KEY ISSUE 3

Where Does Industry Cause Pollution?

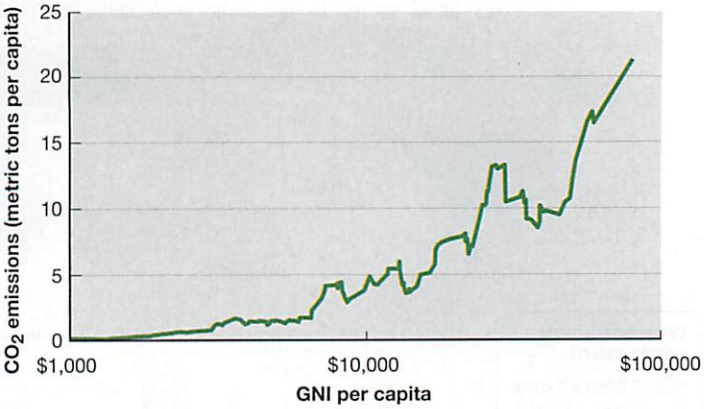
- Air Pollution
- Solid Waste Pollution
- Water Pollution

Learning Outcome 11.3.1

Describe causes and effects of global warming and damage to the ozone layer.

Industry is a major polluter of air, water, and land. People rely on air, water, and land to remove and disperse waste from factories as well as from other human activities. Pollution occurs when more waste is added than air, water, and land resources can handle.

As a country's per capita income increases, its per capita carbon dioxide emissions also increase. Some of the wealthiest countries, located primarily in Europe, with gross national income (GNI) per capita between $30,000 and $50,000, show declines in pollution. However, the world's richest countries, including the United States and several countries in Southwest Asia, display the highest pollution levels (Figure 11-30).



▲ **FIGURE 11-30 GNI AND POLLUTION** Carbon dioxide emissions generally increase with rising income. The principal exception is in Europe, where some relatively wealthy countries have curbed emissions.

Air Pollution

At ground level, Earth's average atmosphere is made up of about 78 percent nitrogen, 21 percent oxygen, and less than 1 percent argon. The remaining 0.04 percent includes several trace gases, some of which are critical. **Air pollution** is concentration of trace substances at a greater level than occurs in average air. Concentrations of these trace gases in the air can damage property and adversely affect the health of people, other animals, and plants.

Most air pollution is generated from factories and power plants, as well as from motor vehicles. Factories and power plants produce sulfur dioxides and solid particulates, primarily from burning coal. Burning petroleum in motor vehicles produces carbon monoxide, hydrocarbons, and nitrogen oxides.

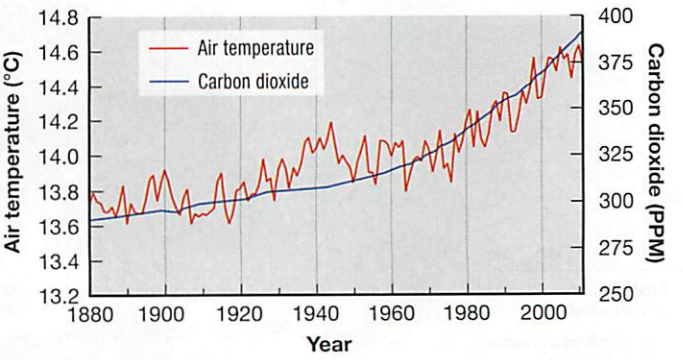
GLOBAL-SCALE AIR POLLUTION

Air pollution concerns geographers at three scales—global, regional, and local. At the global scale, air pollution may contribute to global warming. It may also damage the atmosphere's ozone layer.

GLOBAL WARMING. The average temperature of Earth's surface has increased by 1°C (2°F) since 1880 (Figure 11-31). Human actions, especially the burning of fossil fuels in factories and vehicles, may have caused this.

