

June 1, 2001

## **ANNOTATED BIBLIOGRAPHY OF RECENT STUDIES OF THE HEALTH EFFECTS OF OZONE AIR POLLUTION 1997-2001**

In 2001, the U.S. Environmental Protection Agency (EPA) will commence a periodic review of the National Ambient Air Quality Standards (NAAQS) for ozone, a common and pervasive air pollutant in the United States. The review will begin with a compilation of all the scientific and medical studies published on ozone air pollution since EPA's last review.

In 1997, EPA revised the standard for ozone from 0.12 ppm averaged over one hour, to a standard of 0.08 ppm averaged over eight hours. The new standard was set to reflect the findings of chamber studies performed in the early 1990's, which found that ozone poses health problems when people are exposed to lower levels for longer periods of time.

Ozone is the principle component of ground-level smog. It is formed when hydrocarbon and nitrogen oxide pollution from vehicles, power plants, refineries and other sources react in the atmosphere in the presence of sunlight. Ozone is a powerful oxidizing agent that damages lung tissue.

Recent research with laboratory animals, clinical subjects, and human populations has identified a cascade of adverse health effects from ozone at levels common in the United States. Effects include increased respiratory symptoms, damage to cells of the respiratory tract, pulmonary inflammation, declines in lung function, increased susceptibility to respiratory infections, and increased risk of hospitalization and early death.

Four groups of people are especially sensitive to ozone: children, people with chronic obstructive respiratory disease (chronic bronchitis and emphysema) and asthma, persons who exercise or work outdoors, and people who, for reasons that remain unknown, are more sensitive to the physiologic effects of ozone.

This bibliography represents a sampling of the peer-reviewed scientific literature on the health effects of ozone air pollution published since EPA's last revision of the standards in 1997.

Air pollution research may involve epidemiological studies of human populations, chamber studies where human volunteers are exposed to air pollution under controlled conditions, and toxicological studies with laboratory animals. In recent years, air pollution research funds have been largely directed toward the study of particulate matter. Nevertheless, there

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For nearly 100 years, the American Lung Association, Lung Association affiliates throughout the United States and the American Thoracic Society have worked together in the fight against lung disease.

were some important developments regarding the health effects of ozone. Important new findings include:

- Identification of the possible genetic basis for susceptibility to ozone;
- Increasing evidence of a mortality effect of ozone;
- Evidence of long-term impacts on lung function from chronic exposure; and
- Increased evidence of the effects of ozone on sensitive groups such as children and asthmatics.

This bibliography does not attempt to be comprehensive: exclusion does not imply that a study is unimportant; inclusion does not imply endorsement.

## **LONG-TERM STUDIES**

### **Ozone Harms the Respiratory Health of U.S. Military Academy Cadets**

Researchers from Columbia University and New York University sought to determine whether changes in lung function or respiratory symptoms would occur over the course of a summer among healthy young adults working outdoors in the presence of ozone. The study followed 72 sophomore cadets from the U.S. Military Academy at West Point, New York, during their summer training at **Fort Benning, GA, Fort Leonard Wood, MO, Fort Sill, OK, and Fort Dix, NJ**. All the subjects on average experienced a decline in lung function over the course of the summer. There were also significant increases in reports of cough, chest tightness, and sore throat. The decline in lung function was greatest in the group of military cadets who attended training in Fort Dix, New Jersey, where peak hourly ozone concentrations above 100 ppb occurred frequently. *“These results suggest a possible adverse respiratory-health impact of exposures to particulate matter and ozone in healthy young adults engaged in intensive outdoor training,”* conclude the authors.

Kinney, P.L. and Lippmann, M. Respiratory Effects of Seasonal Exposures to Ozone and Particles. Archives of Environmental Health, Vol. 55, No. 3, pp. 210-216, May/June 2000.

### **Lifetime Ozone Exposure Exerts Negative Effect on Small Airways of Lung**

This pilot study is the first attempt to relate lifetime cumulative ozone exposure to small airway pulmonary function. 130 nonsmoking, non-asthmatic freshmen from the University of California at Berkeley who were lifelong residents of the **Los Angeles Basin** or the **San Francisco Bay Area** volunteered to participate in lung function testing. Researchers observed declines in mid- and end-expiratory flow measures of the small airways that are considered early indicators for pathologic changes that might ultimately

progress to chronic obstructive lung disease. These declines were associated with estimated long-term ozone exposures.

