Environmental Health
267
From the salt on your table to the cleaners in your cabinets, chemicals surround you. Many of them are harmless in small amounts, but some are toxic at low concentrations. Because of this, it is important to know what the harmful chemicals are—and how and when you might encounter them in your daily life.

Chemical Hazards
- All chemicals can be hazardous in large enough quantities.

A chemical hazard, or toxic substance, is any chemical that may harm human health. It’s important to remember that any chemical can be harmful in large enough amounts. For example, a person can die from drinking too much water, too quickly. In moderate amounts though, water is not only harmless, but necessary for human survival. Other chemicals, such as methylmercury that can accumulate in fish tissue, are toxic in small amounts. In essence, “the dose makes the poison.”

As you learned in the first lesson, a substance’s toxicity depends not just on what it is, but on how much of it a person is exposed to. This lesson focuses on chemicals that may be present in the environment at levels that could harm human health.

You may be tempted to think of chemical hazards as simply another term for pollution—but this is not completely true. Pollution is matter or energy that is released into the environment, causing negative effects that impact people, wildlife, and other aspects of the environment. While some pollutants, such as methylmercury, are chemicals, there are other forms of pollution that are not. Similarly, chemical hazards include chemicals that are not pollutants. For example, an oil found in the tissues of poison ivy plants can cause itchy, blistering rashes on human skin (Figure 12). This oil is considered a chemical hazard because it harms human health, but it is not a pollutant because it doesn’t harm the environment.
Types of Chemical Hazards

Chemical hazards can cause cancer, birth defects, and improper functioning of human body systems.

Not every chemical affects human health in the same way. In fact, chemical hazards can be classified by how they affect people. Some chemicals cause cancer. Others cause birth defects. Still others harm the nervous system. Common groups of chemical hazards are carcinogens, chemical mutagens, teratogens, neurotoxins, allergens, and endocrine disruptors.

**Carcinogens** Chemicals that cause cancer are known as carcinogens. Cancer is a disorder in which some of the body’s cells lose the ability to control growth. As a result, the cells grow uncontrollably, forming tumors, damaging the body’s functioning, and often leading to death. Cancer often has a genetic component, but a wide variety of environmental factors are thought to increase the risk of cancer. In our society today, nearly one third of cancer cases are thought to result from carcinogens contained in cigarette smoke. Carcinogens can be difficult to identify because there may be a long lag time between exposure to the agent and the detectable onset of cancer. Cancer is a leading cause of death that kills millions and leaves few families untouched. As a result, the study of carcinogens has influenced the way that toxicologists pursue their work.

**Chemical Mutagens** Chemical mutagens are substances that cause genetic changes, or mutations, in the DNA of an organism. Although most mutations have little or no effect, some can lead to severe problems, including cancer. If a harmful mutation occurs in an individual’s sperm or egg cells, then the individual’s offspring will suffer the effects.

**Teratogens** Chemicals that harm embryos and fetuses are called teratogens. Teratogens that affect the development of human embryos and fetuses can cause birth defects. One example involves the drug thalidomide, developed in the 1950s as a sleeping pill and to prevent nausea during pregnancy. Tragically, the drug turned out to be a powerful teratogen, and its use caused birth defects in thousands of babies. Even a single dose during pregnancy could result in limb deformities (Figure 13) and organ defects. Thalidomide was banned in the 1960s once scientists recognized its connection with birth defects. Ironically, today the drug shows promise in treating a wide range of diseases, including Alzheimer’s disease, AIDS, and various types of cancer.

**Neurotoxins** Chemicals that affect the nervous system are called neurotoxins. Neurotoxins include various heavy metals such as lead, mercury, and cadmium, as well as pesticides and some chemical weapons developed for use in war. A famous case of neurotoxin poisoning occurred in Japan, where a chemical factory dumped mercury waste into Minamata Bay from the 1930s to the 1960s. Thousands of people near the bay ate fish contaminated with the mercury, and soon started showing signs of mercury poisoning, including slurred speech, loss of muscle control, and in some cases death.
In 1968, the Japanese government confirmed that the dumping was causing the mercury poisoning and ordered the company to stop the dumping. Today, the bay has been cleaned up and reopened for fishing.

**Allergens** The human immune system protects our bodies from disease. Some substances weaken the immune system, reducing the body’s ability to defend itself. Other substances, called **allergens**, overactivate the immune system, causing an immune response when one is not necessary. Some common chemical allergens include animal proteins, tobacco smoke, and certain antibiotics. Living organisms, such as mold and bacteria, can also be allergens. Symptoms of an allergic reaction include hives, skin rashes, itchy skin and eyes, swelling, and wheezing. Allergens are not considered to be toxic substances, however, because they affect some people but not others.

