



5.5 SOLID WASTE REDUCTION AND DISPOSAL

College Board Topics 8.9 and 8.10

RSK pg. 608 -629

Learning Objectives and Essential Knowledge

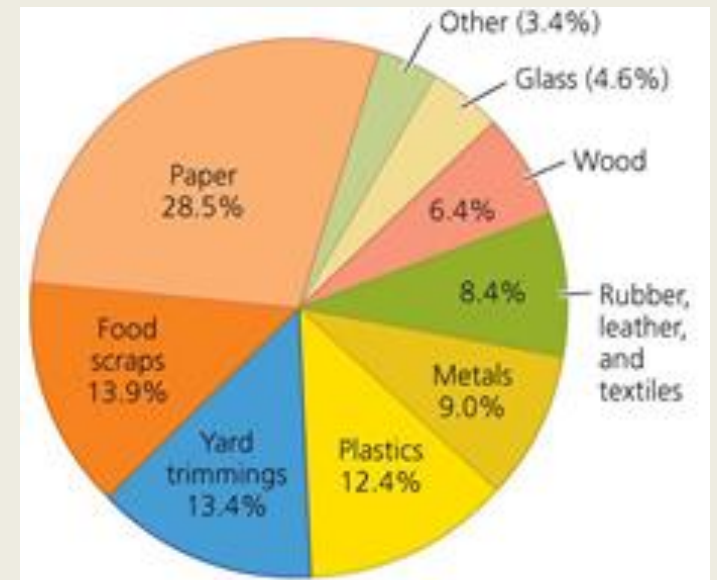
- **Enduring Understanding:** Human activities, including the use of resources, have physical, chemical and biological consequences for ecosystems.
- **Learning Objective:** Describe solid waste disposal methods.
 - **Essential Knowledge:**
 - Solid waste is any discarded item that is not a liquid or gas. It is generated in domestic, industrial, business and agricultural sectors.
 - Solid waste is most often disposed of in landfills. Landfills can contaminate groundwater and release harmful gases.
 - Electronic waste, or E-waste, is composed of discarded electronic devices including televisions, cell phones and computers.
 - A sanitary municipal landfill consists of a bottom liner (plastic and/or clay), a storm water collection system, a leachate collection system, a cap, and a methane collection system.
 - Solid waste can also be disposed of through incineration, where waste is burned at high temperatures. This method significantly reduces the volume of solid waste, but releases air pollutants.
 - Some items are not accepted in sanitary landfills and may be disposed of illegally, leading to environmental problems. One example is used rubber tires, which when left in piles can become breeding grounds for mosquitos that can spread disease.
 - Some countries dispose of their waste by dumping it in the ocean. This practice, along with other sources of plastic, has led to large islands of floating trash in the oceans. Additionally wildlife can become entangled in the waste as well as ingest it.
- **Learning Objective:** Describe the effect of solid waste disposal methods.
 - **Essential Knowledge**
 - Factors in landfill decomposition include the composition of the trash and conditions needed for microbial decomposition of the waste.