Künzli, N., Lurmann, F., Segal, M., Ngo, L., Balmes, J., and Tager, I.B. Association between Lifetime Ambient Ozone Exposure and Pulmonary Function in College Freshmen—Results of a Pilot Study. *Environmental Research*, Vol. 72, pp. 8-23, 1997.

### **Lung Function in Girls and Boys is Diminished by Ozone**

The California Children's Health Study followed 3,300 school children that lived in 12 **Southern California** communities that fell along a gradient of air pollution levels for a period of 10 years. Four different measures of pulmonary function were tested, with different pollutants most strongly associated with each measure. Girls with asthma, and boys who spent more time outdoors experienced diminished lung function in association with ozone.

Peters, J.M., Avol, E., Gauderman, W.J., Linn, W.S., Navidi, W., London, S.J., Margolis, H., Rappaport, E., Vora, H., Gong, H., and Thomas, D.C. A Study of Twelve Southern California Communities with Differing Levels and Types of Air Pollution. II. Effects on Pulmonary Function. *American Journal of Respiratory and Critical Care Medicine*, Vol. 159, pp. 7680775, 1999.

### **Long-Term Ozone Exposure Diminishes Respiratory Health**

Few studies have reported on the respiratory effects of prolonged, multi-year exposures to ozone. This study examined data from health status questionnaires and lung function measurements in relation to residence histories to examine the effect of long-term ozone exposures on over 500 non-smoking Yale college students. Investigators found that *“living for four or more years in regions of the country with high levels of ozone and related copollutants is associated with diminished lung function and more frequent reports of respiratory symptoms.”*

Galizia, A. and Kinney, P.L. Long-Term Residence in Areas of High Ozone: Associations with Respiratory Health in a Nationwide Sample of Nonsmoking Young Adults. *Environ Health Perspect*, Vol. 107, No. 8, pp. 675-679, August 1999.

### **Long-Term Ozone Exposure Might Inhibit Lung Function Growth in Children**

Frischer et al. followed a group of 1,150 first and second grade children in two counties in Austria from 1994-1996, to investigate the long-term effects of ambient ozone. The highest and lowest exposure to ozone differed by a factor of two. Researchers found small but consistent decrements in lung function associated with ambient ozone. They conclude: *“This is the first study that suggests chronic effects of ozone on lung function growth in children. Thus, ozone would constitute a risk factor for premature respiratory morbidity during later life.”*

A subsequent long-term study in Southern California by Gauderman et al. found an association between particulate matter and children's lung function growth, but not with ozone.

Frischer, T., Studnicka, M., Gartner, C., Tauber, E., Horak, F., Veiter, A., Spengler, J., Kühr, J., and Urbanek, R. Lung Function Growth and Ambient Ozone: A Three-Year Population Study in School Children. *Am J Respir Crit Care Med*, Vol. 160, pp. 390-396, 1999.

Gauderman, J.W., McConnell, R., Gilliland, F., London, S., Thomas, D., Avol, E., Vora, H., Berhane, K., Rappaport, E.B., Lurmann, F., Margolis, H.G., and Peters, J. Association between Air Pollution and Lung Function Growth in Southern California Children. *American Journal of Respiratory and Critical Care Medicine*, Vol. 162, pp 1383-1390, 2000.

### **Long-Term Exposure to Ozone is Related to Asthma Development in Men**

Asthma is a multifactor disease with many contributing factors. Air pollution is generally considered to be an exacerbating, rather than a causal factor. This 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.

McDonnell, W.F., Abbey, D.E., Nishino, N., and Lebowitz, M.D. Long-Term Ambient Ozone Concentration and the Incidence of Asthma in Nonsmoking Adults: The Ashmog Study. *Environmental Research, Section A* Vol. 80, pp. 110-121, 1999.

### **Nasal Biopsies from Children Reveal Ozone Damage**

Children in **Mexico City** are routinely exposed to high levels of ozone, particulate, and aldehyde air pollution. Biopsies taken from these children exhibit a wide range of pathologic changes to the cells of the nasal passages. *“The severe structural alteration of the nasal epithelium together with the prominent acquired ciliary defects are likely the result of chronic airway injury in which ozone, particulate matter, and aldehydes are thought to play a crucial role,”* conclude researchers. *“The nasal epithelium in SWMMC [Southwest Metropolitan Mexico City] children is fundamentally disordered, and their mucocilliary defense mechanisms are no longer intact. A compromised nasal epithelium has less ability to protect the lower respiratory tract and may potentially leave the distal acinar airways more vulnerable to reactive gases.”*

Calderón-Garciduenas, L., Valencia-Salazar, G., Rogríguez-Alcaraz, A., Gambling, T.M., García, R., Osnaya, N., Villarreal-Calderón, A., Devlin, R.B., and Carson, J.L. Ultrastructural Nasal Pathology in Children Chronically and Sequentially Exposed to Air Pollutants. *American Journal of Respiratory Cell and Molecular Biology*, Vol. 24, pp. 132-138, 2001.

