6 AIR

We take the atmosphere for granted. We expect clean, fresh air to be present everywhere, both indoors and outdoors. Yet we expel a variety of our wastes into the atmosphere and assume that the air will be able to absorb it all. However, by discharging these wastes we have seriously damaged the quality of the air in many parts of the earth. The result is damage to the health of vegetation, animal life, and people.

When the air is clear, as it may be after rainfall, visibility can extend 200 km or more. Today, however, such occasions are rare. The air around us contains a great deal of dust and many polluting gases. Some of the dust is carried by the wind. Some is natural and comes from pollen, as sufferers from hay fever know only too well. A great deal more comes from the burning of coal and from industrial processes. Transport and mining activities also generate dust.

Of all types of pollution, air pollution is the most difficult to contain. The circulation of winds is unpredictable, ensuring that areas far removed from the pollution source experience its effects. Even the Arctic regions, once famous for clear air, now experience **Arctic haze**, which can cut visibility to 30 km or less. Arctic haze is caused by suspended particles (mainly sulphates) that come from industrial regions.

In this chapter we will examine the four commonly recognized forms of air pollution and the actions being taken to combat them. We will also look at the problems in our indoor environments, where we spend most of our time.

Acid rain

The term **acid rain** was first used in 1872 by a Scottish chemist, but only in recent years has it become a global problem. The more accurate name is **acid deposition**, since dry matter as well as rain and snow carry acids. Normal precipitation is slightly acidic because water droplets absorb some carbon dioxide to form a very diluted carbonic acid. The term **toxic rain** has been used to refer to rain containing heavy metals and other toxic materials.

Acidity is measured on the pH scale, as shown in Figure 6.1. Each drop of one point on the pH scale is a tenfold increase in acidity. Thus pH 6 is ten times as acid as pH 7, which is neutral. Normal, or pure, rainfall is about pH 5.6. In some parts of the globe, including Ontario, precipitation can measure pH 4 or even worse. In parts of the eastern United States the average pH of rainfall has decreased from 6.0 to 4.5 since 1930.

The sources of acid deposition are illustrated in Figure 6.2. Large volumes of gases and dust are discharged into the atmosphere. Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) mix with water droplets in clouds to form diluted sulphuric and nitric acids respectively. Once these pollutants are in the atmosphere they do not recognize international boundaries. For example, pollution from power stations in the Ohio Valley are a major cause of acid deposition in eastern Canada. Figure 6.3 shows the areas of the

Figure 6.1 The pH scale

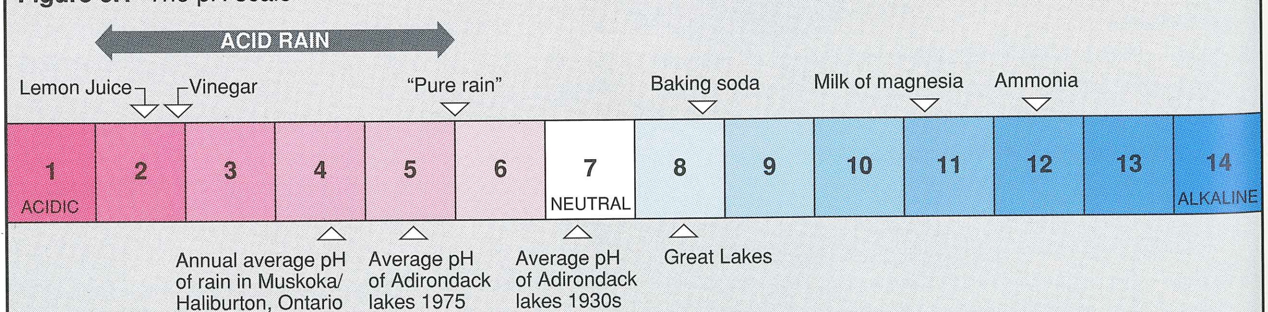

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Figure 6.2 The causes of acid rain