Learning Objectives and Essential Knowledge

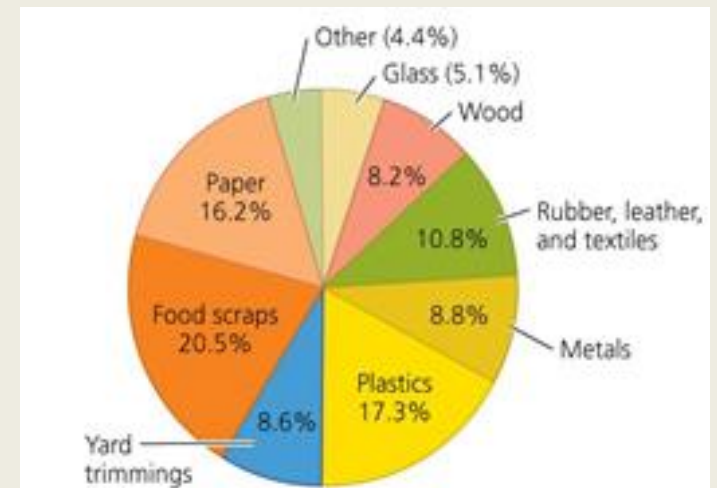
- **Enduring Understanding:** Human activities, including the use of resources, have physical, chemical and biological consequences for ecosystems.
- **Learning Objective:** Describe changes to current practices that could reduce the amount of generated waste and their associated benefits and drawbacks.
 - **Essential Knowledge**
 - Recycling is a process by which certain solid waste materials are processed and converted into new products.
 - Recycling is one way to reduce the current global demand on minerals, but this method is energy –intensive and can be costly.
 - Composting is the process of organic matter such as food scraps, paper, and yard waste decomposing. The product of this decomposition can be used as fertilizer. Drawbacks to composting include odor and rodents.
 - E-waste can be reduced by recycling and reuse. E-wastes may contain hazardous chemicals, including heavy metals, such as lead and mercury, which leach from landfills into groundwater if they are not disposed of properly.
 - Landfill mitigation strategies range from burning waste for energy to restoring habitat on landfills for use as parks.
 - The combustion of gases produced from decomposition of organic materials in landfills can be used to turn turbines and generate electricity. This process reduces landfill volume.

Municipal Solid Waste

- In the United States, paper, yard debris, food scraps, and plastics are the principal components of municipal solid waste
 - Paper and yard waste are recovered at high rates
 - Plastics have accounted for the greatest relative increase in the waste stream over the last few decades
- Most municipal solid waste comes from packaging and nondurable goods (discarded after a short time of use)
- As we acquire more goods, we generate more waste
 - Since 1960, waste generation increased 2.8 times, per capita waste generation increased 65%
- In 2010, close to 1 ton of municipal solid waste was generated per person in the United States
 - About 2 kg per person per day
 - Much more than people in other countries



(a) Before recycling and composting



(b) After recycling and composting

Waste Management



- **Solid Waste**

- Solid waste is any discarded item that is not a liquid or gas. It is generated in domestic, industrial, business and agricultural sectors.
- The **Waste Stream** refers to the flow of waste as it moves from its source toward disposal destinations

- **Waste management goals**

- **Source Reduction**

- Avoids the costs (financial and environmental) of manufacturing, as well as disposal or recycling
- More efficient use of materials, increased durability of consumer goods, repairable goods, minimize packaging, buy less.
- *Industrial ecology*: "Waste is just a resource out of place"