## SHORT-TERM STUDIES

### Lung Function Diminishes Following Exposure to Air Pollution

Swiss researchers followed a group of 3,900 nonsmoking adults from eight areas of **Switzerland** that represent a range of urbanization, air pollution, altitude, and weather conditions. In this study, researchers obtained three different measures of lung function and compared the results with prior days measurements of ozone, total suspended particulates, and nitrogen dioxide. Daily average concentrations of ozone were significantly associated with mean respiratory function measures during the summer months. Associations remained stable after controlling for other pollutants and for pollen. Though the effects were small, researchers conclude that current levels of air pollution have public health significance.

Schindler, C., Künzli, N., Bongard, J.-P., Leuenberger, P., Karrer, W., Rapp, R., Monn, C., Ackermann-Liebrich, U., and The Swiss Study on Air Pollution and Lung Diseases in Adults Investigators. Short-Term Variation in Air Pollution and in Average Lung Function Among Never-Smokers: The Swiss Study on Air Pollution and Lung Diseases in Adults (SAPALDIA). *American Journal of Respiratory and Critical Care Medicine*, Vol. 163, pp. 356-361, 2001.

### School Absences Rise With High Ozone Days

School absenteeism is used as an indicator of the overall health of school-aged children. A study by Chen et al. assessed the association between daily air pollution concentrations and absences among 28,000 elementary school children in **Washoe County, Nevada**, home of **Reno** between 1996 and 1998. Investigators found that ozone and carbon monoxide, but not PM<sub>10</sub>, were statistically significant predictors of daily absenteeism in elementary schools.

The Children's Health Study is being carried out in twelve southern California communities that fall along a gradient of air pollution. This study explored the effect of ozone, PM<sub>10</sub>, and nitrogen dioxide on school absenteeism due to upper- and lower-respiratory illness in a cohort of fourth-graders. Researchers found that relatively small short-term changes in ozone, but not the other pollutants, were associated with increases in school absences due to respiratory illness in children 9-10 years of age. *"Because exposures at the levels observed in this study are common, the increase in school absenteeism from respiratory illnesses associated with relatively modest day-to-day changes in ozone concentration documents an important adverse impact of ozone on children's health and well-being,"* state the authors.

Chen, L., Jennison, B.L., Yang, W., and Omaye, S.T. Elementary School Absenteeism and Air Pollution. *Inhalation Toxicology*, Vol. 12, pp. 997-1016, 2000.

Gilliland, F.D., Berhane, K., Rappaport, E.B., Thomas, D.C., Avol, E., Gauderman, W.J., London, S.J., Margolis, H.G., McConnell, R., Islam, K.T., and Peters, J.M. The Effects of Ambient Air Pollution on School Absenteeism Due to Respiratory Illness. *Epidemiology*, Vol. 12, No. 1, pp. 43-54, January 2001.

## **Summertime Haze Air Pollution Exacerbates Asthma in Children**

This study focused on children ages 7-13 with moderate to severe asthma who attended a summer “asthma camp” in the early 1990’s in the **Connecticut River Valley**. Daily records were kept of environmental conditions, as well as of subject medication use, lung function, and medical symptoms. Air pollution, especially ozone, was consistently correlated with acute asthma exacerbations, chest symptoms, and lung function decrements. *“...the monotonic nature of the relationships of ozone with reduced lung function and increased numbers of asthma symptoms and exacerbations found in this work indicates that these effects extend well below the present 120 ppb concentration level, so that even meeting this standard will not be fully protective for these sensitive individuals. Past medical advice that children with asthma should take care to avoid exposure to air pollutants is further supported by the results of this research.”*

Thurston, G.D., Lippman, M., Scott, M.B., and Fine, J.M. Summertime Haze Air Pollution and Children with Asthma. *Am J Respir Crit Care Med*, Vol. 155, pp. 654-660, 1997.