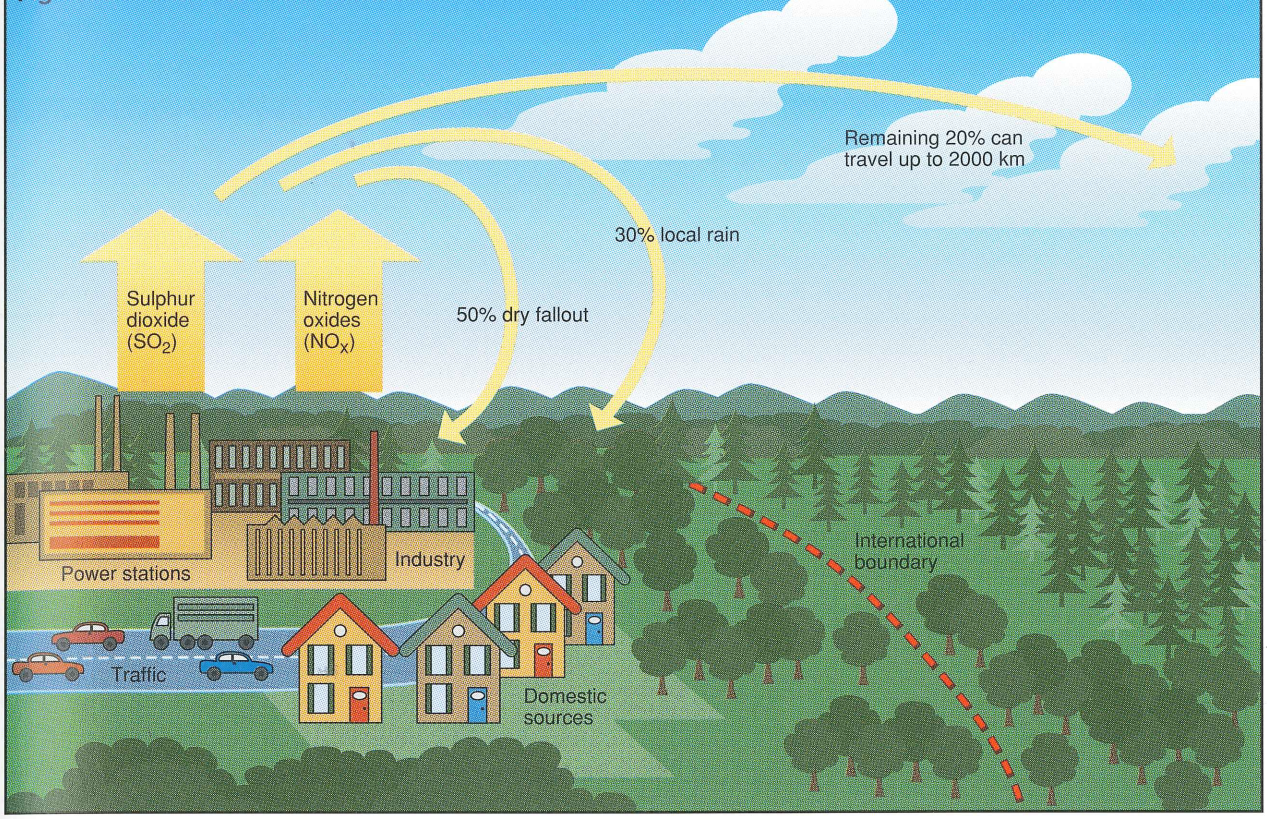
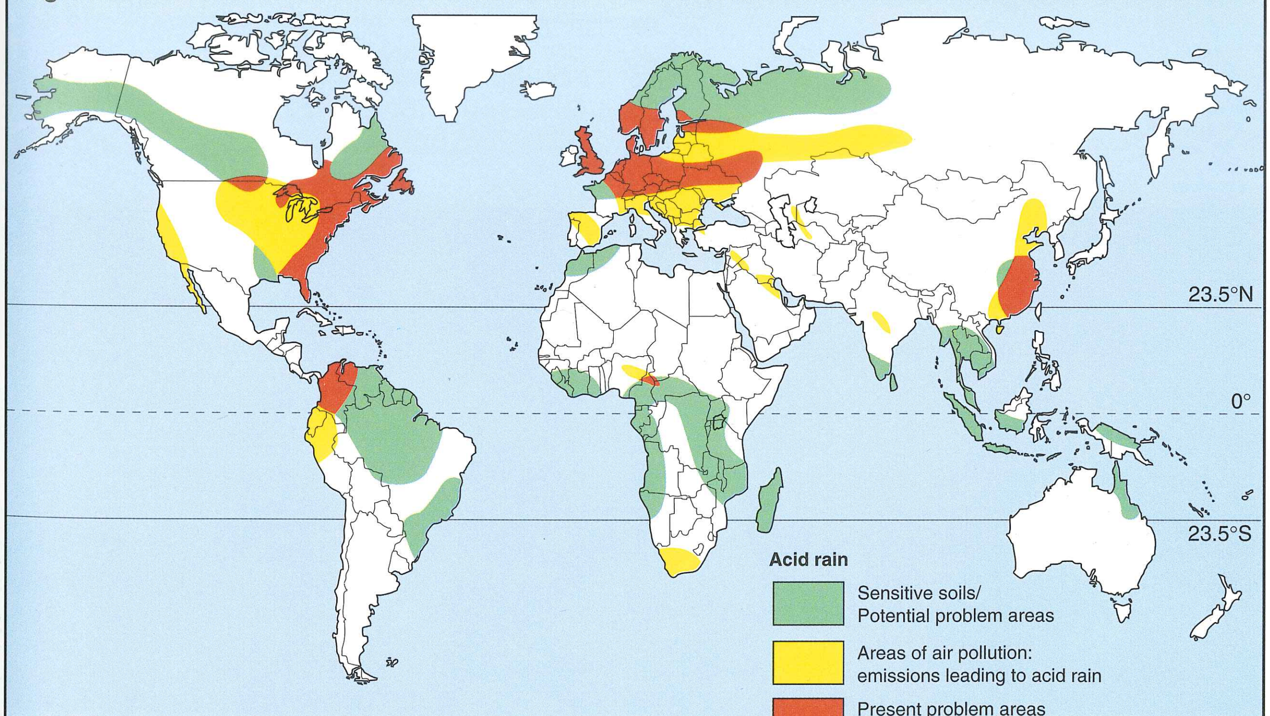


