chapter 21

Our Impact on Water and Air

Chase Jarvis /Getty Images

chapter preview

sections

1 Water Pollution
Lab Elements in Water

2 Air Pollution
Lab What's in the air?

Virtual Lab How can we conserve water?

Do you enjoy the outdoors?

At one time, all the water on Earth was like this. Clean water and air help create a pleasant outdoor experience. Too many substances released into air and water from human activity may damage these resources.

Science Journal Hypothesize what happens to the water in your home after the water goes down the drain.

Start-Up Activities

Launch LAB

Is pollution always obvious?

Some water pollution is easy to see. The water can be discolored, have an odor, or contain dead fish. Suppose the water appears to be clean. Does that mean it's free of pollution? You'll find out during this lab.

1. Pour 125 mL of water into a large jar.
2. Add one drop (0.05 mL) of food coloring to the water and stir.
3. Add an additional 125 mL of water to the jar and stir.
4. Repeat step 3 until you cannot see the food coloring.
5. **Think Critically** Calculate the concentration of food coloring in your jar with each 125-mL addition of water. Will the concentration of food coloring ever become zero by diluting the solution?

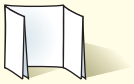
ScienceOnline Preview this chapter's content and activities at earth.msscience.com

FOLDABLES™ Study Organizer

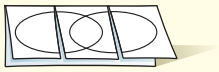
Pollution Make the following Foldable to compare and contrast the characteristics of water pollution and air pollution.

STEP 1 **Fold** one sheet of paper lengthwise.

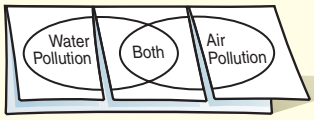
STEP 2 **Fold** into thirds.



STEP 3 **Unfold** and draw overlapping ovals. **Cut** the top sheet along the folds.



STEP 4 **Label** the ovals as shown.



Construct a Venn Diagram As you read this chapter, list the characteristics unique to water pollution under the left tab, those unique to air pollution under the right tab, and those characteristics common to both under the middle tab.

section 1

Water Pollution

as you read

What You'll Learn

- **Identify** types of water pollutants and their effects.
- **Discuss** ways to reduce water pollution.
- **List** ways that you can help reduce water pollution.

Why It's Important

All organisms on Earth depend on water for life.

Review Vocabulary

pollution: the introduction of harmful substances to the environment

New Vocabulary

- point source pollution
- nonpoint source pollution
- pesticide
- fertilizer
- sewage

Importance of Clean Water

All organisms need water. Plants need water to make food from sunlight. Some animals such as fish, frogs, and whales live in water. What about you? You cannot live without drinking water. What happens if water isn't clean? Polluted water contains chemicals and organisms that can cause disease or bring death to many living things. Water also can be polluted with sediments, such as silt and clay.

Sources of Water Pollution

If you were hiking along a stream or lake and became thirsty, would it be safe to drink the water? Many streams and lakes in the United States are polluted in some way. Even streams that look clear and sparkling might not be safe for drinking.

Point source pollution is pollution that enters water from a specific location, such as drainpipes or ditches, as shown in **Figure 1.** Pollution from point sources can be controlled or treated before the water is released to a body of water.

However, many times bodies of water become polluted and no one knows exactly where the pollution comes from. Pollution that enters a body of water from a large area, such as lawns, construction sites, and roads, is called **nonpoint source pollution.** Nonpoint sources also include pollutants in rain or snow. Nonpoint source pollution is the largest source of water quality problems in the United States.

Figure 1 Water can be polluted in two ways.

Point sources include industrial wastes from outfalls.

Nonpoint sources cannot be traced to a single location.

CONTENTS

Sediment The largest source of water pollution in the United States is sediment. Sediment is loose material, such as rock fragments and mineral grains, that is moved by erosion. Rivers always have carried sediment to oceans, but human activities can increase the amount of sediment in rivers, lakes, and oceans. Each year, about 25 billion metric tons of sediment are carried from farm fields to bodies of water on Earth. At least 50 billion additional tons run off of construction sites, cleared forests, and land used to graze livestock. Sediment makes water cloudy and blocks sunlight that underwater plants need to make food. Sediment also covers the eggs of organisms that live in water, preventing organisms from receiving the oxygen they need to develop.

Agriculture and Lawn Care Farmers and home owners apply **pesticides,** which are substances that destroy pests, to keep insects and weeds from destroying their crops and lawns. When farmers and home owners apply pesticides to their crops and lawns, some of the chemicals run off into water. These chemicals might be harmful to people and other organisms, such as the frog in **Figure 2.**

Fertilizers are chemicals that help plants grow. However, rain washes away as much as 25 percent of the fertilizers applied to farms and yards into ponds, streams, and rivers. Fertilizers contain nitrogen and phosphorus that algae, living in water, use to grow and multiply. Lakes or ponds with high nitrogen and phosphorous levels, such as the one shown in **Figure 3,** can be choked with algae. When algae die and decompose, oxygen in the lake is used up more rapidly. This can cause fish and other organisms to die. Earth's nitrogen cycle is modified when fertilizers enter the water system.

Reading Check *How do fertilizers cause water pollution?*

Figure 2 Research suggests that some pesticides in the environment could lead to deformities in frogs, such as missing legs.

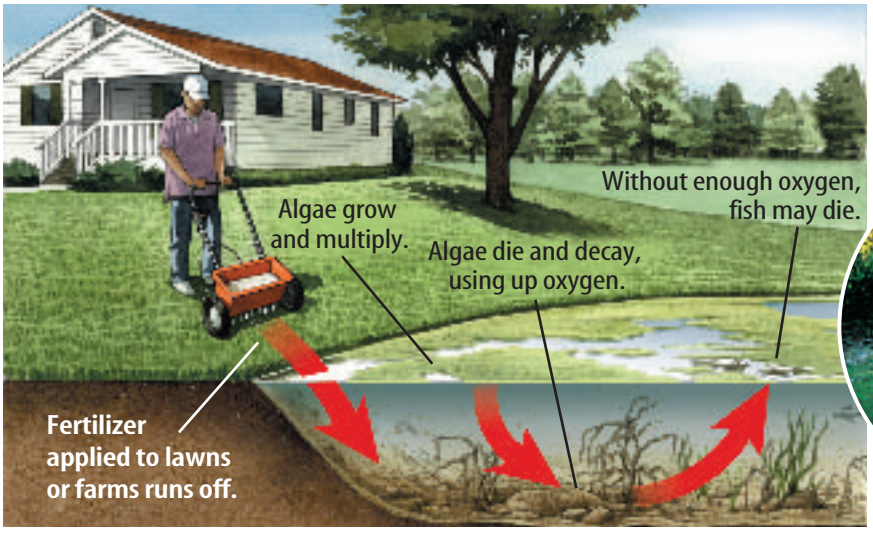


Figure 3 Nitrogen and phosphorus in fertilizer cause algae to grow and multiply. Fish can die when algae decompose, using up oxygen.

Human Waste When you flush a toilet or take a shower, the water that goes into drains, called **sewage,** contains human waste, household detergents, and soaps. Human waste contains harmful organisms that can make people sick.

In most cities and towns in the United States, underground pipes take the water you use from your home to a sewage treatment plant. Sewage treatment plants, such as the one in **Figure 4,** remove pollution using several steps. These steps purify the water by removing solid materials from the sewage, killing harmful bacteria, and reducing the amount of nitrogen and phosphorus.

Applying Math — Calculate Percentages

SURFACE WATER POLLUTION

This table shows the number of sampling stations that have an increased or a decreased level of pollution in a 10-year period. What percent of stations has shown an increase in nitrogen over a 10-year period?

Trends in River and Stream Water Quality

Measured Pollutant	Total No. of Stations Examined	No. of Stations With Decrease in Pollutant Level	No. of Stations With Increase in Pollutant Level
Sediments	324	36	6
Bacteria from sewage	313	41	9
Total phosphorus	410	90	21
Nitrogen	344	27	21

Solution

1 *This is what you know:*

Nitrogen: number of stations with an increase = 21
total number of stations examined = 344

2 *This is what you need to find:*

percentage: _____%

3 *This is the equation you need to use:*

- % = (stations with increase)/(total stations) × 100
- (21)/(344) × 100 = 6.1%

4 *Check your answer:*

Multiply the total stations by the percent in decimal form to obtain the number of stations with an increase.

