

CHAPTER 21 SOLID, TOXIC, AND HAZARDOUS WASTE

Chapter Overview

This material in this chapter explains the different types of wastes, including solid, toxic, and hazardous. It also covers methods of disposal and treatment, as well as the concepts of recycling, reusing, and reducing wastes. Finally, the issues of toxic/hazardous waste are discussed. Major federal legislation, which includes RCRA and CERCLA, are also explained.

Topics and Key Concepts

Pollution

- Identify the components of solid waste.
- Explain the benefits and drawbacks of an open dump, sanitary landfill, and incineration for the disposal of MSW.
- Identify the components of e-waste and appliances and explain the difficulty in the disposal of such wastes.
- Conclude major benefits and drawbacks of recycling and composting.
- Enumerate the various categories of hazardous wastes and describe the various methods which can be utilized to dispose of them.
- Summarize the important legislation which regulates the disposal of hazardous wastes and cleanup in the United States.
- Explain the origin of brownfields.
- Differentiate bioremediation and phytoremediation.
- Identify the five ways that humans can reduce input into the waste stream. (5 Rs)

Key Terms

biodegradable plastics
bioremediation
brownfields
composting
demanufacturing
*waste to energy
recovery
e-waste

hazardous waste
mass burn
MSW
*Open dump
permanent retrievable
storage
photodegradable
plastics

recycling
refuse-derived fuel
sanitary landfills
secure landfills
Superfund
Toxic Release
Inventory
waste stream

Pacing Guide

Spend 3–5 days on waste management practices, and then additional time on legislation and planning to maintain and improve the quality of life for all people.

Approach and Tips

Emphasize that every person in the United States produces approximately 2/3 of a ton of waste *per year*, a far greater amount than citizens of most European and Asian countries. Explain that the United States produces 11 billion tons of solid waste per year. Agricultural wastes account for 50%, which can be recycled into the soil. Over 30% comes from mining and metal processing. The remaining industrial waste can be recycled or disposed of in landfills, with the exception of hazardous and toxic wastes. The flow of waste materials we generate to disposal or recycling is called the waste stream.

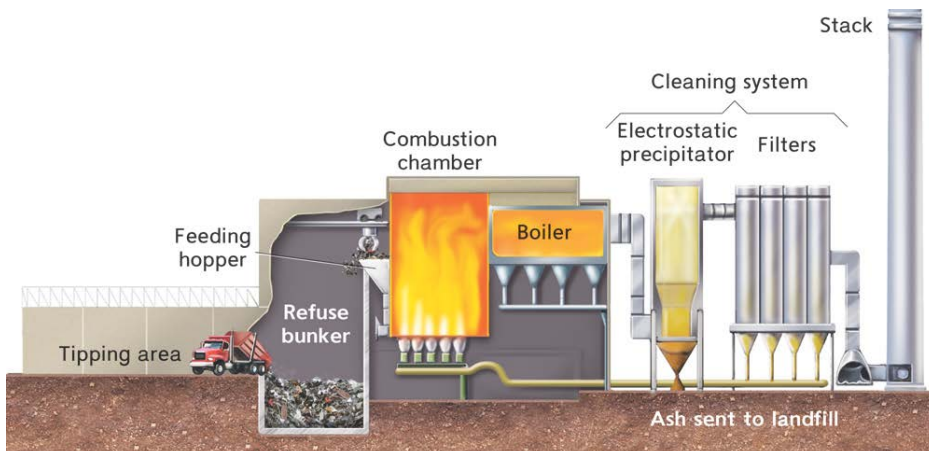
Describe the methods of solid waste disposal. Compare the transition of waste-disposal methods in developing and developed countries. Stress that most developing countries dispose of waste using open dumps, while in developed countries, sanitary landfills and incineration are common practices. Discuss the drawbacks associated with sanitary landfills such as leachate contamination, soil compaction, lack of available space, and methane generation. Define leachate as any liquid that passes through a sanitary landfill that may carry toxins. Waste-to-energy plants also dispose of solid waste. Often called WTE, these plants can produce energy, but leave a toxic ash residue that must be disposed of in a landfill. Make sure students understand that ocean dumping in the United States is now illegal, but was common practice previously. If time permits, students can debate the issues presented in the “What Do You think?” article on environmental justice presented on p. 492.

