

Chapter 21 - Solid, Toxic, and Hazardous Waste

Key Terms

biodegradable plastic	hazardous waste	secure landfill
bioremediation	incineration	Superfund
brownfields	photodegradable plastic	Toxic Release Inventory
composting	phytoremediation	waste to energy
demanufacture	recycle	
e-waste	sanitary landfill	

Skills

1. Compare a sanitary landfill with an open dump.
2. Examine the costs and benefits of recycling wastes.
3. Differentiate between the terms reduce, reuse, and recycle.
4. Analyze the costs and benefits associated with incineration.
5. Define hazardous wastes. Explain how such wastes are disposed of in the United States.

Take Note: Essays on past AP exams have asked students to address pros and cons of recycling. The questions have addressed paper and aluminum recycling, in particular, including recommending specific policies to encourage recycling. On the 2006 exam, one question addressed brownfields and the issues associated with reducing and disposal of hazardous wastes. You must be familiar with the methods used to dispose of wastes and ways to reduce waste. In addition, you must be familiar with what wastes are deemed hazardous and how those wastes must be handled differently from municipal solid wastes.

Solid Waste

Any waste that is not a liquid or gas is considered to be solid waste. The greatest sources of solid waste in the United States are mining and agriculture. Mining waste includes tailings, overburden, and smelter waste. Agricultural waste includes crop residues and animal waste. Other industries contribute to solid waste as well. Municipal solid waste (MSW) makes up a relatively small proportion of the solid waste produced in a country. The components most commonly found in municipal solid wastes are paper and paper products, yard trimmings, food scraps, plastics, metals, textiles, wood, and glass. Frequently household waste contains hazardous materials including paint, cleaners, oils, batteries, or pesticides.

Waste Disposal Methods

In many countries, an open dump is used for waste disposal. They are unsanitary, dangerous sites in which municipal waste is often not separated from hazardous wastes. The dumps are malodorous, vermin-infested sites that tend to catch fire, explode, and collapse under unsuspecting trash scavengers. The fires and explosions are caused by decomposition, which produces the flammable

gas methane. Many disenfranchised poor live on or near these dumps, because they can find food, clothing, and shelter components in the trash. Although developed countries have modern sanitary landfills, illegal dumping on roadsides and vacant lots continues to be a problem. A sanitary landfill is designed to prevent vermin and spread of disease while providing trash disposal. The landfill is lined with layers of clay and plastic to decrease the amount of fluid, called leachate, which would flow out of the landfill. The leachate is collected in a series of pipes and treated as wastewater prior to being released. The trash in the landfill is compacted and covered with a layer of soil before more trash is placed on top of it. There are also pipes that traverse the landfill that collect methane. This methane can be used as a source of energy or burned off. Landfill sites must be geologically stable areas, and should be relatively close to the municipality it serves to save on transportation costs. Most people do not want a landfill in their vicinity, so (Not In My Backyard) is a very prominent factor when building a new facility.

Toxic colonialism is sending solid and hazardous wastes to Third World countries to dispose of it, which exposes the citizens of that country to hazards they would not expect. Industrialized countries have agreed to ban this practice, but illegal dumping continues. The Basel Convention of 1989 banned trade in hazardous waste from developed to developing countries. The United States failed to ratify the Basel Convention and exports much of our e-waste to Asia. E-waste is comprised of discarded computers, printers, cell phones and other technology waste. Additionally, poor neighborhoods and Native American reservations are subject to toxic colonialism because they do not have the wealth or the support to fight waste disposal site development on their land.

Ocean dumping is illegal in the United States due to the Ocean Dumping Ban Act of 1988. The act specifies that sewage sludge, industrial waste, medical wastes, or municipal solid wastes may not be dumped into the ocean. Dredge spoil, produced when channels are dredged to deepen them, are still dumped at sea. These wastes may contain heavy metals, pesticide residue, and other chlorinated hydrocarbons such as PCBs.

