22

Waste Management

Chapter Objectives

This chapter will help students:

Summarize and compare the types of waste we generate

List the major approaches to managing waste

Delineate the scale of the waste dilemma

Describe the conventional waste disposal methods: landfills and incineration

Evaluate approaches for reducing waste: source reduction, reuse, composting, and recycling

Discuss industrial solid waste management and principles of industrial ecology

Assess issues in management of hazardous waste

Lecture Outline

I. Central Case: Transforming New York's Fresh Kills Landfill

A. In 2001 the Fresh Kills Landfill, the primary repository of New York City's garbage for half a century, closed.

B. The plan was to convert the landfill to a public park. It is two-and-a-half times bigger than Central Park, offers panoramic views of the Manhattan skyline, and is the region's largest remaining complex of saltwater tidal marshes, freshwater creeks, and wetlands.

C. With its only landfill closed, New York City began exporting its waste by barge and railroad.

D. Opposition, economic misjudgment, and accusations of favoritism and influence caused problems, and New York City ended up paying truckers exorbitant prices to haul the garbage to five states.

E. The sanitation department's budget nearly doubled, and the city had to scale back its recycling program.

F. After the September 11, 2001, terrorist attacks, the landfill was reopened and the 1.8 million tons of rubble from the attacks was taken to Fresh Kills, and was sorted and buried.
G. Today, plans for a park are proceeding. This public works project will include ecological restoration of wetlands, ball fields, a roller-blade rink, and the creation of scenic public vistas on what once was a symbol of waste of modern culture.

II. Approaches to Waste Management

A. **Waste** refers to any unwanted material that results from a human activity or process.
   1. **Municipal solid waste** is non-liquid waste that comes from homes, institutions, and small businesses.
   2. **Industrial solid waste** includes waste from the production of consumer goods, mining, agriculture, and petroleum extraction and refining.
   3. **Hazardous waste** refers to solid or liquid waste that is toxic, chemically reactive, flammable, or corrosive.
   4. Another major type of waste is *wastewater*—water we use in our households, businesses, industries, or public facilities and drain or flush down our pipes, as well as the polluted runoff from our streets and storm drains.

B. We have several aims in managing waste.
   1. The component aims of **waste management** are:
      a . To minimize the amount of waste we generate.
      b. To recover waste materials and recycle them.
      c . To dispose of waste safely and effectively.
   2. There are several ways to reduce the amount of waste that enters the **waste stream** as it moves from its sources toward disposal destinations.
   3. Manufacturers can use materials more efficiently.
   4. Consumers can buy fewer goods, buy goods with less packaging, and use goods longer. They can also buy used goods, reuse goods already owned, and donate used items for use by others.
   5. *Recovery* is the next-best strategy in waste management—sending used goods to facilities that extract and reprocess raw materials to manufacture new goods (e.g., newspapers, cans, and plastic containers can be reprocessed, and organic waste can be *composted*).
   6. Material that is left is disposed of in landfills or is burned in incinerators.

III. Municipal Solid Waste

1. Municipal solid waste is the waste produced by consumers, public facilities, and small businesses.

A. Patterns in the municipal solid waste stream vary from place to place.
   1. In the United States, paper, yard debris, food scraps, and plastics are the principal components of municipal solid waste, together accounting for over 70% of the waste stream.

2. Most municipal solid waste comes from packaging and from nondurable goods.
3. In 2003 the average U.S. citizen generated about 2.0 kg (4.4 lb) of trash per day.
4. Following the United States in per capita solid waste production are Canada with 1.7 kg (3.75 lb) per day and the Netherlands with roughly 1.4 kg (3.0 lb) per day.
5. Of the developed nations, Germany and Sweden produce the least waste per capita, generating just under 0.9 kg (2.0 lb) per day.
6. The cost of waste disposal accounts for part of the difference among nations; where disposal is expensive, people have the incentive to waste less.
7. People in developing nations generate considerably less waste.
8. Wealthier nations tend to invest more in waste collection and disposal, so they are often better able to manage waste and minimize impacts on human health and the environment.

B. Waste generation is rising in all nations.
   1. To some extent this reflects rising standards of living.
   2. The increase also reflects an increase in packaging, and an increase in poor-quality goods designed to be inexpensive that wear out and pile up quickly as trash.

C. The open dumping of the past has given way to improved disposal methods.
   1. Historically, people dumped their garbage wherever it suited them.
   2. As population and consumption have risen, however, amounts of waste have increased and municipalities have begun consolidating trash at specified locations, burning it from time to time.
   3. In the 1980s in the United States, waste generation increased while incineration was restricted, and recycling was neither economically feasible nor widely popular.

