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Air pollution and health: what the Georgia physician should know

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Air pollution poses a health threat to most residents of Georgia. Nearly three million people living in the 13-county metropolitan Atlanta area (Figure 1) have been exposed to high levels of ozone, which have occurred every summer in the 1980s and 1990s. Other Georgia counties around the state exceeded the new ozone standard during the summer of 1999 (Figure 1). Atlanta-area pollution is caused, in large part, by motor vehicle emissions. Atlanta residents travel more miles per person per day, for all trip purposes, than residents of any other urban region in the United States. Also contributing to the 13-county air pollution problem are point sources, primarily five large power plants to the west and northwest of Atlanta; these sources, account for an estimated 16 percent of the nitrogen oxides in the Atlanta-area compared with 49 percent from cars (Personal communication, Karen Borel, EPA).

The quality of air in our homes, offices, and schools is also important because people in this country tend to spend more time indoors than outdoors. Physicians should be aware of the major local pollutants, their adverse health effects, and their sources so they can advise their patients how to reduce their risk and can become active in improving air quality in their community. This report will highlight the major outdoor and indoor pollutants, their adverse health effects and sources, and suggest several ways physicians can educate their patients and work to improve air quality.

Outdoor Air Pollution
Compelling examples of the harmful health effects of outdoor air pollution include several acute air pollution episodes that occurred earlier in this century in Western Europe and the United States. Perhaps the most serious episode occurred in London, England, in December 1952 when stagnant air trapped fog and air pollutants for several days, resulting in 4,000 excess deaths. Since then, federal and state air-quality and emissions standards have succeeded in reducing our exposure to harmful pollutants. However, research suggests that current ambient air pollution levels can still cause adverse health effects. Ambient air pollution has been associated with decreased lung function, increased airways reactivity, lung inflammation, respiratory illness, altered host immunity, and excess cardio-respiratory mortality. The visible air pollution that blankets many urban areas is called smog. Smog is a mixture of pollutants, many of which are produced by chemical reactions in the air (Figure 2). The health effects and sources for these smog-forming pollutants vary so it is helpful to discuss individual pollutants. We will highlight several pollutants that contribute to the formation of smog.

Ozone
Ozone is the major component of smog. Although ozone is a natural component of the stratosphere, the ozone found in the troposphere, also referred to as ground-level ozone, is formed by emissions from automobiles, power plants, and industries. Ground-level ozone is formed in outdoor air by chemical reactions in the presence of sunlight; these reactions involve other pollutants, primarily nitrogen oxides and volatile organic compounds (VOCs). VOCs are emitted in auto exhaust and through the evaporation of solvents and gasoline. Natural vegetation may also produce substantial quantities of VOCs, especially in the southeastern United States. Ozone concentrations are typically highest in the summer when sunlight is most intense and temperatures are highest, conditions that accelerate the rate of photochemical smog formation. Ozone levels tend to be lowest in the morning hours, increase during midday, and decrease after sunset.

Ozone is the most serious outdoor air pollutant in the 13 county metropolitan Atlanta area. The Environmental Protection Agency (EPA) sets National Ambient Air Quality Standards (NAAQS) for pollutants that pose a threat to public health. Areas where ambient concentrations of these
pollutants exceed the NAAQS are referred to as non-attainment areas. Atlanta has never met the NAAQS for ozone since monitoring for it began in 1980, and it is designated as a "serious" non-attainment area for ground-level ozone. Georgia has prepared a state implementation plan to reduce ground-level ozone in the non-attainment areas. September 8, 1999, marked the end of the public comment period for the plan, and a week later the Board of the Georgia Department of Natural Resources approved the plan which will be sent to EPA for final approval.

Because long-term exposure to relatively low concentrations of ozone has been shown to cause adverse health effects, EPA now recommends measuring the average ozone levels over an 8-hour period rather than over a 1-hour period as was done previously. From May 1, 1999 through September 8, 1999, the Atlanta area exceeded the new ozone standard on 62 (47%) of 131 days, and seven additional ozone monitoring stations in Augusta, central Georgia, Coastal Georgia, Columbus, Macon, the North Georgia mountains, and Savannah exceeded the standard at least once. Atlanta exceeded the 1-hour ozone standard on 24 (18%) of the 131 days; no other areas exceeded the 1-hour standard.