Incineration

Incineration is another method to dispose of solid waste. The process of burning the waste reduces the amount of landfill volume used because only the ash remains to discard. The landfill volume is reduced to 10-20 percent of the original landfill space. Many incinerators remove waste that will not burn, or that may be recycled, prior to combustion. These items include metals, glass, and other noncombustible materials. The trash has been enriched to readily burn and is known as refuse derived fuel. Other incinerators can burn any trash smaller than a refrigerator and are known as mass burn incinerators. These incinerators save money because they do not sort the different noncombustible components. The cost of an incinerator is high, and frequently garbage disposal in areas using incinerators is more expensive.

When waste is burned, it releases many air pollutants, including dioxins, furans, lead, mercury, and cadmium. These toxins are more prevalent in the fly ash than in the bottom ash, thus requiring postcombustion control mechanisms to prevent their release. Both electrostatic precipitators and bag house filters used to control emissions from fossil fuel combustion will function to reduce release of these toxins in incinerator emissions. Precombustion methods may also be used, including removal of batteries and chlorine-containing plastics prior to burning the refuse.

Some incinerators are waste-to-energy or energy recovery units. These units generate electricity by burning the trash to heat water, which becomes steam. The steam spins a turbine connected to an electrical generator. The steam may also be used to directly heat a building.

Some incinerator ash is combined with concrete or asphalt to create road fill. Many people are concerned that hazardous materials in the ash may be released as the road wears away. Incinerator ash that contains large amounts of hazardous materials must be disposed of in a hazardous waste landfill.

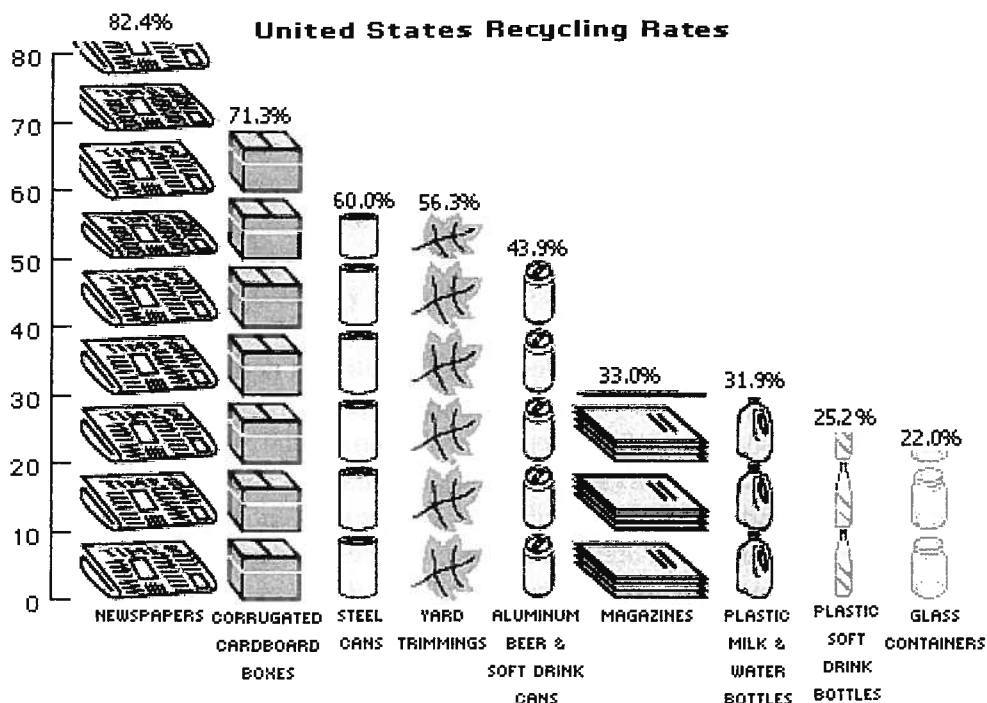
Dioxins

Dioxins are a group of chlorinated hydrocarbon chemicals. The most toxic is 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin or TCDD. They are naturally produced during forest fires but the anthropogenic sources include incineration, smelters, chlorine bleaching at paper mills, and environmental tobacco smoke. Humans are exposed to dioxins when they ingest contaminated animal fat, because the chemicals bioaccumulate in fat and biomagnify. They are highly persistent. Acute exposure in humans results in chloracne, skin rashes, and skin discoloration. Chronic exposure results in liver damage. Dioxins are known to be teratogenic and immunotoxic and are thought to be a human carcinogen.

