

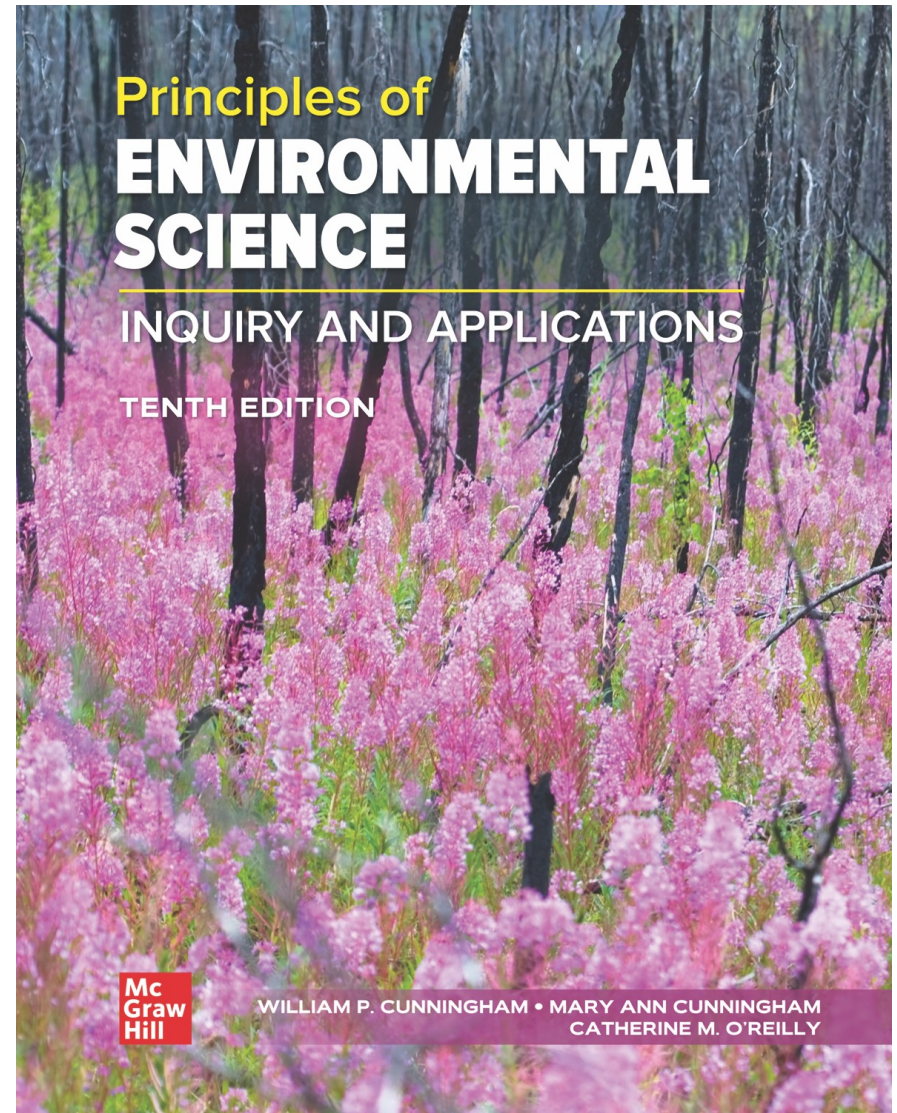


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Chapter 10

Lecture

Outline

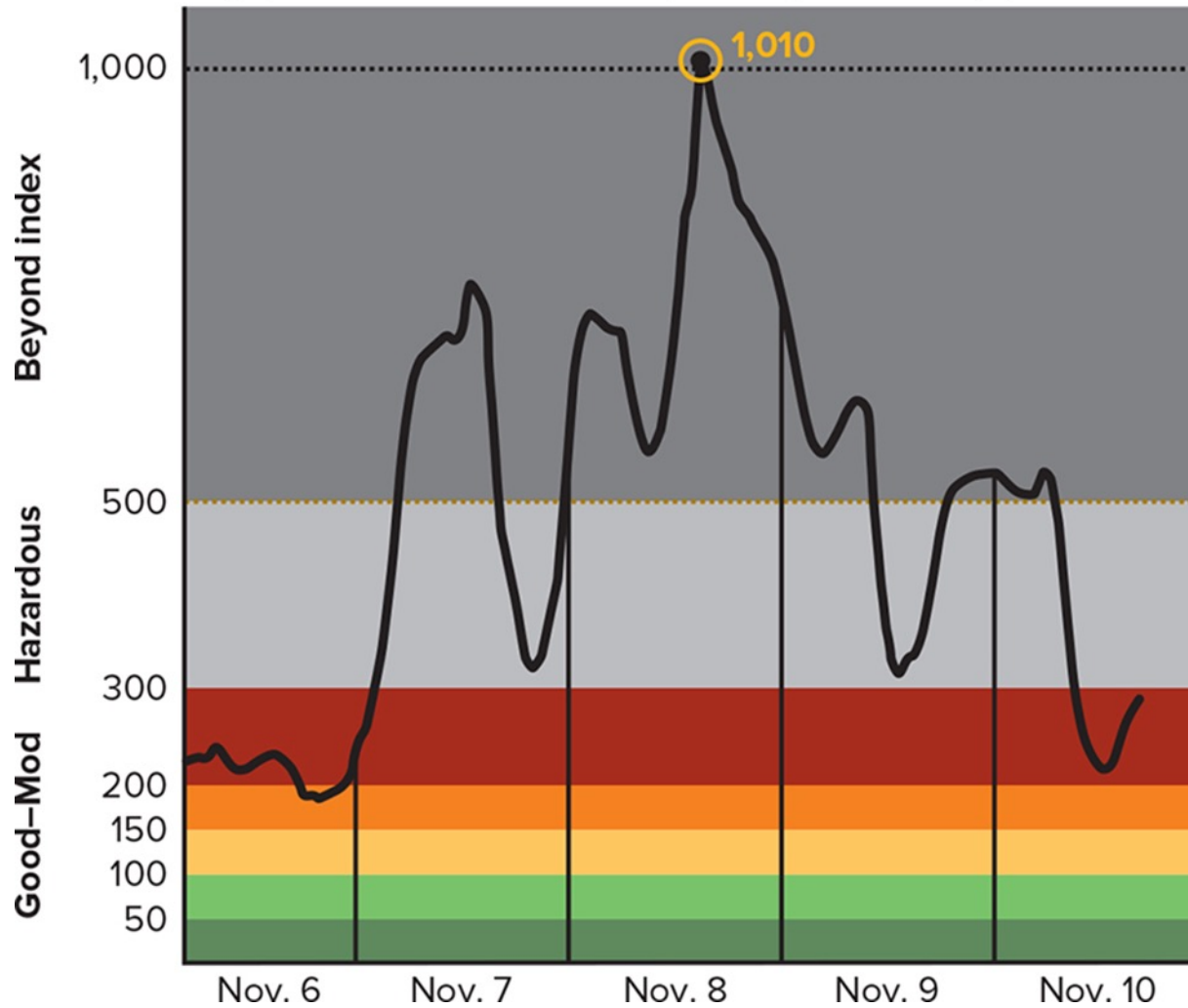


Learning Outcomes

After studying this chapter, you should be able to answer the following questions:

- What are the main types and sources of conventional or “criteria” pollutants?
- Describe several hazardous air pollutants and their effects.
- How do air pollutants affect the climate and stratospheric ozone?
- In what ways can air pollution affect human health?
- What policies and strategies do we have for reducing air pollution?
- Has world air quality been getting better or worse? Why?

CASE STUDY: Delhi Air Quality



***If you think education is expensive, try
ignorance.***

—Derek Bok

10.1 Air Pollution and Health

