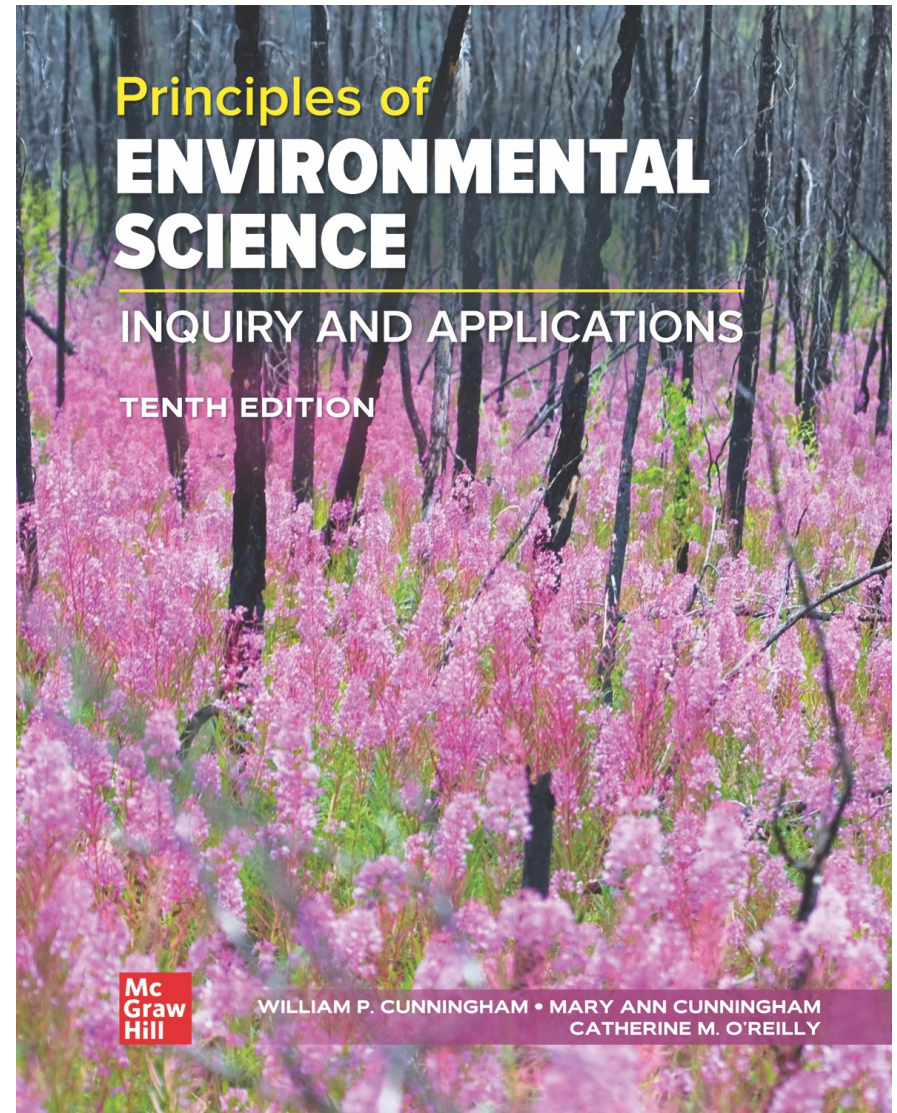


Chapter 14

Lecture Outline



Learning Outcomes

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

- What are the major components of the waste stream?
- How does a sanitary landfill operate? Why are we searching for alternatives to landfills?
- What alternatives do we have to landfills?
- What are the most important steps in the waste management hierarchy?
- Why is plastic recycling a challenge?
- What are toxic and hazardous waste? How do we dispose of them?
- What is bioremediation?
- What is the Superfund, and has it shown progress?

We are living in a false economy where the price of goods and services does not include the cost of waste and pollution.

–Lynn Landes, founder and director of Zero Waste America

CASE STUDY: Plastic Seas



14.1 What Waste Do We Produce?

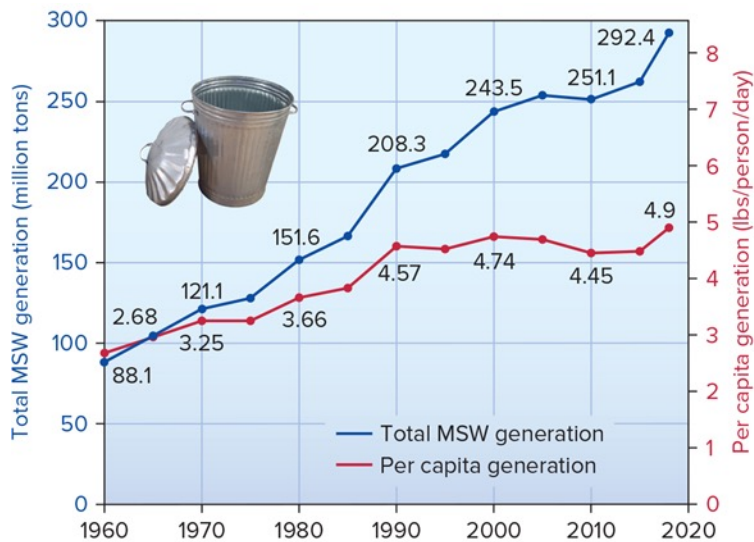
Waste includes:

Agricultural waste – including crop residues and manure

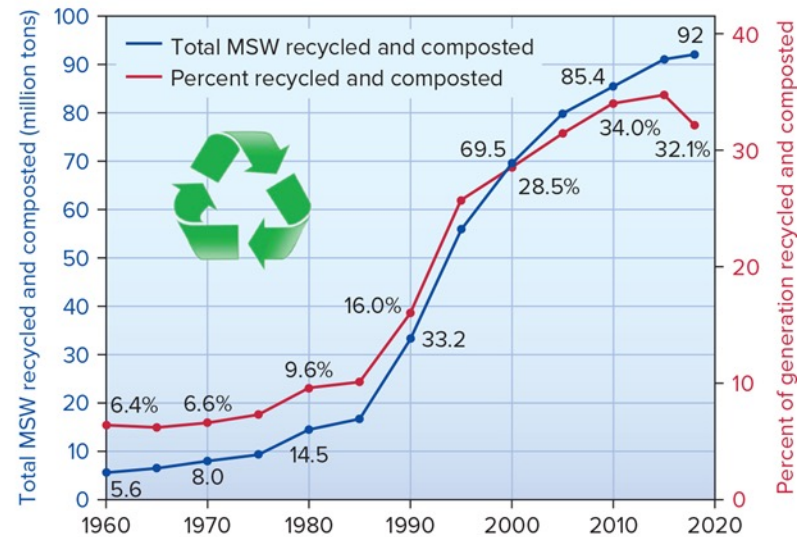
Industrial waste—other than mining and mineral production—amounts to some 400 million metric tons per year in the United States.