Ozone can irritate the respiratory tract, constrict the air passages, and interfere with the lung's defense system. Levels of ozone exposure previously thought to be safe cause immediate but temporary changes in lung function and increased respiratory symptoms in both healthy and susceptible populations. When normal adults were exposed to ozone at concentrations as low as 0.08 parts per million for several hours while exercising, they experienced reversible decrements in lung function as assessed by spirometry, lung inflammation, and respiratory symptoms. A study conducted in Atlanta found that emergency department visits for asthma increased on high-ozone days.

Particulate matter
Particulate matter consists of dust, pollen, soot, and aerosols from combustion activities such as agricultural burning, transportation, manufacturing, and power generation. During the 1952 London air pollution episode, London had high levels of particulate matter and sulfur dioxide in the presence of fog, conditions known to favor catalytic oxidation and the subsequent formation of acid aerosols. Particle exposure has been associated with decreased lung function, increased respiratory symptoms, increased school absenteeism, increased hospital admissions, and increased mortality, especially from respiratory and cardiovascular conditions. Many recent studies have linked temporal, day-to-day variations in levels of particulate air pollution with variations in the number of emergency department visits, unscheduled admissions to hospitals, and total and cause-specific mortality.

Two long-term multi-city studies found that people living in cities with relatively high levels of particulate matter were at greater risk for death and shortened life-spans. Using mortality risk estimates obtained from a study conducted by the American Cancer Society, the Natural Resources Defense Council calculated the number of premature cardiopulmonary deaths due to particulate air pollution in 239 cities in the United States. Estimates for the number of deaths due to particulate matter in four Georgia areas are shown in Table 1. Each year in the Atlanta area exposure to particulate matter may cause nearly 1,000 excess cardiopulmonary deaths. Despite many limitations, including risk estimates based on non-representative samples and difficulty in accurately measuring personal exposure, these estimates provide a sense of the
Table 1. Annual Mean PM$_{10}$* concentration and number of estimated deaths attributable to PM10, in four metropolitan statistical areas (MSA) in Georgia, 1990-1994 and the number of deaths due to acute cardiopulmonary disease and car accidents in 1989.

<table>
<thead>
<tr>
<th>Metropolitan Statistical Area(MSA)</th>
<th>Annual Mean PM$_{10}$ Concentration(µg/m$^3$), 1990-1994</th>
<th>Estimated Annual Cardiopulmonary Deaths Attributable to PM$_{10}$ Air Pollution</th>
<th>Adult Cardiopulmonary Deaths, 1989</th>
<th>Deaths from Auto Accidents, 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, GA</td>
<td>35.1</td>
<td>946 Range: 565 - 1,292 Deaths per 100,000 47</td>
<td>7,608</td>
<td>572</td>
</tr>
<tr>
<td>Augusta, GA-SC</td>
<td>22.0</td>
<td>68 Range: 40 - 94 Deaths per 100,000 21</td>
<td>1,488</td>
<td>92</td>
</tr>
<tr>
<td>Chattanooga, TN-GA</td>
<td>34.9</td>
<td>270 Range: 161 - 368 Deaths per 100,000 63</td>
<td>2,190</td>
<td>103</td>
</tr>
<tr>
<td>Columbia, GA-AL</td>
<td>26.6</td>
<td>76 Range: 45 - 105 Deaths per 100,000 32</td>
<td>1,025</td>
<td>48</td>
</tr>
</tbody>
</table>


Estimates were derived by applying a fish factor reported in a study of an American Cancer Society (ACS) cohort to MSA-specific information on PM$_{10}$ concentrations and mortality from selected causes. Range estimates were derived from the confidence intervals for the risk ratio reported in the ACS study. For comparison, the total number of cardiopulmonary deaths in the MSA and the number of deaths from car accidents is shown.

*PM$_{10}$ refers to particulate matter with an aerodynamic diameter smaller than 10 microns.

Nitrogen dioxide

Nitrogen dioxide is produced by high-temperature combustion, which also produces nitric oxide that is in turn converted to nitrogen dioxide through oxidation reactions involving oxygen, ozone, and organic compounds. Motor vehicle emissions are the primary source of nitrogen dioxide in outdoor air, but power plants and fossil fuel-burning industries also contribute. Nitrogen dioxide is believed to damage the lung epithelium by combining with water in the lung to form nitric and nitrous acids. Its low solubility allows nitrogen dioxide to penetrate to the lung periphery where more than 60 percent is deposited. At very high concentrations, greater than 200 parts per million, nitrogen dioxide causes extensive lung injury, including fatal pulmonary edema and bronchopneumonia. Lower nitrogen dioxide concentrations may alter the lung's defense mechanisms. Patients with asthma and chronic obstructive pulmonary disease (COPD) are particularly sensitive to low concentrations of nitrogen dioxide.