Pollution comes in many forms. Smoke, haze, dust, odors, corrosive gases, noise, and toxic compounds are among our most widespread pollutants.

Pollutants may irritate our eyes and lungs, enter our blood stream when we breathe them, then damage nerves and brain function.

The Organization for Economic Cooperation and Development has projected that by 2050, chronic exposure to pollutants will cause 3.6 million premature deaths every year.

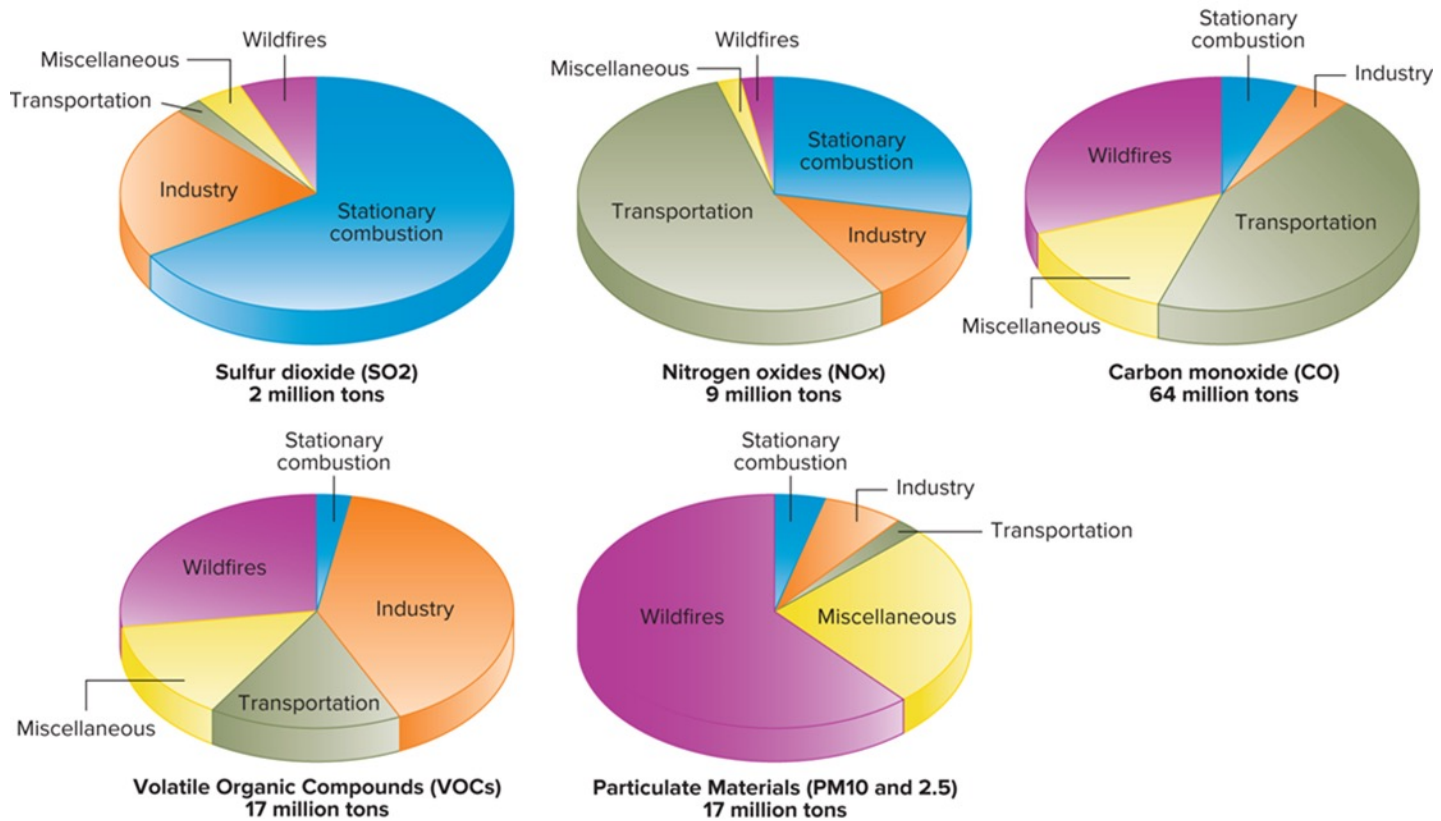
The Clean Air Act Regulates Major Pollutants

In 1970, The Clean Air Act designated new air quality standards, to be applied equally across the country, for six major pollutants.

These six are referred to as **conventional** or **criteria pollutants**, and they include sulfur dioxide, nitrogen oxides, carbon monoxide, ozone (and its precursor volatile organic compounds), lead, and particulate matter.