Describe hazardous waste by using specific examples. Emphasize the use of bioremediation, specifically phytoremediation, as techniques to clean up toxic wastes. Be sure to explain that there are problems with these methods.

All students must know and understand the two major pieces of federal legislation that manage wastes, RCRA and CERCLA. Ensure that students are aware of the Basel Convention, which was enacted to reduce the practice of sending hazardous wastes to developing nations, in the practice of toxic colonialism. The United States has not signed the agreement, making one of the only nations in the world not to sign. The map of the world illustrating this fact is very impactful on students:

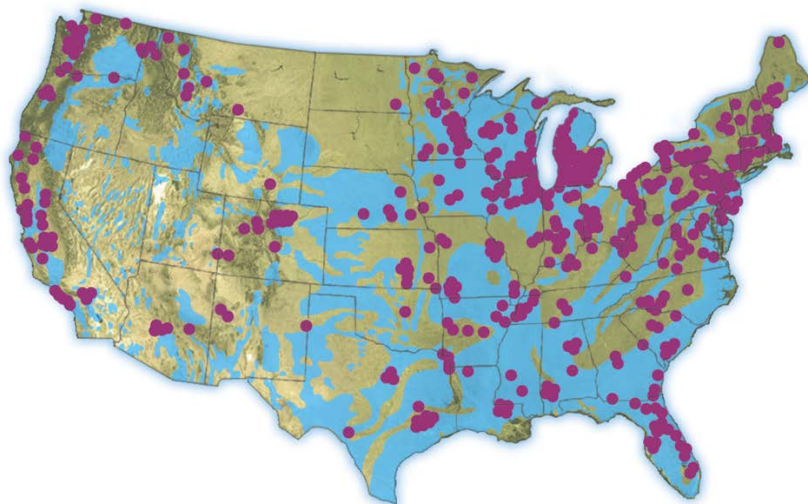
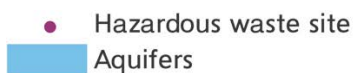
<http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx>

Have students compare the process of energy generation in a coal-fired or nuclear plant with that in the garbage incinerator shown in Figure 21.9.



Discuss the cradle-to-grave philosophy of electronics manufacturing, and why it is important to recycle and reuse components from electronics and appliances. Review Figure 21.19 (p. 490) when discussing this concept. Link the discussion to environmental regulations in developing countries in contrast to those in developed countries.

To shrink the waste stream, recycling, reusing, and reducing wastes are all methods to consider. Recycling has quadrupled in the United States since 1980. Some materials are returned to the same use, while others are transformed into entirely new products. Stress that recycling has issues associated with its implementation. Two problems facing recycling are price fluctuation and contamination. In addition to reducing pollution, recycling saves money, energy consumption, and raw materials. Discuss the issue of electronic waste, and that e-waste recycling is a profitable industry. Explain that primary (closed) recycling occurs when material is changed into the same product, while secondary (open) recycling occurs when material is changed into a different product and requires more energy in its production.



The concept of using plants and bacteria to clean up toxic waste sites has appeared on the AP exam in an essay format. Instruct students to obtain more information on this innovative practice described in the Exploring Science “Phytoremediation: Cleaning Up Toxic Waste with Plants” article on p. 495.

Common Mistakes and Misconceptions

Students must be able to perform calculations in this section as well. A recent AP exam question used a landfill for the basis of one question. Students must be able to calculate volume as well as percentages from information given. Also, students must clearly understand the difference between solid waste and hazardous waste. Students must be able to accurately proscribe an application of specific legislation to a putative problem. CERCLA, RCRA and the Toxics Release Inventory have all been utilized on the exam. Ensure students know the differences.

Activities

Garbage/Landfill Activity

Have students monitor the amount of waste they generate in one week. If appropriate, have them measure the volume as well as the weight of their trash after one week. Garbage collection dates and times vary from neighborhood to neighborhood, so have students design the experiment, with parental approval, based on their collection date for the one-week period. A worksheet for this activity, including follow-up questions, can be found at the end of this chapter.