Sulfur dioxide

Sulfur is a natural contaminant of all fossil fuels. Sulfur dioxide is produced primarily by coal- and oil-fired power plants and by industrial processes involving fossil fuel combustion. Sulfur dioxide emissions have been decreasing in Georgia. New lower-sulfur fuels should further decrease emissions. Sulfur dioxide can be a respiratory irritant which at high concentrations can cause severe airway obstruction and pulmonary dysfunction. Asthmatics and people with allergies and exercise-induced bronchospasm are sensitive to sulfur dioxide.

Carbon monoxide

Carbon monoxide (CO) is produced during the combustion of carbon-containing material, including gasoline, natural gas, oil, coal, wood, and tobacco. The principal source of carbon monoxide in outdoor air is motor vehicle emissions. The concentrations of carbon monoxide vary...
depending on the type of source material and when and where the combustion occurs. For example, in urban areas, CO levels are greatest in downtown areas which have high motor vehicle density, during peak commuting time, and in the passenger compartments of motor vehicles. CO has 240 times the affinity for hemoglobin as oxygen. Therefore, when inhaled, CO enters the blood, binds to hemoglobin, and reduces the oxygen-carrying capacity of the blood and the ability of tissues to extract oxygen from the hemoglobin at low partial pressures. Symptoms can progress from headache to giddiness and tinnitus; to nausea, weakness, and occasionally, vomiting; to coma and death. People with ischemic heart disease are particularly sensitive to the adverse effects of CO.9

Indoor Pollution
Indoor air pollutants probably have a greater impact on our health than outdoor pollutants because people in the United States tend to spend more time indoors than outdoors.10 Tobacco smoke and emissions from unvented combustion appliances, wood stoves, and fireplaces are the principal indoor air pollutants, although other potential pollutants include biologic agents and radon. Outdoor air pollutants also contribute to indoor air pollution; the degree of infiltration depends on the characteristics of a building’s construction. We highlight four common indoor air pollutants of public health concern, their health effects, and how they are produced.

Tobacco smoke
Tobacco smoke contains more than 4,500 compounds, 50 of which are known or suspected carcinogens, and six of which are developmental or reproductive toxicants.11 The undeniable health effects of primary cigarette smoking include premature mortality, lung cancer, and obstructive lung diseases.12 Second-hand tobacco smoke, also referred to as environmental tobacco smoke (ETS), has been associated with low birth weight, sudden infant death syndrome, eye irritation, acute lower respiratory tract infections among children, asthma induction and exacerbations among children, lung cancer, mortality due to heart disease, and acute and chronic heart disease morbidity.13 Approximately 22 percent of Georgians at least 18 years of age smoke cigarettes: more than 1.2 million adults.14

Combustion by-products
Many heating appliances rely on the combustion of carbon-containing fuels and can produce nitrogen oxides, carbon oxides, and particulate matter.15 The concentrations of combustion products in our homes depend on the efficiency of combustion, the quality of ventilation, and the maintenance and function of the heat-generating equipment. Gas stoves, which can produce nitrogen dioxide and carbon monoxide, are used by half of the United States population.16 The risk for lower respiratory illness among school children has been linked with indoor exposure to nitrogen dioxide produced by gas cooking.17 Each year hundreds of people die from carbon monoxide poisoning in homes, automobiles, and other enclosed spaces with improper ventilation. In Georgia, in 1999, there were two separate incidents in which six campers died after bringing either an unvented charcoal grill or a propane gas stove into their tents to keep warm.18

Radon
Radon is a radioactive gas created during the decay of radium, which itself is a decay product of naturally occurring uranium. Natural radon gas in the soil is the main source of radon in buildings and can penetrate through the foundation into the air in homes. EPA estimates that as many as six million homes throughout the country have elevated levels of radon.19 Although radon levels tend to be higher in northern Georgia than in southern Georgia, levels can vary significantly from house to house. Elevated radon concentrations can cause lung cancer.