Transportation and power plants are the dominant sources of most criteria pollutants.

Anthropogenic Sources of Criteria Air Pollutants



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Unconventional Pollutants

The EPA also monitors **unconventional pollutants**, compounds that are produced in less volume than conventional pollutants, but that are especially toxic or hazardous.

Among these are asbestos, benzene, beryllium, mercury, polychlorinated biphenyls (PCBs), and vinyl chloride.

In 2009, the EPA announced that it would add CO₂ and other greenhouse gases to its list of regulated pollutants. This decision remains controversial.

How Do We Define Pollution Sources?

A **point source** is a smokestack or some other concentrated pollution origin.

Primary pollutants are released in a harmful form.

Secondary pollutants become hazardous after reactions in the air.

Fugitive or **nonpoint-source** emissions are those that do not go through a smokestack.

Fugitive Emissions



Conventional Pollutants Are Abundant and Serious ¹

Sulfur dioxide (SO₂) is a colorless, corrosive gas that damages both plants and animals. Once in the atmosphere, it can which reacts with water vapor form sulfuric acid (H₂SO₄).

Nitrogen oxides (NO_x) are highly reactive gases formed when the heat of combustion initiates reactions between atmospheric nitrogen (N₂) and oxygen (O₂). The initial product, nitric oxide (NO), oxidizes further in the atmosphere to nitrogen dioxide (NO₂), a reddish-brown gas that gives photochemical smog its distinctive color.

Sulfur Dioxide Affects Both People and Plants

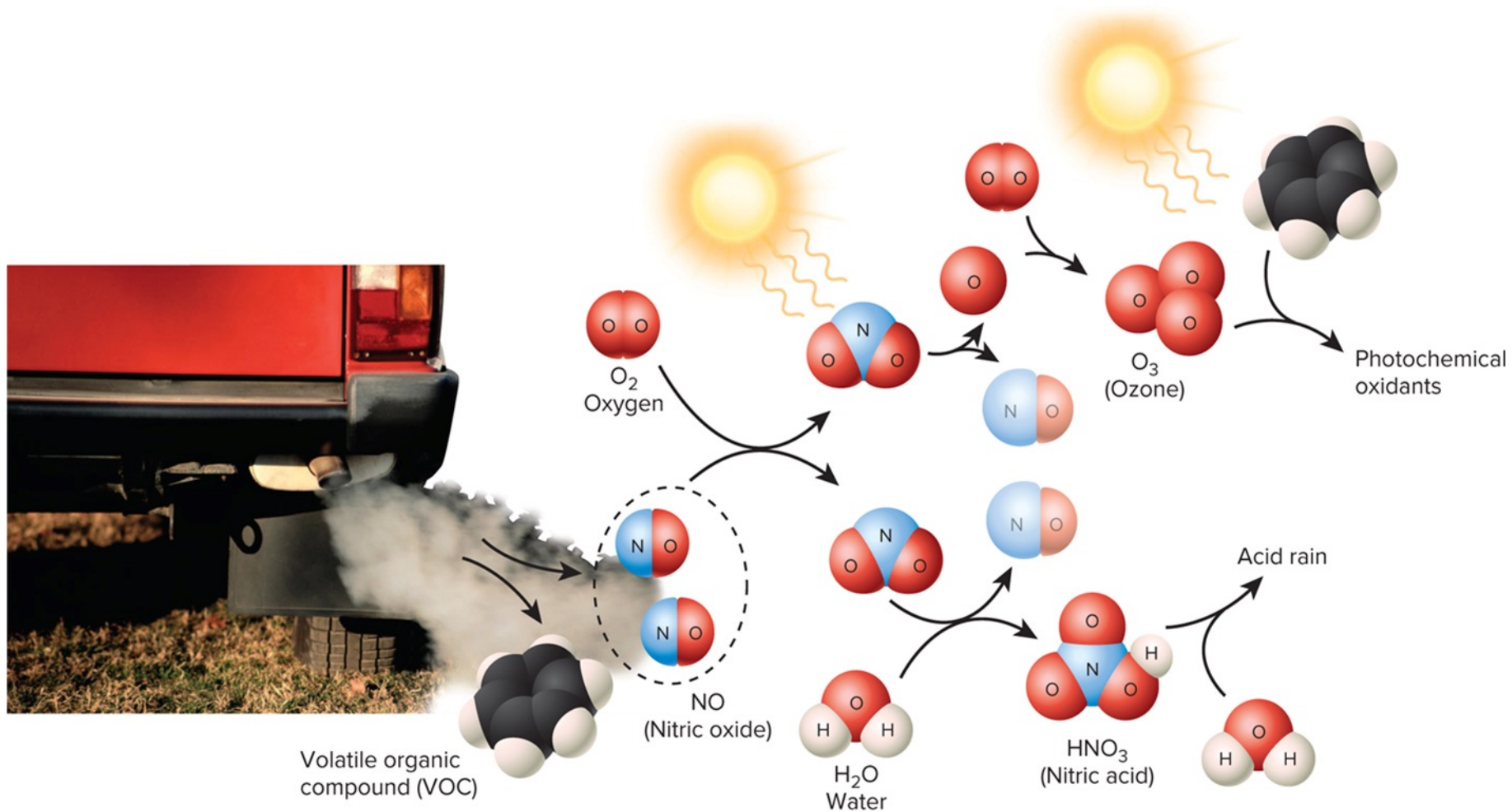


Conventional Pollutants Are Abundant and Serious ²

Carbon monoxide (CO) is a colorless, odorless, but highly toxic gas produced mainly by incomplete combustion of fuel (coal, oil, charcoal, wood, or gas). CO inhibits respiration in animals by binding irreversibly to hemoglobin in blood.

Ozone (O₃) ground level ozone is highly reactive oxidizing agent that damages eyes, lungs, and plant tissues, as well as paint, rubber, and plastics. It is a secondary pollutant, created by chemical reactions that are initiated by solar energy.

How Ground-Level Ozone Forms



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Conventional Pollutants Are Abundant and Serious₃

Interacting with ozone to produce smog are a variety of **volatile organic compounds (VOCs)** contribute to the formation of ozone and other photochemical oxidants. A wide array of these organic (carbon-based), volatile (evaporated) chemicals derive from industrial processes such as refining of oil and gas, or plastics and chemical manufacturing.