Reducing Waste

The three Rs apply when trying to reduce the volume of waste. Reduce, reuse, and recycle are the primary ways to reduce waste, and they are preferred in that order. Reduction is to decrease the amount of wastes by decreasing packaging, or redesigning a product to use less material, which is called source reduction. Source reduction is lowering the amount of material in a product. For example, aluminum cans use much less aluminum now than in the past. Reusing is to use the waste for another or the same purpose. For example, reusing a plastic grocery sack as a garbage bag decreases total waste volume. Reusing glass beverage containers, such as a glass soda bottle, reduces the amount of glass thrown away. A glass bottle can be reused an average of 15 times before it is too damaged to be used any longer.

Recycling also reduces waste by converting the waste into another product or the same product again after processing. Open-loop recycling is converting a product into a different product. For example, newspaper may be remade into another paper product such as notebook paper. Closed-loop recycling is employed when a product may be recycled into the same product. For example, it is estimated that a soda can may be recycled into a new can in less than three months time.



21.1 Recycling rates for components of U.S. municipal solid waste

To create a market for recycled material, it must be economically profitable to recycle. Recycling should also save raw materials and reduce energy use, and landfill space—in addition to being more economical than using the virgin resource. Recycling should also reduce air pollution. One of the most successful recycling programs is the recycling of steel. Nearly all steel in the United States contains at least 25 percent recycled steel and some contain 100 percent recycled steel. Much of this steel comes from steel cans, automobiles, buildings and bridges, and appliances. Mining and smelting iron to obtain steel consumes far more energy than melting old steel and forming new steel cans or girders. Aluminum, derived from an ore called bauxite, must be mined and extracted from the ore in a complicated process. By recycling aluminum in cans, the costs associated with the extraction of virgin ore are dramatically lowered. Aluminum is also easy to recycle and can easily be melted and remade into a can almost immediately. Approximately two-thirds of all aluminum cans are now recycled. Other metals that may be recycled include lead (auto batteries), platinum (catalytic converters), gold, silver, copper (pipes and electrical wiring), and iron.

Lead and Lead Toxicity

Lead is easily recycled from used automobile batteries. Lead is of great concern because it bioaccumulates in bone, unlike most toxins, which bioaccumulate in fat. Lead toxicity, particularly in the young, leads to mental retardation, lowered IQs, hyperactivity, and attention deficit and learning disorders. In the United States the maximum level of lead has been established at 10µg/dL blood. Atmospheric sources of lead include leaded gasoline (banned in the United States in 1976), smelters, and incinerators. Lead also contaminates soil and water from improperly treated leachate, lead pipes, lead solder, and leaded paint.

Paper Recycling

Paper is exposed to open-loop recycling, because as paper is recycled the fibers become shorter and shorter until they are no longer able to be used. Paper is made primarily from trees. The tree bark is stripped from the tree and the tree is pulped into small chips. Chemicals are added to the chips to ensure their breakdown. A large volume of water is required to repeatedly rinse the pulp. The paper is bleached, usually using chlorine. Other bleaching agents include hydrogen peroxide and oxygen gas.

Recycling paper involves de-inking first. The waste paper is usually mixed with fresh pulp, because the fibers shorten each time the paper is recycled. For example, old newspaper is usually recycled into newspaper, egg cartons, or paperboard. Recycled paper requires the use of less chlorine and water to create than does virgin paper. Virgin paper production usually results in air contamination, particularly sulfur dioxide and particulates from the burning of fossil fuels to operate the plant. These air pollutants are reduced in recycling facilities, because it takes 20 percent less energy to recycle paper than to make virgin paper. Recycled paper requires that fewer trees be harvested, thus reducing all of the environmental impacts associated with deforestation.

Composting

Yard waste is an unusual problem. It makes up such a large proportion of U.S. municipal solid waste, so many communities have made it illegal to dispose of yard wastes in their trash. Instead, these communities have established area composting facilities, in which the yard waste and tree trimmings are dropped at a central location to be pulverized into mulch. This mulch can then be used as a green fertilizer. Mulch not only increases the nutrients in soil, it improves the water holding capacity and oxygenation of the soil, in addition to preventing erosion.