Practice Problems

1. What percent of stations has shown a decrease in bacteria?
2. What percent of stations has shown an increase in sediment?

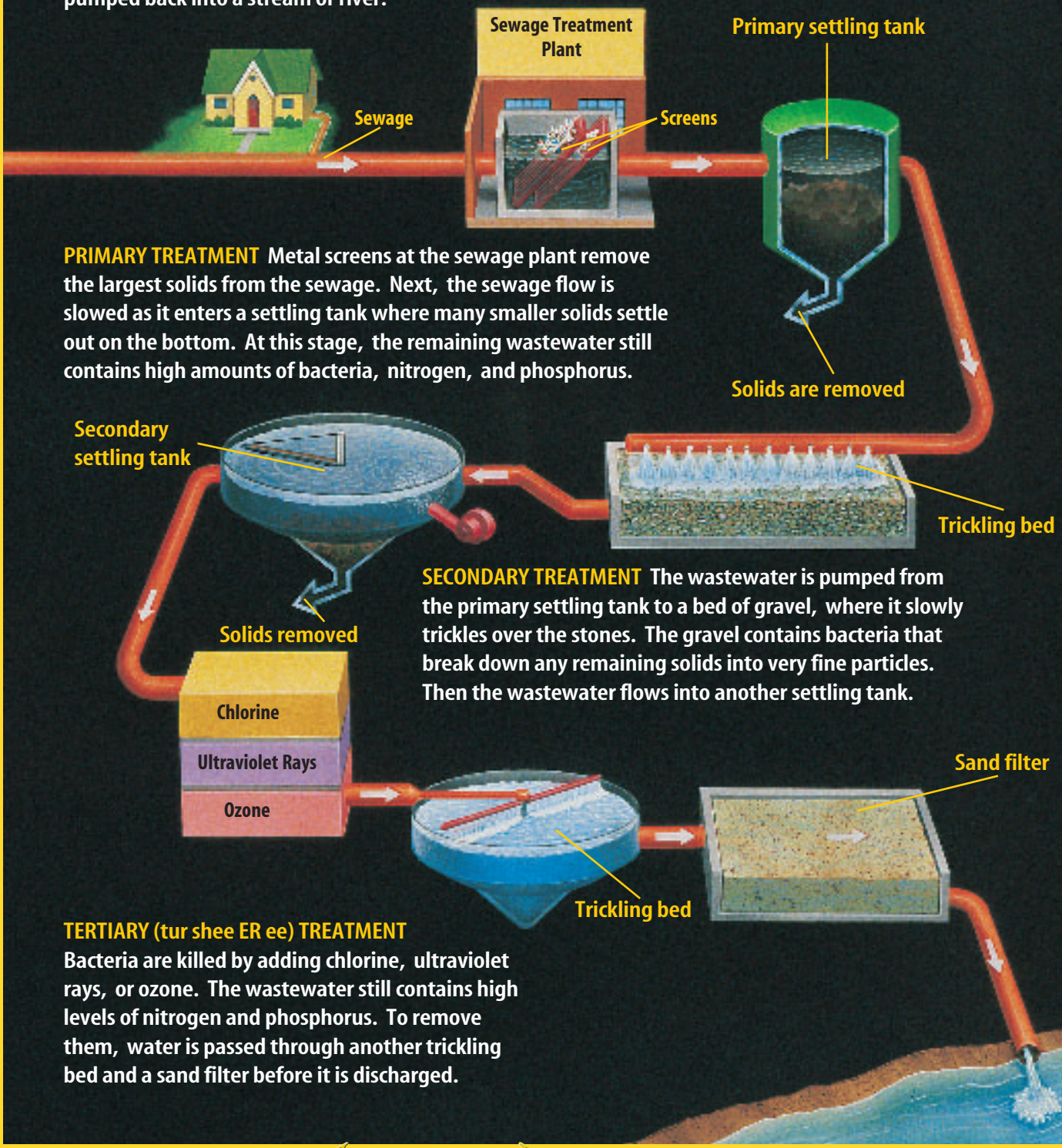
ScienceOnline For more practice, visit earth.msscience.com/math_practice

NATIONAL GEOGRAPHIC

VISUALIZING SEWAGE TREATMENT

Figure 4

Sewage from most towns and cities is treated at municipal sewage treatment plants. Wastewater entering a sewage plant contains organic matter, paper, grease, bacteria, nitrogen, and phosphorus. As shown below, the wastewater from homes and businesses is purified in three stages—primary, secondary, and tertiary—before it is pumped back into a stream or river.



PRIMARY TREATMENT Metal screens at the sewage plant remove the largest solids from the sewage. Next, the sewage flow is slowed as it enters a settling tank where many smaller solids settle out on the bottom. At this stage, the remaining wastewater still contains high amounts of bacteria, nitrogen, and phosphorus.

SECONDARY TREATMENT The wastewater is pumped from the primary settling tank to a bed of gravel, where it slowly trickles over the stones. The gravel contains bacteria that break down any remaining solids into very fine particles. Then the wastewater flows into another settling tank.

TERTIARY (tur shee ER ee) TREATMENT Bacteria are killed by adding chlorine, ultraviolet rays, or ozone. The wastewater still contains high levels of nitrogen and phosphorus. To remove them, water is passed through another trickling bed and a sand filter before it is discharged.

Environmental Engineering Earth's atmosphere and oceans have a limited capacity to absorb wastes and recycle materials naturally. However, overabundance of pollutants has negative effects. Environmental engineering offers opportunities to work in environmental protection. Major areas include air pollution control, water supply, wastewater management, and storm water management.

Metals Many metals such as mercury, lead, nickel, and cadmium can be poisonous, even in small amounts. For example, lead and mercury in drinking water can damage the nervous system. However, metals such as these are valuable in making items you use such as paints and stereos. Before environmental laws were written, a large amount of metals was released with wastewater from factories. Today, laws control how much metal can be released. Because metals remain in the environment for a long time, metals released many years ago still are polluting bodies of water today.

Mining also releases metals into water. For example, in the state of Tennessee, more than 43 percent of all streams and lakes contain metals from mining activities. In the mid 1980s, gold was found near the Amazon River in South America. Miners use mercury to trap the gold and separate it from sediments. Each year, more than 130 tons of mercury end up in the Amazon River.

Oil and Gasoline Oil and gasoline run off roads and parking lots into streams and rivers when it rains. These compounds contain pollutants that might cause cancer. Gasoline is stored at gas stations in tanks below the ground. In the past, the tanks were made of steel. Some of these tanks rusted and leaked gasoline into the surrounding soil and groundwater. As little as one gallon of gasoline can make an entire city's water supply unsafe for drinking.

Federal laws passed in 1988 require all new gasoline tanks to have a double layer of steel or fiberglass. In addition, by 1998, all new and old underground tanks must have had equipment installed that detects spills and must be made of materials that will not develop holes. These laws help protect soil and groundwater from gasoline and oil stored in underground tanks.

Colin Raw/Stone/Getty Images

Figure 5 During the manufacture of many products, such as electricity from this power plant, water is needed for cooling the machinery. Heated water remains in large towers and ponds until it has cooled to a temperature that is safe for fish and other organisms.

Heat When a factory makes a product, heat often is released. Sometimes, cool water from a nearby ocean, river, lake, or underground supply is used to cool factory machines. The heated water then is released. This water can pollute because it contains less oxygen than cool water does. In addition, organisms that live in water are sensitive to changes in temperature. A sudden release of heated water can kill a large number of fish in a short time. Water can be cooled before it is released into a river by using a cooling tower or pond, as shown in **Figure 5.**

Reducing Water Pollution

One way to reduce water pollution is by treating water before it enters a stream, lake, or river. In 1972, the United States Congress amended the Water Pollution Control Act. This law provided funds to build sewage-treatment facilities. It required industries to remove or treat pollution in water discharged to a lake or stream. The Clean Water Act of 1987 made additional money available for sewage treatment and set goals for reducing point source and nonpoint source pollution.