Conventional Pollutants Are Abundant and Serious⁴

Lead, our most abundantly produced metal air pollutant, impairs nerve and brain functions. A wide range of industrial and mining processes produce lead, especially smelting of metal ores, mining, and burning of coal and municipal waste, in which lead is a trace element, and burning of gasoline to which lead has been added.

Particulate material includes dust, ash, soot, lint, smoke, pollen, spores, algal cells, and many other suspended materials like aerosols.

Hazardous Air Pollutants Can Cause Cancer and Nerve Damage

A special category of toxins is monitored by the U.S. EPA because they are particularly dangerous.

Called **hazardous air pollutants (HAPs)**, these chemicals cause cancer, nerve damage, disrupt hormone function, and fetal development.

These persistent substances remain in ecosystems for long periods of time, and accumulate in animal and human tissues.

TRI Informs Communities About Toxics

In 1986, Congress established the **Toxic Release Inventory (TRI)** to help inform communities about toxic substances produced and handled in their area.

This inventory collects self-reported statistics from 23,000 factories, refineries, hard rock mines, power plants, and chemical manufacturers to report on toxin releases (above certain minimum amounts) and waste management methods for 667 toxic chemicals.

TRI: Toxic Release Inventory



Mercury Is a Key Neurotoxin

Airborne metals originate mainly from combustion of fuel, especially coal.

Airborne mercury has received special attention because it is a persistent neurotoxin (a substance that damages the brain and nervous system).

Minute doses can cause nerve damage and other impairments, especially in young children and developing fetuses.

Some 70 % of airborne mercury is released by coal-burning power plants.

Canned Tuna Is a Source of Mercury



Indoor Air Can Be More Dangerous Than Outdoor Air



10.2 Air Pollution and the Climate

Physical processes in the atmosphere transport, concentrate, and disperse air pollutants.

Global warming, in which pollutants are altering the earth's energy budget, is the best-known case of interaction between anthropogenic pollutants and the atmosphere.

In this section we survey other important climate-pollution interactions.

Air Pollutants Travel the Globe

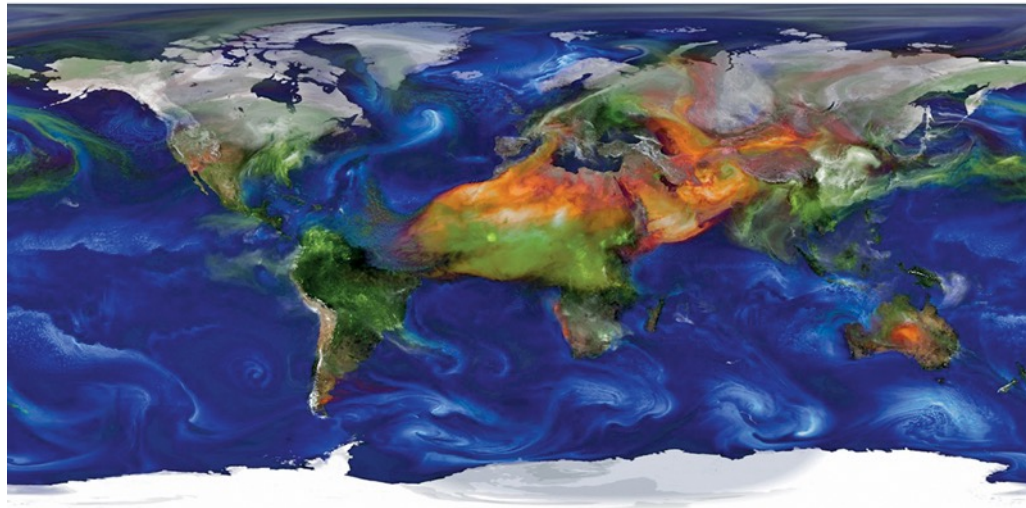
Air pollutants can travel far:

- Dust and fine aerosols can be carried great distances by the wind.
- Pollution from the industrial belt between the Great Lakes and the Ohio River Valley regularly contaminates the Canadian Maritime Provinces and sometimes can be traced as far as Ireland.
- Similarly, dust storms from China's Gobi and Takla Makan Deserts routinely close schools, factories, and airports in Korea, Japan, and even Seattle in the U.S.

Dust Blowing From the Sahara

Dust from North Africa regularly crosses the Atlantic and contaminates the air in Florida and the Caribbean Islands.

This dust can carry pathogens and is thought to be the source of diseases attacking Caribbean corals.



