DID YOU EVER THINK about all the items you throw in the trash each day? A paper napkin and empty yogurt container at breakfast; the contents of your lunch tray; the empty water bottle and apple core from an afternoon snack. And those are just items related to your meals! How about the plastic wrap that surrounds your news magazine? Or those dried-up pens and markers you threw in the trash? The list is probably much longer than you ever imagined. Now, think about the other people who live in your house … your city or town. Suddenly, the amount of garbage becomes overwhelming.

What Is Waste?

The three main categories of waste include municipal solid waste, industrial waste, and hazardous waste.

As the world’s human population increases, and as we produce and consume more material goods, we generate more waste. But, what exactly is waste? For the purpose of this chapter, waste is any unwanted material or substance that results from a human activity or process. Waste pollutes our water, air, and soil. It’s ugly to look at and even worse to smell. In order to safeguard public health and protect the environment, we need safe and effective waste management. In this lesson, you will learn about where our waste comes from and where it ends up.
Municipal Solid Waste  Municipal solid waste is waste that is produced by consumers, public facilities, and small businesses. It is what we commonly refer to as “trash” or “garbage.” Everything from paper, to tires, to food scraps, to roadside litter, to old appliances and furniture is considered municipal solid waste.

In the United States, paper, yard debris, food scraps, and plastics are the main components of municipal solid waste. Even after recycling, paper is the largest component of U.S. municipal solid waste. The average American generates more than 2.0 kilograms (4.5 pounds) of trash per day, or 745 kilograms (1643 pounds) per year!

► Packaging and Nondurable Goods  A large portion of municipal solid waste comes from packaging and nondurable goods. Packaging includes bubble wrap, blocks of styrofoam, and packing “peanuts.” Nondurable goods are products that we discard after a short period of use. Nondurable goods include items such as pens, disposable cameras, clothing, and furniture.

In addition, we throw away old durable goods and outdated equipment as we purchase new products. For example, do you know someone who got a new cell phone just because his or her contract had expired or because a new model became available? The “old” cell phone was probably in good working condition, but the person wanted something new. As we acquire more goods, we generate more waste.

► Plastic Products  During the 1970s, plastic products became widely available to consumers. They were inexpensive, nondurable goods. Most plastic products were made for temporary use. They wore out quickly and soon piled up in dumps. Since the 1970s, plastic products have accounted for a significant increase in solid waste.

How do our choices as consumers and waste producers affect our environment?

Explanation  Help students connect the information in Figure 1 to the Big Question. First, call on several volunteers to summarize the information in Figure 1. Then, have each student write an explanation of a specific way that consumer choices could affect the production of one category of waste.

FIGURE 1 Components of Municipal Waste  Paper products make up the largest component of the municipal solid waste stream in the United States. In total, the average U.S. citizen generates about 1600 pounds of solid waste each year. Tires are not accepted with regular garbage collection anymore and they pile up in dumps.

ANSWERS

Reading Checkpoint  Paper
**Industrial Waste**  The U.S. Environmental Protection Agency (EPA) classifies industrial waste as waste that is neither hazardous nor municipal solid waste. Industrial waste includes waste from factories, farms, mines, and refineries, as well as materials from construction sites. Industrial waste can also include medical waste, such as used surgical gloves and needles that have been used for drawing blood or giving injections.

Each year, U.S. industrial facilities generate about 7.6 billion tons of waste. Almost 97 percent of that waste is wastewater. The rest is solid waste—about 228 million tons. This amount almost equals the amount of municipal solid waste we dispose of each year. Most of the time, private companies collect and dispose of industrial waste.

**Methods of Solid Waste Disposal**

Current solid waste disposal methods are based on ancient practices of dumping, burying, or burning waste.

Historically, people dumped their garbage wherever it suited them. As cities and towns became more crowded, the garbage began to pile up. Local authorities took on the task of consolidating trash into open dumps at specified locations to keep other areas clean. To decrease the volume of trash, these dumps would be burned from time to time.

