HEALTH & CLEAN AIR
newsletter

Welcome

Each year air pollution claims upwards of 50,000 lives in the United States alone, but this and other information too often fails to make its way out of the pages of scientific journals and into the hands and minds of ordinary citizens to whom it is vitally important. The *Health and Clean Air Newsletter* is our attempt to make this information available to readers ranging from the heads of parent teacher associations to reporters, without sacrificing accuracy. We intend to publish three newsletters in the first year, four in the second, and then evaluate whether this experiment should continue and, if so, on what terms.

The printed version of the Newsletter omits citations, except for those found in the "For Expert Readers" section, which is directed toward physicians and others in the research and related communities. However, citations to, and abstracts of, the studies can be found at the *Newsletter* website, which is www.healthandcleanair.org.

This newsletter is made possible by assistance from the California Air Resources Board, which we deeply appreciate. We welcome your comments, suggestions, and questions, which can be mailed to 1100 Eleventh Street, Suite 311, Sacramento, CA 95814 or left at our web site, www.healthandcleanair.org.

CURTIS MOORE AND DAVID BATES, M.D.
The Editors

Air Pollution Causes Asthma

A Review of Recent Studies

A long-held consensus view of the health effects of air pollution—namely, that outdoor pollutants exacerbate, but do not necessarily cause the most common chronic disease of childhood, asthma—must be reexamined in light of several recent studies. At sites as distant and varied as Taiwan, Israel, and California, researchers have demonstrated an association between outdoor air pollution and the development of asthma in children and adults alike. These findings may help explain not only how and why asthma develops, but shed light on the cause of epidemic-like increases in its prevalence.

In the United States, an estimated 4.8 million children—one in 15—under 18 years of age have asthma. Rates have increased 160 percent in the past 15 years in children under five years of age, making asthma the leading chronic illness in children of the United States and the leading cause of school absenteeism due to chronic illness.

It is widely accepted that air pollution exacerbates asthma. For example, when traffic controls were put in place during the 1996 Summer Olympic Games in Atlanta, Georgia, morning peak traffic counts declined by 23 percent which, in turn, lowered ozone (O_3) concentrations by 13 percent, carbon monoxide (CO) by 19 percent, and nitrogen dioxide (NO_2) by 7 percent. Associated with these declines in ambient air pollution were drops in Medicaid-related emergency room visits and hospitalizations for asthma (down 42 percent), asthma-related care for health maintenance organizations (down 44 percent), and citywide hospitalizations for asthma (down 19 percent). These declines could not have been due to a general improvement in health in the Atlanta region because other Medicaid emergency visits declined by only 3 percent, while emergency visits among HMO enrollees and non-asthma hospitalizations actually increased slightly.

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Despite such striking relationships between exposure to air pollution and asthma aggravation, air pollution has not been regarded as a cause of the disease. Increasingly, however, recent studies have been suggesting that air pollution may, indeed, be a cause of asthma.

Asthma Development and Ozone

Children: the Southern California Children's Health Study. Starting in 1993, researchers at the University of Southern California (USC) in collaboration with the California Air Resources Board began recruiting children to participate in the Children's Health Study (CHS). A total of 3,535 children with no lifetime history of physician-diagnosed asthma were selected from the fourth, seventh, and tenth grades from 12 communities in Southern California. These children were followed for five years and during that period 265 reported a new physician diagnosis of asthma.

Analysis of CHS data has shown that children living in communities with high ozone levels who played three or more sports developed asthma more often than those in the less polluted areas. Both factors—high ozone and high exercise levels—were important, suggesting that there may be a dose-response relationship: the more ozone breathed, the greater the chance of developing asthma. Children who exercised heavily but lived in the low-ozone communities developed asthma less often, as did those with lower exercise levels, whether they lived where the air was dirtier or cleaner. It should be noted that this ozone/exercise effect accounts for a minority of new asthma.