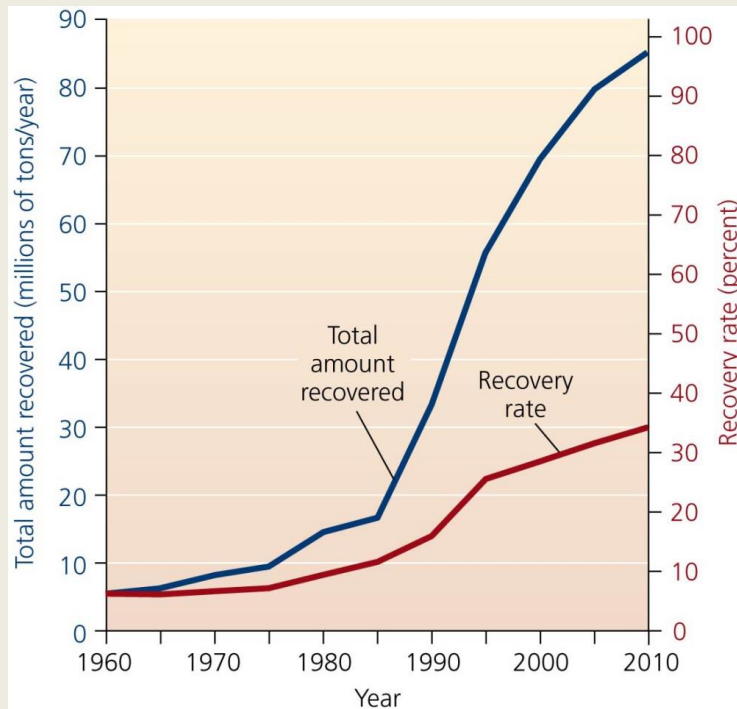
- **Recycling**

- Diversion of recyclable goods from the waste stream

- **Safe Disposal**

- Landfilling (most common) or incineration

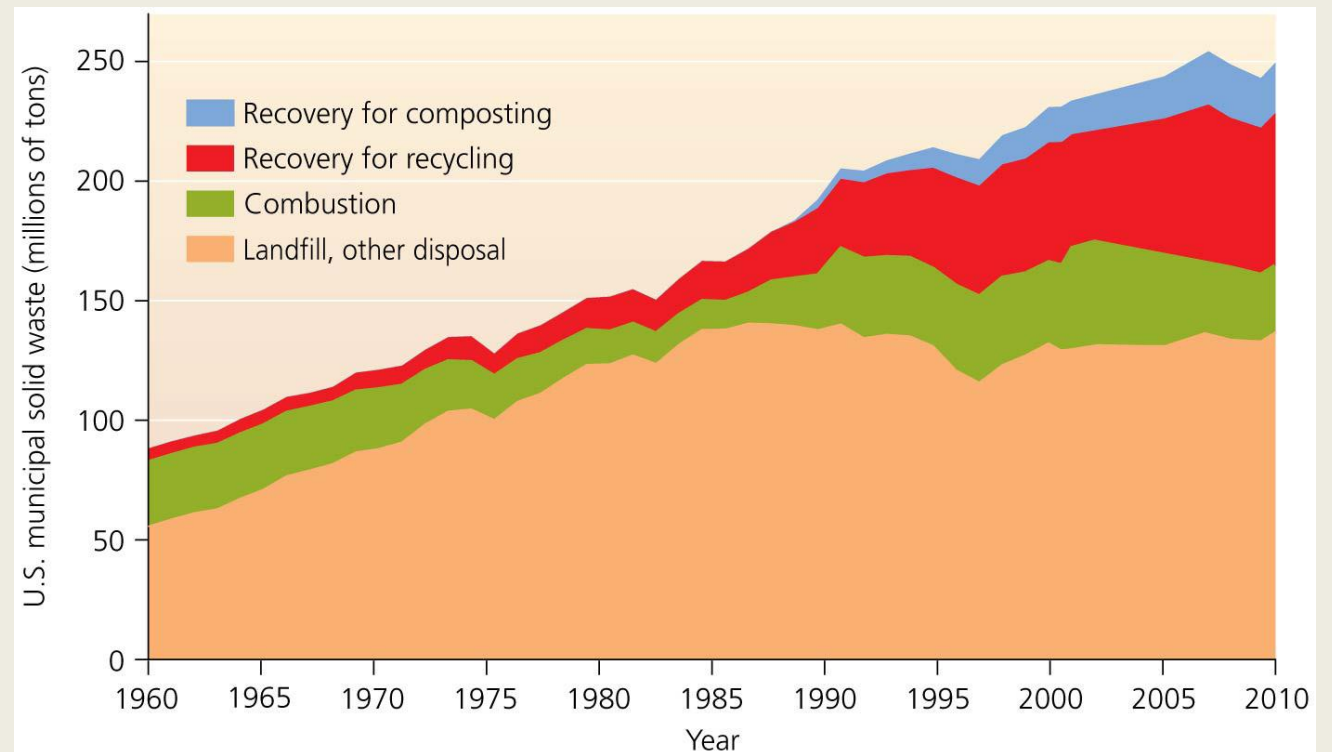
Recycling and Composting



- **Recycling can keep usable materials out of the landfill.**
 - Recycling also limits the amount of natural resources (timber, minerals and fossil fuels) we must extract from the environment
 - Recycling requires diverting the recyclable materials from the landfill, processing it into materials that are useful to manufacturers, using the recycled materials to produce new goods, and encouraging consumers to choose goods made from recycled materials.
 - Recycling rates are rising.
- **Composting diverts yard waste and food scraps from the waste stream**
 - Earthworms, bacteria, and other organisms convert organic waste into high-quality compost
 - The resulting compost can be used for gardens and landscaping
 - Enriches soil, improves water holding capacity, and encourages soil biodiversity
 - Reduces the need for chemical fertilizers
- **Nearly half of U.S. states now ban yard wastes from the municipal waste stream**
- **Financial incentives can limit the waste households generate**