Another law, the Safe Drinking Water Act of 1996, strengthens health standards for drinking water. This legislation also protects rivers, lakes, and streams that are sources of drinking water.

International Cooperation Several countries have worked together to reduce water pollution. Lake Erie is on the border between the United States and Canada. Prior to the 1970s, phosphorus and nitrogen from sewage, soaps, and fertilizers entered Lake Erie from homes, yards, and farms, causing algae to grow and reproduce. The lake became a green, soupy mess. In the summer, the algae died and sank to the lake bottom. As the dead algae decayed, large areas of the lake bottom no longer had oxygen and, therefore, no life.

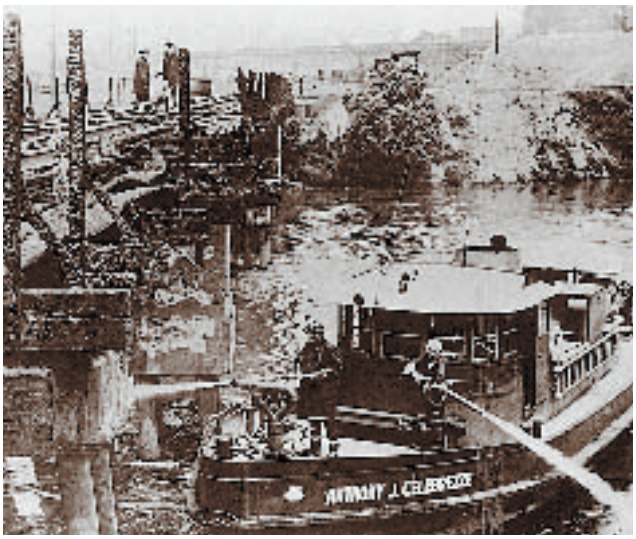
Pollutants also were discharged from many steel, automobile, and other factories along Lake Erie. **Figure 6** shows how on June 22, 1969, greasy debris on a large river flowing through Cleveland, Ohio, caught fire. This event was a wake-up call for everyone concerned about the quality of water in the United States and around the world.

In the 1970s, the United States and Canada made two water-quality agreements. These agreements set goals for reducing pollution in the Great Lakes. As a result of these agreements, limits were placed on the amount of phosphorus and other pollutants allowed into Lake Erie.

Today, the green slime is gone and the fish are back. However, more than 300 human-made chemicals still can be found in Lake Erie, and some of them are hazardous. The United States and Canada are studying ways to remove them from the lake.

Reading Check ***Which countries worked together to control water pollution in Lake Erie?***

Figure 6 Because of laws passed since 1972, Lake Erie's water has improved.



A fire on the Cuyahoga River in Cleveland, Ohio, alerted people in the United States to water pollution problems.

Today, millions of people enjoy this natural resource.

Hazardous Wastes
Some wastes are called hazardous because they are carcinogenic (kar sih nuh JEH nik). What does carcinogenic mean? What may happen if hazardous wastes seeped into a drinking water supply?

How can you help?

Through laws and regulations, the quality of many streams, rivers, and lakes in the United States has improved. However, as **Figure 7** shows, much remains to be done. Individuals and industries alike need to continue to work to reduce water pollution. You easily can help by keeping contaminants out of Earth's water supply and by conserving water.

Dispose of Wastes Safely When you dispose of household chemicals such as paint and motor oil, don't pour them onto the ground or down the drain. Hazardous wastes that are poured directly onto the ground move through the soil and eventually might reach the groundwater below. Pouring them down the drain is no better because they flow through the sewer, through the wastewater-treatment plant, and into a stream or river where they can harm the organisms living there.

What should you do with these wastes? First, read the label on the container for instructions on disposal. Don't throw the container into the trash if the label tells you not to. Store chemical wastes so that they can't leak. Call your local government officials and ask how to dispose of these wastes in your area safely. Many communities have specific times each year when they collect hazardous wastes. These wastes then are disposed of at special hazardous waste sites.

Topic: Water Conservation
Visit earth.msscience.com for Web links to information about water conservation.

Activity Turn on a faucet until it drips. Collect the water for 10 min. Calculate how much water goes down the drain each day.

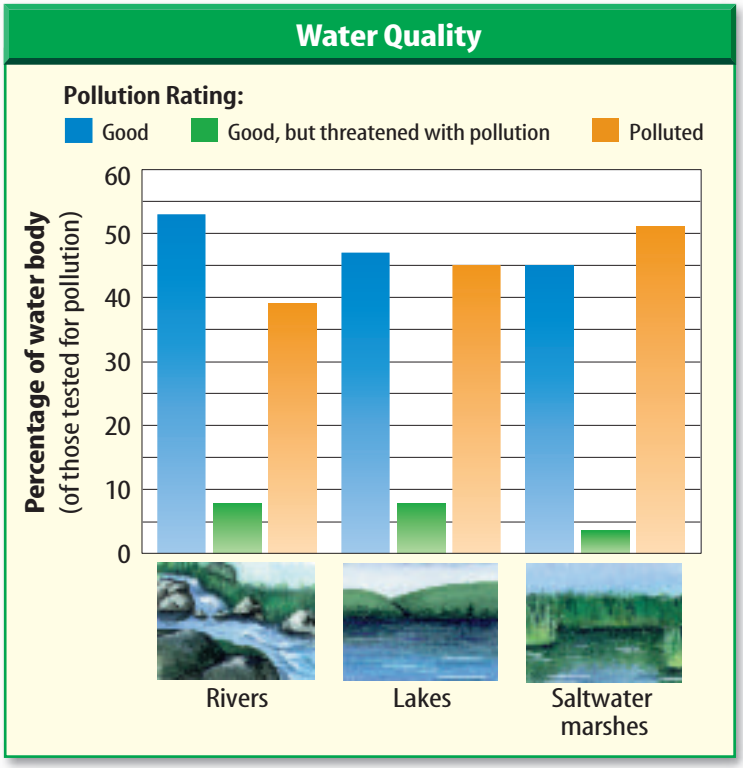


Figure 7 This graph shows that water pollution is still a problem in the United States.
Determine *the percentage of rivers that are listed as polluted.*

Figure 8 Water pollution can be reduced if less water is used.

One drip every 5 s from a leaky faucet will waste nearly 7,500 L of water per year.

Toilets made before 1994 use nearly 12 L of water per flush. Replacing your old toilet with a new one can save 56 L of water in just ten flushes.

Turning off the water while brushing your teeth will save more than 19 L per day.

Conserve Water How much water do you use every day? You use water every time you flush a toilet, take a bath, clean your clothes, wash dishes, wash a car, or use a hose or lawn sprinkler. A typical U.S. citizen uses an average of 375 L of water per day. Unless it comes from a home well, this water must be purified before it reaches your home. After you use it, it must be treated again. **Figure 8** shows how using simple conservation methods can save water. Conserving water reduces the need for water treatment and reduces water pollution.

section 1 review

Summary

Importance of Clean Water

- All life on Earth needs water.
- Water pollution can harm living things.

Sources of Water Pollution

- Pollution enters water from point and non-point sources.
- Lawn and farm chemicals, sewage, metals, oil and heat all contribute to water pollution.

Reducing Water Pollution

- Federal laws and international agreements have helped reduce water pollution.

How can you help?

- Conserving water helps reduce pollution.

Self Check

1. **Compare and contrast** point source and nonpoint source pollution.
2. **Infer** how U.S. laws have helped reduce water pollution.
3. **Describe** ways you can conserve water.
4. **Think Critically** Southern Florida has many dairy farms and sugarcane fields. It also contains Everglades National Park—a shallow river system. What kinds of pollutants might be in the Everglades? How did they get there?

Applying Skills

5. **Use graphics software** to design a pamphlet that informs people how to reduce the amount of water they use.