Asthma, an inflammation of the respiratory system, is a major health problem in the United States. In fact, it has become the most common chronic childhood disease, affecting 7 million American children in 2008. One hypothesis for the increase in asthma occurrences is that allergenic synthetic chemicals are more prevalent in our environment.

**Endocrine Disruptors** Another type of chemical hazard, endocrine disruptors, interferes with the endocrine system. The endocrine system is the body system that sends and receives chemical signals, called hormones. It regulates body functions such as growth, development, and sexual maturity. The endocrine system also regulates brain function, appetite, and many other aspects of our physiology and behavior. Some hormone-disrupting substances can affect an animal’s endocrine system by blocking the action of hormones or accelerating their breakdown. Others are so similar to certain hormones in their molecular structure and chemistry that they “mimic” the hormone by interacting with receptor molecules just as the actual hormone would. Because endocrine disruptors affect the development of the body’s organs and endocrine system, fetuses, infants, and small children are at the greatest risk.

<table>
<thead>
<tr>
<th>Type of Chemical Hazard</th>
<th>Example</th>
<th>Found In</th>
<th>Effects on Humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcinogen</td>
<td>Tobacco smoke</td>
<td>Burning tobacco products</td>
<td>Lung cancer and chronic respiratory ailments</td>
</tr>
<tr>
<td>Chemical mutagen</td>
<td>Benzene</td>
<td>Secondhand smoke, gasoline, air pollution</td>
<td>Lowsers white blood cell count and can cause leukemia</td>
</tr>
<tr>
<td>Teratogen</td>
<td>Alcohol</td>
<td>Alcoholic beverages</td>
<td>Mental retardation and birth defects in developing embryos and fetuses</td>
</tr>
<tr>
<td>Neurotoxin</td>
<td>Methylmercury</td>
<td>Contaminated fish tissues</td>
<td>Speech, hearing, vision, and walking impairments; skin tingling; movement coordination loss; muscle weakness; impaired nervous system development in fetuses</td>
</tr>
<tr>
<td>Allergen</td>
<td>Animal skin and saliva proteins</td>
<td>Cats, dogs, and other animals</td>
<td>Itchy eyes, sneezing, runny nose, congestion, postnasal drip, cough</td>
</tr>
<tr>
<td>Endocrine disruptor</td>
<td>PCBs</td>
<td>Fish tissues, soil, contaminated water</td>
<td>Altered thyroid hormone levels</td>
</tr>
</tbody>
</table>
Indoor Chemical Hazards

Our homes and buildings may contain chemical hazards including asbestos, radon, volatile organic compounds, carbon monoxide, and lead.

Many of the most obvious chemical hazards are outdoors—oil spills, toxic waste dumps, and smoke-filled air. However, significant amounts of chemical hazards are also found indoors. Since many Americans spend most of their day indoors, it is important to consider how these hazards may affect our health.

Indoor Air Pollution The air inside homes and buildings can contain chemical hazards. Sometimes, these hazards are not easy to detect. However, they can have noticeable effects on human health. Asbestos, radon, and volatile organic compounds (VOCs) are just a few examples of indoor air pollutants.
**Asbestos** Asbestos is a mineral that forms long, thin microscopic fibers as shown in the inset of Figure 16. This structure allows asbestos to insulate heat, muffle sound, and resist fire. Because of these qualities, asbestos was used widely as insulation in buildings and in many products.

When disturbed, asbestos-containing insulation and products can release the fibers into the air. These fibers can then be inhaled and may lodge in lung tissue. Fibers embedded in the lung tissue may cause serious lung diseases, including cancer and asbestosis.

Because of these risks, asbestos has been removed from many schools and offices. However, removing asbestos may sometimes be more dangerous than leaving it in place because improper removal of asbestos increases airborne exposure.

**Radon** Another indoor hazard is radon. Radon is a colorless, odorless, highly toxic radioactive gas. It is made and released naturally when uranium in rock, soil, and water decays. It can seep up from the ground and build up inside basements and homes with poor air circulation. The U.S. EPA estimates that slightly less than 1 person in 1000 may contract lung cancer as a result of a lifetime of radon exposure at average levels.

The level of radon exposure a person might experience depends in part upon the geology of the place he or she lives. Certain areas have a higher risk for radon exposure than others. Figure 17 shows the relative risk of radon exposure for different locations in the United States.

Radon is detected using special kits. If high levels of radon are found in your home, there are ways to reduce your exposure. For example, a technique called soil suction involves installing one or more pipes under your home. Radon is then vented above ground through the pipe.