Adult Californians: the AHSMOG Study. The hypothesis that ozone might cause asthma is reinforced by a study of 3,091 adult, non-smoking Californians aged 27 to 87 years who were followed for a 15-year period, starting in 1977. The results of this study showed that 3.2 percent (54) of the men and 4.3 percent (83) of women reported new doctor-diag-

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nosed asthma. The factors that increased the risk of developing asthma included a history of:

- 'ever smoking' in men and of working with a smoker in women;
- childhood pneumonia or bronchitis; and,
- in men, exposure to ozone.

The asthma-ozone relationship was unaffected by addition of other pollutants, particulate matter (PM), sulfate, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), so it appears—as in the USC study of children—that ozone is the most likely cause of air pollution-related asthma.

The researchers concluded that there was "a positive association between ozone concentration and development or redevelopment of asthma symptoms in those who reported a doctor's diagnosis, but no current symptoms, of asthma in 1977." Although the proposed new federal eight-hour standard was exceeded on some days, findings in the study suggest that there may have been an excess of asthma in even cleaner "moderate" areas. The federal Clean Air Act and the California Clean Air Act both require that an air pollution standard be set at a level that protects the health of sensitive populations (children, for example) against the adverse effects of air pollution and that provides an adequate margin of safety. The AHSMOG study results suggest that the current and proposed standards should be re-examined for their adequacy in light of its findings.

Although these two studies demonstrate an association between ozone exposure and development of asthma, other studies seem to implicate other pollutants.

Asthma Development and Particulate Matter

Particulate Matter-Asthma Association in Israel. In a rural area of Israel researchers compared the health status of two communities, one unpolluted and the other exposed to pollution from a cement factory and quarries. In the polluted community, there were 638 children aged seven to 13 compared to 338 in the "clean" community. The levels of particulate matter smaller than 10 microns in diameter (PM_{10}) were relatively high: a level of 150 micrograms per cubic meter was said to have been violated very often in the polluted region, and an examination of the study's data suggests that peaks might have exceeded 300 micrograms per cubic meter.

Asthma was more prevalent in children from the polluted region, as were respiratory symptoms, cough, and cough accompanied by sputum. In addition, a measure of airway obstruction—the peak expiratory flow rate (PEFR)—was lower in children who lived in the polluted region.

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Other researchers have also found an association between asthma development and measures of particulate matter. In London, for example, researchers analyzed data from the medical practices that had contributed information to the General Practice Research Database during 1992-4. This represented more than one-quarter million patients.

Researchers found associations between asthma in children and exposures to nitrogen dioxide (NO_2), carbon monoxide (CO), and sulfur dioxide (SO_2). When researchers examined the frequency of complaints on the day after exposure, they found that in the summer, asthma consultations increased 13.2 percent with NO_2, 11.4 percent with CO, and 9.0 percent with SO_2. In winter, consultations for lower respiratory disease increased 7.2 percent with NO_2, 6.2 percent with CO, and 5.8 percent with SO_2. In adults, the only consistent association was with PM_{10}, which was associated with an increase of 9.2 percent.

Asthma Development and Other Pollutants

Some researchers have found significant associations between the development of asthma and air pollution in general, but have either been unable to disentangle the impact of specific contaminants or have found multiple associations.

Taiwan School Children. In a Taiwanese study, for example, researchers found associations between asthma development and a number of individual pollutants, with an aggregate increase in prevalence by as much as 29 percent. The researchers surveyed 165,173 high school students aged 11 to 16 in 2 communities in Taiwan.

The study area, Kaohsiung City and County, had some more and some less-polluted regions. The overall asthma prevalence was around 13 percent, but the regional prevalences were increased in areas with higher levels of specific air pollutants—PM_{10}, SO_2, NO_2, CO, and total suspended particulate matter (TSP). In the aggregate, asthma prevalence was increased by as much as 29 percent in association with these major outdoor pollutants, leading the authors to conclude that they had "observed a statistically significant association between outdoor air pollution and asthma, after controlling for potential confounding variables." (Interestingly, the researchers corrected for exposure to environmental tobacco smoke (ETS), and found that this correction did not have a major effect on the associa-

tions between asthma prevalence and air pollutants.)