Municipal solid waste, the garbage we produce in our houses, offices, and cities, accounts for a small percentage of total waste, but it is hard to reuse and recycle because it contains many different materials.

Good News and Bad News in Solid Waste Removal



(a) Waste generation rates



(b) Recycling rates

[Access the text alternative for slide images.](#)

The Waste Stream Is Everything We Throw Away

The **waste stream** is a term that describes the steady flow of varied wastes that we all produce, from domestic garbage and yard wastes to industrial, commercial, and construction refuse.

Many of the materials in our waste stream would be valuable resources if they were not mixed with other garbage.

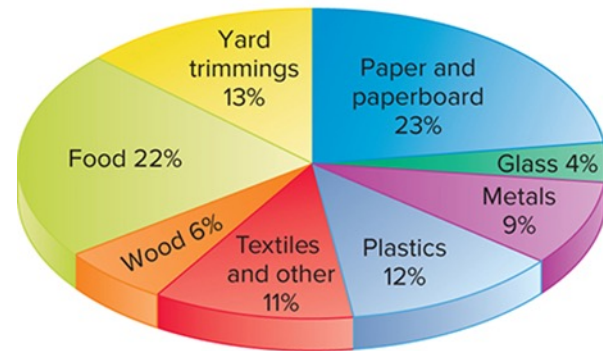
Unfortunately, our collecting and dumping processes mix and crush everything together, making separation an expensive and sometimes impossible task.

What Is in the Waste Stream?

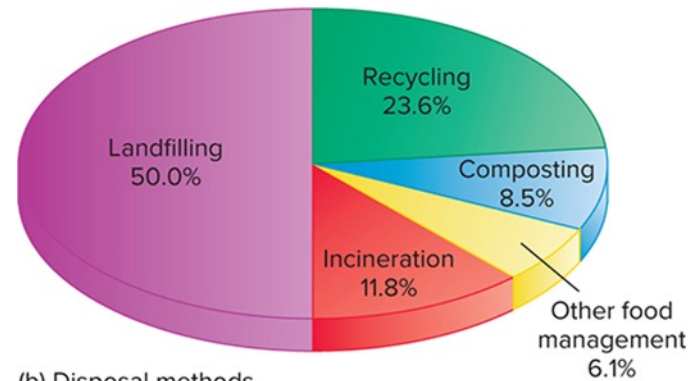
Organic materials, such as yard and garden wastes, food wastes, and sewage sludge.

Junked cars, worn-out furniture and consumer products.

Newspapers, magazines, packaging, ads, and paper office refuse.



(a) Amount generated, by weight



(b) Disposal methods

[Access the text alternative for slide images.](#)

14.2 Waste Disposal Methods

Where do our wastes go now?

We will examine some historic methods of waste disposal, as well as some future options.

Open Dumping Releases Trash to Air and Water

Open, unregulated dumps are still the predominant method of waste disposal in most developing countries.

Most developed countries forbid open dumping, at least in urban areas, but illegal dumping is still a problem.

Much of this trash washes into sewers and then into the ocean.

Illegally dumped garbage often includes toxic chemicals which show up in the groundwater.

Trash Disposal Has Become a Crisis in the Developing World



Ocean Dumping Is Mostly Uncontrolled

Every year some 25,000 metric tons (55 million lbs) of packaging, including half a million bottles, cans, and plastic containers, are dumped at sea.

Even in remote regions, beaches are littered with the non-degradable flotsam and jetsam.

About 150,000 tons (330 million lbs) of fishing gear—including more than 1,000 kilometers (660 miles) of nets—are lost or discarded at sea each year.

Until recently, many cities in the United States dumped municipal refuse, industrial waste, sewage, and sewage sludge into the ocean.

Federal legislation now prohibits this dumping.

Plastic Pollution Ends up at Sea and Is Ingested by Wildlife



(a)



(b)

The Great Pacific Garbage Patch

The **Great Pacific Garbage Patch**, discovered in 1997 by sailing captain Charles More, is the best known of these plastic debris fields.

In all the world's oceans, vast circulating currents known as gyres are driven by the earth's rotation.

These currents collect floating plastic debris, much of it tiny fragments, in regions thousands of km wide.

The North Pacific gyre has captured at least 100 million tons of plastic.

Landfills Receive Half of Our Waste

Landfills receive 50% of all U.S. municipal solid waste.

A modern **sanitary landfill** is designed to contain waste.

Refuse is compacted and covered daily with a layer of dirt, to decrease smells and discourage bugs and rats.

To reduce leaks, landfills use impermeable linings.



Methane and Landfills

Sanitary landfills must also manage methane, a greenhouse gas produced when organic material is inside a landfill.

Landfills are the single largest anthropogenic source of methane in the United States.

Globally, landfills are estimated to produce more than 700 million metric tons of methane annually.

Now about half of all landfill gas in the United States is either flared (burned) on site or is collected and used as fuel for electrical generation.

We Often Export Waste to Countries Ill-Equipped to Handle it

Most industrialized nations agreed to stop shipping hazardous and toxic waste to less-developed countries in 1989, but the practice still continues.

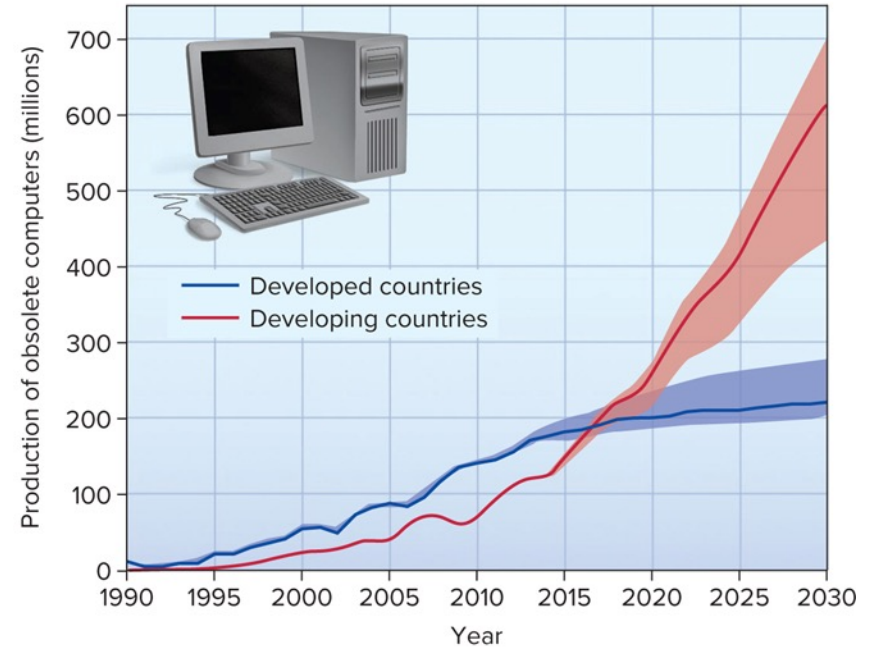
Most of the world's obsolete ships are now dismantled and recycled in poor countries. The work is dangerous, and old ships are often full of toxic and hazardous materials.