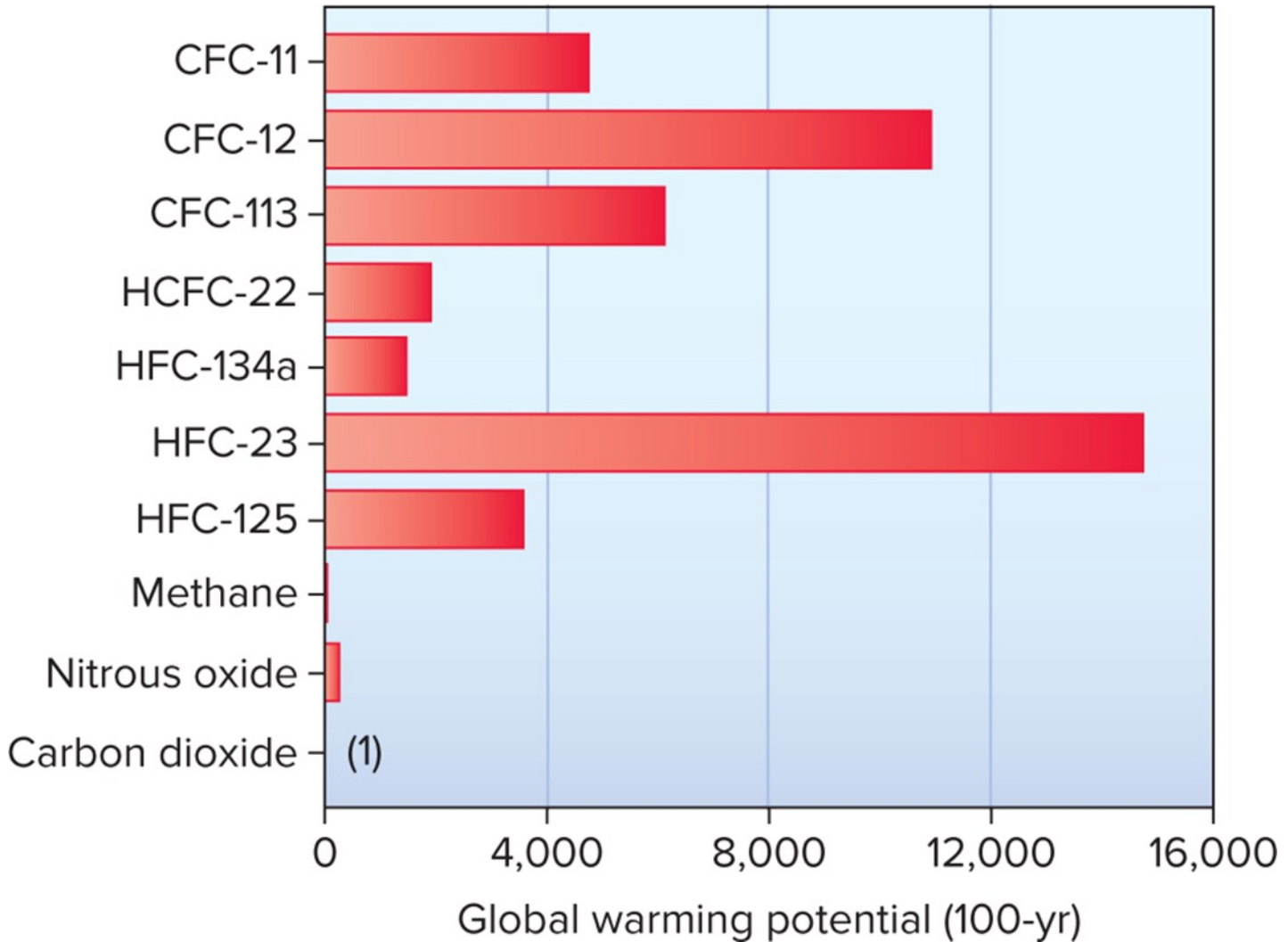
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Carbon Dioxide and Halogens Are Key Greenhouse Gases

CO₂ concentrations in the atmosphere have been steadily increasing due to human activities and are now causing global climate change, but it is not alone as a greenhouse gas. Five other greenhouse gases are : methane, nitrous, oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.

These gases are far more potent greenhouse gases per molecule than CO₂ and since the recent Supreme Court ruling, the EPA is charged with regulating emissions of all these gases.

Greenhouse Gases

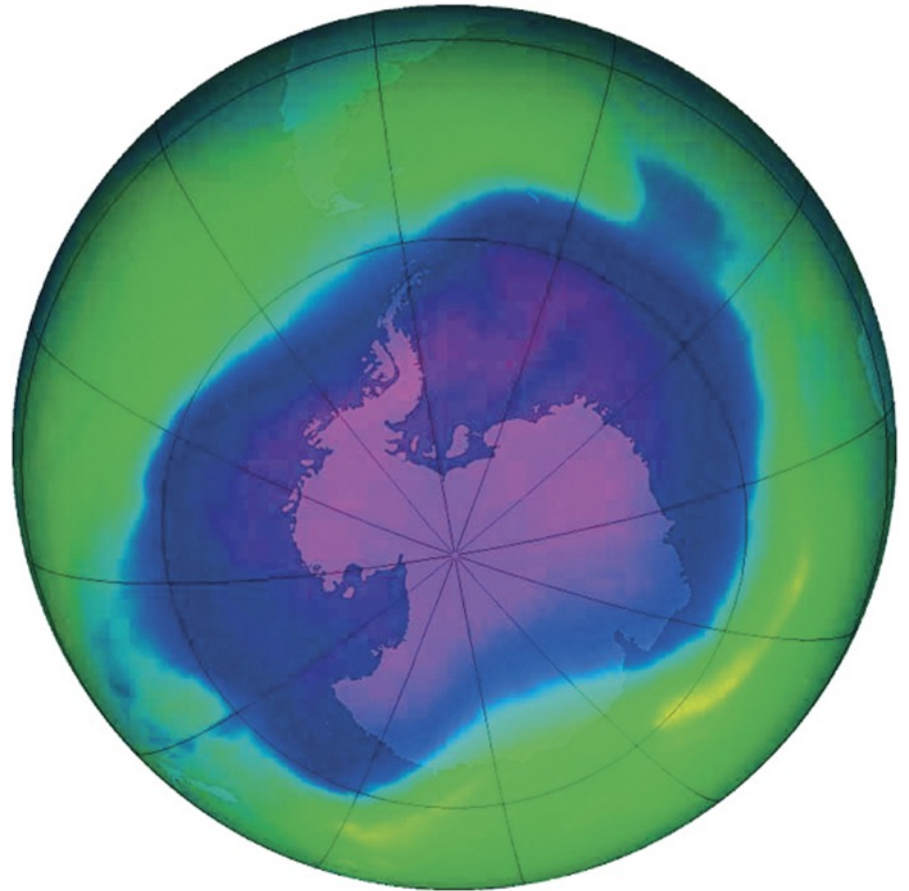


CFCs Also Destroy Ozone in the Stratosphere

Chemical reactions of atmospheric gases and pollution produce the phenomenon known as the **ozone hole**.

Chlorine-based aerosols, such as CFC's and HCFC's, are the principal agents of ozone depletion.

Excessive UV exposure could cause cancer, reduce agricultural production and disrupt ecosystems.



