA* 2004; 292:2372-2378.

[20] Gryparis A, Forsberg B, Katsouyanni K, Analitis A, Touloumi G, Schwartz J, Samoli E, Medina S, Anderson HR, Niciu EM, Wichmann E, Kriz B, Kosnik M, Skorkovsky J, Vonk JM, Dortbudak Z. Acute effects of ozone on mortality from the "Air Pollution and Health: A European Approach" project. *Am J Respir Crit Care Med* 2004;170:1080-1087.

[21] Schwartz J. How sensitive is the association between ozone and daily deaths to control for temperature? *Am J Resp Crit Care Med* 2005; 171: 627- 631.

[22] Bell ML, Peng RD, Dominici F. The Exposure-Response Curve for Ozone and Risk of Mortality and the Adequacy of Current Ozone Regulations. *Environ Health Perspec* 2006;114:532-536.

[23] Bell ML, Dominici F, and Samet JM. A Meta-Analysis of Time-Series Studies of Ozone and Mortality with Comparison to the National Morbidity, Mortality, and Air Pollution Study. *Epidemiology* 2005; 16:436-445.

[24] Levy JI, Chermerynski SM, Sarnat JA. Ozone Exposure and Mortality: An Empiric Bayes Metaregression Analysis. *Epidemiology* 2005: 16:458-468.

[25] Ito K, De Leon SF, Lippmann M. Associations Between Ozone and Daily Mortality: Analysis and Meta-Analysis. *Epidemiology* 2005; 16:446-429.