Earth is warmed by sunlight that passes through the atmosphere, strikes the surface, and is converted to heat. When the heat tries to pass back through the atmosphere to space, some gets through and some is trapped. This process keeps Earth's temperatures moderate and allows life to flourish on the planet. A concentration of trace gases in the atmosphere can block or delay the return of some of the heat leaving the surface heading for space, thereby raising Earth's temperatures. When fossil fuels are burned, one of the trace gases, carbon dioxide, is discharged into the atmosphere. Plants and oceans absorb much of the discharges, but increased fossil fuel burning during the past 200 years, as shown in Figure 11-30, has caused the level of carbon dioxide in the atmosphere to rise by more than one-fourth, according to the UN Intergovernmental Panel on Climate Change.

The anticipated increase in Earth's temperature, caused by carbon dioxide and other greenhouse gases trapping some of the radiation emitted by the surface, is called the **greenhouse effect**. The term is somewhat misleading because a greenhouse does not work in the same way as do trace gases in the atmosphere. In a real greenhouse, the interior gets very warm when the windows remain closed on a sunny day. The Sun's light energy passes through the glass

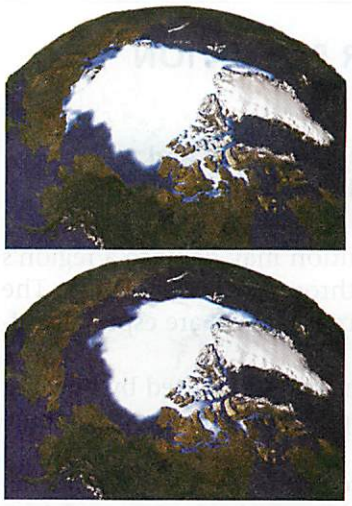


▲ **FIGURE 11-31 GLOBAL-SCALE AIR POLLUTION: GLOBAL WARMING AND CARBON DIOXIDE CONCENTRATIONS, 1880–2010** Since 1880, carbon dioxide concentration has increased by more than one-third, and Earth has warmed by about 1°C (2°F).

into the greenhouse and is converted to heat, and the heat trapped inside the building is unable to escape out through the glass. Although this is an imprecise analogy, "greenhouse effect" is a term that has been widely adopted to describe the anticipated warming of Earth's surface when trace gases block some of the heat trying to escape into space.

Regardless of what it is called, global warming of only a few degrees could melt the polar ice sheets and raise the level of the oceans many meters (Figure 11-32). Coastal cities such as New York, Los Angeles, Rio de Janeiro, and Hong Kong would flood (see the Sustainability and Inequality in Our Global Village feature). Global patterns of precipitation could shift: Some deserts could receive more rainfall, and currently productive agricultural regions, such as the U.S. Midwest, could become too dry for farming. Humans can adapt to a warmer planet, but the shifts in coastlines and precipitation patterns could require massive migration and could be accompanied by political disputes.

GLOBAL-SCALE OZONE DAMAGE. Earth's atmosphere has zones with distinct characteristics. The stratosphere—the zone 15 to 50 kilometers (9 to 30 miles) above Earth's surface—contains a concentration of **ozone** gas. The ozone layer absorbs dangerous ultraviolet (UV) rays from the Sun. Were it not for the ozone in the stratosphere, UV rays would damage plants, cause skin cancer, and disrupt food chains.



◀ **FIGURE 11-32 RECEDING NORTH POLAR ICE SHEET** These images taken by NASA show that between 1979 (top) and 2005 (bottom), the north polar ice sheet melted visibly.

Earth's protective ozone layer is threatened by pollutants called **chlorofluorocarbons (CFCs)**. CFCs such as Freon were once widely used as coolants in refrigerators and air conditioners. When they leak from these appliances, the CFCs are carried into the stratosphere, where they break down Earth's protective layer of ozone gas. In 2007, virtually all countries of the world agreed to cease using CFCs, by 2020 in developed countries and by 2030 in developing countries.

Pause and Reflect 11.3.1

What gas is now most commonly used as a coolant instead of CFC? Google "what replaced CFCs?"