**FIGURE 16 Asbestos** The long, thin fibers of asbestos (inset) make it a good insulator, but when inhaled they can cause lung disease. Only trained personnel wearing protective gear should remove asbestos.

**FIGURE 17 Radon Risk in the United States** This map shows U.S. regions that, due to their geology, have low, moderate, and high levels of radon risk.
**Volatile Organic Compounds (VOCs)** The most diverse group of indoor air pollutants are volatile organic compounds (VOCs). These carbon-containing compounds are released into the air by many products including plastics, perfumes, and pesticides. Although we are surrounded by products that give off VOCs, volatile organic compounds tend to be released in very small amounts.

Since there are so many different types of VOCs, and we are exposed to them at such low levels, it is difficult to determine exactly how VOC exposure may affect our health. An exception is formaldehyde, which has known health impacts. Formaldehyde is a VOC used in pressed wood and insulation, among other products. Exposure to formaldehyde can irritate the eyes, nose, throat, and skin.

**Carbon Monoxide** A colorless and odorless gas, carbon monoxide can be difficult to detect without special equipment. At low levels, carbon monoxide can cause headaches, dizziness, nausea, and fatigue. With higher exposure, impaired vision, chest pain, lowered brain function, and death can occur.

Sources of carbon monoxide include leaky or unvented stoves, car exhaust, and tobacco smoke. One way to protect yourself against carbon monoxide poisoning is to install a carbon monoxide detector in your home. If your carbon monoxide alarm goes off, leave your house immediately. Then, call your local emergency number.

**Lead** Another indoor health hazard is lead. People can be exposed to lead through the air, drinking water, contaminated soil, lead-based paint, and dust. Lead poisoning can result from drinking water that has passed through lead pipes or pipes that have been joined with lead solder. Lead paint is another dangerous source of lead, especially for young children. Until 1978, most paints contained lead and the walls of many houses were painted with it. When this paint peels off walls, babies and young children may ingest or inhale it. When ingested, it can damage the brain, liver, kidneys, and stomach. Lead poisoning can also lead to learning problems, behavior abnormalities, anemia, hearing loss, and even death. Today, about one in six children under age 6 are likely affected by lead poisoning. In many states, young children are now tested for lead at their yearly doctor’s appointments.

FIGURE 18 Lead Poisoning In many older homes and apartments, lead-based paint covers the walls both inside and out. Unfortunately, curious young children may eat this peeling paint. Over time, lead poisoning could result.
Outdoor Chemical Hazards

There are chemical hazards in the air, on land, and in the water. Thousands of chemicals have found their way into the air, land, and water. A 2002 study found that one or more of 82 wastewater contaminants was found in 80 percent of streams in the United States. These contaminants include antibiotics, detergents, drugs, disinfectants, solvents, perfumes, and other substances.

Chemical Hazards in Air Chemical hazards in air come from both natural sources and human activity. For example, volcanic eruptions can release huge amounts of small particles, sulfur dioxide, and other gases. Human activities also release chemical hazards, such as carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead into the air.

Understanding what chemical hazards exist in the air is especially important because winds can carry chemicals far away from their original source. As a result, chemicals released into the air at one site can affect people and other organisms far away. Airborne transport of pesticides is sometimes called pesticide drift. The Central Valley of California is widely considered the most productive agricultural region in the world. But because it is a naturally arid area, food production depends on intensive use of irrigation, fertilizers, and pesticides. The region's frequent winds often blow the airborne spray—and dust particles containing pesticide residue—for long distances. In the mountains of the Sierra Nevada, research has associated pesticide drift from the Central Valley with population declines in four species of frogs. Families living in towns in the Central Valley have suffered health impacts, and activists for farm workers maintain that hundreds of thousands of the state's residents are at risk.
Chemical Hazards on Land  Land can also become contaminated with chemical hazards. Chemical hazards get into the soil in many ways. For example, when you use pesticides or improperly dispose of electronic equipment, you may be adding chemical hazards to the ground. Some common soil toxicants include pesticides and heavy metals such as lead.

Chemical hazards on or in land can affect both human and ecosystem health. People can inhale them, absorb them by touching contaminated soils, or ingest them while working with soil or eating produce grown in the area. In addition, soil toxicants can also be picked up by water that runs off of land.

Chemical Hazards in Water  Many chemicals are soluble in water and enter organisms’ tissues through drinking or absorption. For this reason, aquatic animals such as fish, frogs, and stream invertebrates are effective indicators of pollution. When aquatic organisms become sick, we can take it as an early warning that something is amiss. This is why many scientists see findings that show the effects of low concentrations of pesticides on frogs, fish, and invertebrates as a warning that humans could be next. The contaminants that wash into streams and rivers also flow and seep into the water we drink and drift through the air we breathe.