## **Ozone Plus Allergens Exacerbates Asthma**

Asthma is an inflammatory disease of the airways. This is the first epidemiologic study to demonstrate a difference in the inflammatory reaction of the upper airways to ozone as compared to allergens in patients with intermittent to severe persistent asthma. The study of sixty asthmatic patients of the **Leiden** University Hospital in **The Netherlands** took samples of nasal lavage and analyzed it in the laboratory for signs of inflammation. Researchers found that *“both ambient ozone and allergen exposure are associated with inflammatory responses in the upper airways of subjects with asthma, although the type of inflammation is qualitatively different.”* They speculate that *“during episodes with both increased allergen levels and high ambient photochemical air pollution asthma exacerbations are more likely to develop than during periods with either increased allergens or ambient photochemical air pollution alone.”*

Hiltermann, T.J.N., de Bruijne, C.R., Stolk, J., Zwinderman, A.H., Spiksma, F.T.M., Roemer, W., Steerenberg, P.A., Fischer, P.H., van Bree, L., and Hiemstra, P.S. Effects of Photochemical Air Pollution and Allergen Exposure on Upper Respiratory Tract Inflammation in Asthmatics. *Am J Respir Crit Care Med*, Vol.156, pp. 1765-1772, 1997.

## **Children with Mild Asthma Suffer the Effects of Air Pollution**

A number of important studies have been conducted in **Mexico City** where air pollution levels are high. This study involved a panel of Mexican children ages 5-13 with mild asthma. Researchers determined that a 50 ppb increase in the daily 1-hour maximum ozone was related to an 8 percent increase in cough, a 24 percent increase in phlegm, and an 11 percent increase in other respiratory symptoms in the study population.

Romieu, I., Meneses, F., Ruiz, S., Huerta, J., Sienna, J.J., White, M., Etzel, R., and Hernandez, M. Effects of Intermittent Ozone Exposure on Peak Expiratory Flow and Respiratory Symptoms among Asthmatic Children in Mexico City. *Archives of Environmental Health*, Vol. 52(5), pp. 368-376, Sep-Oct 1997.

## **Ozone is a Risk Factor for Respiratory Problems in Kids, Especially Babies, Toddlers, and Adolescents**

Burnett et al. examined the association between air pollution and hospital admissions for acute respiratory problems in babies and toddlers during a 15-year period in **Toronto, Canada**. A 35 percent increase in the daily hospitalization rate for respiratory problem was associated average ozone concentrations in the summer, but not during other seasons. The ozone effect persisted after adjustment for other air pollutants and weather.

Braga and coworkers examined daily hospital admission records for children of different ages, compared to daily concentrations of ozone, particulate matter, sulfur dioxide, carbon monoxide, and nitrogen dioxide over a five-year period in **Sao Paulo, Brazil**. The study showed that daily respiratory hospital admissions for children and adolescents increased with air pollution, with children less than two years old the most susceptible, and adolescents were the next most susceptible age group.

Burnett, R.T., Smith-Doiron, M., Stieb, D., Raizenne, M.E., Brook, J.R., Dales, R.E., Leech, J.A., Cakmak, S., and Krewski, D. Association between Ozone and Hospitalization for Acute Respiratory Diseases in Children Less than 2 Years of Age. *American Journal of Epidemiology*, Vol. 153, No. 5, pp. 444-452, 2001.

Braga, A.L., Saldiva, P.H., Pereira, L.A., Menezes, J.J., Conceicao, G.M., Lin, C.A., Zanobetti, A., Schwartz, J., and Dockery, D.W. Health Effects of Air Pollution Exposure on Children and Adolescents in Sao Paulo, Brazil. *Pediatric Pulmonology*, Vol. 31 (2), pp. 106-113, Feb. 2001.

## **Low Levels of Ozone Contribute to Hospitalization for Respiratory Disease**

A study by Health Canada researcher Richard Burnett et al. compared air pollution data to hospital admissions in 16 Canadian cities, over a ten-year period. The study controlled for many factors including day of week, season, other air pollutants, and climate. The prior day's peak hourly ozone concentration was positively associated with respiratory hospital admissions during the April-December period. The effects varied from city to city. Researchers conclude that *“these results suggest that ambient air pollution at the relatively low concentrations observed in this study, including tropospheric ozone, is associated with excess admissions to hospital for respiratory diseases in populations experiencing diverse climates and air pollution profiles.”*

In **Brisbane, Australia**, ozone levels are reasonably constant year round. This large study of daily admissions to public hospitals during the period 1987-1994 found that ozone was consistently associated with admissions for asthma and respiratory disease—with little evidence of a threshold.