LAB

Elements in Water

When you look at water, it is often clear and looks as if there is not much in it. However, there are many compounds, microscopic organisms, and other substances that can be in the water, but aren't easily visible. How can you find out what else might be in the water? Can you also find out how much of it is in the water?

Real-World Question

What is the nitrate and phosphate content of water?

Goals

- **Determine** the nitrate and phosphate content of two samples of water.
- **Compare** the levels and explain any differences you find.

Materials

beakers (2)
tap water
plant fertilizer
teaspoon
nitrate test kit
phosphate test kit
stirrer

Safety Precautions

Never eat or drink anything in the lab. Use gloves and goggles when handling fertilizer.

Procedure

1. Half-fill two large beakers with tap water.
2. Add a teaspoon of plant fertilizer to one of the beakers and stir well.
3. **Predict** which beaker might have a greater level of nitrate.
4. Using an appropriate kit, measure the nitrate content of each beaker of water.
5. Clean the test kit between measurements. Record your measurements.
6. **Predict** which beaker might have a greater level of phosphates.
7. Using an appropriate kit, measure the phosphate content of each beaker of water. Be sure to clean the kit between measurements. Record your measurements.

Conclude and Apply

1. **Describe** your results. Were the levels of each compound you measured the same in both samples?
2. **Infer** if your predictions were correct.
3. **Explain** any differences that you found.
4. **Explain** how the use of fertilizers can cause problems in lakes and streams.

Communicating Your Data

Compare your results with those of others in your class. **Discuss** any differences found in your measurements.

Mark Burnett
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section 2

Air Pollution

Alan Pitcairn from Grant Heilman

Causes of Air Pollution

Cities can be exciting because they are centers of business, culture, and entertainment. Unfortunately, cities also have many cars, buses, and trucks that burn fuel for energy. The brown haze you sometimes see forms from the exhaust of these vehicles. Air pollution also comes from burning fuels in factories, generating electricity, and burning trash. Dust from plowed fields, construction sites, and mines also contributes to air pollution.

Natural sources add pollutants to the air, too. For example, radon is a naturally occurring gas given off by certain kinds of rock. This gas can seep into basements of homes built on these rocks. Exposure to radon can increase the risk of lung cancer. Natural sources of pollution also include particles and gases emitted into air from erupting volcanoes and fires.

What is smog?

One type of air pollution found in urban areas is called smog, a term originally used to describe the combination of smoke and fog. Major sources of smog, shown in **Figure 9,** include cars, factories, and power plants.

Figure 9 Cars are one of the main sources of air pollution in the United States.
Calculate *the percentage of smog that comes from power plants and industry combined.*

as you read

What You'll Learn

- **List** the different sources of air pollutants.
- **Describe** how air pollution affects people and the environment.
- **Discuss** how air pollution can be reduced.

Why It's Important

Air pollution can adversely affect your health and the health of others.

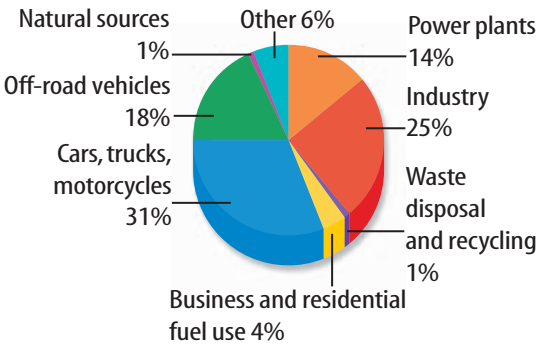
Review Vocabulary

ozone layer: a layer of the stratosphere that absorbs most of the Sun's ultraviolet radiation

New Vocabulary

- photochemical smog
- acid rain
- pH scale
- acid
- base
- carbon monoxide
- particulate matter
- scrubber

Sources of Smog (Photochemical)



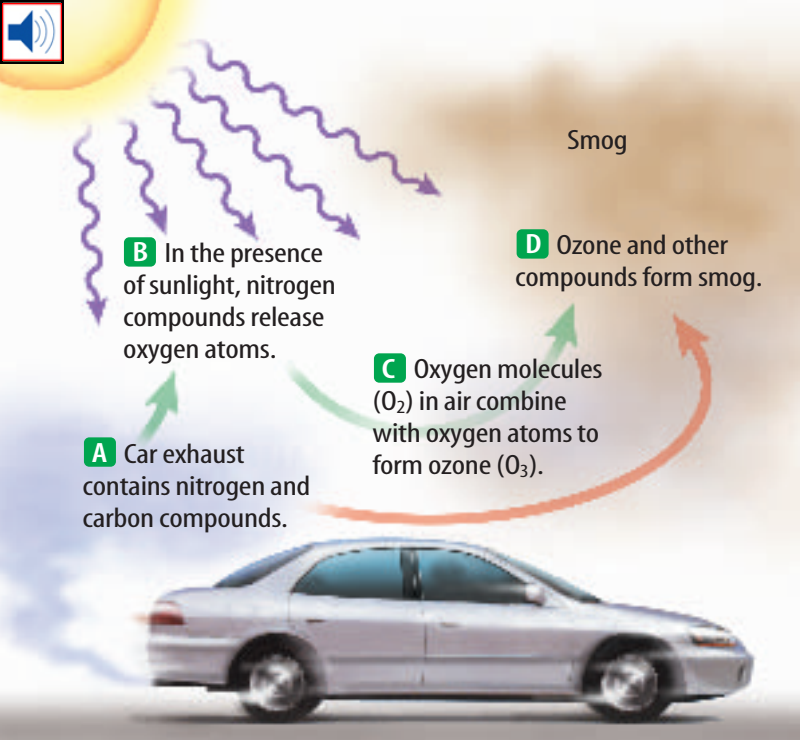


Figure 10 Exhaust from cars can form smog in the presence of sunlight.

How Smog Forms

The hazy, yellowish brown blanket of smog that is sometimes found over cities is called **photochemical smog** because it forms with the help of sunlight. Pollutants get into the air when gasoline is burned, releasing nitrogen and carbon compounds. These compounds, as shown in **Figure 10,** react in the presence of sunlight to produce other substances. One of the substances produced is ozone. Ozone high in the atmosphere protects you from the Sun's ultraviolet radiation. However, ozone near Earth's surface is a major component of smog. Smog can damage sensitive tissues, like plants or your lungs.

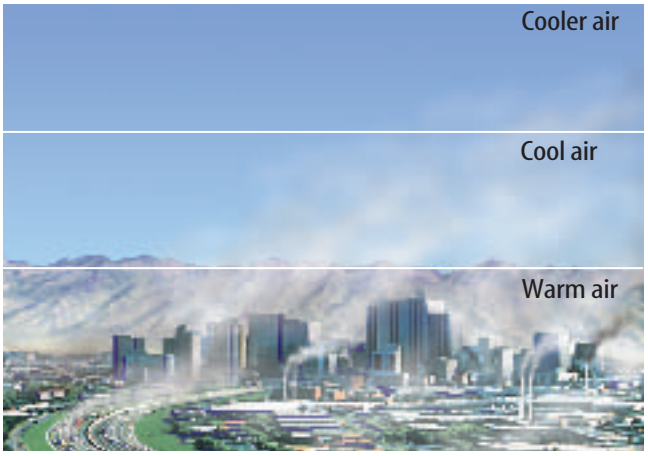
Nature and Smog

Certain natural conditions contribute to smoggy air. For example, some cities do not have serious smog problems because their pollutants often are dispersed by winds. In other areas, landforms add to smog development. The mountains surrounding Los Angeles, for example, can prevent smog from being carried away by winds.

Figure 11 shows how the atmosphere also can influence the formation of smog. Normally, warmer air is found near Earth's surface. However, sometimes warm air traps cool air near the ground. This is called a temperature inversion, and it reduces the capacity of the atmosphere to mix materials, causing pollutants to accumulate near Earth's surface.

Figure 11 Conditions in the atmosphere can worsen air pollution.

Normal Conditions



Usually, air temperature decreases with distance above Earth's surface. Air pollutants can be carried far away from their source.

Temperature Inversion

During a temperature inversion, warm air overlies cool air. Air pollutants can't be dispersed and can accumulate to unhealthy levels.