Hong Kong School Children. A study of 1,660 school children aged eight to 12 in two areas of Hong Kong, one highly polluted and the other less so, followed a roughly similar approach to that employed in Taiwan. All children completed respiratory questionnaires, and 1,294 also were tested for several different measures of lung function.

As in the Taiwan study, there was a marked difference between the respiratory health of the two sets of children. As air pollution increased, the ability to breathe normally, as measured by the lung function tests, dropped and the prevalence of respiratory complaints increased. In addition, asthma was more prevalent in the high pollution district.

Sulfur Dioxide, Perhaps as an Indicator. From 1974–1976, data were collected in 24 areas of seven French towns as part of the French Pollution Atmospherique et Affections Respiratoires Chroniques (PAARC). In the late 1990s, researchers reanalyzed this data to assess the relationship between the prevalence of asthma and several common air pollutants: sulfur dioxide (SO_2), total suspended particles (TSP), black smoke (BS), nitrogen dioxide (NO_2), and nitric oxide (NO).

As air pollution increases, the ability to breathe normally, as measured by the lung function tests, drops and the prevalence of respiratory complaints increases.

Of the 20,310 adults between 25 and 59 years of age, 1,291 (6.4 percent) were found to be asthmatics. So were 195 (6.1 percent) of the 3,193 children between the ages of five to nine. In the adults, researchers found a geographic correlation between asthma and the annual average of SO_2, but not in children.

When the annual average concentration of SO_2 was less than 30 micrograms per cubic meter, the prevalence of asthma in adults was about four percent. But when the when SO_2 annual average was more than 80 micrograms per cubic meter, the asthma prevalence ranged from five to six percent. The authors concluded, "it is possible that SO_2 in the present study is just a sensitive indicator of air pollution."

Policy Implications: What Can Be Done

These studies are important for at least two reasons:

First, they demonstrate that air pollution is almost certainly a cause of asthma, though it may or may not be powerful enough to account for the virtual epidemic of the disease that has gripped the world; and,

Second, they provide potentially valuable clues to other causes of the disease and, if the mechanism by which air pollution leads to asthma can be fully defined, that may help reveal other as-yet-unknown causes and ultimately prevent asthma.

It is important to bear in mind that if air pollution exposure does contribute to asthma development—and that certainly appears to be the case based on these studies—it is unlikely, based on currently available data that it is the "smoking bullet" for the asthma epidemic. For air pollution to be a major cause of this vast increase, one would expect any study which was done to show very strong relationships between air pollution and development of asthma. This has not been the case. Having said that, these studies call for several responses:

- The air quality standards for certain pollutants, especially ozone, may need to be revised to take into account the possibility that air pollution causes asthma.
- Research efforts should be mounted to confirm whether air pollution does indeed cause asthma and identify possible biological mechanisms.
- The manner in which air quality standards are developed should be revised. The method currently followed by the U.S. Environmental Protection Agency and the California Air Resources Board is to collect pollutant-specific studies, which are then published in a Criteria Document, which may be several thousand pages in length. Organizing and analyzing information in such a pollutant-specific way makes it extremely difficult for associations between exposure to ambient air pollution in general and illness—in this case asthma—to be developed. The conventional approach should be augmented by new programs that attempt to characterize the public health impact of exposure to pollutant mixtures. Some research programs are designed to collect information on multiple pollutant exposures and a variety of health outcomes, including asthma, for both specific and broad population-level exposures, but the legal and regulatory mechanisms for translating findings into protective measures do not currently exist.

the scale of the threat

Asthma is a cause of human suffering on a massive scale, and it is spreading rapidly—though for reasons that are poorly understood. Globally, between 100 and 150 million people suffer from asthma, and roughly 180,000 die from the disease each year. The numbers of both illnesses and deaths are growing rapidly.