D. **Sanitary landfills** are regulated by health and environmental guidelines.
   1. In modern sanitary landfills, waste is buried in the ground or piled up in large, carefully engineered mounds designed to prevent waste from contaminating the environment.
   2. Guidelines set forth by the federal **Resource Conservation and Recovery Act (RCRA)** specify how waste is to be added to a landfill; it cannot simply be heaped on.
   3. Following regulations to ensure public health and safety is not cheap, and in developing countries, landfill operators often lack the technology or funds to safely dispose of waste. In the U.S., a variety of layers are required to store and protect the materials inside the landfill from exposure to air or groundwater, and to encourage plant growth atop the capped landfill.
   4. Landfills produce **leachate**—liquid that results when substances in trash dissolve in water—and have collection and treatment systems.

5. New closure regulations require that a barrier (plastic) be included on the top of the landfill to keep water from infiltrating into the landfill and gas from escaping. Gravel is used to direct the flow of water away from the landfill and 24 inches of soil is added to the final cover.

E. Landfills can be transformed after closure.
   1. A number of cities have converted closed landfills into public parks.

F. Landfills have drawbacks.
   1. Despite improvements in liner technology and landfill siting, many experts believe that leachate will eventually escape from even well-lined landfills.
   2. Another problem is finding suitable areas to locate landfills, because most communities do not want them nearby—the NIMBY (not-in-my-backyard) reaction.
   3. One famed case of long-distance waste transport involved "the garbage barge" full of garbage that left New York and traveled 9,700 km (6,000 mi) before eventually returning to New York. North Carolina, Louisiana, and Mexico rejected the shipment because it was contaminated with medical waste.

G. Incinerating trash reduces pressure on landfills.
   1. **Incineration** is a controlled process of burning in which mixed garbage is combusted at very high temperatures.
   2. Simply reducing the volume and weight does not rid trash of its toxic components. The ash must still be disposed of in hazardous waste landfills.
   3. As a result of real and perceived health threats from incinerator emissions, and because of community oppositions to incinerator plants, several technologies have been developed to mitigate emissions.

H. Many incinerators burn waste to create energy.
   1. Most North American incinerators today use the heat generated by waste combustion to generate electricity or to fuel heating systems.
   2. There are over 100 **waste-to-energy (WTE)** facilities across the United States, with a total capacity to process nearly 100,000 tons of waste per day.
   3. Although burning waste is an effective means of reducing its volume, the considerable financial cost of incineration is not usually offset by power generation, and it may take many years for a WTE facility to become profitable.
   4. Contracts between cities and private contractors guaranteeing WTE facilities a minimum amount of garbage over a long period have interfered with communities' later attempts to reduce waste through recycling or other waste-reduction methods.

I. Landfills can produce gas for energy.
   1. *Landfill gas* can be collected, processed, and used in the same way as natural gas, one of our primary sources of fossil-fuel energy.
   2. Today, more than 330 operational projects collect landfill gas in the United States.

J. Reducing waste is a better option than disposal.
    1. **Source reduction** means reducing the amount of material entering the waste stream.
    2. A number of strategies for source reduction exist, some of which involve manufacturers' choices of packaging, and some of which involve consumer preferences.
    3. Producers prefer short-lived goods that need frequent replacement. Consumer demand can change that.

K. Reuse is one main strategy for waste reduction.
    1. Consumers can save items to use again, or choose durable goods instead of disposable ones.
    2. Using already-used goods and donating unwanted items are major ways to reduce waste.
    3. Used items can be every bit as functional as new ones, and much cheaper.

L. **Composting** recovers organic waste.
    1. Composting is the conversion of organic waste into mulch or humus through the natural biological processes of decomposition.
    2. Many municipalities are reducing waste through community composting programs, where they produce mulch that community residents can use for gardens and landscaping.
    3. Nearly half of U.S. states now ban yard waste from the municipal waste stream, helping accelerate the drive toward composting.

M. **Recycling** consists of three steps.
    1. Recycling consists of collecting materials that can be broken down and reprocessed to manufacture new items.
    2. Curbside recycling has grown rapidly and boosted recycling rates. Nearly half of all people in the U.S. now have some type of curbside recycling. This is the first step in recycling—collection.
    3. Collected items are taken to **materials recovery facilities (MRFs),** where they are sorted, cleaned, shredded, and prepared for reprocessing. This is the second step in recycling—reprocessing and manufacturing new items.
    4. Consumers and businesses complete the third step by purchasing products made from recycled materials.

N. Recycling has grown rapidly and can expand further.
    1. According to the EPA the growth of recycling is "one of the best environmental success stories of the late 20th century."
    2. Recycling reduces waste and increases citizen satisfaction, but most municipal recycling programs are run at an economic loss.
    3. Recycling advocates point out that market prices do not take into account external costs, including the environmental and health impacts of *not* recycling.

O. Financial incentives can help address waste.
    1. Waste managers use economic incentives to influence consumer behavior, such as the "pay-as-you-throw" approach to garbage collection, with municipalities charging residents for trash pickup according to the amount of trash discarded.

2. Some states have “bottle bills” allowing refunds for returned bottles and cans. Research shows that states with bottle bills reduce their beverage container trash by up to 84% and their overall solid waste burden by up to 64%.
3. It is a testament to the lobbying power of the beverage industries, which have traditionally opposed the passage of bottle bills, that more states do not have such legislation.
4. One consideration is whether to add more types of containers to bottle bills.
5. A second issue is whether and how to adjust refunds to account for inflation.