Landfill Activity

In this activity, students will simulate a landfill and investigate the decomposition of several substances. This can be an inquiry-based activity.

Have students set up a landfill in a plastic container. Let them choose what types of substances they will include. Have students determine how they will collect the data. This activity can run for two months, or you can simply allow students to determine the time frame.

Supplemental Video

“The Works” Garbage TV episode can be purchased on iTunes. The video illustrates the disposal of municipal solid waste from curbside pick up to a municipal recover facility and waste to incineration.

Superfund Search

Have students look at the EPA Superfund site and search for the number of Superfund sites in your state. The concept is somewhat intangible until you demonstrate that some sites are very close to home.

<https://www.epa.gov/superfund/search-superfund-sites-where-you-live>

Classroom Vermicompost

Students could set up a vermicomposting containers to observe how quickly worms can promote composting. Many instructions can be found online, such as this one from the Indiana Department of Environmental Management:

<http://www.in.gov/idem/iee/2367.htm>

Questions for Review

1. In the Case Study “Plastic Seas,” what is the origin of the plastic that killed the albatross chick? How does this plastic affect the albatross chick?

An ocean current in the Pacific concentrates this plastic garbage in a particular area in the Pacific Ocean. 50-80% of this plastic trash originates onshore, while the remainder is discarded or lost at sea. These birds ingest the plastic, thinking that it is food. When they do this, the plastic creates a blockage in their digestive system, and they starve to death.

2. What happens to your household garbage?

In the United States, most household garbage ends up in a landfill. Smaller percentages are incinerated, composted, or recycled.

3. What is demanufacturing? Give an example.

It is the disassembly of obsolete equipment in which the parts are recycled. An example of demanufacturing is the recycling of electronic waste, or e-waste. Parts of computers, TVs, and other types of electronics are disassembled and recycled.

4. How do industries manage hazardous waste?

Several methods can be used to manage hazardous wastes. They can convert these wastes to less hazardous forms, produce less waste, and they can find permanent storage for the wastes.

5. What is phytoremediation, and how is it used?

Phytoremediation is the use of plants for remediation or clean-up of hazardous or contaminated soils. Some plants naturally do this. This technique can be used to clean up areas that are contaminated with hazardous substances. However, once the plants take the chemical out of the soil, the plants then have to be disposed of as well.

6. What are three alternatives to hazardous household chemicals?

The answers to this question will vary but may include vinegar, toothpaste, or club soda. The “What Can You Do?” on p. 490 in the textbook has various alternatives.

7. What is the difference between RCRA and CERCLA?

RCRA is a comprehensive program that requires rigorous testing and management of toxic and hazardous substances. It is often called “cradle-to-grave” in its scope of hazardous-chemical monitoring. CERCLA is aimed at rapid containment, cleanup, or remediation of abandoned toxic waste sites.

Practice Questions

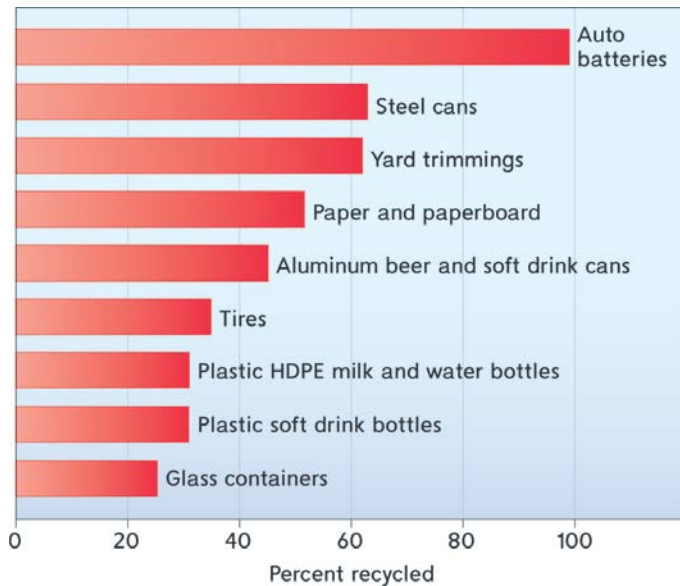
Multiple Choice:

Directions for questions 1–5: The lettered choices below correspond to the descriptions given in questions 1–5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