In the United States, the number of asthmatics has jumped more than 60 percent since the early 1980s. U.S. deaths due to asthma have doubled, and now amount to about 5,000 a year. In 1998, based on trends for the previous 15 years, the Centers for Disease Control estimated that more than 15 million Americans suffer from asthma. According to CDC—

> *The increase in asthma cases and deaths affects all ages, spans across all racial groups and occurs throughout the U.S. However, higher rates of hospitalization and emergency room visits were reported in the northeast; and blacks reported higher rates of emergency visits, hospitalization and deaths.*

The same seems to be true in almost all developed nations: in Switzerland, for example, roughly 8 percent of the population suffers from asthma, up from only 2 percent 25 to 30 years ago. In Western Europe as a whole, asthma has doubled in ten years, while there are about three million asthmatics in Japan of whom 7 percent have severe and 30 percent have moderate asthma. In Australia, one child in six under the age of 16 is affected.

In developing countries the incidence of asthma varies greatly. It is virtually zero in Papua New Guinea, while in Brazil, Costa Rica, Panama, Peru, and Uruguay, prevalence of asthma symptoms in children varies from 20 to 30 percent. In Kenya, the prevalence of asthma symptoms approaches 20 percent, while in India, rough estimates indicate a prevalence of between 10 and 15 percent in five to 11 year old children.

The Centers for Disease Control estimates that there were 2,268,300 asthmatics in California in 1998, while in 1995 there were 42,333 asthma-related hospitalizations, 42 percent, or 17,860, of which were children, with over 600 deaths. The hospitalization rate for blacks, especially black children, is very high, as is mortality—two to four times that of whites in 1985-89. The same is true of non-white Hispanics.

What is Asthma?

Asthma attacks all age groups but often starts in childhood. It is a disease characterized by recurrent attacks of breathlessness and wheezing, which can vary in severity and frequency from person to person and even from hour to hour in the same individual. Doctors agree that the lung's air passages become inflamed, boosting the sensitivity of airway nerve endings so they become easily irritated. In an attack—which can be triggered by cold air, pollen, air pollution, and a variety of other stimuli—the linings of the passages swell, narrowing the airways and reducing the flow of air in and out of the lungs.

Asthma rates world-wide are, on average, rising 50 percent every decade, but there is no consensus on the cause. Suspected causes and triggers include house dust mites, whose numbers have increased and, with them, asthma prevalence. Tightened homes, slab foundations, and other improvements in construction have reduced exchanges of indoor and outdoor air, thus increasing household and workplace levels of some chemicals, molds, and other known asthma triggers. The air is, thus, effectively a single medium that can affect asthma development and attacks, whether exposures are indoor or out.

by David V. Bates, MD, FRCP, FRCPC, FACP, FRSC

Abstract of the H_2S Study

LEGATOR, M.S., SINGLETON, C.R., MORRIS, D.L., & PHILIPS, D.L. Health Effects from chronic low-level exposure to Hydrogen Sulfide Arch Environ Health 56; 123-131; 2001 Notes previous studies, including one in Rotorua in New Zealand which found an elevated prevalence of eye and CNS disease. Two exposed communities were Odessa in Texas, where contaminated ponds released H_2S (3-40 micrograms/m^3 or 7-27 ppb as an annual average with an eight hour maximum of 335-503 ppb or 500-750 micrograms/m^3; and Puna in Hawaii where wells for geothermal power have been drilled; here H_2S is in the low ppb range, though a single peak of 301 ppb was recorded and releases in the range of 200-500 ppb have been reported. These communities were compared to Hilo Hawaii, Midlothian Texas, and Waxachie in Texas. Selection process for subjects is described in some detail. Numbers were Odessa = 126; Puna = 97; Midlothian = 58; Waxachie = 54; and Hilo = 58. Interviewer selection and training procedures. Self reported symptom comparisons revealed excess ORs between clean and contaminated communities as follows:

CNS symptoms = 12.7	Cardiovascular = 2.03
Ear/nose/ throat = 7.24	Digestive = 4.05
Respiratory = 11.92	Teeth/gums = 6.31
Muscle/bone = 3.06	Urinary system = 2.48
Skin = 3.6	Blood = 8.07
Immune system = 5.35	Endocrine = 1.06

Of CNS symptoms, fatigue, restlessness, depression, memory loss, balance, difficulty sleeping, anxiety, lethargy, headache, dizziness and change in senses were noted in between 30-50% of those in contaminated regions compared to 10-25% in clean regions. Respiratory symptoms, wheezing, shortness of breath, persistent cough, bronchitis all between 20-30% in contaminated locations compared to about 5% in clean areas. Anemia and easy bruising twice as common in contaminated locations. Good discussion of interpretation of findings from this kind of survey, and discussion is cautious but generally convincing. This appears to be one of first reputable attempts to establish the reality of chronic symptoms as a consequence of low level H_2S exposure.