Figure 6.3 Estimated world distribution of acid rain in the late 1980s



Adapted from G. Lean and D. Hinrichsen, *Atlas of the Environment*, © Banson Marketing Ltd, 1990, 1992.

world most affected by acid rain in the late 1980s.

The gases that cause acid rain come from several sources. Figure 6.4 shows that power utilities, especially those that burn coal, are the main cause of sulphur dioxide. On the other hand, vehicles are the leading source of nitrogen oxides.

The effects of acid rain

Forestry, fisheries, wildlife, and farming may all be seriously affected by acid rain, as are buildings, vehicles, and even human health. However, it is wrong to attribute all problems to this one single cause. For example, in the 1980s the sugar maple forests of Québec and Ontario were believed to be slowly dying as a result of acid rain. The losses in the industry were estimated at about $100 million (CDN). It was claimed that acidity was affecting the root systems of trees, causing metal poisoning and nutrient starvation. While acid rain may have been a factor in the sugar maple's decline in the 1980s, there has been an improvement in the 1990s, leading to the theory that bad weather may have been another cause of the problem.

Forests There is strong evidence, however, that acid rain leads to lower resistance to disease and insects in forests. The growth of seedlings is also harmed by acidity. Since our forests play a vital role in regulating water supply, preventing soil erosion and maintaining wildlife, we cannot take the risk of allowing acidity to harm them.

Lakes and rivers Acid deposition seriously affects the water cycle as acidity works its way through streams, lakes, and rivers. The problem of acidification in eastern Canada is particularly severe and not just because the level of pollutants is high. It is made

Figure 6.4 Emissions of gases that cause acid rain (1992)

	SULPHUR DIOXIDE (%)		NITROGEN OXIDES (%)	
Canada	Industry	61	Transport	59
	Utilities	23	Industry	23
	Other	16	Utilities	14
	Transport	0	Other	4
United States	Utilities	70	Transport	45
	Industry	23	Utilities	32
	Other	7	Industry	19
	Transport	0	Other	4

From EPA and Environment Canada

Acid rain is causing this forest at Mt. Mégantic, Québec, to die slowly.

worse by the lack of alkaline materials in the rocks and soils that could act as a natural "buffer" or neutralizer for the acidity. Sometimes lime is added to lakes to counteract the acidity. Adding lime is similar to taking an antacid tablet to settle your stomach.

Most aquatic life dies when the acidity reaches pH 5 or below. (See Figure 6.5.) The lowest pH levels often occur in the spring when acid snowmelt is suddenly released into lakes, creating **acid shock**. This coincides with spawning time and inhibits the reproduction of many species of fish.

The effects on lake ecosystems are serious. Eggs fail to hatch and young fish die. The predators also become affected and soon struggle to survive. Waterfowl migrate elsewhere. However, some varieties of algal blooms begin to spread and give the lake a bad odour. At the end of the process, a lake with an initial pH of 6.5 may be reduced to an acid reservoir with a pH of 4.3.