SUSTAINABILITY AND INEQUALITY IN OUR GLOBAL VILLAGE

Climate Change in the South Pacific

One consequence of global warming is a rise in the level of the oceans. The large percentage of the world's population—including one-half of Americans—who live near the sea face increased threat of flooding. The threat is especially severe for island countries in the Pacific Ocean; they could be wiped off the map entirely.

Kiribati is a collection of approximately 32 small islands, one of the world's most isolated countries (Figure 11-33). Despite its extreme isolation, global forces threaten Kiribati's existence. Rising sea levels due to global warming threaten Kiribati because the entire country is within a few meters of sea level. Two of Kiribati's islands—Tebua Tarawa and Abanuea—have already disappeared.

Kiribati and other Pacific island microstates are atolls—that is, islands made of coral reefs. A coral is a small sedentary marine animal that has a horny or calcareous skeleton. Corals form colonies, and the skeletons build up to form coral reefs. Coral is very fragile. Humans are attracted to coral for its beauty and the diversity of species it supports, but handling coral can kill it. The threat of global warming to coral is especially severe: Coral stays alive in only a narrow range of ocean temperatures, between 23°C and 25°C (between 73°F and 77°F), so global warming threatens the ecology of Kiribati, even if it remains above sea level.

Kiribati has an emergency response to rising sea levels. The government has negotiated with Fiji to purchase 2,000 hectares (5,000 acres) of land on the island of Vanua Levu to relocate people from *Kiribati* someday.

◀ **FIGURE 11-33 KIRIBATI** Global warming may cause the oceans to rise, submerging small island countries such as Kiribati.

REGIONAL-SCALE AIR POLLUTION

Learning Outcome 11.3.2

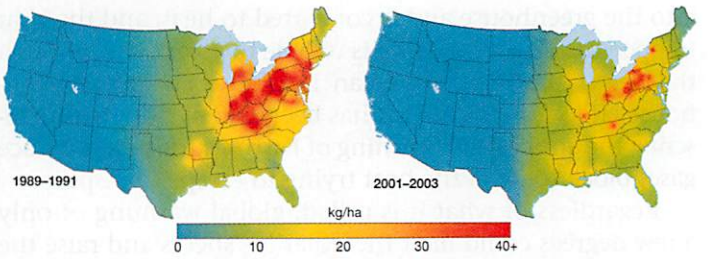
Describe causes and effects of regional and local-scale air pollution and solid waste pollution.

At the regional scale, air pollution may damage a region's vegetation and water supply through acid deposition. The world's three principal industrial regions are especially affected by acid deposition.

Sulfur oxides and nitrogen oxides, emitted by burning fossil fuels, enter the atmosphere, where they combine with oxygen and water. Tiny droplets of sulfuric acid and nitric acid form and return to Earth's surface as **acid deposition**. When dissolved in water, the acids may fall as **acid precipitation**—rain, snow, or fog. The acids can also be deposited in dust. Before they reach the surface, these acidic droplets might be carried hundreds of kilometers.

Acid precipitation damages lakes, killing fish and plants. On land, concentrations of acid in the soil can injure plants by depriving them of nutrients and can harm worms and insects. Buildings and monuments made of marble and limestone have suffered corrosion from acid rain.

Geographers are particularly interested in the effects of acid precipitation because the worst damage is not experienced at the same location as the emission of the pollutants. Within the United States the major generators of acid deposition are in Ohio and other industrial states along the southern Great Lakes. However, the severest effects of acid rain are felt in several areas farther east. The United States reduced sulfur dioxide emissions significantly during the late twentieth century (Figure 11-34).



▲ **FIGURE 11-34 REGIONAL-SCALE AIR POLLUTION: ACID DEPOSITION IN THE UNITED STATES** As a result of emissions controls, the rate of acid deposition has declined.