- (A) e-waste
- (B) solid waste
- (C) hazardous waste
- (D) recycled waste
- (E) organic waste

1. can be composted
2. computers are this type
3. household garbage
4. substance that is fatal to humans
5. an old PlayStation® video game
6. Large areas of contaminated properties that have been abandoned or under-utilized because of real or suspected pollution are called _____.
 - (A) brownfields
 - (B) greenfields
 - (C) habitat-contaminated areas
 - (D) environmental conditions unfit for living organisms
 - (E) conservation development areas
7. A secure landfill consists of all of the following except
 - (A) a leachate-removal system.
 - (B) a clay cap.
 - (C) a methane-removal system.
 - (D) a connected power plant that burns coal.
 - (E) an underground monitoring system.

Use the following for questions 8–10.



8. Approximately what percentage of plastics is recycled?
- (A) 32%
 - (B) 64%
 - (C) 75%
 - (D) 80%
 - (E) 85%
9. Which substance has the highest recycling rate?
- (A) paper
 - (B) plastic
 - (C) aluminum cans
 - (D) car batteries
 - (E) tires
10. Why do you think more people recycle car batteries than glass containers?
- (A) They don't need the car battery anymore.
 - (B) They know the dangers of lead, and want to make the world safer.
 - (C) Recycling a car battery is easy to do.
 - (D) They need car batteries more than glass containers.
 - (E) They get money back for turning in their old battery.

Free-Response Question:

Directions: Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. The town of Knightland has a sanitary landfill. The town consists of 1000 households, and each household produces 15 pounds of garbage twice a week. There is a major highway that leads to the landfill. This landfill first opened in 1950.
 - (a) What type of waste is transported to the sanitary landfill?
 - (b) How many pounds of garbage does each household produce in one year?
 - (i) How many pounds of garbage does the entire town produce in one year?
 - (ii) If 20% of the garbage could have been recycled, what is the mass of this potentially recycled material?
 - (iii) Other than recycling, describe **TWO** steps the residents might take in order to reduce their waste stream.
 - (c) The town is considering expanding its landfill to an adjacent, vacant lot that is forested. However, this landfill would be a secure landfill.
 - (i) Explain one environmental cost associated with this plan.
 - (ii) Describe one piece of federal legislation that might affect this plan.

Answers to Practice Questions

Multiple Choice:

1. E
2. A
3. B
4. C
5. A
6. A
7. D
8. B
9. D
10. E

Free-Response Question:

This question is based on 10 points.

1. (a) 1 point for indicating that solid waste is being transported to the landfill.

(b) 2 points total. 1 point for set-up, and 1 point for the correct answer.

15 pounds garbage/household \times 2 \times 52 weeks/year = 1560 lbs/household each year

- (i) 1 point for the answer with set-up

1560 lbs/household year \times 1000 households = 1,560,000 lbs/year

- (ii) 2 points total. 1 point for set-up, and 1 point for the answer.

.20 \times 1,560,000 lbs/year = 312,000 lbs/year

- (iii) 2 points total. 1 point for each reasonable alternative, such as reusing materials, watching what you buy in terms of packaging, buying less.

- (c) (i) 1 point for explaining an environmental cost such as habitat destruction, possible leachate contamination, hazardous to transport on major highways, possible accidents.

- (ii) 1 point for describing a particular federal law. Laws include, but are not limited to: ESA, Clean Water Act, NEPA, RCRA.

Answers to questions in the Student Edition:

Case Study AP Document-Based Question (page 479)

- (A) Plastic can end up far away from its point of origin and can even make its way to a remote desert island because plastic lasts for a very, very long time so it can travel very far. It is not biodegradable, so instead of breaking down it just breaks into smaller and smaller pieces. It persists for so long in the environment and so it can easily travel with ocean currents to remote, and even uninhabited, desert islands.
- (B) Plastic and waste persist in the environment and can travel very long distances, even from places that are hundreds and even thousands of miles from a coastline. Waste produced in the middle of the U.S., or any country for that matter, can travel and end up in the ocean. Areas that are nowhere near a coast still need to recycle and make efforts to reduce their waste production so they do not contribute to accumulated waste in these locations.
- (C) It is very difficult to clean up the Pacific Garbage Gyre because contrary to what most people think, it is not just one large, compact pile of trash in the ocean. It covers a very large area, which makes it very difficult to clean up. Adding to this difficulty, the trash in the Garbage Gyre does not just float on the surface, much of it is floating below the surface at various depths in the water column.