Acid Rain

INTEGRATE Chemistry

When sulfur oxides from coal-burning power plants and nitrogen oxides from cars combine with moisture in the air, they form acids. When acidic moisture falls to Earth as rain or snow, it is called **acid rain.** Acid rain can corrode structures, damage forests, and harm organisms. The amount of acid is measured using the **pH scale.** A lower number means greater acidity. Substances with a pH lower than 7 are **acids.** Substances with a pH above 7 are **bases.**

Natural lakes and streams have a pH between 6 and 8. Acid rain is precipitation with a pH below 5.6. When rain is acidic, the pH of streams and lakes may decrease. As **Figure 12** shows, certain organisms, like snails, can't live in acidic water.

CFCs

About 20 km above Earth's surface is a layer of atmosphere that contains a higher concentration of ozone, called the ozone layer. Recall that ozone is a molecule made of three oxygen atoms and is found in smog. However, unlike smog, the ozone that exists at high altitudes helps Earth's organisms by absorbing some of the Sun's harmful ultraviolet (UV) rays. Chlorofluorocarbons (CFCs) from air conditioners and refrigerators might be destroying this ozone layer. Each CFC molecule can destroy thousands of ozone molecules. Even though the use of CFCs has been declining worldwide, these compounds can remain in the upper atmosphere for many decades.

Mini LAB

Identifying Acid Rain

Procedure

1. Use a clean **glass or plastic container** to collect a **sample of precipitation.**
2. Use **pH paper** or a **pH computer probe** to determine the acidity level of your sample. If you have collected snow, allow it to melt before measuring its pH.
3. Record the indicated pH of your sample and compare it with the results of other classmates who have followed the same procedure.

Analysis

1. What is the average pH of the samples obtained from this precipitation?
2. Compare and contrast the pH of your samples with those of the substances shown on a pH scale.

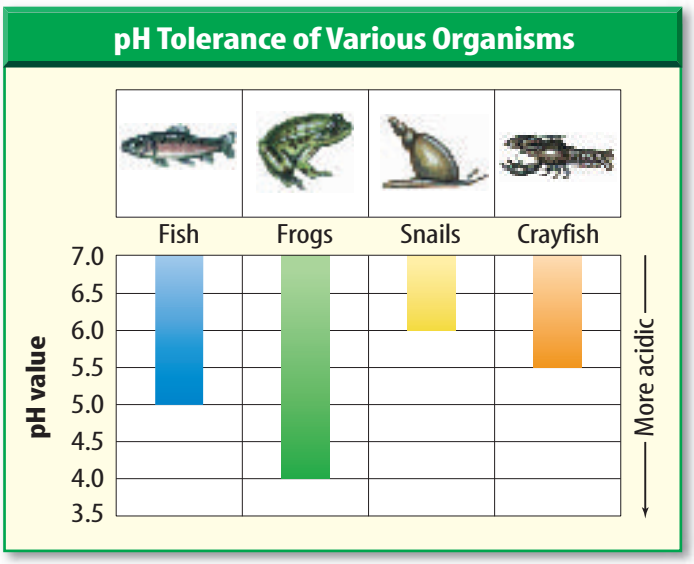


Figure 12 This chart shows water acidity levels where different organisms can live. **Infer** *which types of organisms you might find in a pond with a pH of 5.5 or greater. Which organisms would be in the pond if the pH dropped to 4.5?*

Air Pollution and Your Health

Suppose you're an athlete in a large city training for a competition. You might have to get up at 4:30 A.M. to exercise. Later in the day, the smog levels might be so high that it wouldn't be safe for you to exercise outdoors. In some large cities, athletes adjust their training schedules to avoid exposure to ozone and other pollutants. Schools schedule football games for Saturday afternoons when smog levels are lower. Parents are warned to keep their children indoors when smog exceeds certain levels.

Health Disorders How hazardous is dirty air? Approximately 250,000 people in the United States suffer from pollution-related breathing disorders. About 70,000 deaths each year in the United States are blamed on air pollution. **Figure 13** illustrates some of the health problems caused by air pollution. Ozone damages lung tissue, making people more susceptible to diseases such as pneumonia and asthma. Less severe symptoms of ozone include burning eyes, dry throat, and headache.

How do you know if ozone levels in your community are safe? You may have seen the Air Quality Index reported in your newspaper. **Table 1** shows the index along with ways to protect your health when ozone levels are high.

Carbon monoxide, a colorless, odorless gas found in car exhaust, also contributes to air pollution. This gas can make people ill, even in small concentrations because it replaces oxygen in your blood.

Science Online

Topic: Air Quality

Visit earth.msscience.com for Web links to information about air quality indices.

Activity Look up the air quality index of a city near you each day for 10 days. Graph the results.

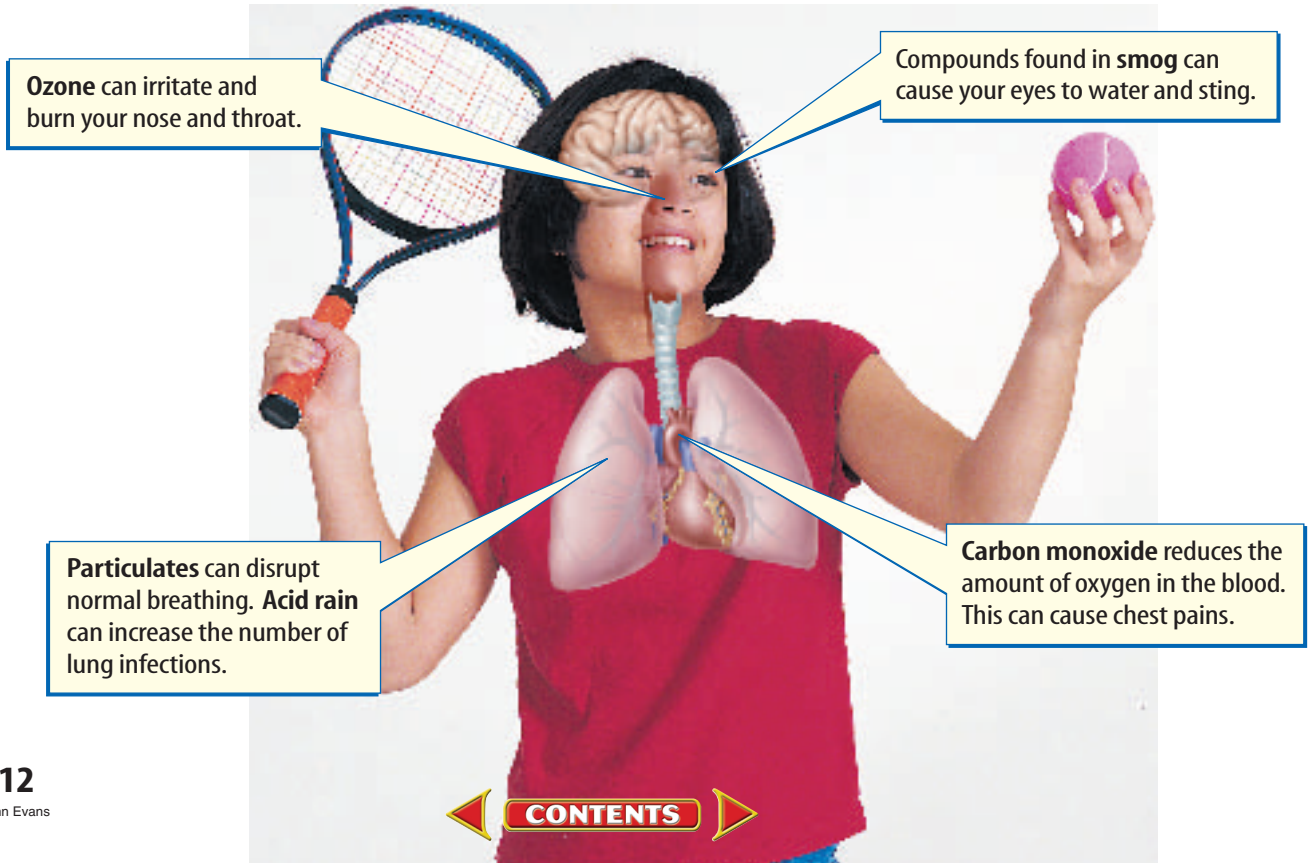


Figure 13 Air pollution can be a health hazard. Compounds in the air can affect your body.