LOCAL-SCALE AIR POLLUTION

At the local scale, air pollution is especially severe in places where emission sources are concentrated, such as in urban areas. The air above urban areas may be polluted because a large number of factories, motor vehicles, and other polluters emit residuals in a concentrated area. Urban air pollution has three basic components:

- **Carbon monoxide.** Breathing carbon monoxide reduces the oxygen level in blood, impairs vision and alertness, and threatens those with breathing problems.
- **Hydrocarbons.** In the presence of sunlight, hydrocarbons, as well as nitrogen oxides, form **photochemical smog**, which causes respiratory problems, stinging in the eyes, and an ugly haze over cities.
- **Particulates.** They include dust and smoke particles. The dark plume of smoke from a factory stack and the exhaust of a diesel truck are examples of particulate emission.

The worst urban air pollution occurs when winds are slight, skies are clear, and a temperature inversion exists. When the wind blows, it disperses pollutants; when it is calm, pollutants build. Sunlight provides the energy for the formation of smog. Air is normally cooler at higher elevations, but during temperature inversions—in which air is warmer at higher elevations—pollutants are trapped near the ground.

According to the American Lung Association, the worst area in the United States for concentrations of particulates is in southern California, including Los Angeles and nearby communities. Worldwide, according to the World Health Organization, the 10 most polluted cities are all in developing regions, including 4 each in Iran and South Asia. Mexico City is an example of a city in a developing country that has improved its air quality since the 1990s (Figure 11-35).

Pause and Reflect 11.3.2

What environmental features can be seen in Mexico City on a clear day but not during smog periods? What is their role in the city's air pollution problem?

Progress in controlling urban air pollution is mixed. In developed countries, air has improved where strict clean-air regulations are enforced. Limited emission controls in developing countries are contributing to severe urban air pollution. Changes in manufacturing processes, motor vehicle engines, and electric generation have all helped. For example, since the 1970s, when the U.S. government began to require catalytic converters on motor vehicles, carbon monoxide emissions have been reduced by more than three-fourths, and nitrogen oxide and hydrocarbon emissions have been reduced by more than 95 percent. But more people are driving, offsetting gains made by emission controls.

Solid Waste Pollution

About 2 kilograms (4 pounds) of solid waste per person is generated daily in the United States, about 60 percent from residences and 40 percent from businesses. Paper products, such as corrugated cardboard and newspapers, account for the largest percentage of solid waste in the United States, especially among residences and retailers. Manufacturers discard large quantities of metals as well as paper.

SANITARY LANDFILL

Using a **sanitary landfill** is by far the most common strategy for disposal of solid waste in the United States: More than one-half of the country's waste is trucked to landfills

▲ **FIGURE 11-35 LOCAL-SCALE AIR POLLUTION: MEXICO CITY SMOG** Downtown Mexico City without smog (left) and with smog (right).

and buried under soil. But the number of landfills in the United States has declined by three-fourths since 1990.