Recycling Difficulties

Plastics can be difficult to recycle. The plastics in a soda bottle, egg carton, garbage bag, and a shampoo bottle are all different compositions. Soda bottles are made of a plastic called PET, which can be recycled into carpets, clothing, bottles, and packaging. Contamination with a minuscule amount of PVC plastic can render PET unusable for recycling. Recycled plastic is also more expensive than virgin plastic, due to the low price of petroleum. Mixed plastics can be made into toys and plastic lumber.

Some plastics are marketed as biodegradable, as they contain some materials that can be broken down by bacteria. These products are only partially degradable, because the plastic component still cannot be degraded. Other plastics are photodegradable, which means they are broken down by exposure to light. The obvious problem in this case is that in a sanitary landfill, light penetration is highly unlikely, and these plastics never degrade.

Tires cannot be easily recycled, although they can be reused. Tires are made of vulcanized rubber, which cannot be remelted and used as rubber again. Tires tend to rise in landfills, which make them difficult to bury. Shredded tires fit more easily into landfills. These tire shreds can be used

on playgrounds and as artificial mulch. Tires may also be burned in an incinerator to produce energy.

Demanufacturing

Demanufacturing is taking apart complex household items and retrieving the recyclable components. Items subject to demanufacturing include refrigerators, stoves, televisions, and air conditioners. Personal computers contain heavy metals, plastics, and valuable metals that can be removed and recycled as previously noted. Eighty percent of the e-waste produced in the United States is sent to Asia for disposal, which is legal because the United States never ratified the Basel Convention.

Hazardous Wastes

Hazardous wastes include any wastes that are flammable, explosive, corrosive, or highly reactive. In addition, chemicals that are toxic, or that induce cancer, mutation, or birth defects in living organisms are considered hazardous. Hazardous wastes do not include radioactive wastes. Much of the hazardous waste produced in the United States is recycled, stored, or converted into a less hazardous material.

The easiest way to control hazardous wastes is to avoid using hazardous materials in manufacturing processes. The wastes can also be reused and recycled during industrial processes, which will decrease the amount of wastes. Green, or environmental chemistry, is the study of chemistry to redesign chemical processes to be less hazardous. Some physical processes to remove hazardous material include using charcoal to absorb toxins and distilling hazardous chemicals out of aqueous solutions. Some chemicals, such as PCBs, may be destroyed by high-temperature incineration. However, this procedure is difficult when soil or water is involved. Incineration may release dioxins and create an ash that must be permanently stored. The ash is usually much less toxic than the original waste. Long-term storage is also an option. It involves encasing the chemicals in noncorroding containers to be stored for long periods. The storage is in specially modified landfills called secure landfills. The leachate from these sites is carefully monitored. Permanent retrievable storage is keeping the wastes in a secure location where they can be inspected periodically and retrieved as needed.

Bioremediation is using bacteria and other microbes to break down hazardous wastes. Bacteria have been found, or genetically engineered, that can degrade chemicals such as PCBs, organic solvents, and pesticides. Phytoremediation is using plants, which may be genetically engineered, to absorb and accumulate toxic material from the soil. For example, sunflowers remove lead, poplar trees remove many contaminants, and canola removes selenium. These plants become contaminated with the material and must be disposed of properly. Phytoremediation is a slow process and works only as deeply as the roots of the plant can penetrate the soil.

The Problem of PCBs

Polychlorinated biphenyls, or PCBs, are a group of chlorinated hydrocarbons that are unusually persistent and bioaccumulate in fat. They also biomagnify in the food chain. The chemicals were made in the United States until 1976 and were used in electrical transformers, capacitors, vacuum

pumps, and turbines. The liquid PCBs were used as adhesives, lubricants, fire retardants, and hydraulic fluids. Acute exposure to PCBs causes nausea, diarrhea, and vomiting. Chronic exposure interferes with the endocrine system and may cause cancers. PCBs can be removed by bioremediation and destroyed by high-temperature incineration.

RCRA

The main legislation that controls hazardous waste disposal is the Resource Conservation and Recovery Act (RCRA). This act was passed in 1976 to ensure testing and correct disposal methods for all hazardous materials. The legislation requires cradle-to-grave tracking of all hazardous material used in the United States.