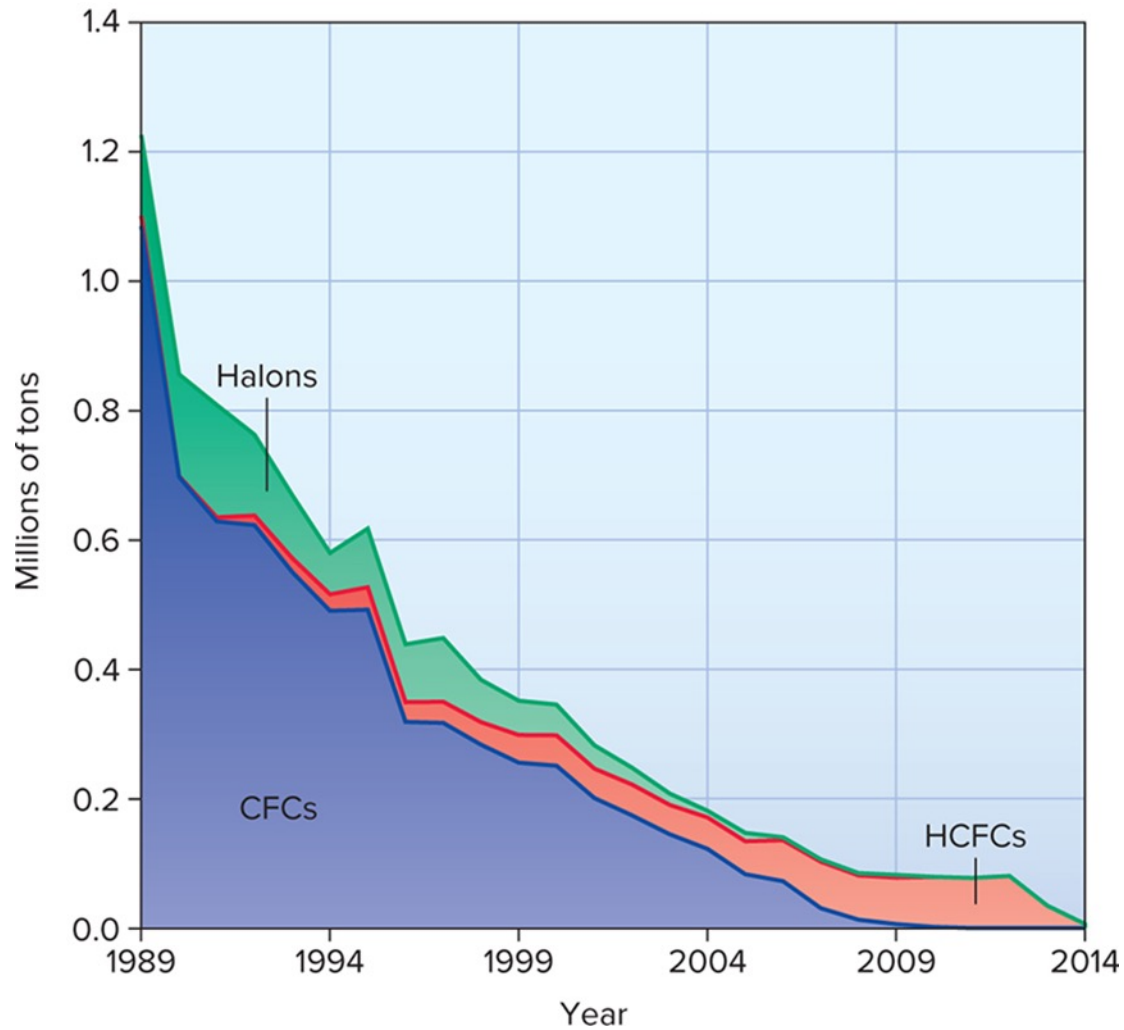
CFC Control Has Shown Remarkable Success

In 1987 an international meeting in Montreal, Canada, produced the **Montreal Protocol**, the first of several major international agreements on phasing out most uses of CFCs by 2000.

As evidence accumulated, showing that losses were larger and more widespread than previously thought, the deadline for the elimination of all CFCs was moved up to 1996.

CFCs are now being removed from the atmosphere more rapidly than they are being added.

Success of the Montreal Protocol



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10.3 Environmental and Health Effects

Consequences of breathing dirty air include: increased probability of heart attacks, respiratory diseases, and lung cancer.

This can mean as much as a five to ten-year decrease in life expectancy if you live in a large city.

How does air pollution cause these health effects? Pollutants can irritate and damage delicate tissues in the eyes and lungs and cause scarring, and even tumor growth. They can stress the heart and even bind to hemoglobin, reducing oxygen flow to the brain.

Acid Deposition Results from SO_4 and NO_x

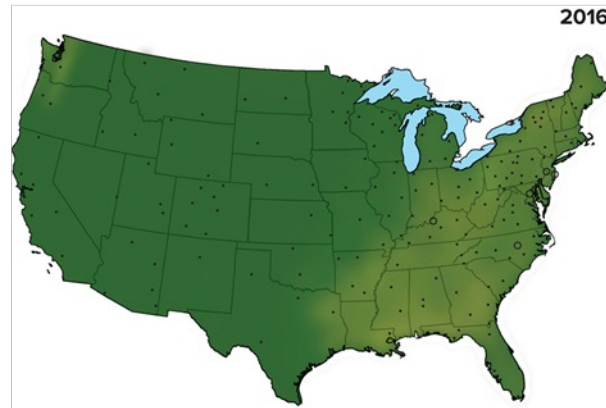
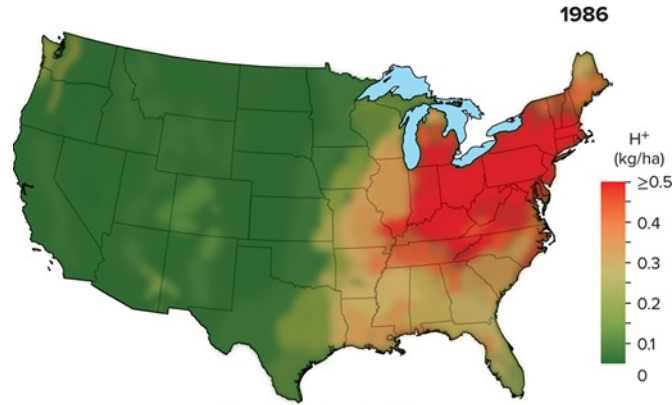
Deposition of acidic droplets or particles, from rain, fog, snow, or aerosols in the atmosphere, became recognized as a widespread pollution in the 1980s.