Acid rain also leads to the accumulation of toxic metals, which are leached by the rain into lakes and rivers. Higher than normal levels of metals, such as aluminum and mercury, are dangerous both to fish and to humans who may eat them.

According to Environment Canada, 150 000 lakes are being damaged in eastern Canada, 14 000 of them seriously. Some have become so acidified that they are unable to support aquatic life, and many more are approaching that condition. Sweden has about 18 000 acidified lakes. The Baltic Shield in Scandinavia has a nonalkaline bedrock like that of eastern Canada.

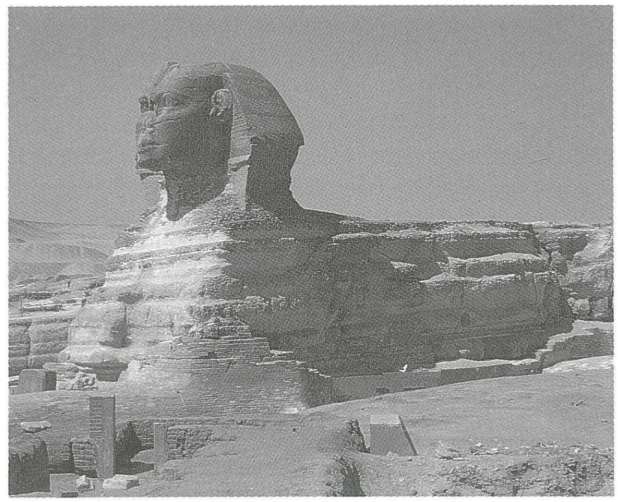
Figure 6.5 The impact of acidity on aquatic life

Water boatman	○	○	○	○	○	○	○
Whirligig	○	○	○	○	○	○	○
Yellow perch	○	○	○	○	○		
Lake trout	○	○	○	○	○		
Brown trout	○	○	○	○			
Salamander	○	○	○	○			
Mayfly	○	○	○				
Smallmouth bass	○	○	○		The circles indicate at what point aquatic life dies due to acidity.		
Mussel	○	○					
pH	6.5	6.0	5.5	5.0	4.5	4.0	3.5

From Daniel D. Chiras, "A framework for Decision Making," in *Environmental Science*, 2nd ed. (Menlo Park, CA: 1988.)

Farming In eastern Canada, particularly in Ontario, 84 percent of productive farmlands are affected by acid rain. The root systems of crops are unable to absorb nutrients properly. As a result, crop yields fall and millions of dollars are lost.

Buildings and Vehicles Acid rain causes the corrosion of buildings. Classic monuments such as the Sphinx in Egypt and the Parthenon in Greece have deteriorated more during the past half a century than during the previous thousands of years of their existence. Stained glass windows in Europe's cathedrals are suffering the same fate. Acid rain is also blamed for about half the corrosion of vehicles in Canada.



Egypt's famous Sphinx has been badly disfigured by acidity.

Health Evidence shows that the pollutants that cause acid rain also create health hazards. One study compares children living in an acid rain location (Tillsonburg, Ontario) with those living in an area relatively free of it (Portage la Prairie, Manitoba). It shows a significant difference in the occurrence of colds, allergies, and respiratory diseases. Researchers working at the University of California claim that high levels of sulphur dioxide can lead to colon and breast cancer. The increased leaching of mercury and aluminum by acid rainwater can also damage health through contamination of the drinking water.

Stopping acid rain

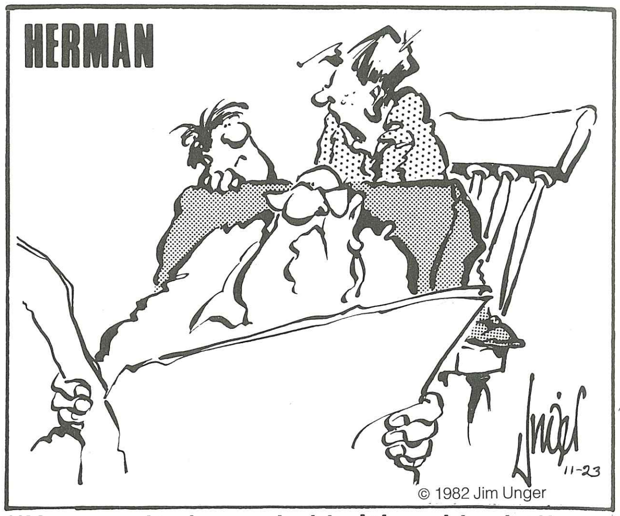
The United Nations Environment Program (UNEP) calculates that the damage caused by acid rain in a Western country may be equivalent to 1 or 2 percent of the entire **GNP (Gross National Product)**. Therefore there is a strong economic incentive to control acid rain.