John Evans

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Acid Rain What do you suppose happens when you inhale the humid air from acid rain? Acid is breathed deep inside your lungs. This may cause irritation and reduce your ability to fight respiratory infections. When you breathe, oxygen travels from the air to your lungs. Lungs damaged by acid rain cannot move oxygen to the blood easily. This puts stress on your heart.

Table 1 Air Quality Index

Air Quality	Air Quality Index	Protect Your Health
Good	0–50	No health impacts occur.
Moderate	51–100	People with breathing problems should limit outdoor exercise.
Unhealthy for certain people	101–150	Everyone, especially children and elderly, should not exercise outside for long periods of time.
Unhealthy	151–200	People with breathing problems should avoid outdoor activities.

Particulates Thick, black smoke from a forest fire, exhaust from school buses and large trucks, smoke billowing from a factory, and dust picked up by the wind all contain particulate (par TIH kyuh luht) matter. **Particulate matter** consists of fine particles such as dust, pollen, mold, ash, and soot that are in the air.

Particulate matter ranges in size from large, visible solids like dust and soil particles to microscopic particles that form when substances are burned. Smaller particles are more dangerous, because they can travel deeper into the lungs. When particulate matter is breathed in, it can irritate and damage the lungs, causing breathing problems.

Reading Check *Why are small particles dangerous to your health?*

Reducing Air Pollution

Pollutants moving through the atmosphere don't stop when they reach the borders between states and countries. They go wherever the wind carries them. This makes them difficult to control. Even if one state or country reduces its air pollution levels, pollutants from another state or country can blow across the border. For example, burning coal in midwestern states might cause acid rain in the northeast and Canada.

When states and nations cooperate, pollution problems can be reduced. People from around the world have met on several occasions to try to eliminate some kinds of air pollution. At one meeting in Montreal, Canada, an agreement called the Montreal Protocol was written to phase out the manufacture and use of CFCs by 2000. In 1989, 29 countries that consumed 82 percent of CFCs signed the agreement. By 1999, 184 countries signed it.

Mini LAB

Examining the Content of Air

WARNING: *Use caution when reaching high places. Students with dust allergies should not perform this lab.*

Procedure

1. Find a **high shelf or the top of a tall cabinet** in your home—someplace that hasn't been cleaned for a while.
2. Using a **white cloth,** thoroughly dust the surface.
3. Observe the cloth under a **magnifying lens.**

Analysis

1. What did you see on your cloth? Where did these particles come from?
2. Explain what you think happens when you breathe in these particles.

Try at Home

Table 2 Clean Air Regulations

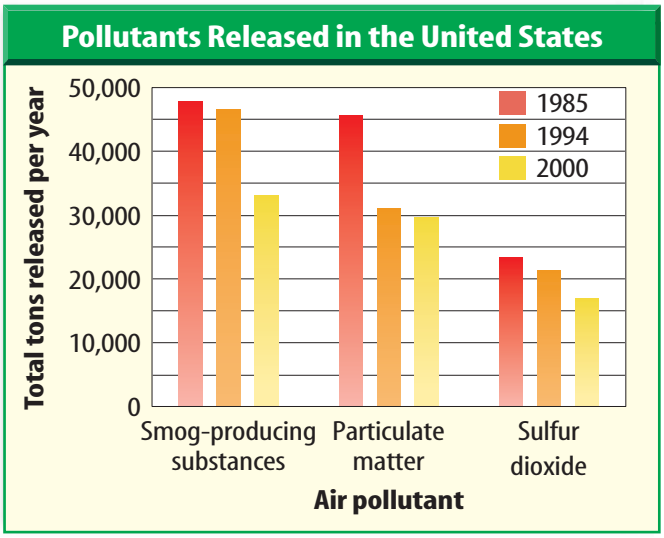
Urban air pollution	All cars manufactured since 1996 must reduce nitrogen oxide emissions by 60 percent and hydrocarbons by 35 percent from their 1990 levels.
Acid rain	Sulfur dioxide emissions had to be reduced by 14 million tons from 1990 levels by the year 2000.
Airborne toxins	Industries must limit the emission of 200 compounds that cause cancer and birth defects.
Ozone-depleting chemicals	Industries were required to immediately cease production of many ozone-depleting substances in 1996.

Air Pollution in the United States

The United States Congress passed several laws to protect the air. The Clean Air Act of 1990, summarized in **Table 2,** addressed some air pollution problems by regulating emissions from cars, energy production, and other industries. In 1997, new levels for ozone and particulate matter were proposed.

Since the passage of the Clean Air Act, the amount of some pollutants released into the air has decreased, as shown in **Figure 14.** However, millions of people in the United States still breathe unhealthy air.

Figure 14 This graph shows that some air pollutants have decreased since the passage of the Clean Air Act.
Determine *how many tons of particulates were released to the air in 1994.*



Reducing Emissions

More than 80 percent of sulfur dioxide emissions comes from coal-burning power plants. Coal from some parts of the United States contains a lot of sulfur. When this coal is burned, sulfur dioxides combine with moisture in the air to form sulfuric acid, causing acid rain. Sulfur dioxide can be removed by passing the smoke through a scrubber. A **scrubber** lets the gases react with a limestone and water mixture. Another way to decrease the amount of sulfur dioxide is by burning low-sulfur coal.

Electric power plants that burn fossil fuels emit particulates into the atmosphere. Particulate matter in smoke from power plants can be removed with an electrostatic separator, shown in **Figure 15.** Plates in the separator give the smoke particles a positive charge. As the smoke particles move past negatively-charged plates, the positively-charged particles adhere to the negatively-charged plates.

Getting Around Recent improvements in vehicle design and in how gasoline is made, as well as the use of emissions-control devices such as catalytic converters, have reduced automobile emissions significantly. Future advances in technology might reduce emissions further. Why is this important? Americans are driving more today than they did in the past. More time spent driving leads to more traffic congestion. Cars and trucks produce more pollution when they are stopped in traffic.

The Clean Air Act can work only if we all cooperate. Cleaning the air takes money, time, and effort. How might you take part in this cleanup? You can change your lifestyle. For example, you can walk, ride a bike, or use public transportation to get to a friend's house instead of asking for a ride. You also can set the thermostat in your house lower in the winter and higher in the summer.

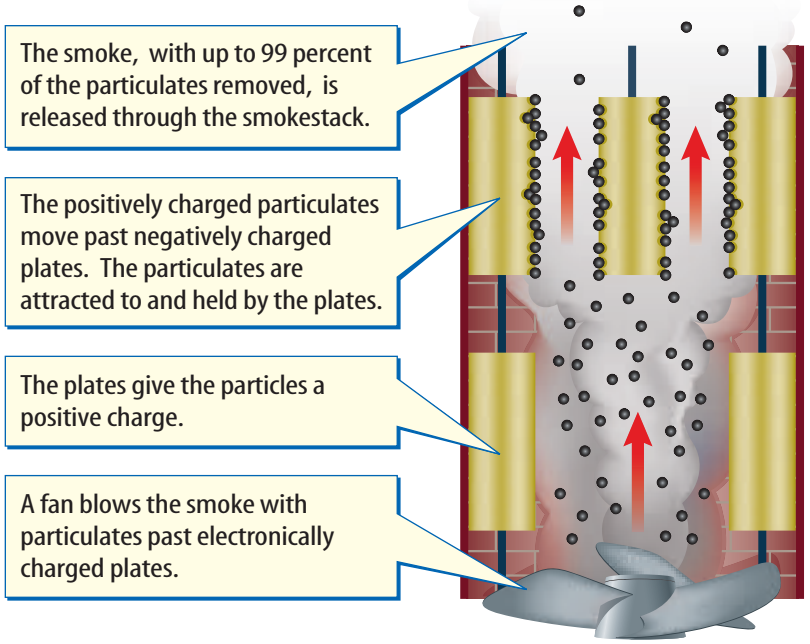


Figure 15 Electrostatic separators can remove almost all of the particulates in industrial smoke.