Acidic deposition is now understood to affect forests and croplands far from industrial centers. Rain is normally slightly acidic (pH 5.6). Industrial emissions of sulfur dioxide (SO_2), sulfate (SO_4), and nitrogen oxides (NO_x) can acidify rain, fog, snow, and mist to pH 4 or lower. Ongoing exposure to acid fog, snow, mist, and dew cause permanent damage to plants, lake ecosystems, and buildings.

Forest Damage by Acid Rain



Acid Precipitation Over the United States



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Buildings and Monuments Show Clear Damage

Air pollution is destroying some of the oldest and most glorious buildings and works of art.

Smoke and soot coat buildings, paintings, and textiles.

Acids dissolve limestone and marble, destroying features and structures of historic buildings.



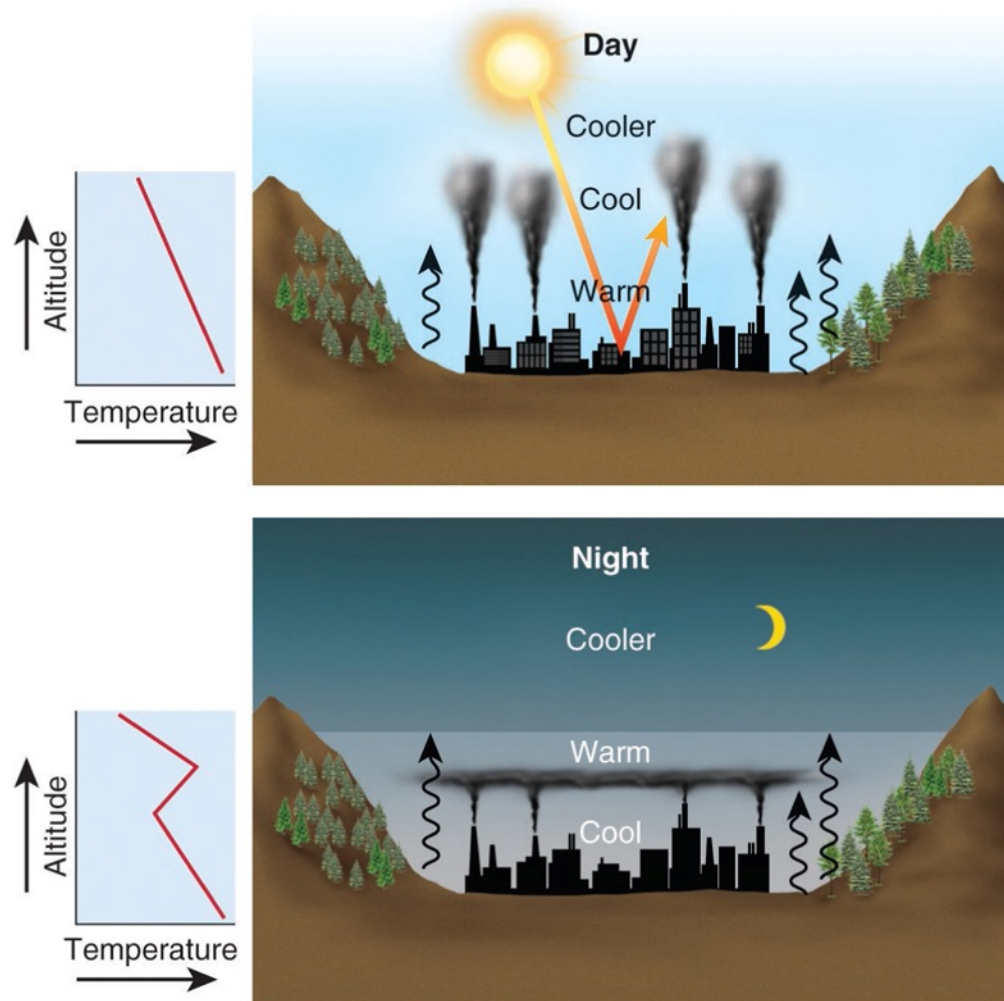
Inversions and Heat Islands Affect Urban Areas

In urban areas, pollution is most extreme when **temperature inversions** develop, concentrating dangerous levels of pollutants.

A temperature inversion is a situation in which stable, cold air rests near the ground, with warm layers above. This situation reverses the normal conditions.

Los Angeles has ideal conditions for inversions.

Temperature Inversions Can Trap Air Pollution Over Cities



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Heat Islands and Dust Domes

With their low albedo, concrete and brick surfaces in cities absorb large amounts of solar energy.

As a result, temperatures in cities are frequently 3° to 5 °C (5 ° to 9° F) warmer than in the surrounding countryside, a condition known as an **urban heat island**.

Tall buildings create convective updrafts that sweep pollutants into the air. Stable air masses created by this heat island over the city concentrate pollutants in a **dust dome**.

Poor Visibility Over Los Angeles



Smog and Haze Reduce Visibility

Pollution affects rural areas as well as cities.

Grand Canyon National Park, where maximum visibility used to be 300 kilometers (185 miles), is now so smoggy on some days that visibility is only 20 kilometers (12.5 miles) across the canyon.

Huge regions are affected by pollution. A gigantic “haze blob” as much as 3,000 kilometers (about 2,000 miles) across covers much of the eastern U.S. in the summer, cutting visibility as much as 80 percent.