 - “Pay-as-you-throw” and bottle/can deposits or redemption values

Open dumping has led to improved disposal

- **Historically, people dumped their garbage wherever it suited them**
 - As populations increased, waste was consolidated into open dumps that were burned to reduce volume
 - Most industrialized nations now bury waste in lined and covered landfills or burn it in specialized incineration facilities
- **In the 1980s in the United States, increased waste generation and restricted incineration have led to limits on landfill space**
 - In the 1980's there was talk of a looming "solid waste crisis"
 - Since the late 1980s, recycling has decreased pressure on landfills
 - As of 2010, 54% of waste was landfilled, 12% incinerated, and 34% recovered



Sanitary landfills are regulated with health and environmental guidelines

- ***Sanitary landfills***

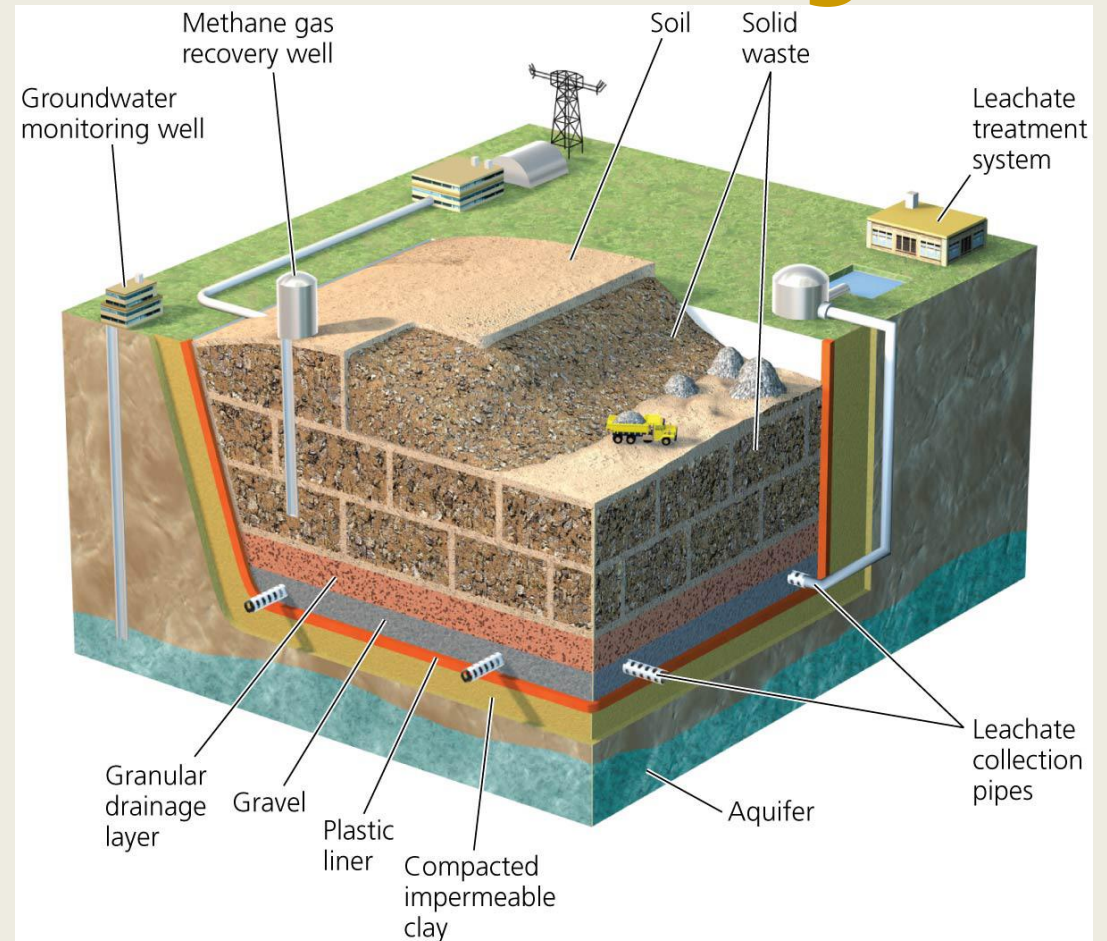
- waste buried in the ground or piled in large, engineered mounds to prevent contamination and health threats
- Soil is layered in to reduce odor, speed decomposition, and reduce infestation by pests
- Waste is partly decomposed by bacteria and compresses under its own weight to make more space
- Some water is allowed in to help decomposition