Chemicals get into our waterways in many different ways. For example, water can pick up toxic substances when it runs off land. If a car leaks oil onto a road, this oil may wash off the road during a rainstorm. The runoff, carrying the oil with it, may eventually find its way into a nearby river. Runoff is of particular concern to environmental scientists because it carries toxic substances from large areas of land and concentrates them in small amounts of surface water. In addition, chemical hazards may drain directly into a waterway from a specific source, such as a storm drain, as shown in Figure 20.
**Biomagnification**

Toxic chemicals accumulate in organisms as they feed on one another.

Of the toxic substances that organisms absorb, breathe, or consume, some are quickly excreted. Others are broken down into harmless products. Still others can last for months or years. How long a chemical lasts, or persists, can be a major concern for environmental scientists.

**Bioaccumulation** Organisms absorb, breathe, and ingest toxic substances from their environments. If these chemicals are persistent, or last a long time, organisms may end up storing them in their bodies. Eventually, organisms can build up large concentrations of toxic substances in their bodies, through a process called bioaccumulation. For example, DDT can accumulate in fatty tissues. Methylmercury can be stored in muscle tissue.

**The Process of Biomagnification** Toxic substances that bioaccumulate in the tissues of one organism may be transferred to other organisms as predators consume prey. When one organism consumes another, it takes in any stored toxic substances and stores them itself, along with the toxic substances it has received from eating other prey. Thus with each step up the food chain, from producers to primary consumer to secondary consumer and so on, concentrations of toxic substances can be greatly magnified, in a process called biomagnification.

The biomagnification of DDT is a good example of this process. In the 1940s through 1960s, DDT was a commonly used pesticide. However, it ran off land into waterways and was taken up by aquatic producers called phytoplankton. Zooplankton then fed on the phytoplankton and accumulated an increased concentration of DDT in their bodies. When small fish ate the zooplankton, they accumulated an even higher concentration of DDT in their tissues. Larger fish fed on smaller fish and fish-eating birds fed on larger fish. At each step up the food chain, the concentration of DDT was further increased in organisms’ bodies. Eventually, DDT concentrations were so high in bird tissues that it affected their ability to reproduce. Their eggshells became so thin they broke in the nest. Osprey populations started declining, and peregrine falcons were nearly wiped out. Figure 21 shows how DDT can be biomagnified up an aquatic food chain.

**Figure 21 Biomagnification** DDT becomes more concentrated in the tissues of organisms at each step up the food chain.
### Persistent Organic Pollutants (POPs)

Some toxic chemicals persist in the environment, biomagnify through the food web, and cause adverse effects to human health and the environment. These chemicals are called persistent organic pollutants (POPs). DDT is a persistent organic pollutant, as are PCBs (polychlorinated biphenyls).

POPs can be carried long distances by water and wind. This means that POPs released in one place can accumulate in locations far away. Because contaminants often cross international boundaries, an international treaty seemed the best way of dealing fairly with such transboundary pollution. The global nature of addressing POPs has led to an international response. For example, the *Stockholm Convention on Persistent Organic Pollutants* came into force in 2004 and was ratified by roughly 140 nations. The Stockholm Convention’s initial goal is to end the use and release of 12 of the most dangerous POPs, a group nicknamed the “dirty dozen” (Figure 22). It sets guidelines for phasing out these chemicals and encourages transition to safer alternatives. As of February 2009, a total of 152 countries had signed the treaty, including the United States.

Many of the POPs included in the Stockholm Convention are no longer produced in the United States. However, people and ecosystems can still be at risk from those that persist in the environment, or those that travel from elsewhere by wind or water.

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**ANSWERS**

**Lesson 3 Assessment** For answers to the Lesson 3 Assessment, see page A–14 at the back of the book.

1. **Review** Explain the phrase “The dose makes the poison.”
2. **Classify** List two types of chemical hazards that affect human health.
3. **Review** Name one indoor chemical hazard and describe how it can affect human health.
4. **Apply Concepts** A pollutant released on one continent is found concentrated in the tissues of organisms on another continent. Is this likely an air, land, or water pollutant? Explain.
5. **Explain** Describe the process of biomagnification.
6. **THINK IT THROUGH** A farmer decides to use a new pesticide on her fields to combat some new pests. She continues to apply it for several years. Over time, a neighbor notices that there are fewer and fewer big fish in a nearby pond. She can’t think of any explanation, so she notifies scientists at a local university. The scientists look into the issue and find that high levels of the pesticide have accumulated in the fishes’ tissues. Describe how this might have occurred.