Discarded electronics, or **e-waste**, is one of the greatest sources of toxic material currently going to developing countries.

E-waste Is a Growing Problem



(a)



(b)

[Access the text alternative for slide images.](#)

Incineration Produces Energy from Trash

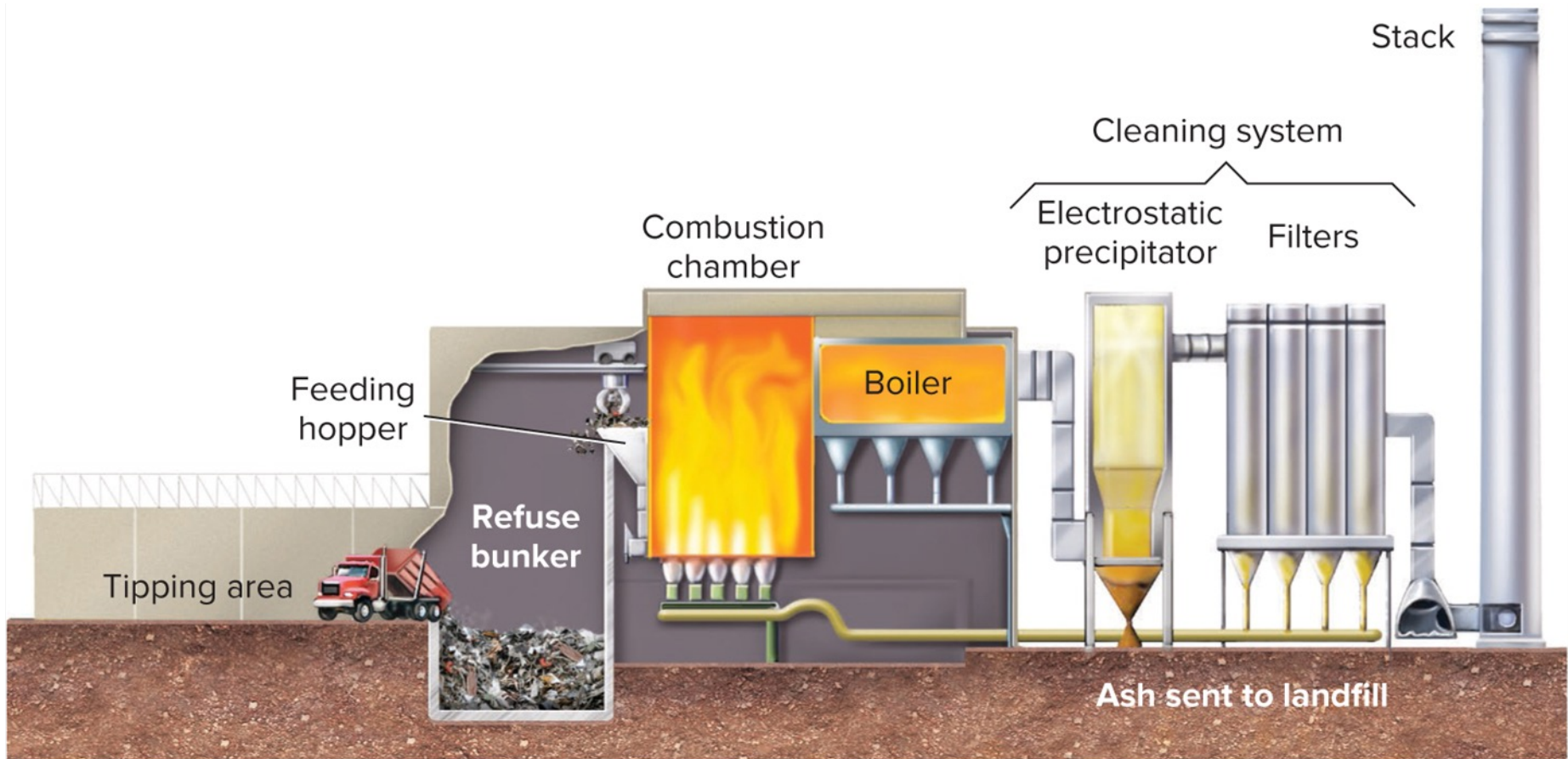
Many cities use waste incinerators to burn municipal waste.

Most incinerators do some degree of **energy recovery**, using the heat derived from incinerated refuse to heat nearby buildings or to produce steam and generate electricity.

Refuse-derived fuel is what's left after unburnable or recyclable materials are removed.

Another approach, called a **mass burn**, and burn as much as possible is to dump everything into a giant furnace, unsorted.

Mass Burn Garbage Incineration



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Incinerators Can Produce Health Risks