Use the Math (page 480)

Total waste has increased 184% from 1960 to 2005. Total recycling has increased 1316% over the same time period. Though we are recycling more than we were fifty years ago, our waste generation is still increasing as our human population increases. If these trends remain, we will continue to generate more waste, and recycling will need to increase even more. Landfills, dumps, incinerators, etc. will continue to be filled and built, which compete for space with humans and natural ecosystems unless we find a way to reduce our waste, or reuse and recycle the waste that we create.

Use the Math (page 482)

Developed countries are experiencing logarithmic growth, and developing countries are experiencing exponential (J-curve) growth. Treating 2016 – 2030 linearly, developing countries are producing obsolete computers at approximately 30.4 million computers/year ($(600 - 175)/14$, in millions), and developed countries are producing approximately 2.5 million obsolete computers/year ($(210 - 175)/14$, in millions). If nothing changes, developing countries will be producing approximately 1.2 billion obsolete computers per year.

Use the Math (page 489)

Chemical and petroleum industries produce 188.15 billion kg of waste annually.
265 million metric tons $\times 0.71 = 188,150,000$ metrics tons $\times 1000 = 188,150,000,000$ kg
 $\ast 1$ metric ton = 1000 kg

AP Connections Review Answers (pages 496-497)

Multiple-Choice

1. c. Dioxins. They are released from incinerators, but they are not metals.
2. b. reduce, reuse, recycle
3. b. The cost of recycled aluminum compared to virgin aluminum is an economic, not environmental consideration when recycling aluminum.
4. e. A closed sanitary landfill should not be contaminated with hazardous wastes, and thus would not be considered a brownfield.
5. d. Refuse derived fuel is garbage sorted to remove noncombustible or recyclable material. This material has a higher energy content and produces less air pollution than a mass burn technique.
6. c. identifies the worst hazardous waste sites and places them on the National Priorities List for cleanup with financing from the federal program.

Data Analysis and Free-Response Questions

1A Answers will vary depending on parameters chosen.

1B Answers will vary depending on the parameters chosen and the results obtained.

2A Waste disposal strategies include landfill, recycle, compost, and incineration.

2B Answers will vary depending on strategy chosen. Landfills are convenient and relatively inexpensive, and methane recovery can be used for fuel. Disadvantages of landfills are that they are becoming more expensive as land prices and shipping costs increase and communities fight to not have a landfill located near them. Recycling saves energy, materials, and landfill space and reduces pollution. Disadvantages of recycling are it can be confusing and difficult to recycle certain items and prices for recycled material are more expensive because industries receive virgin material below cost. Compost creates a valuable soil amendment and reduces landfill waste. Disadvantages of composting are it can take up space and requires understanding of compost maintenance and the soil amendments only have a modest market value. Incineration produces energy and reduces the amount of material that needs to be sent to landfills. Disadvantages of incineration are that it creates a lot of air pollution and can discourage recycling because of volume needed to operate the incinerators.

2C Difficulties with hazardous waste disposal strategies include the cost, the location of permanent storage, and the time it takes for some toxins, like radioactive material, to degrade. Hazardous waste disposal requires a lot of planning and understanding of disposal rules.

Garbage/Landfill Activity Worksheet

Look up information on landfills and recycling centers to find out:

1. Which laws regulate landfills?
2. Which government agency oversees landfills?
3. How do landfills work?
4. Find three things that are forbidden from going into a landfill. Explain how an individual is to dispose of such wastes.
5. Who purchases recycled materials from recycling centers?
6. Which types of recycled material have the biggest demand?
7. What is done with the materials that are recycled, but not sold?
8. What does the future look like regarding landfills?
9. What does the future look like regarding recycling centers?
10. What are some problems you see regarding landfills?
11. What are some problems you see regarding recycling centers?
12. List at least five diseases/disorders that have been attributed to older dumps.