Chapter 24

AIR POLLUTION

Case Study: London Smog and Indonesian Fires

●These are case studies of two notorious air pollution episodes. The London Smog of 1952 was the worst of a series of toxic fogs. Between 4 and 10 December, during an inversion, about 4,000 people died from the pollution. This was an era in which coal was widely used for home heating, and the byproduct, sulfur dioxide, is toxic. A more recent episode occurred when climate conditions made possible by El Nino enabled fire to ravage tropical forests in Indonesia. The smoke created a health crisis and endangered a number of species.

24.1 A BRIEF HISTORY OF AIR POLLUTION

● There is a long history of air pollution. Written accounts can be found in the 16th century. Acid rain was described in the 17th century, and its potential to do harm was established by the 18th century. In the U.S. a air pollution episode in Donora PA in 1948 that caused 20 deaths and 5,000 illnesses. The Donora event was followed by the London event in 1952.

24.2 STATIONARY AND MOBILE SOURCES OF AIR POLLUTION

● Air pollutants are either from mobile or stationary sources. Stationary sources are further described as being point sources (e.g. a smoke stack), fugitive sources, and area sources. Fugitive sources generate air pollutants from open areas exposed to wind (e.g. dust from a construction site). Area sources are defined areas, such as an urban community or an industrial complex. Mobile sources derive from transportation.

24.3 GENERAL EFFECTS OF AIR POLLUTION

● There are effects on fauna and flora as well as infrastructure (see Table 24.1). The effects on vegetation include damage to leaves, suppression of growth/photosynthesis, increased susceptibility to disease, and increased susceptibility to extreme climate.
● Air pollution is a significant source of mortality for people in urban areas and carries a health cost estimated to be $50 billion annually in the U.S. The primary health effects include toxic poisoning, cancer, birth defects, irritation of the eyes and respiratory system. Exposure to air pollutants also increases susceptibility to hearth disease, emphysema, viral and bacterial infection.

24.4 PRIMARY AND SECONDARY POLLUTANTS, NATURAL AND HUMAN

● Major air pollutants either occur in gaseous form or as particulate matter (PM). Particulates are solids or liquids, and they are further classified according to size, e.g. PM10 is a particulate less than 10 um. The gases include SO_2 or SOx, NOx, CO, O_3, volatile organic cpds (VOCs), H_2S, and hydrogen fluoride (HF).

● Air pollutants are also classified as being primary or secondary. Primary pollutants are those emitted directly (e.g. CO), while secondary pollutants are produced through reactions among primary pollutants and normal atmospheric compounds. Some 140 million metric tons of primary pollutants are emitted annually in the U.S., consisting mostly of CO, NOx, SOx, and particulates (see Table 24.2). In addition to the human sources of pollutants, there are natural pollutant sources, including forest fire (particulates and NOx), volcanic eruptions (SOx), vegetation (VOCs), and hot springs, geysers, and salt marshes (H_2S), and natural hydrocarbon seeps.

24.5 MAJOR AIR POLLUTANTS: SOME DETAILS

● SO_2 – colorless, toxic and even fatal at high concentrations, oxidizes to SO_4 in the ● atmosphere and combines with water to from H_2SO_4, the main component of acid rain. Combustion of coal is the major source

● NOx – occurs in several oxide forms, but largely as NO and NO_2, it contributes to acid rain as nitric acid, and is a major contributor to smog and secondary pollutants (PANs). Nearly all NOx is anthropogenic and from combustion sources. NO and NO_2 suppress plant growth, but NO_3 stimulates plant growth and contributes to aquatic eutrophication.

● CO is colorless and odorless and extremely toxic to humans and animals. CO has a greater affinity for hemoglobin than O_2. About 90% of the CO in the atmosphere is from natural sources, the other comes from fires, autos, and other sources of incomplete burning of organic compounds. Emissions in the U.S. peaked in the early 1970s.

● O_3 and other photochemical oxidants result from atmospheric interactions of NO2 and sunlight, hence they are secondary pollutants and are components of smog. O_3 is most common and is extremely reactive. It has a short half-life. It is extremely toxic to plants and animals, and in low concentrations it burns the eyes and irritates the sinuses. It attacks rubber and plastic. O_3 sometimes manufactured for use as a sterilizing agent. It is sometimes used instead of Cl^- to sanitize drinking water. It forms naturally in the stratosphere, where it forms a protective layer that blocks much of the UV radiation.

●VOCs include a variety of organic compounds, including solvents, gasoline vapors, natural gas, and may others. Many are toxic and some are carcinogenic (e.g. benzene). About 15% of VOCs emitted globally are anthropogenic, and about 50% of VOC emissions in the U.S. are anthropogenic. Catalytic converters have greatly reduced VOC emissions from autos.

● Particulate matter (PM 10 and PM 2.5) (less than 10 μm and 2.5 μm respectively) applies to solid particles in the air and is often visible as smoke (see Fig. 24.7). The composition of PM varies greatly, and includes heavy metals, arsenic and asbestos. PM 2.5 is of greatest concern because they can embed in lug tissue for long periods. 2-9% of mortality in urban areas is attributed to PMs.

● H_2S is highly toxic, corrosive, and has a rotten egg odor. It is produced from natural sources (sulfate reduction in salt marshes, volcanoes) and industrial sources.

● HF (hydrogen fluoride) is released from industrial sources and is extremely toxic, even at 1 ppb.

● Other hazardous gases, such as Cl, are also common, but tend to be produced episodically as a consequence of accidents. For example, in 1984 an accident in Bhopal, India released a cloud of methyl isocyanate that killed over 2,000 people.