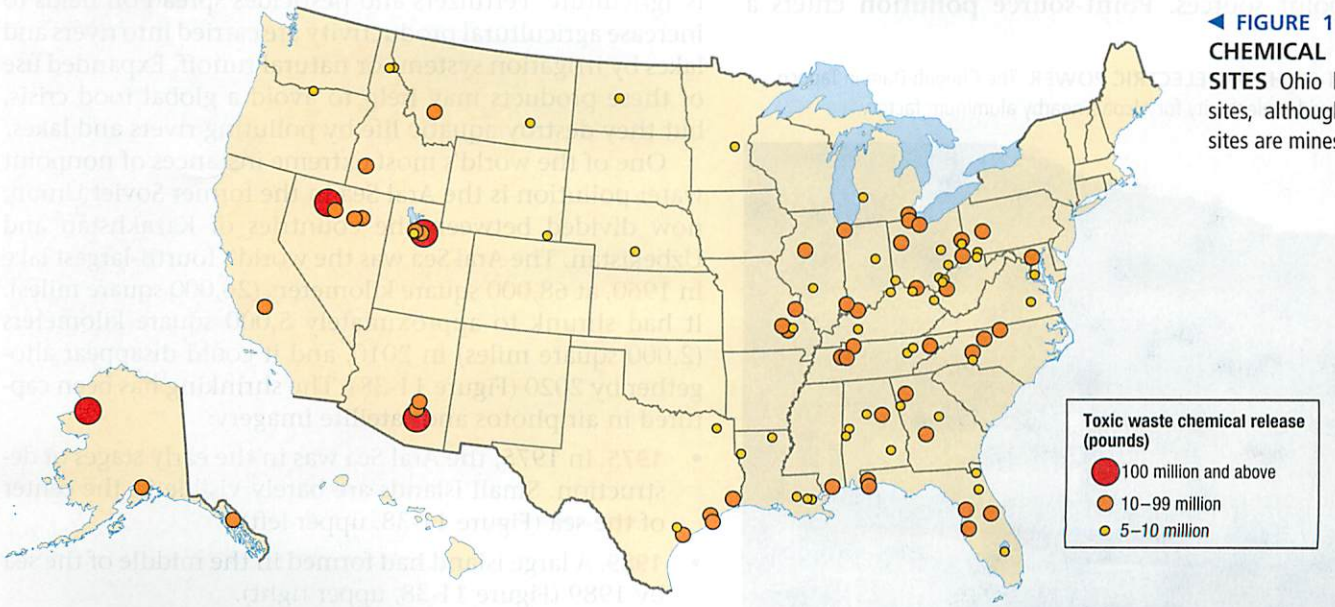
Given the shortage of space in landfills, alternatives have been sought to disposal of solid waste. A rapidly growing alternative is incineration. Burning trash reduces its bulk by about three-fourths, and the remaining ash demands less landfill space. Incineration also provides energy: The incinerator's heat can boil water to produce steam heat or operate a turbine that generates electricity.

HAZARDOUS WASTE

Disposing of hazardous waste is especially difficult. Hazardous wastes include heavy metals (including mercury, cadmium, and zinc), PCB oils from electrical equipment, cyanides, strong solvents, acids, and caustics. These may be unwanted by-products generated in manufacturing or waste to be discarded after usage.

According to the toxic waste inventory published by the U.S. Environmental Protection Agency (EPA), 1.78 billion kilograms (3.93 billion pounds) of toxic chemicals were released into the environment in 2010. Mining operations were the largest polluters. Ohio had 10 of the 100 largest polluting firms (Figure 11-36).

If poisonous industrial residuals are not carefully placed in protective containers, the chemicals may leach into the soil and contaminate groundwater or escape into the atmosphere. Breathing air or consuming water contaminated with toxic wastes can cause cancer, mutations, chronic ailments, and even immediate death.



◀ **FIGURE 11-36 TOXIC CHEMICAL RELEASE SITES** Ohio has the most sites, although the largest sites are mines in the West.

Water Pollution

Learning Outcome 11.3.3

Compare and contrast point and nonpoint sources of water pollution.

Some manufacturers are heavy users of water. One example is the aluminum industry. Aluminum producers locate near dams to take advantage of cheap hydroelectric power. A large amount of electricity is needed to separate pure aluminum from bauxite ore (Figure 11-37). Alcoa, the world's largest aluminum producer, even owns dams in North Carolina and Tennessee.

Water also serves many human purposes:

- It must be drunk to survive.
- It is used for cooking.
- It is used for bathing.
- It provides a location for boating, swimming, fishing, and other recreation activities.
- It is home to fish and other edible aquatic life.

When all these uses are totaled, the average American consumes 5,300 liters (1,400 gallons) of water per day, including 680 liters (180 gallons) for drinking, cooking, and bathing. These uses require fresh, clean, unpolluted water.

But clean water is not always available because people and industries also use water for purposes that pollute it. Pollution is widespread because it is easy to dump waste into a river and let the water carry it downstream, where it becomes someone else's problem. By polluting water, humans harm the health of aquatic life and the health of land-based life (including humans themselves).