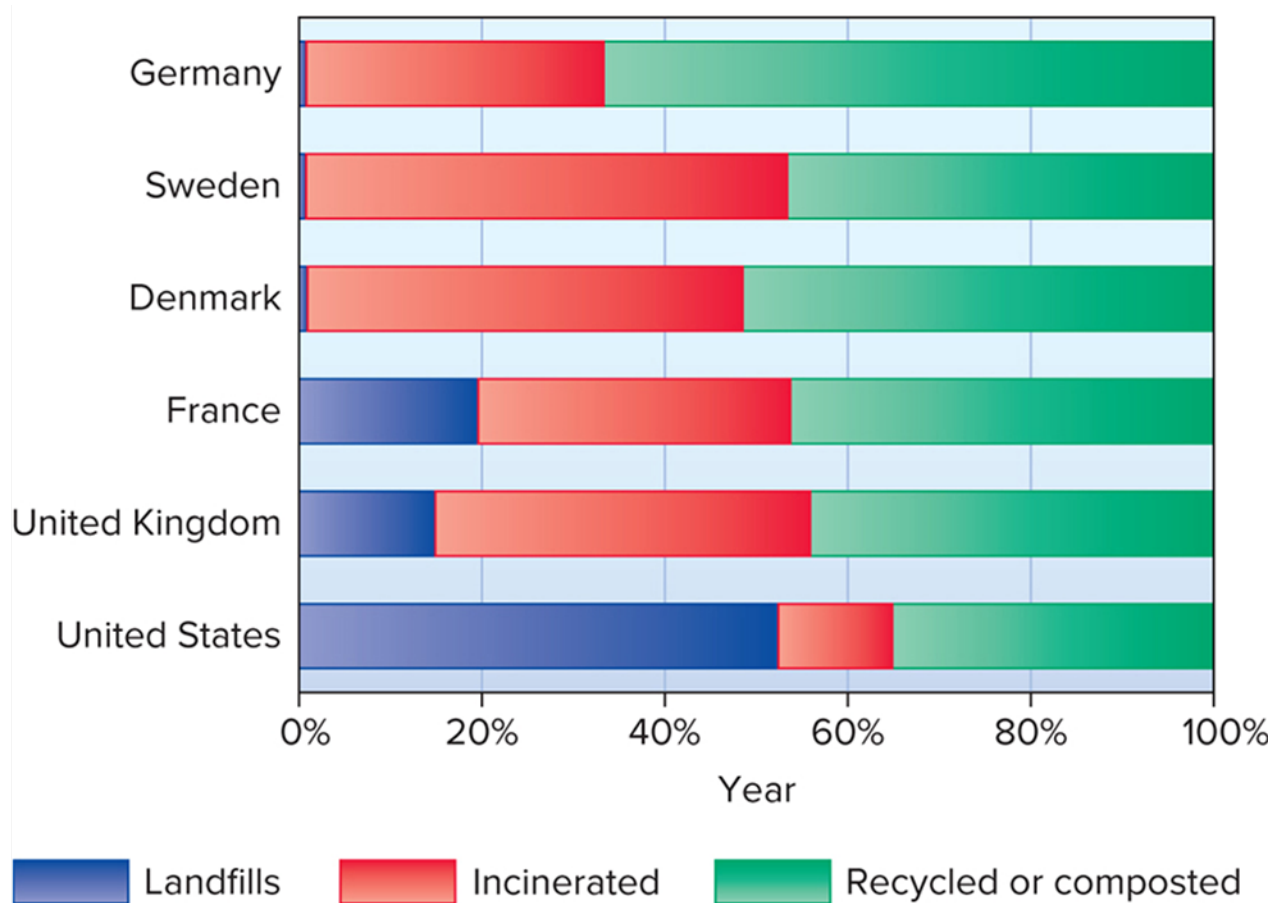
If they are not well built and well managed, incinerators can produce large amounts of ash and hazardous airborne emissions.

Residue from a mass burn often contains a variety of toxic components, including dioxins and furans, lead, and cadmium in incinerator ash.

These toxic materials are more concentrated in the fly ash which can penetrate deep into the lungs.

In one EPA study, all of the incinerators examined exceeded cadmium standards, and 80 percent exceeded lead standards.

Waste Disposal Methods Vary Among Countries



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14.3 Shrinking the Waste Stream

Compared to landfilling and incineration, recycling saves money, energy, raw materials, land space, and pollution.

Recycling is the reprocessing of discarded materials into new products.

Sometimes the same products are re-made: for instance, old aluminum cans and glass bottles are usually melted and recast into new cans and bottles.

Alternately, entirely new products can be made from old. For instance, old tires can be shredded and turned into rubberized playground or road surfacing.

Recycling Saves Raw Materials

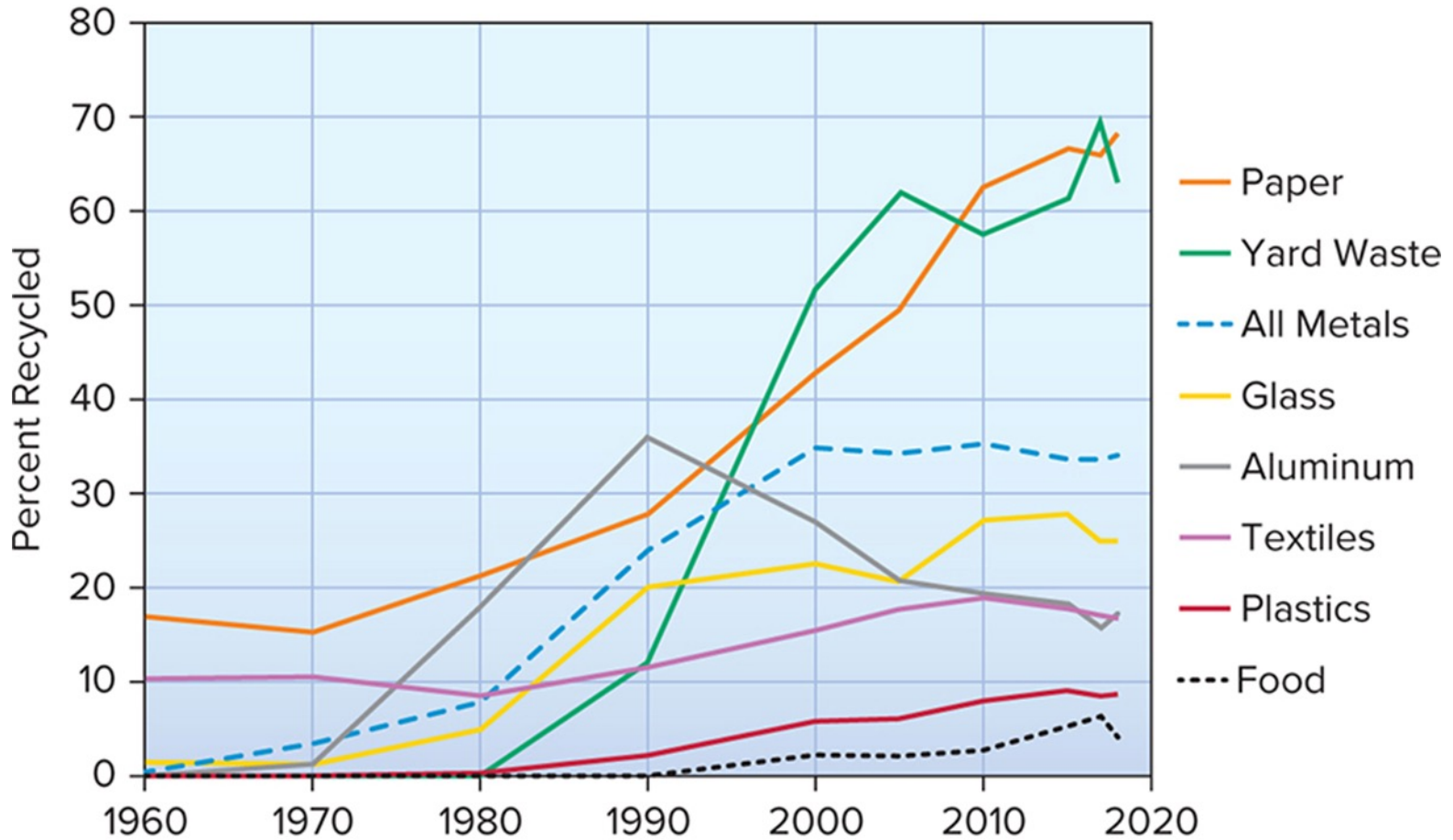
There have been some dramatic successes in recycling in recent years. Nationally, the U.S. recycles or composts one-third of all municipal solid waste.