- **U.S. landfills must meet the EPA's national standards under the *Resource Conservation and Recovery Act (RCRA) of 1976***

- Sets standards for landfill design, permitting, and locations
- Regulates what can be disposed of in landfills and requires tracking and monitoring of hazardous waste from "cradle to grave"
- Finding suitable areas to put landfills is difficult because of the ***not-in-my-backyard (NIMBY) syndrome***

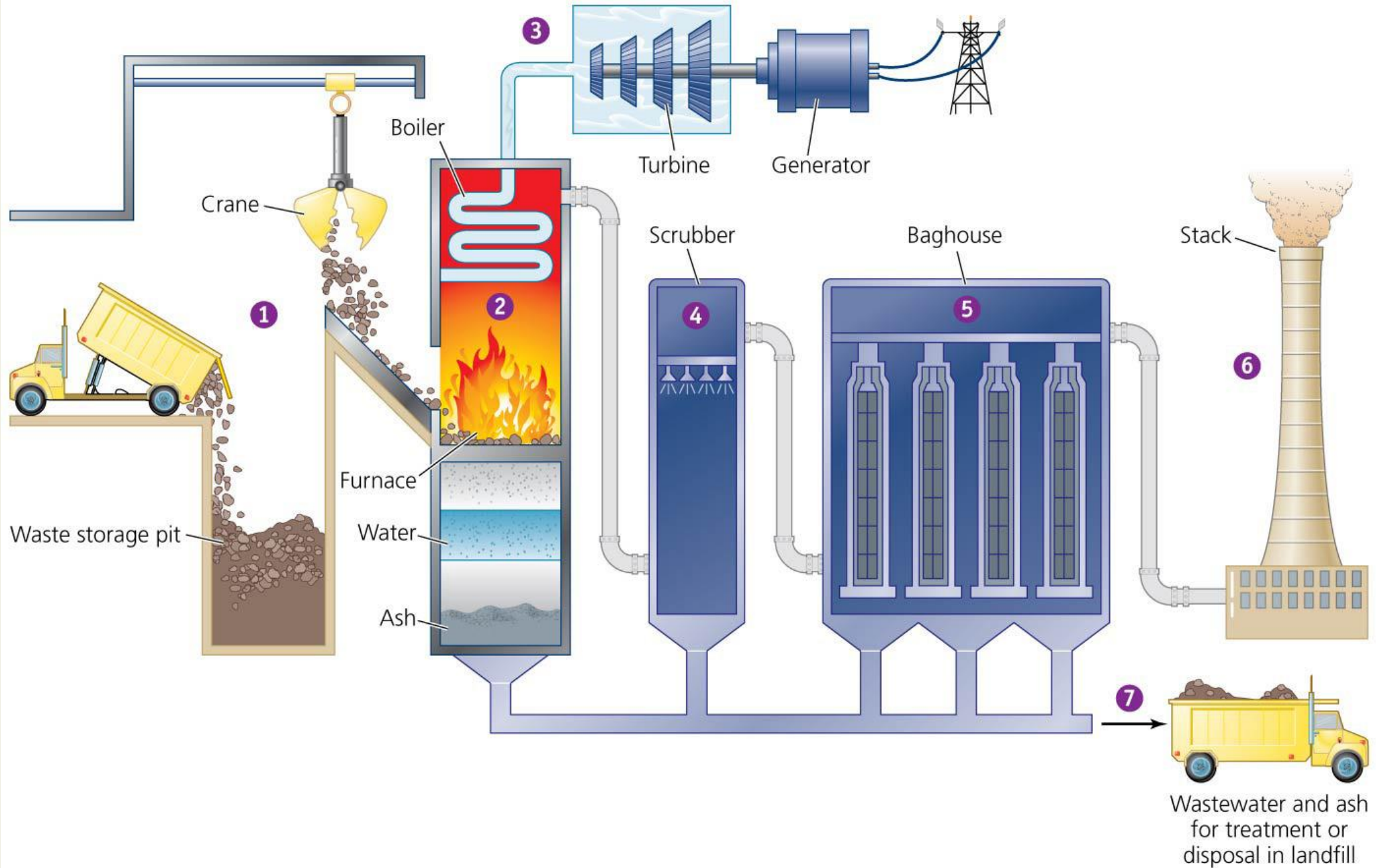
- Landfills are lined with thick plastic tarps and/or clay to isolate waste from the soil.
- Landfills must be located away from surface water, well above the water table and away from earthquake-prone faults.
- Storm water must be diverted away from landfills in order to minimize contaminated runoff.
- **Leachate** that forms as water percolates through the landfill must be collected and treated.
- Groundwater is monitored through monitoring wells.
- Methane gas produced by anaerobic decomposition must vented and recovered. In some cases it used to produce electricity.
- Waste is periodically covered with soil to limit odors and pests, as well as limit dispersal of the waste by winds
- Once closed, landfills receive a clay cap and are monitored for an additional 30 years. Landfill sites may be repurposed for land intensive uses such as open spaces, nature preserves, golf courses, that require minimal construction