Reading Check *What can you do to prevent air pollution?*

section 2 review

Summary

Causes of Air Pollution

- Vehicles, electric generation, and dust from human activity contribute to air pollution.

What is smog?

- Smog forms when compounds react in the presence of sunlight to form ozone.
- Temperature inversions can worsen smog.

Acid Rain

- Exhaust from burning coal and gasoline can form acid rain.

CFCs

- Chlorofluorcarbons can damage Earth's ozone layer.

Air Pollution and Your Health

- Air pollution can cause breathing problems.

Self Check

1. **List** three pollutants released into the air when fuels are burned.
2. **Explain** how smog forms.
3. **Infer** how people can reduce air pollution.
4. **Think Critically** Laws were passed in 1970 requiring coal-burning power plants to use tall smokestacks to disperse pollutants. Power plants in the midwestern states complied with that law, and people in eastern Canada began complaining about acid rain. Explain the connection.

Applying Skills

5. **Classify** Use the information in **Table 1** to classify the following air quality indices: 43, 152, 7, 52, 147, and 98. Explain why it is important to have limits on pollutants from cars and factories as the U.S. population grows and people drive more.

LAB

Design Your Own

WHAT'S IN THE AIR?

Goals

- **Design** an experiment to collect and analyze particulate matter in the air in your community.
- **Observe and describe** the particulate matter you collect.

Possible Materials

small box of plain gelatin
hot plate
pan or pot
water
marker
refrigerator
plastic lids (4)
microscope
**magnifying lens*
**Alternate materials*

Safety Precautions

Wear a thermal mitt, safety goggles, and an apron while working with a hot plate and while pouring the gelatin from the pan or pot into the lids. Never eat anything in the lab.

Real-World Question

When you dust items in your household, you are cleaning up particles that settled out of the air. How often do you have to dust to keep your furniture clean? Just imagine how many pieces of particulate matter the air must hold. Do some areas of your environment have more particulates than other areas?

Form a Hypothesis

Based on your knowledge of your neighborhood, form a hypothesis to explain whether all areas in your community contain the same types and amounts of particulate matter.

Test Your Hypothesis

Make a Plan

1. As a group, agree upon your hypothesis and decide how you will test it.
2. **List** the steps you need to take to test your hypothesis. Describe exactly what you will do at each step. List your materials.
3. Prepare a data table in your Science Journal to record your observations.
4. Label your lids with the location where you decide to place them.
5. Mix the gelatin according to the directions on the box. Carefully pour a thin layer of gelatin into each lid. Use this to collect air particulate matter.
6. Read over your entire experiment to make sure that all steps are in a logical order.
7. Identify any constants, variables, and controls of the experiment.

Follow Your Plan

1. Make sure your teacher approves your plan.
2. Carry out the experiment as planned.
3. **Record** any observations that you make and complete the data table in your Science Journal.

Analyze Your Data

1. **Describe** the types of materials you collected in each lid.
2. **Calculate** the number of particles on each lid.
3. **Compare and contrast** your controls and your variables in this experiment.
4. **Graph** your results using a bar graph. Place the number of particulates on the *y*-axis and the test site location on the *x*-axis.

Conclude and Apply

1. **Determine** if the results support your hypothesis.
2. **Explain** why different sizes of particulate matter may be found at different locations.
3. **Infer** why some test-site locations showed more particulates than other sites did.

Communicating Your Data

Develop Multimedia Presentations

Give an oral presentation of your experiment on air pollution in your community to another class. **For more help, refer to the Science Skill Handbook.**

A biologist and writer who made people aware of the fragility of nature

MEET RACHEL CARSON

In 1958, retired biologist Rachel Carson (1907–1964) received a letter from a worried friend. Several songbirds had died immediately after the pesticide DDT was sprayed over an area of woods. In the 1940s and 1950s, DDT was sprayed over large areas of land to kill insects that caused crop damage and to eliminate diseases such as malaria. DDT was considered to be a scientific miracle. The letter Carson received, however, indicated something she had long suspected—there was a downside to the miracle.

After four years of research, interviews, and analysis, Carson wrote her famous book, *Silent Spring.* In it, she stated her findings that pesticides were killing birds and fish, and poisoning human food supplies. She wrote that unless action was taken, an eerie stillness would settle over the world, a world without songbirds—a silent spring.

The publication of *Silent Spring* led to a heated debate in the United States over the use of pesticides. But it also led to a change in how people thought about the natural world. Before Carson's book, few people thought about nature and how human activities might affect Earth's organisms. Thanks to *Silent Spring,* many people began to realize that Earth and the organisms living on Earth are closely connected.

Carson's findings were verified and DDT was banned. Many species of birds owe their continuing existence to her efforts. The most famous example is the national symbol of the United States—the bald eagle. DDT caused the bald eagles' eggs to weaken and break, bringing the species close to extinction. Since the ban on DDT, bald eagles have been making a comeback.

Make Posters **Research an environmental issue you are concerned about. Make posters to educate others in your school or community about the issue. Look for quotes you'd like to use to help illustrate your poster. You might find some in Carson's book.**

ScienceOnline
For more information, visit earth.msscience.com/time

Reviewing Main Ideas

Section 1 Water Pollution

1. Water pollution comes from industrial discharge; runoff of pesticides and fertilizers from lawns and farms; and sewage.
2. Sewage from homes and businesses is purified before it is released back into a stream or river.
3. National and international cooperation is necessary to reduce water pollution. In the United States, the 1990 Clean Water Act set up standards for sewage and wastewater-treatment facilities and for nonpoint sources.
4. Conserving water in your daily activities can help reduce water pollution.

Section 2 Air Pollution

1. Exhaust from vehicles pollutes the air. Other sources of air pollution include power plants, fires and volcanoes.
2. Natural conditions, such as landforms and temperature inversions, can affect the ability of the atmosphere to disperse air pollutants.
3. Polluted air can affect human health. Breathing particles, ozone, and acid rain can damage your lungs. Carbon monoxide can replace oxygen in your blood.
4. Air pollutants don't have boundaries. They drift between states and countries. National and international cooperation is necessary to reduce the problem.

Visualizing Main Ideas

Copy and complete the following concept map on types of pollution.

chapter 21 Review

Using Vocabulary

acid p. 611
acid rain p. 611
base p. 611
carbon monoxide p. 612
fertilizer p. 601
nonpoint source pollution p. 600
particulate matter p. 613
pesticide p. 601
pH scale p. 611
photochemical smog p. 610
point source pollution p. 600
scrubber p. 614
sewage p. 602

Fill in the blanks with the correct word or words.

1. A type of pollution that forms when nitrogen and carbon compounds are exposed to sunlight is called _____.
2. _____ can be controlled or treated because it enters water from a specific location.
3. The water that goes into drains, called _____ contains wastes and detergent.
4. Substance with a pH higher than 7 is called a(n)_____.
5. _____ are fine solids such as dust, ash and soot.

Checking Concepts

Choose the word or phrase that best answers the question.

6. Which describes warm air over cool air?
   A) inversion **C)** pollution
   B) CFCs **D)** scrubber
7. Which of the following describes substances with a low pH?
   A) neutral **C)** dense
   B) acidic **D)** basic
8. What combines with moisture in the air to form acid rain?
   A) ozone **C)** lead
   B) sulfur oxides **D)** oxygen
9. Which of the following is a nonpoint source?
   A) runoff from a golf course
   B) discharge from a sewage treatment plant
   C) wastewater from industry
   D) discharge from a ditch into a river
10. What is the largest source of water pollution in the United States?
    A) sediment **C)** heat
    B) metals **D)** gasoline
11. What is the pH of acid rain?
    A) less than 5.6
    B) between 5.6 and 7.0
    C) greater than 7.0
    D) greater than 9.5
12. What kind of pollution are airborne solids that range in size from large grains to microscopic?
    A) pH **C)** particulate matter
    B) ozone **D)** acid rain
13. Which of the following causes algae to grow?
    A) pesticides **C)** metals
    B) sediment **D)** fertilizers

Use the table below to answer question 14.