Love Canal

Love Canal, New York, has the dubious honor of being the first location in the United States to be declared a national emergency disaster. The entire community was evacuated once it was realized the inhabitants were living on a site filled with toxins and carcinogens. A chemical company had been storing hazardous wastes in a canal for decades. The dump site was closed and a neighborhood built upon it. After a particularly rainy year, the chemical storage tanks began leaking their toxic materials. Children began getting chemical burns and the area smelled like chemicals. The families suffered numerous miscarriages and birth defects. After years of litigation, the chemical company was required to clean up the site. The situation at Love Canal was the impetus for passing the Superfund Act.

CERCLA and SARA

The Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA), also known as the Superfund Act was ratified by congress in 1980. In 1984 the act was amended by the Superfund Amendments and Reauthorization Act (SARA). The acts are intended to allow the federal government to respond quickly to hazardous waste site contamination. The EPA administers the act and determines which sites require immediate attention due to supertoxic, carcinogenic, mutagenic, or teratogenic chemicals. The chemicals of greatest health concern on Superfund sites are lead, trichloroethylene, toluene, benzene, PCBs, chloroform, phenol, arsenic, cadmium, and chromium. These sites are placed upon the National Priorities List. There are currently 1,244 sites on the National Priorities List. The sites include abandoned factories, smelters, mills, refineries, and chemical plants. If the government cannot establish who is responsible for the damage, the cleanup is paid for from the Superfund. The Superfund money has been generated by taxing chemical and hazardous materials. The tax expired in 1995 and has not been reauthorized. Current funding comes from public funds. Companies are required to report their Toxic Release Inventory, a report on the hazardous materials they release in a year.

Brownfields

Brownfields are sites contaminated with toxic or hazardous materials. These properties have been abandoned and are not contaminated enough to be placed on the National Priorities List. Many industrial areas in the interior of urban areas are brownfields. These areas are subject to

remediation to allow the area to be reclaimed and repopulated by humans. These reclaimed areas can provide jobs, a tax base, and housing in urban areas previously unavailable. Urban sprawl is curtailed when brownfields are used.

Chapter 21 Questions

Use the following for questions 1-4.

- a. phytoremediation
 - b. photodegradable
 - c. composting
 - d. incineration
 - e. sanitary landfill
1. exemplified by sunflowers removing lead from contaminated soil
 2. exemplified by household food waste decomposing into a soil conditioner
 3. used to dispose of more than 50 percent of the U.S. solid waste
 4. exemplified by plastics that break down upon exposure to light
5. Refuse derived fuel
 - a. is trash that has not been sorted.
 - b. consists primarily of agricultural wastes.
 - c. is used in mass burn incinerators.
 - d. is garbage sorted to remove noncombustible or recyclable materials.
 - e. is used to reduce the toxic materials in hazardous wastes.
6. All of the following are metals released from incinerators except
 - a. lead.
 - b. mercury.
 - c. dioxins.
 - d. cadmium.
 - e. copper.
7. Place the following terms in order with regard to saving energy (lowest energy first).
 - a. reuse, reduce, recycle
 - b. reduce, reuse, recycle
 - c. reduce, recycle, reuse
 - d. reuse, recycle, reduce
 - e. recycle, reuse, reduce
8. Which of the following is not an environmental consideration when recycling aluminum?
 - a. erosion caused by mining bauxite
 - b. cost of recycled aluminum compared to virgin aluminum
 - c. landfill space saved by recycling aluminum
 - d. less energy required to recycle aluminum compared to energy required to smelt ore
 - e. damage to habitats caused by mining of aluminum ore

9. The Superfund
 - a. is used only to clean up hazardous waste sites owned by the Department of Defense (DOD).
 - b. pays companies to clean up the land that the company accidentally contaminated.
 - c. identifies the worst hazardous waste sites and places them on the National Priorities List.
 - d. regulates the closure of sanitary landfills.
 - e. promotes conversion of open dumps to sanitary landfills in developing countries.

10. All of the following would be considered brownfields except
 - a. an abandoned fertilizer plant.
 - b. an obsolete closed chemical plant.
 - c. a closed smelter.
 - d. an abandoned dry cleaning facility.
 - e. a closed sanitary landfill.