Landfill Design



Incinerating trash reduces pressure on landfills

- ***Incineration***
 - a controlled process that burns garbage at very high temperatures
 - Incinerating waste reduces weight by 75% and volume by 90%
- **Hazardous chemicals are created and can be released into the atmosphere**
 - Some countries ban incineration outright
 - Scrubbers can chemically treat the gases produced in combustion
 - A *baghouse* removes polluted *fly ash* from the exhaust
 - The remaining ash must be disposed of as hazardous waste landfill
 - Burning waste may release or create heavy metals, PCBs, and dioxins
- **Because of these risks, incineration is an expensive way to deal with solid waste.**
 - ***Waste-to-energy (WTE) facilities*** use the heat produced by waste combustion to create electricity.
 - WTE facilities take many years to become profitable and may interfere with the communities' efforts to reduce and recycle waste since waste is a resource to WTE facilities



Hazardous Waste

- ***The Resource Conservation and Recovery Act (RCRA)*** defines hazardous wastes as substances that pose an especially high risk to human or environmental health. RCRA categorizes hazardous wastes as liquids, solids, or gases which are one of the following:
 - *Ignitable* = easily catches fire (natural gas, alcohol)
 - *Corrosive* = corrodes metals in storage tanks or equipment (strong acids and bases)
 - *Reactive* = chemically unstable and readily reacts with other compounds, often explosively or by producing noxious fumes
 - *Toxic* = harms human health when inhaled, ingested, or touched to human skin (pesticides, heavy metals)
- **Industry produces the largest amount of hazardous waste**
 - Mining, small businesses, agriculture, utilities, and building demolition all produce hazardous wastes
 - But hazardous waste generation and disposal from industry are highly regulated
- **Households are the largest source of unregulated hazardous waste**
 - 1.6 million tons of *household hazardous waste* is produced in the United States annually
 - Paint, batteries, solvents, cleaners, pesticides, etc.