● Pb is a constituent of auto batteries and was an additive in gasoline. Pb was phased out of gasoline when catalytic converters were added to cars, because the Pb poisoned the

> **A CLOSER LOOK 24.1: Acid Rain**
>
> ● Acid rain is precipitation in which the pH is below 5.6. pH is a measure of the concentration of hydrogen ions. As pH decreases, the concentration hydrogen ion rises and the concentration of hydroxyl ion (OH^-) declines. pH 7 is neutral (equal concentrations of H and OH. Acid rain is caused primarily by SOx emissions, with a significant contribution made by NOx. Coal-burning electric power plants are the major source of SOx for acid rain. Ironically, the problem was made worse when higher air quality standards forced electric utilities to raise the heights of their smoke stacks based on the premise that dilution is the solution to pollution. Acid rain dissolves stone monuments and bridge supports, corrodes metals, damages aquatic systems (there are lakes in the Adirondacks that are too acidic to support fish), damages the foliage on vegetation (removes protective waxes) making the leaves susceptible to fungal attack, and solubilizes aluminum in the soil (toxic to plants). The sensitivity of the environment to acid rain varies with the buffering capacity of the soil. Regions with thin soils over granite are most sensitive.

catalytic converters. Pb causes mental retardation. When used in gas, at concentrations it was the major source of airborne Pb pollutions. Since the phase-out, Pb emissions have greatly declined (see Fig. 24.6). This is one of the success stories.

24.6 VARIABILITY OF AIR POLLUTION

● The severity of air pollution varies regionally and temporally with climate and source strength. Some areas are more prone to inversions than others, for example.

24.7 URBAN AIR POLLUTION

● Meteorological conditions can determine if air pollution if a nuisance or a major health threat. Air pollution can become severe during atmospheric inversions, which occur when a blanket of cool air is trapped at ground level and overtopped by warmer air. Since cooler air is denser than warm air, the cool air does not rise and pollutants can accumulate (see Fig. 24.14). The susceptibility of an area to inversion is a function of local topography and weather.

● The potential for air pollution depends on 1) the rate of emissions, 2) the average wind speed, and mixing.

● Photochemical smog is a particular problem in urban areas during daylight hours where concentrations of the precursor, primary pollutants are sufficiently high as they often are on the road during rush hour.

● Strategies to reduce air pollution include reducing the use of automobiles, stricter emission controls and fuel efficiency for autos, encouragement of greater use of electric and hybrid vehicles, use of cleaner burning fuels, improved public transportation, and improved controls on industrial pollutants, and mandatory car pooling. Developing nations have a long way to go.

24.8 POLLUTION CONTROL

● Industrial PMs can be controlled with electrostatic precipitators, scrubbers and filters. Catalytic converters are used on autos to reduce VOCs and CO. Auto emissions of NOx are reduced by recirculating exhaust gas and adjusting the air:fuel ratio. SO_2 can be controlled by using scrubbers on smoke stacks and by using gasified coal as a fuel source.

24.9 AIR POLLUTION LEGISLATION AND STANDARDS

● The Clean Air Amendments of 1990 are comprehensive regulations that address acid rain, toxic emissions, ozone depletion, and auto exhaust. The legislation provides incentives to utilities to reduce SO_2 emissions by providing marketable permits that allow companies to buy and sell the right to pollute. The total amount of pollution allowed is divided into a fixed number of permits. This provides an economic incentive for using clean technologies. The legislation also called mandated a reduction in NO_2. The law also dealt with O_3 depletion by phasing out CFC production completely by 2030. Tougher standards for PM 2.5 and ozone were established in 1997 by the EPA.
● National ambient air quality standards (NAAQS) are a set of target standards that have been established by the EPA for each major air pollutant (see Table 24.3).
●The Air Quality Index (AQI) (Table 24.4) is a standard used to define the quality of air. The index is expressed on a continuous scale from 0, with 0-50 being good and healthy, 51-100 moderate and unhealthy for some, and over 300 being hazardous. If the AQI exceeds 400, an air pollution emergency is declared, and people are requested to remain indoors. Moreover, the EPA is empowered to limit the use of automobiles and emissions by industry.

24.10 COST OF AIR POLLUTION CONTROL

● Cost varies by industry. Cost increases with the degree of control, and while the effectiveness of pollution control rises to an asymptotic level, the cost has no limit. Consequently, the cost effectiveness of pollution control declines as the amount of control increases. However, as the controls for air pollution increase, the loss from pollution damages decreases. The total cost of air pollution is the cost of pollution control plus the environmental damages of the pollution.

CRITICAL THINKING

● Where does arctic haze come from, and how does it affect the environment?
The air pollutants in arctic haze tend to deposit onto the ground surface at a rate that is lower than in temperate or tropical regions. What is different about the arctic environment that could account for this?
● Air quality standards have been developed to protect the people most at risk; these are people that suffer from asthma, emphysema, and other respiratory ailments. Air pollution control adds to the price of goods and services. Should healthy people have to pay this added cost?
● The major industrial powers went through a phase of development in which there were no pollution controls. These wealthy nations have now taken steps to improve the environment, including air quality. Should these nations expect that developing countries should adopt the same costly standards?

● Given that transportation is one of the major sources of urban air pollution, what could be done to change the habits of people so that they would rely on alternative and cleaner forms of transportation?

Web Resources

http://www.epa.gov/airlinks/ This is the EPA portal to air quality information, acid rain, climate change, and other related topics.

http://books.nap.edu/books/0309086094/html/index.html The National Academy of Sciences report, 'Estimating the Public Health Benefits of Proposed Air Pollution Regulations (2002).

http://www.flexcar.com/ This is the Flexcar site. Flexcar provides a revolutionary way of mass transit for urban people who commute to or live in the city and need a car only infrequently while in the city.