Burnett, R.T., Brook, J.R., Yung, W.T., Dales, R.E., and Krewski, D. Association between Ozone and Hospitalization for Respiratory Diseases in 16 Canadian Cities. *Environmental Research*, Vol. 72, pp. 24-31, 1997.

Petroeschevsky, A., Simpson, R.W., Thalib, L., and Rutherford, S. Associations between Outdoor Air Pollution and Hospital Admissions in Brisbane, Australia. *Archives of Environmental Health*, Vol. 56(1), pp. 37-52, Jan-Feb 2001.

## **Summertime Ozone Sends the Elderly to the Emergency Room**

This study examined daily emergency room visits for respiratory illnesses in 25 hospitals in **Montreal, Quebec** in relation to summertime air pollution. Though the ozone levels never exceeded the 1-hour NAAQS of 120 ppb, statistically significant relationships were found between respiratory emergency room visits for patients over age 64, and both 1-hour and 8-hour maximum ozone levels measured the day before. *“These findings confirm the impression that while air quality standards may protect the respiratory health of the general population, this is not the case for susceptible subgroups such as the elderly,”* conclude the researchers.

Delfino, R.J., Murphy-Moulton, A.M., and Becklake, M.R. Emergency Room Visits for Respiratory Illnesses among the Elderly in Montreal: Association with Low Level Ozone Exposure. Environmental Research, Section A, Vol. 76, pp. 67-77, 1998.

## **Ozone Exposure May Make the Heart Work Harder**

This study is the first chamber study to directly measure the effect of ozone on the function of the human heart. Investigators studied a small group of healthy adult males and those with high blood pressure. Overall, researchers did not find evidence of major short-term cardiovascular effects from ozone exposure. However, they reported that their results *“suggest that ozone exposure can increase myocardial work and impair pulmonary gas exchange to a degree that might be clinically important in persons with significant preexisting cardiovascular impairment, with or without concomitant lung disease.”*

Gong, H. Jr., Wong, R., Sarma, R.J., Linn, W.S., Sullivan, E.D., Shamoo, D.A., Anderson, K.R., and Prasad, S.B. Cardiovascular Effects of Ozone Exposure in Human Volunteers. Am J Respir Crit Care Med, Vol. 158, pp. 538-546, 1998.

## **Ozone Damages the Lungs of Exercisers**

The lungs work harder and take in more air when people are exercising. A study by Frampton et al. of healthy adult smokers and nonsmokers subjected volunteers to exercise while exposing them to ozone and filtered air in a laboratory chamber. The authors conclude that: *“exposure to ozone with exercise, at concentrations relevant to urban outdoor air, results in ozonation of lipids in the airway epithelial lining fluid of humans.”*

A study of adult cyclists in **Parma, Italy** measured levels of lung-specific proteins in the blood following a two hour bicycle ride during the summer, under differing ozone smog conditions. Researchers Broeckaert et al. found increased airway permeability in moderately exercising participants exposed to an average of 0.07 ppm ozone over 2 hours.



Frampton, M.W., Pryor, W.A., Cueto, R., Cox, C., Morrow, P.E., and Utell, M.J. Ozone Exposure Increases Aldehydes in Epithelial Lining Fluid in Human Lung. *Am J Respir Crit Care Med*, Vol., 159, pp. 11134-1137, 1999.

Broeckaert, F., Arsalane, K., Hermans, C., Bergamaschi, Brustolin, A., Mutti, A., and Bernard, A. Lung Epithelial Damage at Low Concentrations of Ambient Ozone. *The Lancet*, Vol. 353, pp. 900-901, March 13, 1999.

## **Ozone Increasingly Implicated in Premature Mortality**

Recent studies of air pollution and mortality have looked at the impacts of all the major pollutants, and have increasingly been reporting positive associations with ozone. Dr. Jonathan M. Samet and coauthors from the Johns Hopkins University School of Public Health examined five major air pollutants in 20 of the largest cities in the United States from 1987 to 1994, as part of NMMAPS – the National Morbidity, Mortality, and Air Pollution Study. Ozone levels were positively associated with mortality rates during the summer months when ozone levels were highest, though effects are not as strong as with particulate matter.