Since the early 1970s some Western countries have had considerable success in reducing emissions of SO_2 and other pollutants, indicating that clean air laws have had some effect. Canadian reductions in air pollutants are shown in Figure 6.6.

Figure 6.6 Reduction in air pollutants in Canadian cities

POLLUTANT	CHANGE (%) 1974-1992
Sulphur dioxide	–61
Carbon monoxide	–70
Nitrogen dioxide	–38
Suspended particulates	–54

From Environment Canada



"He wasn't always bald. It's acid rain."

Reductions of sulphur dioxide, carbon monoxide, and nitrogen dioxide have reduced acid rain significantly. The burning of fuels containing less sulphur has helped air quality considerably. Many factories have installed desulphurizing or **scrubbing devices** in chimneys. New techniques for burning coal can also help to reduce the problem. In New Brunswick and Prince Edward Island, demonstration plants show how **fluidized bed combustion** can remove 90 percent of sulphur and nitrogen emissions. This technology burns finely ground limestone along with coal. Coal-water fuel technology is used in Nova Scotia with similar results. This technique removes sulphur from finely ground coal mixed with water. In addition to burning coal efficiently, the coal-water mixture can be transported by pipeline. In Alberta, a method called Low NO_x/SO_x Burner (LNSB) is being used to reduce emissions.

On a global scale, however, the burning of fossil fuels continues to increase. Acid rain is likely to become a growing problem in developing countries where laws curbing emissions are less strict. This problem is particularly true in China, where low-grade coal is being used on a large scale in the nation's rush to become industrialized. These countries insist that since the developed countries created the problem of acid rain in the first place, they should help poorer countries in their efforts to protect the environment. This suggestion would involve financial assistance and the availability of anti-pollution technology at minimal cost.

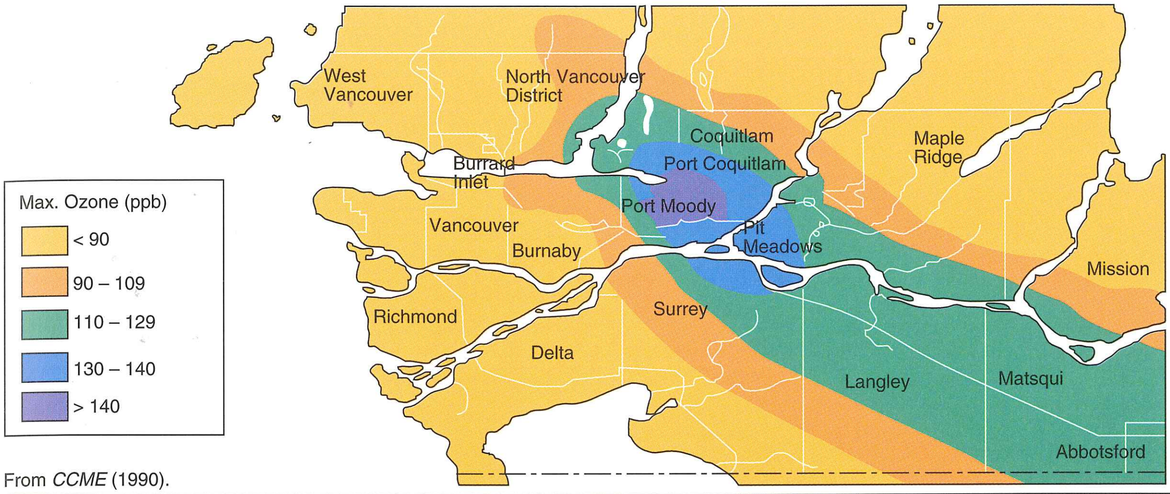
Monitoring acid deposition in Canada

In order to regulate emissions of air pollutants, the environment must be monitored carefully. Figure 6.7 shows the air pollution standards accepted in various parts of Canada in the late 1980s. Note that these standards distinguish between *acceptable* and *desirable* levels, the latter being a strict standard to be attained over the long term. Of course, pollutants cannot be eliminated from the environment completely. For example, forest fires started by lightning will create smoke.