Although exposure to low levels of hydrogen sulphide probably does not cause serious chronic disease, the symptoms are very unpleasant; the differentiation between "illness" and "disease" becomes important in this context. The study is important because every attempt was made to obtain as reliable a measurement as possible of subjective symptoms—an inherently difficult task.

Abstract of Hodgkin's Disease Study

RAASCHOU-NIELSEN, O., HERTEL, O., THOMSEN, B.L., & OLSEN, J.H. Air Pollution from traffic at the residence of children with cancer, Am J Epidemiol 2001: 153; 433-443

1,989 children recorded with cancer at the Danish Cancer Registry. With diagnosis of leukemia, CNS tumors, or malignant lymphoma during 1968-1991 compared with 5,506 control children selected at random. Residential histories traced from nine months before birth till the time of diagnosis. Information on traffic and configuration of streets collected, and average concentrations of benzene and NO_2 (indicators of traffic related air pollution) calculated. Risk of lymphomas (Hodgkin's disease) increased by 25% for a doubling of the calculated concentrations of benzene and NO_2. Good discussion of measurements and calculation of traffic exposure from NO_2.

Abstracts of Remaining Studies and citations may be found at www.healthandcleanair.org

Worth Noting

Benzene as a Cause of Lymph System Cancer

Evidence continues to accumulate that air pollution poses special, and sometimes quite grave, risks for children. A recent study in Denmark, for example, suggests that those risks may include a cancer of the lymphatic system, or lymphoma, known as Hodgkin's disease.

Benzene, a colorless liquid with a sweet odor, is a demonstrated cause of cancer in humans. Benzene is both a constituent of gasoline and a combustion by product. Up to 80 percent of the emissions of benzene in urban areas are from gasoline evaporation and combustion.

There is no question that at levels encountered in workplaces such as refineries and chemical plants, benzene can cause leukemia or cancers of the bone marrow and blood, in humans. However, it has been unclear whether benzene could do this at the much lower levels found, for example, near highways or adjacent to truck or bus marshaling yards.

To probe these possible relationships, researchers in Denmark compared the residential histories of 1,989 children who had a diagnosis of leukemia, central nervous system tumor, or malignant lymphoma reported to the Danish Cancer Registry from 1968 to 1991. Their histories were compared with those of 5,506 control children selected at random.

The researchers traced the residential histories of each child from nine months before birth to the time of diagnosis. They collected information on traffic and street configuration, and calculated concentrations of benzene and nitrogen dioxide (NO_2). They found that a doubling of the calculated levels of benzene and NO_2 increased the risk of a child developing Hodgkin's disease by 25 percent.

What can be done: (1) benzene-free fuels other than gasoline (e.g. natural gas) can be used; (2) benzene can be removed at refineries; (3) destroyed at the tailpipe with catalysts.

Hydrogen Sulfide: That "Rotten Egg" Smell

One of the largest single categories of complaints lodged with the California Air Resources Board involves the rotten egg smell associated with hydrogen sulfide (H_2S). This invisible gas is found around sewers, paper mills, and oil and gas drilling or refining operations. At high concentrations H_2S can kill. But what are its effects at much lower concentrations—the kind that many people encounter every day?

To answer this question, researchers examined two communities, one in Odessa, Texas, the other in Puna, Hawaii, where H_2S concentrations were in the parts per billion, or about 2/1,000ths or less of the lethal level. Researchers compared the health of these residents to that of people in Midlothian and Waxachie, Texas; and, Hilo, Hawaii, with remarkable results. (For expanded discussion, see box "For Expert Readers").