Aluminum is probably the easiest and most valuable material to recycle, yet only half of aluminum cans are recycled in the United States.

Americans still throw away nearly 350,000 metric tons of aluminum cans each year--enough to make 3,800 Boeing 747 airplanes.

Wild fluctuations in commodity prices are also a challenge to developing a market for recyclables.

U.S. Recycling Rates



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Recycling Saves Money, Energy, and Space

Curbside pickup of recyclables costs around \$35 per ton, as opposed to the \$80 paid to dispose of them at an average metropolitan landfill.

Recycling lowers demand for raw resources.

Recycling also reduces energy consumption and air pollution.

Making new steel from old scrap offers up to 75 percent energy savings. Producing aluminum from scrap instead of bauxite ore cuts energy use by 95 percent.

Keeping Material Out of Landfills Has Multiple Benefits



Composting Recycles Organic Waste ¹

Pressed for landfill space, many cities have banned yard waste from municipal garbage.

Rather than bury this valuable organic material, they are turning it into a useful product through **composting**.

Composting is the biological degradation of organic matter under aerobic conditions.

The organic compost resulting from this process makes a nutrient-rich soil amendment that aids water retention, slows soil erosion, and improves crop yields.

Composting Recycles Organic Waste ₂



Reuse Is Even Better Than Recycling

Even better than recycling or composting is cleaning and reusing materials in their present form, thus saving the cost and energy of remaking them into something else.

Auto parts are regularly sold from junkyards.

Stained-glass windows, brass fittings, fine woodwork, and bricks salvaged from old houses are all reused in construction.

Some communities sort and reuse a variety of materials received in their dumps.

Reusing Discarded Products is a Creative Way to Reduce Waste



Reducing Waste Is Often the Cheapest Option

Recycling is good, but slowing the consumption of throw-away products is by far the most effective way to save energy, materials, and money.

Industries are increasingly finding that reducing saves money. Soft-drink makers use less aluminum per can than they did 20 years ago.

Excessive packaging of food and consumer products is one of our greatest sources of unnecessary waste.

Where disposable packaging is necessary, we still can reduce the waste by using degradable materials.

Garbage: Liability or Resource

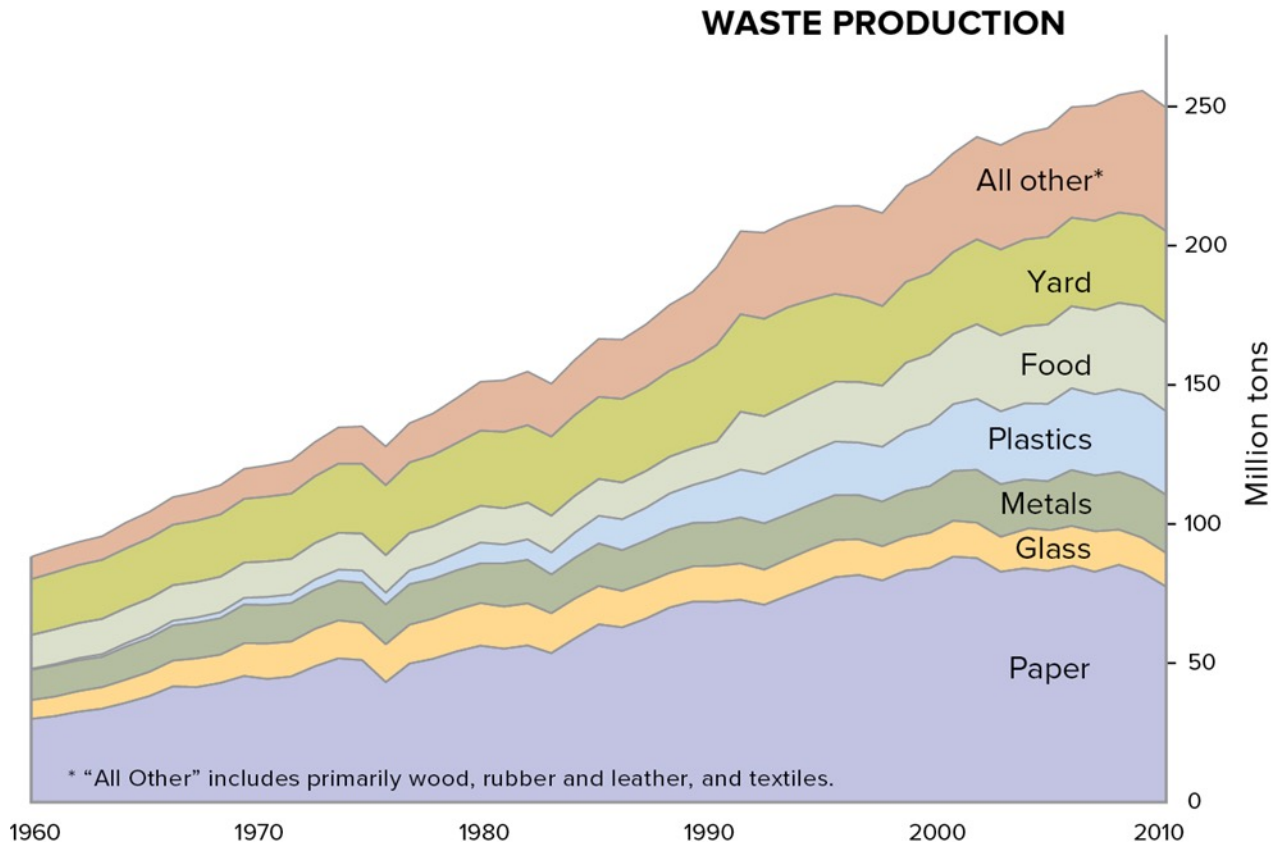
Municipal solid waste includes all our mixed refuse.

Most of us don't spend much time thinking about where our waste ends up, but as you know from the principle of conservation of matter, materials are never destroyed or created; they're just transformed from one shape to another.