Hazardous Waste

- **Under RCRA, large generators of hazardous waste must obtain permits**
 - Materials must be tracked “**from cradle to grave**”; all the way from production until properly disposed of
 - Intended to prevent illegal dumping
- **Many hazardous wastes can be recycled safely and effectively, while other wastes will be treated and disposed of in landfills or incinerators.**
- **High costs of disposal and permitting encourage companies to invest in reducing the amount of hazardous waste they generate.**
 - Industrial ecology and life cycle analysis can help find safer alternatives to some products.
 - Surface impoundments (clay or plastic lined holding ponds) can be used to evaporate liquid hazardous wastes and reduce its volume before disposal
 - The liners of surface impoundments can leak and flooding can cause them to overflow.
 - Deep well injection is used to dispose of contaminated liquids from oil and gas extraction.
 - There is the risk of contamination to soils and groundwater.
- **Proper disposal is costly, so illegal dumping still occurs**
 - Industrial nations found it cheaper to illegally pay developing nations to take waste rather than pay to have it properly disposed of.
 - Waste disposal is often unregulated in less developed countries.

Contaminated sites are being cleaned up, slowly

- **Globally, thousands of sites are contaminated with hazardous waste**
 - Former military, industrial, or commercial sites and *brownfields*
 - Dealing with them is difficult, time consuming, and expensive (too expensive for some countries)
- **The *Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (1980)*, also called *Superfund*, is administered by the EPA**
 - CERCLA operates under the polluter pays principle. For roughly 30% of sites so far, the responsible party cannot be found or held liable.
 - For sites without a responsible party, a trust fund was established by a federal tax on petroleum and chemical industries
- **Once a Superfund site is identified, EPA scientists prioritize the clean up and place sites on the *National Priority List (currently 1320 sites)***
 - Priority is based on how close the site is to human habitation, if wastes are currently confined or likely to spread, if the site threatens drinking water supplies
 - Cleanup is on a site-by-site basis, as funds are available.
 - The average cleanup costs \$25 million and takes 12–15 years

Love Canal led to creation of CERCLA

In the *Love Canal* community of Niagara Falls, New York, in 1978–1980, families were evacuated after buried chemicals rose to the surface.

- The site was a landfill used by the state of New York in the 1920's. Then it became a hazardous waste disposal site for the Hooker Chemical Company in the 1940's
- In 1953 the local school board purchased the site for \$1 with a contract disclosing the land use history and preventing future law suits against Hooker Chemical company.
 - An elementary school and planned community was built on top of the now closed dump site.
 - Over the next 2 decades residents complained about noxious odors and strange liquids seeping through the ground and into basements. The issue came to a head during an especially wet winter in 1977.
- Residents experienced high rates of leukemia, nervous system disorders, birth defects, and miscarriages.
 - 33% of Love Canal residents were found to have some form of chromosomal abnormality.



E-Waste is Increasing

- Proliferation of computers, smart phones, printers, TV's and other electronic devices has increased the amount of E-waste
 - Many of these products have short life spans because of the rapid evolution of new technologies and a lack of software support for older devices.
 - Many discarded devices are still in working order.
- E-waste now makes up 2% of the U.S. waste stream. Only about 25% of devices are recycled.
 - E-waste contains rare precious metals that are dangerous and environmentally damaging to mine.
 - 1 ton of computer scrap contains more gold than 16 tons of ore from a gold mine.
 - E-waste also contains heavy metals (lead, mercury) and toxic flame retardants (*PBDE's, Polybrominated diphenyl ethers*) which are considered hazardous materials.
 - E-waste can be recycled by disassembling devices and refurbishing the parts and materials to use in new products.
 - Recycling puts workers at risk of exposure to these hazardous materials.
 - Much of the recycling work is done in developing nations where workers are not protected by the safety regulations found in more developed countries