Central nervous system symptoms—such as fatigue, restlessness, depression, memory loss, balance, difficulty sleeping, anxiety, lethargy, headache, dizziness, and change in senses—were noted in 30 to 50 percent of those in contaminated regions compared to 10 to 25 percent in clean regions. Similarly, respiratory symptoms—wheezing, shortness of breath, persistent cough, and bronchitis—were found in 20 to 30 percent of those in contaminated locations, compared to about 5 percent in clean areas. Anemia and easy bruising were twice as common for people residing in contaminated locations.

What can be done: (1) H_2S formation can be prevented at sources such as sewage treatment plants; (2) emissions can be captured and destroyed at these and other sources.

Diesel Soot

Diesel particulate matter, that noxious mixture of soot and other pollutants that pours from the tail pipes of trucks, buses, and some cars, consists of particles so small that they that can readily penetrate into the deepest recesses of the lungs. But what happens then?

According to researchers who exposed 15 healthy human volunteers to air and diluted diesel exhaust for one hour with intermittent exercise, the result is a significant increase in substances that signal an allergic reaction on the part of the body. The scientists found no reduction in the ability of subjects to breathe normally, but when a segment of the lungs was rinsed with a salt water solution six hours after the end of exposure, they found significant increases in neutrophils (a kind of white blood cell that enters the body's tissues to attack and kill invading threats such as bacteria) and B lymphocytes (another kind of white blood cell), as well as other signs of the body mounting a defense to an external threat.

The concentration of diesel soot was 300 micrograms per cubic meter—fairly high for an outdoor setting, but about 75 percent of the level that miners are allowed to breathe under federal regulations.

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What can be done: (1) fuels other than oil-based diesel (e.g. natural gas) can be used; (2) tighter tailpipe standards can be adopted; (3) residential communities can be placed off-limits to diesel; (4) diesels currently in use can be retrofitted with pollution control systems.

Burning Issues

There is little doubt that extremely fine particles— what most would call soot— cause illness and death. The number of studies demonstrating this association has increased sharply in the past several years. For most North Americans, the dominant sources of these particles are probably cars, trucks, and buses, as well as factories and coal-burning electricity generators. But for hundreds of millions of other people, the source of fine particulate matter exposure is the burning of forests, agricultural residues, or other forms of biomass. In developing nations where biomass ranging from twigs to dried dung is burned for heating and cooking, indoor levels can be extraordinarily high, with devastating consequences. Altogether, roughly 4.1 million children under the age of five die in developing nations each year from acute respiratory illness, and about one million of these deaths are estimated to be due to indoor smoke exposures. This compares to three million deaths from intestinal diseases and 680,000 from malaria.

In India, when scientists analyzed *Family Health Survey* data from 260,162 people aged 20 and over, they concluded that the results "strongly suggest that use of biomass fuels for cooking substantially increases the risk of tuberculosis." Even outdoor soot exposures are associated with increased illness. In June-July 1998, for example, forest fires raged in parched areas of Florida, burning 499,477 acres. Researchers pooled data from eight area hospitals, finding that emergency visits increased 91 percent for asthma, 132 percent for acute bronchitis and 37 percent for chest pain. Similarly, after lightning strikes touched off fires that eventually burned over 600,000 acres of woodland in California during August 1987, researchers compared hospital data during that time with two other relatively fire-free periods. They found a 40 percent increase in emergency room visits for asthma, as well as increases for sinusitis, upper respiratory infections, and laryngitis.

These surges in smoke can pose a special threat to those already suffering from respiratory illness, as a study in Winnipeg, Canada demonstrates. When smoke levels there increased sharply from September 25 to October 12, 1992 due to the burning of agricultural residue, 428 people with mild-to-moderate airway obstruction were already enrolled in an on-going study. Researchers were able to closely monitor lung health. They found that virtually all of the 163 women reported difficulty in breathing, though only 16 percent of the 265 men did so. Their symptoms included cough, wheezing, chest tightness, and shortness of breath.

What can be done: (1) in developing nations, replace biomass with cleaner fuels (e.g. natural gas, electricity and solar); (2) in developed nations, convert crop, forest, and other residues to useful energy through advanced technologies (e.g. gasification); (3) avoid creating residues by altering farming techniques.

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