Elements in our waste such as aluminum, lead, carbon, or nitrogen don't disappear.

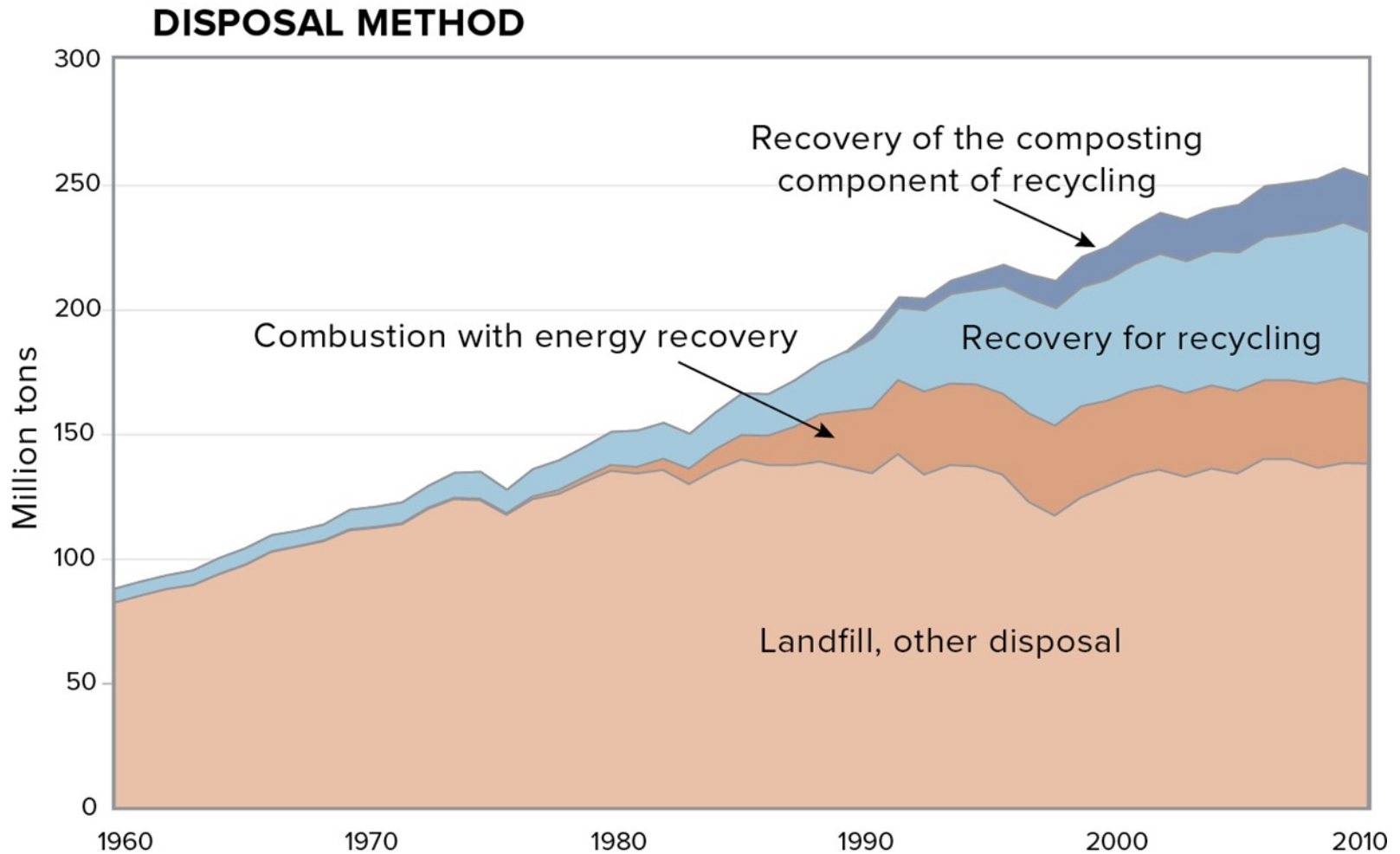
They may sit in a landfill for centuries, or they may be incinerated and emitted into the atmosphere, or they may be recycled and transformed into another useful object.

Waste Production



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Waste Disposal Method



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What Can You Do? Reducing Waste

Buy foods that come with less packaging; shop at farmer's markets or co-ops, using your own containers.

Take your own washable, refillable beverage container to meetings or convenience stores.

When you have a choice at the grocery store among plastic, glass, or metal containers for the same food, buy the reusable or easier-to-recycle glass or metal.

Separate your cans, bottles, papers, and plastics for recycling.

Wash and reuse bottles, aluminum foil, and plastic bags.

Compost yard and garden wastes, leaves, and grass clippings.

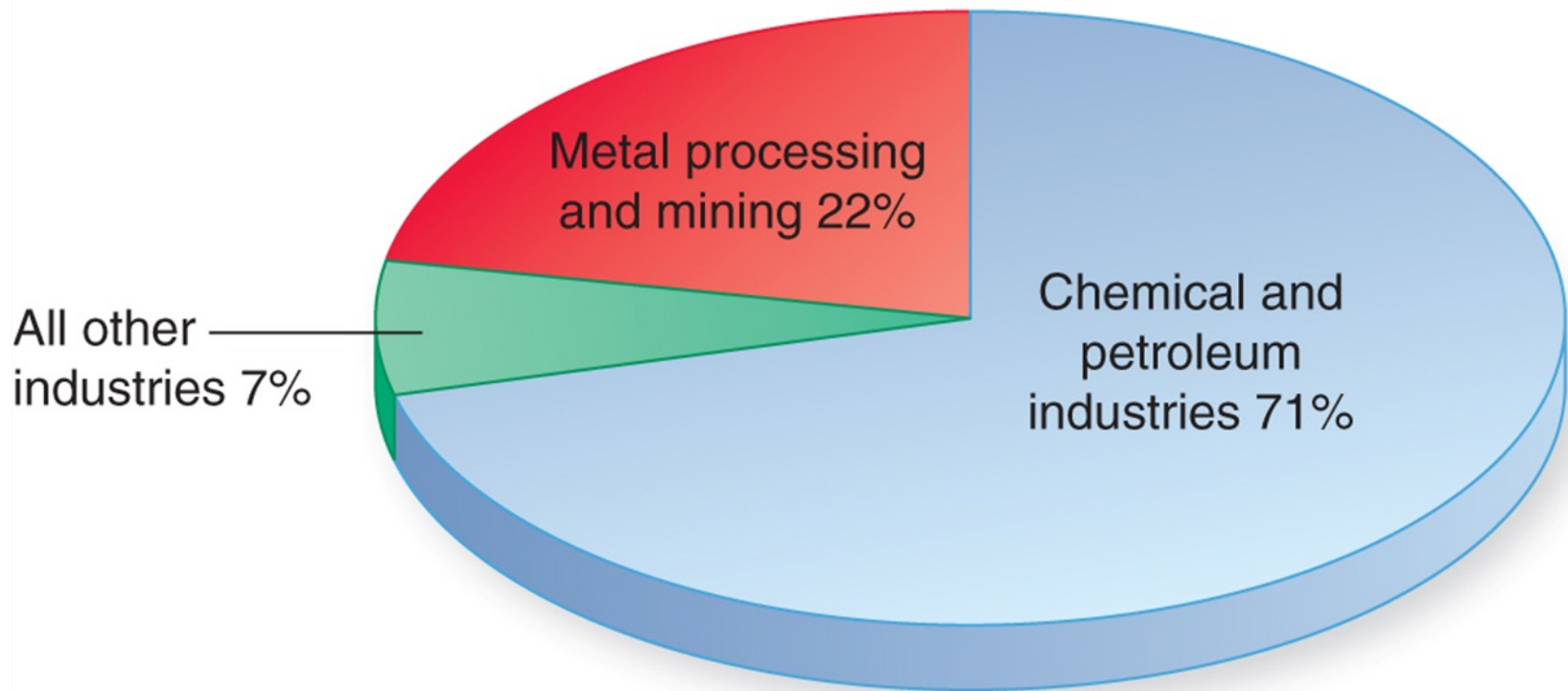
Help your school develop responsible systems for disposing of electronics and other waste.