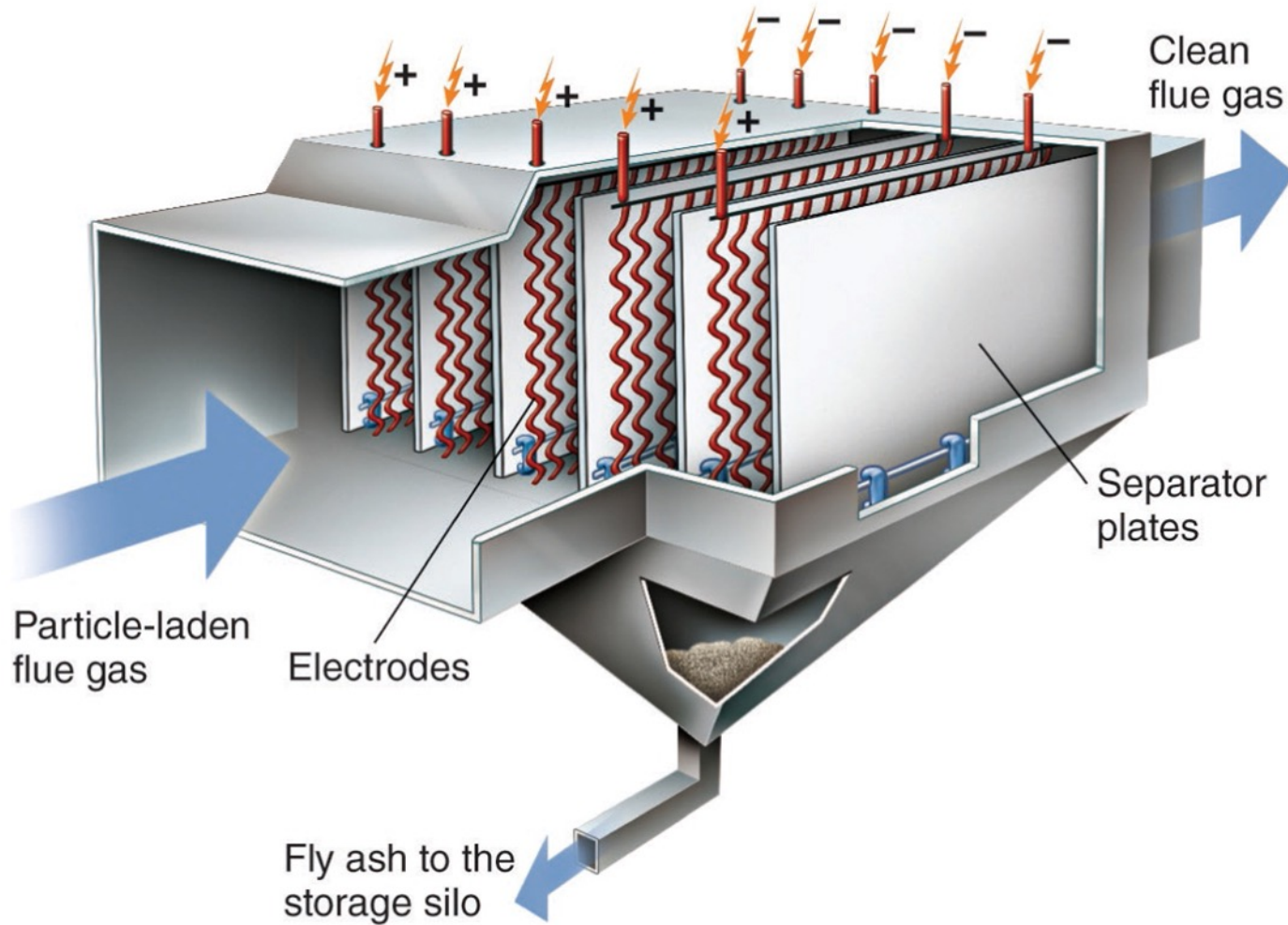
10.4 Air Pollution Control

“Dilution is the solution to pollution:” this catch phrase has long characterized our main approach to air pollution control.

Tall smokestacks were built to send emissions far from the source, where they became difficult to detect or trace to their source.

With increasing global industrialization, though, dilution is no longer an effective strategy. We have needed to find different strategies for pollution control

Electrostatic Precipitator Can Remove 99% of Unburned Particulates



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The Best Strategy Is Reducing Production

The best strategy is reducing pollution, but pollutants can also be captured from effluent after burning.

- *Particulate removal involves filtering air emissions.* Filters trap particulates in a mesh, or electrostatic precipitators are used.
- *Sulfur removal* is important because sulfur oxides are among the most damaging of all air pollutants in terms of human health.
- *Nitrogen oxides (NO_x)* can be reduced in both internal combustion engines and industrial boilers.
- *Hydrocarbon controls* mainly involve complete combustion or the control of evaporation.

Clean Air Legislation Is Controversial but Extremely Successful

The **Clean Air Act** of 1963 was the first national legislation in the United States aimed at air pollution control.

In 1970, an extensive set of amendments essentially rewrote the Clean Air Act.

The 1990 amendments included major changes in incentives as well as rules for additional pollutants.

The 1990 amendments also provided incentives and rules to support development of alternative fuels and technology.

Trading Pollution Credits Is One Approach

A cap-and-trade approach sets maximum emission levels for pollutants.

Facilities can then buy and sell emission “credits,” or permitted allotments of pollutants.

Companies can decide if it’s cheaper to install pollution control equipment or to simply buy someone else’s credits.

Cap-and-trade has worked well for sulfur dioxide.

10.5 The Ongoing Challenge

Although the United States has not yet achieved the Clean Air Act goals in many parts of the country, air quality has improved dramatically.

Eighty percent of the United States now meets the National Ambient Air Quality Standards.

Most pollutants have declined sharply since the introduction of Clean Air Act rules.

Pollution Persists in Developing Areas

The major metropolitan areas of many developing countries are growing at explosive rates to incredible sizes, and environmental quality is abysmal in many of them.

Mexico City is notorious for bad air. Its pollution levels exceed WHO health standards 350 days per year.

While China is making efforts to control air pollution Seven of the ten cities in the world with the worst air quality are in China.

Many Places Have Improved

Low-income countries can control air pollution, too. Delhi, India was once considered one of the world's ten most polluted cities.

In the 1990s, catalytic converters were required for automobiles, and unleaded gasoline and low-sulfur diesel fuel were introduced. In 2000, private automobiles were required to meet European standards, and in 2002, more than 80,000 buses, autorickshaws, and taxis were required to switch from liquid fuels to compressed natural gas.

Take-Away Points

Air pollution is often the most obvious and widespread type of pollution.

Health effects of these pollutants include respiratory diseases, birth defects, heart attacks, cancer, and developmental disabilities in children. Environmental impacts include destruction of stratospheric ozone, poisoning of forests and waters by acid rain, and corrosion of building materials.

We have made encouraging progress in controlling air pollution, progress that has economic benefits as well as health benefits.



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