Acid rain control in Ontario Eighty percent of Ontario's sulphur dioxide comes from only four companies — Ontario Hydro, Falconbridge, the International Nickel Company (INCO), and Algoma Steel. Each of these companies has already greatly reduced its output of SO_2. INCO had a peak emission of 5500 t of SO_2 per day in the 1960s and reduced that amount to just over 2000 t by the early 1980s. In 1994 it achieved a low of 444 t per day. Ontario Hydro, Canada's largest power utility has cut its SO_2 emissions from 1240 t a day in 1980 to 285 t a day in 1994.

Further reductions will be needed to solve the acid rain problem, but the progress made so far is clearly visible on the landscape. Around Sudbury, Ontario, vegetation has reappeared near the INCO and Falconbridge smelters. In Trail, British Columbia, where the Cominco smelter has installed scrubbers to recover its emissions of sulphur and other chemicals, the forests are well on their way to regrowth. Cominco now makes fertilizers from the recovered materials.

Figure 6.7 Maximum 1-hour ozone concentrations in the Vancouver/Chilliwack area, based on an average of the three highest years during 1983–89



From *CCME* (1990).

Canada/United States acid rain agreement

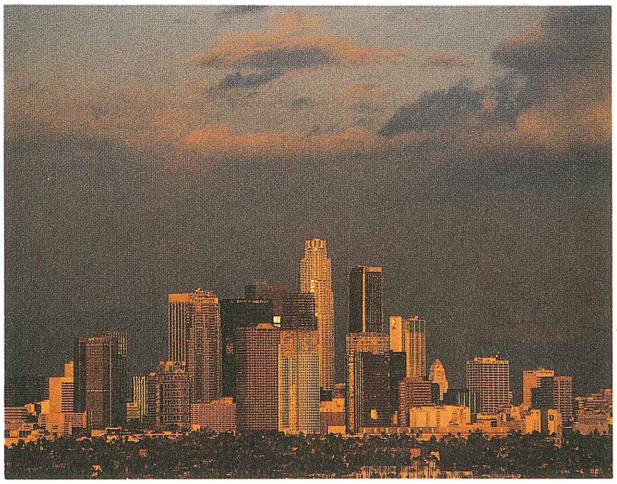
Because the winds carry acid rain across national boundaries, an international solution to the problem is required. For this reason the Canadian government has placed a high priority on reaching an agreement on acid rain with the United States. A bill revising the Clean Air Act was passed by the US Congress in 1990 to cut sulphur dioxide emissions by 40 percent (from 1980 levels) by the year 2000. The Act allowed states to trade their emissions targets with each other. Canada also had a program of emissions reductions in place dating from February 1985. In 1991 the United States and Canada jointly signed an Air Quality Agreement, in which both countries undertook to reduce sulphur dioxide and nitrogen oxides emissions. They also agreed to set tighter standards for coal burning boilers and for vehicle exhausts.

Photochemical and industrial smog

Smog (smoke + fog) takes two forms. **Industrial smog** occurs when particles and gasses such as SO_2 are emitted by industries and build up in the atmosphere. Before the days of smoke control industrial smog was common in the cities of Europe and North America.

Today western cities are more affected by **photochemical smog.** This form of smog is recognizable by its yellow-brown haze, often forming a "brown dome"over cities in calm weather. It is caused when nitrogen reacts with oxygen to form nitrogen dioxide (NO_2). Sunlight causes a photochemical reaction in which nitrogen oxides combine with hydrocarbons, mainly from car exhaust, to form ozone and a compound called peroxyacetyl nitrate (PAN), as shown in Figure 6.8. Ozone is highly desirable in the upper atmosphere, but at ground level it causes coughing and serious breathing problems. Research shows that healthy young adults exercising in air containing ozone above 82 parts per billion (ppb) may suffer a loss of one-third of their lung capacity.

The Canadian government has placed the maximum acceptable level of ozone at 82 ppb. However, this limit is unenforceable. In 1988 it was surpassed 157 times in north Toronto and 189 times in Windsor. Since then, however, these levels have not been surpassed. Smog is one of the major problems facing many large cities, especially those surrounded by higher land. The problem is at its worst when temperatures are high and the air is calm.



Smog obscures the view of Los Angeles.