14.4 Hazardous and Toxic Wastes

The most dangerous aspect of the waste stream is that it often contains highly toxic and hazardous materials that are injurious to both human health and environmental quality.



Chemical and Petroleum Industries Produce the Most Hazardous Waste



Hazardous Waste Includes Many Dangerous Substances

Legally, a **hazardous waste** is any discarded material, liquid or solid, that contains substances known to be:

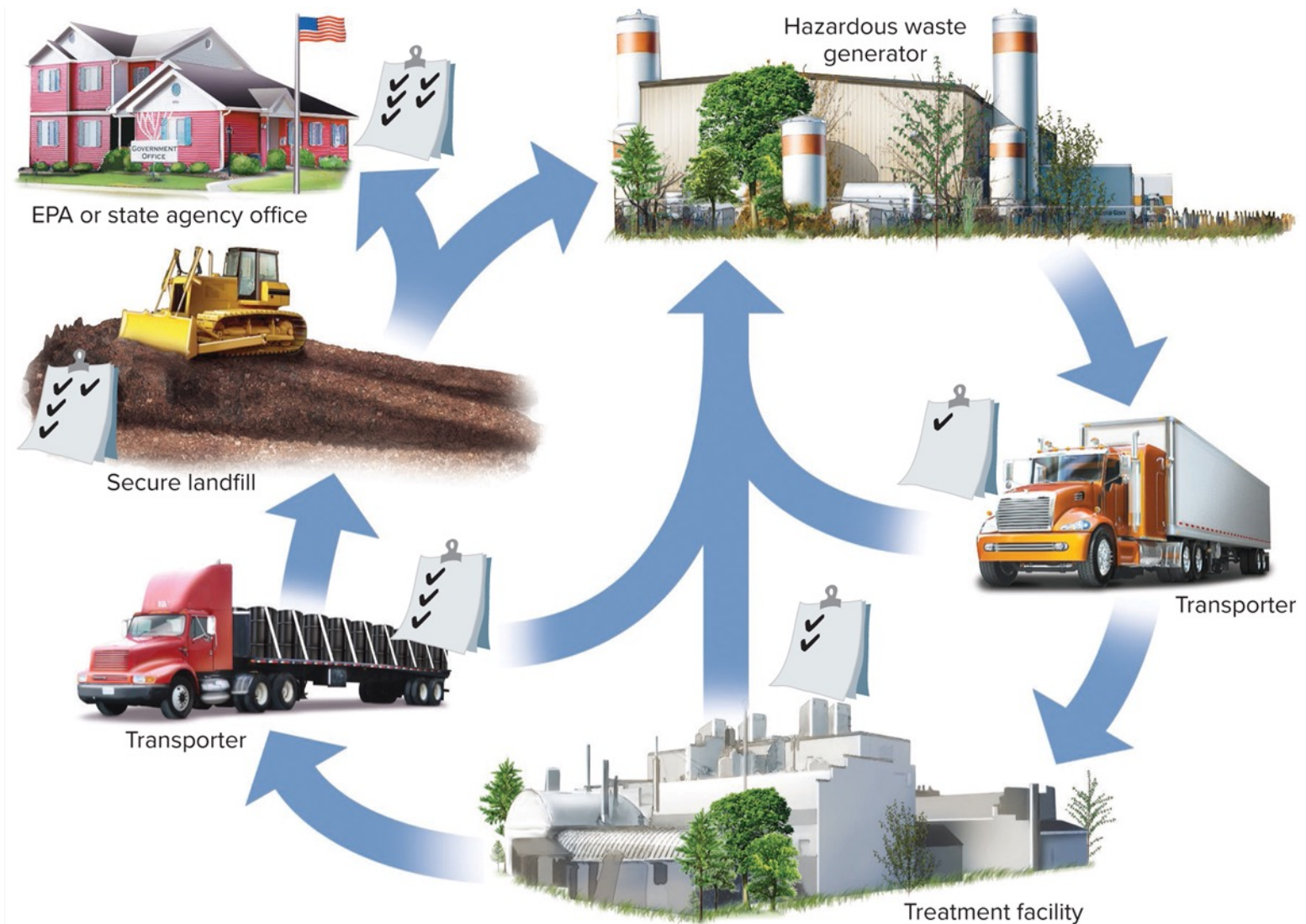
- fatal to humans or laboratory animals in low doses;
- toxic, carcinogenic, mutagenic, or teratogenic to humans or other life-forms;
- ignitable with a flash point less than 60° C;
- corrosive;
- explosive or highly reactive (undergoes violent chemical reactions either by itself or when mixed with other materials).

Federal Legislation Regulates Hazardous Wastes

Two important federal laws regulate hazardous waste management and disposal in the United States.

- The Resource Conservation and Recovery Act (RCRA, pronounced “rickra”) of 1976.
- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund Act), passed in 1980 and modified in 1984 by the Superfund Amendments and Reauthorization Act (SARA), is aimed at rapid containment, cleanup, or remediation of abandoned toxic waste sites.