Phosphorus Entering Lake Erie

Year	Metric Tons
1976	15,000
1982	12,000
1988	8,000
1995	7,000

14. Which of the following is the best estimate of the decrease in phosphorous entering Lake Erie from 1976 to 1995?
    A) 10% **C)** 75%
    B) 20% **D)** 50%

Thinking Critically

15. Describe how cities with smog problems might lessen the dangers to people who live and work in the cities.

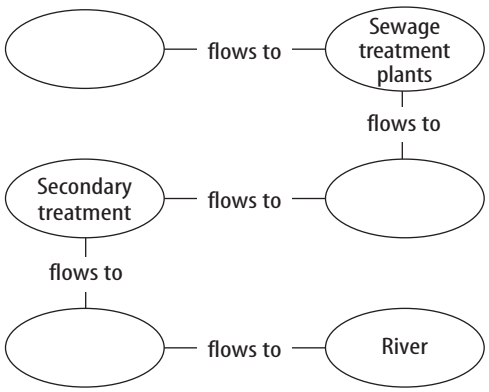
16. List some ways to control nonpoint pollution sources.

17. Recognize Cause and Effect Why is it important to place stricter limits on pollutants from cars and factories as the U.S. population grows and people drive more?

18. Draw Conlusions Pollution occurs when heated water is released into a nearby body of water. What effects does this type of pollution have on organisms living in the water?

19. Infer how a community in a desert might cope with water-supply problems.

20. Concept Map Copy and complete this concept map about sewage treatment.



21. Communicate Explain what you personally can do to reduce air pollution.

22. List three ways air pollution can affect your health.

23. Recognize Cause and Effect Your community is downstream from a large metropolitan area. Explain why it might cost more money to produce clean drinking water for your community than a similar community upstream.

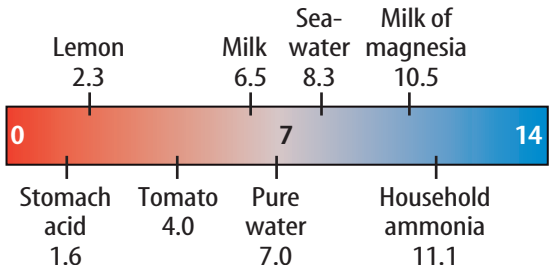
Performance Activities

24. Design and Perform an Experiment to test the effects of acid rain on vegetation. You might choose to use different types of vegetation as your variable and use acidity level as your constant or you might want to use the pH of the solution as your variable and use the type of vegetation as your constant. Remember to test one variable at a time.

25. Letter to the Editor Survey your town for evidence of air and water pollution. Write a letter to the editor of your local newspaper communicating what you have observed. Include suggestions for reducing pollution.

Applying Math

Use the figure below to answer questions 26 and 27.



26. pH Scale A decrease of one pH unit on the pH scale means that the solution is ten times more acidic. A decrease of two means the solution is 100 times more acidic. How much more acidic is tomato juice than pure water?

27. Estimate How much more acidic is milk than milk of magnesia?

28. Travel Your family car travels 20 miles on one gallon of gas. You visit your friend who lives two miles away three times a week. Calculate how much gas you would save in five weeks if you walked or rode your bike to your friend's house. Estimate how much gas you would save in one year.

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. This term describes pollution from industrial outfalls or ditches.
- **A.** point source pollution
- **B.** nonpoint source pollution
- **C.** runoff pollution
- **D.** chemical pollution

Use the photo below to answer question 2.

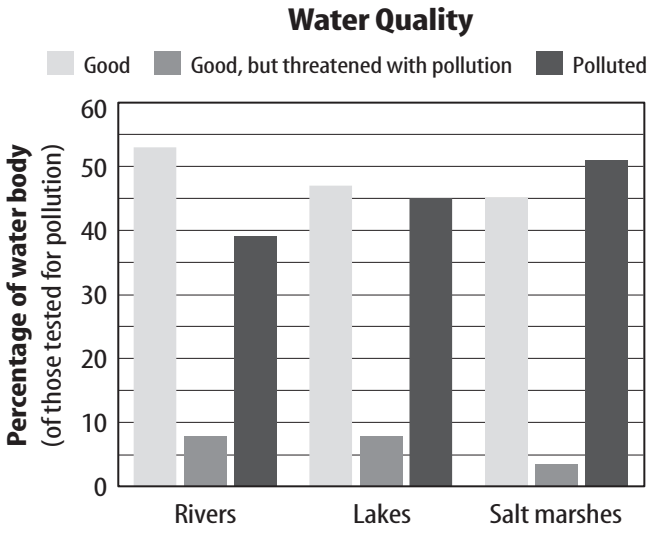
2. Which type of pollution might come from this site?
- **A.** point source pollution
- **B.** nonpoint source pollution
- **C.** acid rain
- **D.** smog

3. Which is the largest source of water pollution in the United States?
- **A.** sewage
- **B.** metals
- **C.** oil
- **D.** sediment

4. Which substance in fertilizers can cause an overgrowth of algae?
- **A.** carbon
- **B.** nitrogen
- **C.** hydrogen
- **D.** oil

5. Which areas have the most smog?
- **A.** urban areas
- **B.** mountains
- **C.** deserts
- **D.** saltwater marshes

Use the graph below to answer questions 6 and 7.



6. What is the estimated percentage of rivers with a pollution rating of good?
- **A.** 17%
- **B.** 38%
- **C.** 45%
- **D.** 53%

7. What percentage of lakes are polluted?
- **A.** 8%
- **B.** 45%
- **C.** 53%
- **D.** 50%

8. What might happen if heated water is released to a body of water?
- **A.** oxygen levels decrease
- **B.** oxygen levels increase
- **C.** pH decreases
- **D.** pH increases

9. Acid rain has what affect on the pH of natural lakes and streams?
- **A.** it increase the pH
- **B.** it decreases the pH
- **C.** it stabilizes the pH
- **D.** it doesn't affect the pH

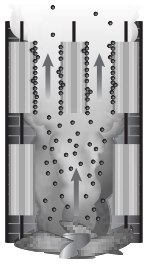
Scott T. Smith/CORBIS
CONTENTS

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. List three pollutants that can be removed by a sewage treatment plant.

Use the illustration below to answer questions 11 and 12.



11. What type of pollution is removed by this device?

12. Explain how this device removes pollutants from smoke.

13. Why is it better for the environment for countries to work together to reduce pollution?

14. What type of damage does acid rain cause?

15. What is the ozone layer and how is it being damaged?

16. How do particulates get into the air and what type of damage do they cause to your lungs?

17. What pollution sources contribute to smog?

18. What pollutant was addressed by the Montreal Protocol?

19. What device can lower sulfur dioxide emissions from coal-burning power plants?

Test-Taking Tip

Diagrams Study a diagram carefully, being sure to read all labels and captions.

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the table below to answer question 20.

Source of Water Pollution	Example of Water Pollution from Source
Agriculture and lawn care	pesticide
Sewage	human waste
Highway runoff	oil and gasoline
Factories using water to cool equipment	heat

20. List one method that might be used to reduce each example of water pollution.

21. In a year, a family can save 2,400 L of water by fixing a leaky faucet, 82,000 L by replacing an old toilet, and 7,000 L by turning the water off while brushing their teeth. How much water would be saved if 50 families did these water conservation efforts for 5 years? Show your results in a bar graph showing the total amount saved for each conservation measure.

22. The United States Department of Commerce Census Bureau reported that construction rates raised 1.6 percent during the first five months of 2003. How might this rate effect water pollution? What type of damages might be caused?

23. How did the old gasoline storage tanks at gas stations contribute to water pollution? How is this problem being solved?

24. How did Lake Erie become polluted? What measures have been taken to reduce the amount of pollution?

25. Explain how sunny days and other conditions in the atmosphere can worsen air pollution and smog.