WATER POLLUTION SOURCES

The sources of pollution can be divided into point sources and nonpoint sources. **Point-source pollution** enters a body of water at a specific location, whereas **nonpoint-source pollution** comes from a large, diffuse area.

▼ **FIGURE 11-37 HYDROELECTRIC POWER** The Cheoah Dam in Tapoco, Tennessee, provides electricity for Alcoa's nearby aluminum factory.

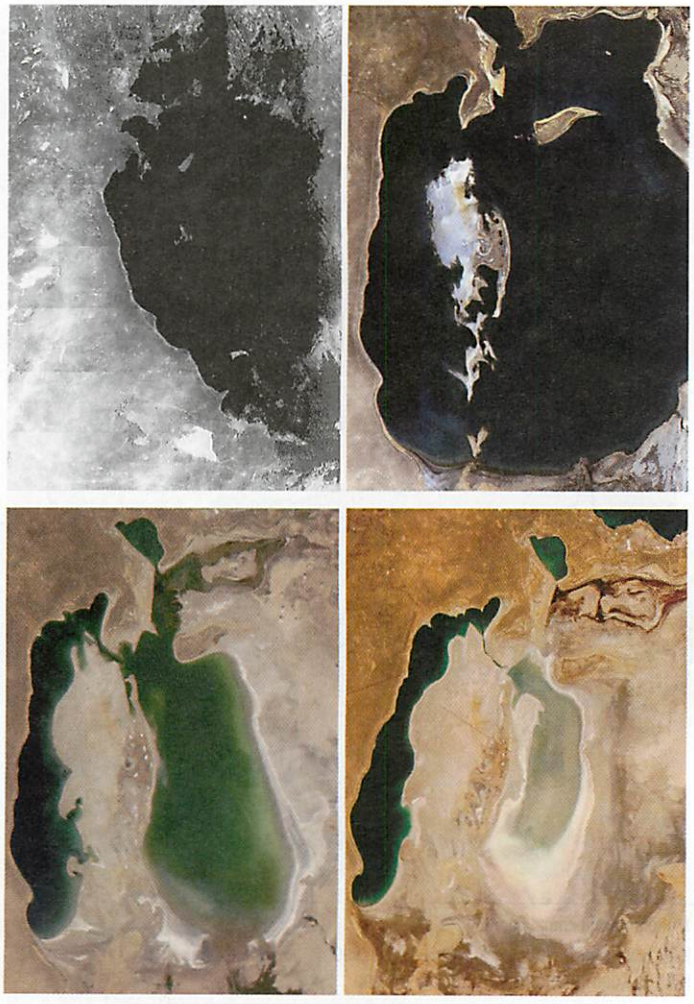
POINT SOURCES. Point-source pollutants are usually smaller in quantity and much easier to control than nonpoint-source pollutants. Point-source water pollution originates from a specific point, such as a pipe from a wastewater treatment plant. The two main point sources of pollution are manufacturers and municipal sewage systems:

- **Water-using manufacturers.** Steel, chemicals, paper products, and food processing are major industrial polluters of water. Each requires a large amount of water in the manufacturing process and generates a lot of wastewater. Food processors, for example, wash pesticides and chemicals from fruit and vegetables. They also use water to remove skins, stems, and other parts. Water can also be polluted by industrial accidents, such as petroleum spills from ocean tankers and leaks from underground tanks at gasoline stations.
- **Municipal sewage.** In developed countries, sewers carry wastewater from sinks, bathtubs, and toilets to a municipal treatment plant, where most—but not all—of the pollutants are removed. The treated wastewater is then typically dumped back into a river or lake. Since passage of the U.S. Clean Water Act and equivalent laws in other developed countries, most treatment plants meet high water-quality standards. In developing countries, sewer systems are rare, and wastewater usually drains, untreated, into rivers and lakes. The drinking water, usually removed from the same rivers, may be inadequately treated as well. The combination of untreated water and poor sanitation makes drinking water deadly in developing countries. Waterborne diseases such as cholera, typhoid, and dysentery are major causes of death.