Hazardous Waste Tracking Chart



Superfund Sites Are Those Listed for Federal Cleanup

The **Superfund** is a revolving pool designed to

- provide an immediate response to emergency situations that pose imminent hazards and
- to clean up or remediate abandoned or inactive sites.

There may be over 400,000 “Superfund” sites in the U.S.

Total costs for hazardous waste cleanup in the U.S. are estimated to be between \$370 billion and \$1.7 trillion.

Toxic Waste Disposal Must Be Secure and Permanent



Brownfields Present Both Liability and Opportunity

In many cities, there are large areas of contaminated properties, known as **brownfields**, that have been abandoned or are not being used to their potential because of real or suspected pollution.

Up to 1/3 of all commercial and industrial sites in the urban core of many big cities fall in this category.

It is hard to find buyers for such property, as who would be interested in redeveloping brownfields knowing that they might be forced to pay millions of dollars to clean pollution they didn't create?

Hazardous Waste Must Be Processed or Stored Permanently

What shall we do with toxic and hazardous wastes? In our homes, we can reduce waste generation and choose less toxic materials.

Buy only what you need for the job at hand. Use up the last little bit, or share leftovers with a friend or neighbor.

Many common materials that you probably already have make excellent alternatives to commercial products

Produce Less Waste

As with other wastes, the safest and least expensive way to avoid hazardous waste problems is to avoid creating the wastes in the first place.

Manufacturing processes can be modified to reduce or eliminate waste production.

It is frequently found that these new processes not only spared the environment but also saved money by using less energy and fewer raw materials.

Convert to Less Hazardous Substances

Several processes are available to make hazardous materials less toxic:

Physical treatments tie up or isolate substances.

Incineration is applicable to mixtures of wastes. A permanent solution to many problems, it is quick and relatively easy.

Chemical processing can transform materials to make them nontoxic. Included in this category are neutralization, removal of metals or halogens (chlorine, bromine, etc.), and oxidation.

Some Hazardous Waste Must Be Permanently Stored



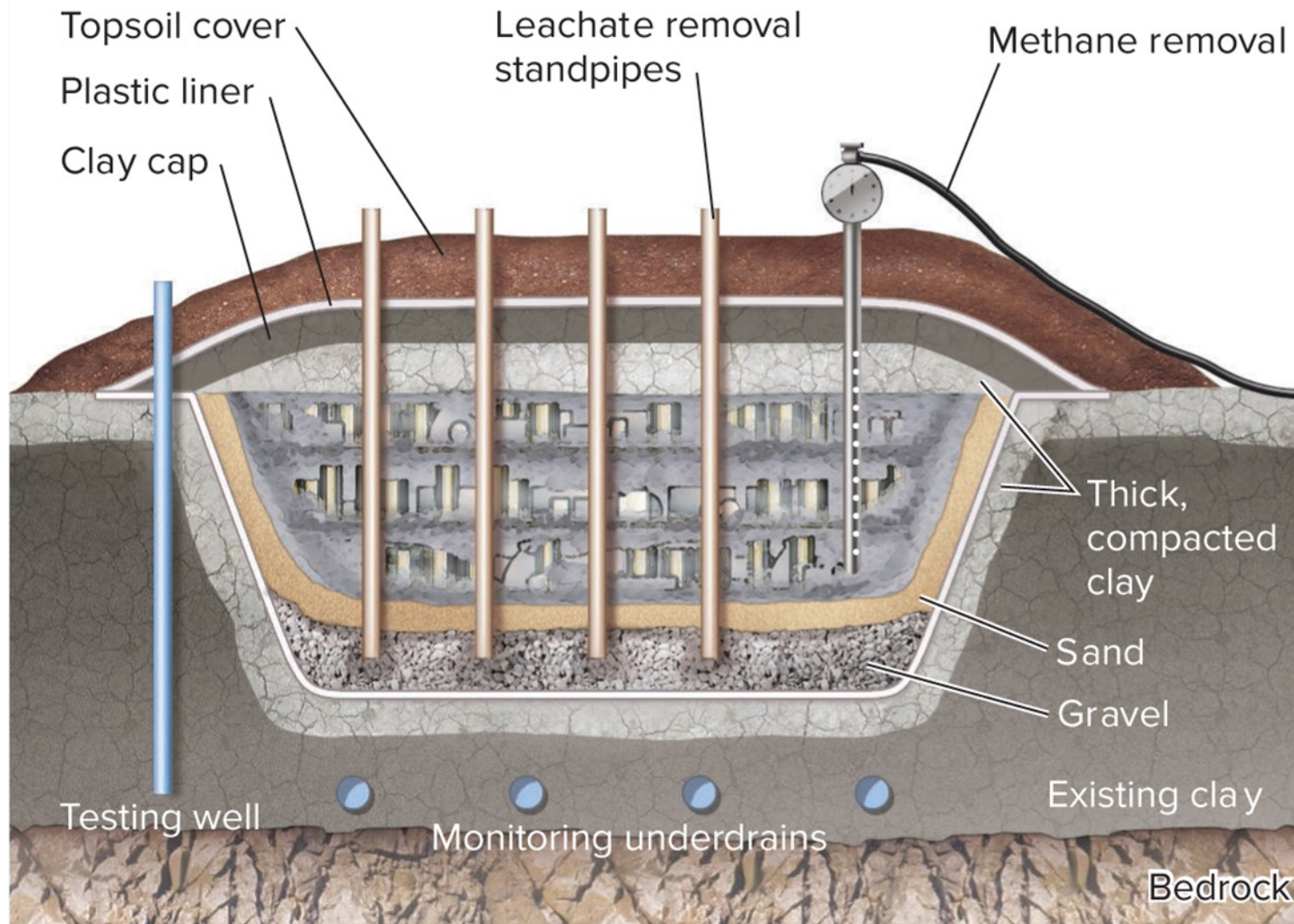
Store Permanently

Inevitably, there are some materials we will have to store them out of harm's way.

Permanent retrievable storage involves placing waste storage containers in a secure place such as a salt mine or bedrock cavern, where they can be inspected periodically and retrieved if necessary.

Secure landfills are the most popular solutions for hazardous waste disposal. Newer techniques make it possible to create safe, secure modern landfills that can contain many hazardous wastes.

A Secure Landfill for Toxic Waste



Take-Away Points

Modern society, however, produces a prodigious amount of waste.

Government policies and economies of scale make it cheaper and more convenient to extract virgin raw materials rather than to reuse or recycle items.

The rising cost and declining availability of landfills have led to new and creative strategies to reduce, reuse, and recycle waste.

Paying attention to recycling, reusing, and reducing household and hazardous waste can greatly improve our awareness of our environmental liabilities.



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