Open dumping and burning still occur throughout much of the world, as shown in Figure 2. As populations and consumption rise, waste is increasing and dumps are growing larger. As cities and suburbs expand, more people end up living next to dumps. These residents are repeatedly exposed to the harmful, toxic, and foul-smelling smoke from dump burning. As a result, more people are aware that unregulated dumping and burning damages their health and degrades the environment. In response to these hazards, many nations are improving their methods of waste disposal. Most industrialized nations now bury waste in landfills or use incinerators to burn waste.
**Sanitary Landfills** In modern **sanitary landfills**, waste is buried in the ground or piled up in large, carefully engineered mounds. In contrast to open dumps, sanitary landfills are designed to prevent contamination of groundwater and to reduce soil and air pollution. Most municipal landfills in the United States are regulated locally or by the states, but they must meet national standards set by the EPA.

You can see the parts of a sanitary landfill in **Figure 3**. In a sanitary landfill, waste is partially decomposed by bacteria and compressed under its own weight to take up less space. Waste is layered along with soil, a method that speeds decomposition, reduces odor, and reduces infestation by pests. Some infiltration of rainwater allows for biodegradation by different types of bacteria. However, if too much water gets in, some contaminants may escape as the excess water flows out.

To protect against environmental contamination, U.S. regulations require that landfills be located away from wetlands and earthquake-prone faults and be at least 6 meters (20 feet) above the water table. The bottom and sides of sanitary landfills must be lined with heavy-duty plastic and 60 to 120 centimeters (2 to 4 feet) of impermeable clay to help prevent contaminants from seeping into aquifers. Sanitary landfills must also have systems of pipes, collection ponds, and treatment facilities to collect and treat leachate. **Leachate** is the liquid that results when substances from the trash dissolve in water as rainwater percolates downward. Landfill managers are required to maintain leachate collection systems for 30 years after a landfill has closed. Regulations also require that area groundwater be monitored regularly for contamination.

**FIGURE 3 Sanitary Landfills**
Sanitary landfills are engineered to prevent waste from contaminating soil and groundwater. Waste is laid in a large depression lined with plastic and impermeable clay to prevent liquids from leaching out. Leachate collection pipes draw out these liquids from the bottom of the landfill. Waste is layered along with soil until the depression is filled, and it continues to be built up until the landfill is capped. Landfill gas produced by bacteria may be recovered, and waste managers monitor groundwater for contamination.
Closing Landfills

After a landfill is closed, it is capped with an engineered cover that must be maintained. This cap consists of a hydraulic barrier of plastic that prevents water from seeping down and gas from seeping up; a gravel layer above the hydraulic barrier that drains water, lessening pressure on the hydraulic barrier; a soil barrier of at least 60 centimeters (24 inches) that stores water and protects the hydraulic layer from weather extremes; and a topsoil layer of at least 15 centimeters (6 inches) that encourages plant growth, helping to prevent erosion.

Today thousands of landfills lie abandoned. One reason is that waste managers have closed many smaller landfills and consolidated the trash into fewer, much larger, landfills. In 1988 the United States had nearly 8000 landfills, but today it has fewer than 1700. Some landfills have been converted to recreational areas (Figure 4).

Drawbacks of Landfills

Despite improvements in liner technology, many experts believe that leachate will eventually escape even from well-lined landfills. Liners can be punctured, and leachate collection systems eventually cease to be maintained. Moreover, landfills are kept dry to reduce leachate, but the bacteria that break down material thrive in wet conditions. Dryness, therefore, slows waste decomposition. In fact, it is surprising how slowly some materials biodegrade when they are tightly compressed in a landfill. Innovative archaeological research has revealed that landfills often contain food that has not decomposed and 40-year-old newspapers that are still legible (Figure 5).

Another problem is finding suitable areas to locate landfills, because most communities do not want them nearby. This not-in-my-backyard (NIMBY) reaction is one reason why New York decided to export its waste and why residents of states receiving that waste are increasingly protesting. As a result of the NIMBY syndrome, landfills are rarely located in neighborhoods that are home to wealthy and educated people with the political clout to keep them out.