NONPOINT SOURCES. Nonpoint sources usually pollute in greater quantities and are much harder to control than point sources of pollution. The principal nonpoint source is agriculture. Fertilizers and pesticides spread on fields to increase agricultural productivity are carried into rivers and lakes by irrigation systems or natural runoff. Expanded use of these products may help to avoid a global food crisis, but they destroy aquatic life by polluting rivers and lakes.

One of the world's most extreme instances of nonpoint water pollution is the Aral Sea in the former Soviet Union, now divided between the countries of Kazakhstan and Uzbekistan. The Aral Sea was the world's fourth-largest lake in 1960, at 68,000 square kilometers (26,000 square miles). It had shrunk to approximately 5,000 square kilometers (2,000 square miles) in 2010, and it could disappear altogether by 2020 (Figure 11-38). The shrinking has been captured in air photos and satellite imagery:

- **1975.** In 1975, the Aral Sea was in the early stages of destruction. Small islands are barely visible in the center of the sea (Figure 11-38, upper left).
- **1989.** A large island had formed in the middle of the sea by 1989 (Figure 11-38, upper right).



▲ FIGURE 11-38 THE DISAPPEARING ARAL SEA In 1975 (upper left), 1989 (upper right), 2003 (lower left), and 2009 (lower right).

- **2003.** By 2003, the sea was divided into two portions, western and eastern (Figure 11-38, lower left).
- **2009.** In 2009, the western portion had not changed much, but the eastern portion had dried up into a wasteland of salt. A small northern lake also remained (Figure 11-38, lower right).

The Aral Sea died because beginning in 1954, the Soviet Union diverted its tributary rivers, the Amu Dar'ya and the Syr Dar'ya, to irrigate cotton fields. Ironically, the cotton now is withering because winds pick up salt from the exposed lakebed and deposit it on the cotton fields. Carp, sturgeon, and other fish species have disappeared; the last fish died in 1983. Large ships lie aground in salt flats that were once the lakebed, outside abandoned fishing villages that now lay tens of kilometers from the rapidly receding shore.

Pause and Reflect 11.3.3

How might sustainable agriculture practices , as discussed in Chapter 10, help to improve water quality?

IMPACT OF WATER POLLUTION ON AQUATIC LIFE

Polluted water can harm aquatic life. Aquatic plants and animals consume oxygen, and so does the decomposing organic waste that humans dump in the water. The oxygen consumed by the decomposing organic waste constitutes the **biochemical oxygen demand (BOD)**. If too much waste is discharged into water, the water becomes oxygen starved and fish die.

This condition is typical when water becomes loaded with municipal sewage or industrial waste. The sewage and industrial pollutants consume so much oxygen that the water can become unlivable for normal plants and animals, creating a "dead" stream or lake. Similarly, when runoff carries fertilizer from farm fields into streams or lakes, the fertilizer nourishes excessive aquatic plant production—a "pond scum" of algae—that consumes too much oxygen. Either type of pollution reduces the normal oxygen level, threatening aquatic plants and animals. Some of the residuals may become concentrated in the fish, making them unsafe for human consumption. For example, salmon from the Great Lakes became unfit to eat because of high concentrations of the pesticide DDT, which washed into streams from farm fields.

Many factories and power plants use water for cooling and then discharge the warm water back into the river or lake. The warm water may not be polluted with chemicals, but it raises the temperature of the body of water it enters. Fish adapted to cold water, such as salmon and trout, might not be able to survive in the warmer water.

CHECK IN: KEY ISSUE 3

Where Does Industry Cause Pollution?

- ✓ **Industry is a major polluter of air, land, and water.**
- ✓ **Air pollution can occur at global, regional, and local scales.**
- ✓ **Solid waste that is not recycled is either transported to landfills or incinerated; some of it is hazardous.**
- ✓ **Water pollution can have point or nonpoint sources.**