A similar study known as the APHEA project – Air Pollution and Health: a European Approach --of six cities in Central and Western Europe examined data on daily deaths and daily air pollution levels. Significant positive associations were found between daily deaths and ozone. Positive associations were also reported for nitrogen dioxide, but study authors believe this may be due to confounding by other vehicle-derived pollutants and needs further study.

Thurston and Ito pooled data from 15 studies and estimated a small effect of ozone on total mortality. According to Samet et al.: *“Taken together, the results of these three studies provide consistent evidence that exposure to ozone also increases the risk of death.”*

Samet, J.M., Dominici, F., Curriero, F.C., Coursac, I., and Zeger, S.L. Fine Particulate Air Pollution and Mortality in 20 U.S. Cities, 1987-1994. *New England Journal of Medicine*, Vol. 343, No. 24, pp. 1742-1749, December 14, 2000

Tuoloumi, G., Katsouyanni, K., Zmirou, D., Schwartz, J., Spix, C., de Leon, A.P., Tobias, A., Quennel, P., Rabczenko, D., Bacharova, L., Bisanti, L., Vonk, J.M., and Ponka, A. Short-Term Effects of Ambient Oxidant Exposure on Mortality: A Combined Analysis Within the APHEA Project. *American Journal of Epidemiology*, Vol. 146: No. 2, pp. 177-185, 1997.

Thurston, G.D., and Ito, K. Epidemiological Studies of Ozone Exposure Effects. In, *Air Pollution and Health*, Edited by S.T. Holgate, J.M. Samet, H.S. Koren, and R.L. Maynard, Academic Press, 1999.

## **OTHER STUDIES**

### **Genetic Basis for Ozone Responsiveness Identified**

It is well established that ozone induces lung hyperpermeability and inflammation in humans and in laboratory animals, and that some individuals are more susceptible than others to ozone damage. A number of factors may contribute to this differential responsiveness, including age, sex, nutrition, and pre-existing disease, such as asthma. This study by Dr. Steven Kleeberger of the Johns Hopkins School of Hygiene and Public

Health explores the genetic basis for susceptibility, after controlling for other known susceptibility factors. The study identifies a likely ozone “susceptibility gene” in mice.

Kleeberger, S.R., Reddy, S., Zhang, L.-Y., and Jedlicka, A.E. Genetic Susceptibility to Ozone-Induced Lung Hyperpermeability. *Am J Respir Cell Mol Biol*, Vol. 22, pp. 620-627, 2000.

### **Inner-City Asthmatic Children Born Prematurely or with Low Birth Weight Have Greatest Response to Ozone**

This study 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. The children were recruited from emergency departments and primary care clinics in the **Bronx and East Harlem in New York City, Baltimore, Washington, DC, Detroit, Cleveland, Chicago, and St. Louis, MO**. 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 birthweight or full-term gestation.”*

Mortimer, K.M., Tager, I.B., Dockery, D.W., Neas, L.M., and Redline, S. The Effect of Ozone on Inner-City Children with Asthma: Identification of Susceptible Subgroups. *Am J Respir Crit Care Med*, Vol. 162, pp. 1838-1845, 2000.

### **During Atlanta Summer Olympics, Decreased Traffic Reduced Asthma Incidents in Children**

The 1996 Summer Olympics in **Atlanta**, a concerted effort was made to lower traffic congestion to enable spectators to get to the games. Public transit was enhanced, the downtown was closed to private cars, and businesses were encouraged to promote telecommuting and alternative work hours. As a result, there were large and significant decreases in ozone concentrations, and somewhat lesser reductions in carbon monoxide and PM<sub>10</sub> concentrations. During this period, researchers found significant reductions in the numbers of urgent care visits, emergency care visits, and hospitalizations for asthma among children ages 1 – 16 years. Dr. Michael S. Friedman of the Centers for Disease Control and Prevention and coauthors conclude: *“Our finding suggest that efforts to decrease ozone and PM<sub>10</sub> concentrations from moderate to low levels can decrease the burden of asthma.”*

Friedman, M.S., Powell, K.E., Hutwagner, L., Graham, L.M., and Teague, W.G. Impact of Changes in Transportation and Commuting Behaviors During the 1996 Summer Olympic Games in Atlanta on Air Quality and Childhood Asthma. *Journal of the American Medical Association*, Vol. 285, No. 7, pp. 897-905, 2001.