Biologic contaminants
Biologic contaminants, which require an environment that provides nutrients and moisture for their growth, are present to some extent in all buildings. Such
contaminants include pollens; house dust mites; insect excreta and body parts; animal dander and excreta; and microbes such as viruses, bacteria, fungal spores, protozoans, and algae. Biologic contaminants are capable of becoming airborne and entering our respiratory systems, where they can cause infections and disease, as well as trigger allergic reactions and asth- 
ma attacks.

What Physicians Can Do
Clinicians can advise their patients to take actions to reduce their exposure to air pollution. Adverse health effects from air pollution can occur in patients who do not seek medical attention. For example, some patients may be symptomatic and increase medications or rest, whereas others may feel fine but may experience lung inflammation. People who are particularly susceptible to the adverse effects of air pollution include children; the elderly; tobacco smokers; and people with acquired immunodeficiency syndrome (AIDS) and pre-existing cardiopulmonary diseases, including asthma, allergic rhinitis, and cystic fibrosis. Children, the largest susceptible group, spend more time than adults engaged in vigorous activities; as a result they have a higher relative minute ventilation and intake of pollutants into their lungs. Children also spend more time outdoors than adults, particularly in the summer when ozone levels are highest. Patients who are susceptible should be advised to stay indoors during ambient pollution episodes.

Clinicians and their patients can access air-quality data on the Internet. Some Web sites that may be helpful to clinicians and their patients are listed below in Resources. EPA developed the Air Quality Index (AQI) to enhance the public's understanding of the level of air pollution. The AQI replaces the Pollutant Standard Index and includes an additional risk category. The AQI has six categories: good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous. The AQI allows clinicians and patients to determine how safe the outdoor air is for various activities.

When pollutant concentrations are elevated, clinicians may advise patients to avoid vigorous outdoor exercise, which increases the dose of pollution delivered to the respiratory tract. The Georgia Department of Natural Resources posts on its Web site the concentrations of several major pollutants at monitoring sites throughout Georgia and the PSI, which corresponds with EPAs AQI, in Atlanta, Augusta, Columbus, Macon, and Savannah.

Some physicians may want to encourage their patients and staff members to take steps to reduce air pollution. A program that offers information about the health effects of and ways to reduce ground-level ozone is the Partnership for a Smog-Free Georgia (PSG). The PSG encourages simple and effective voluntary actions that employers, employees, and all Georgians can take to reduce ozone-causing emissions on days when weather conditions support the formation of high levels of ground-level ozone. Physicians may also want to become active in their community or organizations to help improve air quality. Physicians for Social Responsibility sponsored a training workshop for physicians on Air Pollution and Health in June 1999 in Atlanta.

Recommendations for reducing indoor air pollution depend on the pollutant of concern. Tobacco smoke is probably the most common indoor air pollutant. Physicians can advise their patients to quit smoking for their own health and that of others exposed to their smoke. The American Medical Association (AMA) encourages physi- cians and medical societies to take a leadership role in defending the health of the public from ETS risks and from political assaults by the tobacco industry. Inexpensive kits can be purchased to test for radon. Levels of radon above four picocuries per liter of air on a yearly average should be remediated. Strategies for the control of indoor biologic contaminants include reducing relative humidity; repairing leaks and seepage; properly maintaining heating, ventilating, and air conditioning (HVAC) equipment; and cleaning buildings regularly using appropriate techniques.

Resources
Physicians can learn more about indoor air pollution by calling EPAs Indoor Air Quality (IAQ) Information Clearinghouse, IAQ INFO, at (800) 438-4318. IAQ INFO has operators who can answer your questions. They can also send you most of EPAs indoor air publications.

There are several Web sites that contain information on indoor and outdoor air issues. A few are listed below-

- For AMA policies: http://www.ama-assn.org/
- American Lung Association: http://www.lungusa.org/
- EPAs Office of Air and Radiation: http://www.epa.gov/oa/oarpubs.html#basic
- EPAs Air Links: http://www.epa.gov/airlinks
- Georgia Department of Natural Resources: http://www.dnr.state.ga.us/dnr/environ/
- American Academy of Allergy, Asthma, and Immunology: http://www.aaaai.org/nab
• EPA's Indoor Air Quality: [http://www.epa.gov/iaq/]

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References