Capturing Energy From Landfills

Deep inside landfills, bacteria decompose waste in an oxygen-deficient (anaerobic) environment. This anaerobic decomposition produces landfill gas, a mix of gases of which almost 50 percent is methane. We can collect, process, and use landfill gas the same way we use natural gas. At Fresh Kills, collection wells pull landfill gas upward through a network of pipes by vacuum pressure. This tapped gas should soon provide enough energy for 25,000 homes.

Reading Checkpoint

What are two benefits and two costs of landfills?
Incineration  Just as sanitary landfills are an improvement over open dumping, incineration in specially constructed facilities can be an improvement over open-air burning of trash. **Incineration** is a controlled process in which mixed garbage is burned at very high temperatures (see Figure 6 on next page). Pollution control technology removes most, but not all, of the pollutants from the emissions. At incineration facilities, waste is generally sorted and metals removed. Metal-free waste gets chopped into small pieces so that it burns more easily. Incinerating waste reduces its weight by up to 75% and its volume by up to 90%.

As a result of real and perceived health threats from incinerator emissions—and of community opposition to these plants—engineers have developed several technologies to mitigate emissions. **Scrubbers** chemically treat the gases produced in combustion to remove hazardous components and neutralize acidic gases, such as sulfur dioxide and hydrochloric acid, turning them into water and salt. Scrubbers generally do this either by spraying liquids formulated to neutralize the gases or by passing the gases through dry lime. These scrubbers are similar to the ones used to treat smokestack emissions from coal-fired plants.

Particulate matter is physically removed from incinerator emissions in a system of huge filters known as a **baghouse**. These tiny particles, called fly ash, often contain some of the worst dioxin and heavy metal pollutants. In addition, burning garbage at especially high temperatures can destroy certain pollutants, such as PCBs. Even all these measures, however, do not fully eliminate toxic emissions.

**Drawbacks of Incineration**  Simply reducing the volume and weight of trash does not get rid of the toxins. The ash remaining after trash is incinerated therefore must be disposed of in hazardous waste landfills. Moreover, when trash is burned, hazardous chemicals—including dioxins, heavy metals, and PCBs—can be created and released into the atmosphere. Such releases caused a backlash against incineration from citizens concerned about health hazards. Most developed nations now regulate incinerator emissions, and some have banned incineration outright.

**Energy From Incineration**  Incineration was initially practiced simply to reduce the volume of waste, but today it serves as a way to generate electricity as well. Most North American incinerators today are waste-to-energy (WTE) facilities. These incinerators use the heat from burning waste to boil water, which creates steam that then drives a generator to make electricity. Steam from incinerators can also fuel heating systems. Burning waste equals almost 35 percent of the energy from burning coal.

Revenues from power generation, however, are usually not enough to offset the financial cost of building and running incinerators. Because it can take many years for a WTE facility to make a profit, many companies that build and operate these facilities require municipalities to guarantee a minimum amount of garbage. On occasion, such long-term commitments can defeat efforts to reduce waste through recycling because towns are required to “guarantee” a certain amount of trash.
In a waste-to-energy facility, solid waste is burned at extremely high temperatures, heating water in a boiler turning it to steam.

The steam turns a turbine which powers a generator to create electricity.

In an incinerator outfitted with pollution-control technology, toxic gases produced by combustion are mitigated by a scrubber.

Airborne particulate matter is filtered physically in a baghouse before air is emitted from the stack.

Ash remaining from the combustion process is disposed of in a landfill.

FIGURE 6 Incineration Incinerators reduce the volume of solid waste by burning it, but as a result may emit toxic compounds into the air. Many incinerators are waste-to-energy (WTE) facilities that use the heat of combustion to generate electricity.

ANSWERS
Lesson 1 Assessment For answers to the Lesson 1 Assessment, see page A-31 at the back of the book.

Lesson 1 Assessment

1. **Review** Define waste. What are the three main categories of waste?
2. **Explain** When it comes to solid waste disposal, how does incineration affect landfills?
3. **THINK IT THROUGH** Do the costs of incineration outweigh the benefits? (Hint: Prepare a cost-benefit analysis to help you answer the question.)