P. One Canadian city showcases the shift from disposal to reduction and recycling.
1. Edmonton, Alberta, has created one of the world’s most advanced programs for waste management.
2. When Edmonton’s residents put out their trash, city trucks take it to the city’s new co-composting plant.
3. Besides the co-composting facility and a sanitary landfill, Edmonton’s waste program also includes a state-of-the-art MRF, a leachate treatment plant, and a wetland and landfill vegetation program.

IV. Industrial Solid Waste

1. According to the EPA, each year U.S. industrial facilities generate about 7.6 billion tons of waste, about 97% of which is wastewater.

A. Regulation and economics both influence industrial waste generation.
1. Businesses that manage their own waste on-site most often dispose of it in landfills that must meet state, local, or tribal guidelines.
2. Regulation varies greatly, but in most cases state and local regulation of industrial solid waste is less strict than federal regulation of municipal solid waste.
3. It is often cheaper for industry to manufacture its products or perform its services quickly but messily. Economic efficiency is maximized, but physical efficiency is not.

B. **Industrial ecology** seeks to make industry more sustainable.
1. Industrial ecology redesigns industrial systems in order to reduce resource inputs and minimize physical inefficiency while maximizing economic efficiency.
2. Industrial ecologists examine the entire life cycle of a given product and look for ways to make the process more ecologically efficient; this is called **life-cycle analysis.**
3. Industrial ecologists also try to identify points at which waste products from one manufacturing process could be used as raw materials for a different process.
4. The Swiss Zero Emission Research and Initiatives (ZERI) Foundation, for example, supported research in several countries to use brewer’s waste products to generate animal food, bread,

mushrooms, pigs, and fish. While not fully a closed-loop system, it is getting closer to that ideal.

V. Hazardous Waste

A. Hazardous waste is waste that poses a danger or potential danger because of its chemical nature.
   1. Public awareness of hazardous waste has increased greatly in recent decades, driven by highly publicized instances of toxic contamination at abandoned industrial sites.
   2. By EPA definition, hazardous waste is waste that meets one of the following four criteria:
      a. *Ignitability:* substances that easily catch fire (for example, natural gas or alcohol).
      b. *Corrosivity:* substances that corrode metals in storage tanks or equipment.
      c. *Reactivity:* substances that are chemically unstable and readily react with other compounds, often explosively or by producing noxious fumes.
      d. *Toxicity:* substances that are harmful to human health when they are inhaled or ingested, or come in contact with human skin.

B. Organic compounds and heavy metals can be hazardous.
   1. In our day-to-day lives, we rely on the capacity of synthetic organic compounds and petroleum-derived compounds to resist bacterial, fungal, and insect activity.
   2. Heavy metals such as lead, chromium, mercury, arsenic, cadmium, tin, and copper are used widely in industry.
   3. Computers, televisions, VCRs, cell phones, and other electronic devices represent major new sources of potential heavy metal contamination.
   4. Research indicates that this *e-waste* should be treated as hazardous waste. Electronic equipment contains heavy metals and flame retardants. There is also concern that those involved in recycling these products through "de-manufacturing" are exposed to these toxic materials.

C. Several steps precede the disposal of hazardous waste.
   1. For many years we produced hazardous waste and discarded it carelessly into the environment.
   2. Today, several disposal methods for hazardous waste have been developed, though none are completely satisfactory.
   3. U.S. law mandates that large generators of hazardous materials have permits, and that the materials be tracked "from cradle to grave."
   4. Because current U.S. laws make disposing of hazardous waste quite costly, irresponsible companies have sometimes been guilty of illegally and anonymously dumping waste on abandoned property.
   5. Many biologically hazardous materials can be treated by incineration, bacterial bioremediation, or phytoremediation with plants that either take up specific contaminants and break them down or concentrate heavy metals in their tissues.

D. We have three main disposal methods for hazardous waste.
    1. Hazardous waste landfills have several impervious liners and leachate removal systems, and are located far from aquifers.
    2. A method of storing liquid hazardous waste is through **surface impoundments.** Water is allowed to evaporate, leaving a solid hazardous waste residue that can be removed and transported elsewhere for permanent disposal.
    3. In **deep-well injection,** a well is drilled deep beneath an area's water table and wastes are injected into it. In practice, wells corrode and leak wastes, allowing the hazardous wastes to enter aquifers.
    4. These methods do not reduce the toxicity of the materials, but they do help to isolate people, wildlife, and ecosystems from them.

E. Radioactive waste is a special type of hazardous waste.
    1. The dilemma of safe disposal has dogged the industry and the U.S. military for decades.
    2. Yucca Mountain in Nevada has been approved as the single-site repository for all U.S. nuclear waste.
    3. Currently, a site in the Chihuahuan Desert in southeastern New Mexico serves as a permanent disposal site for radioactive waste.

F. Contaminated sites are being cleaned up, slowly.
    1. Many thousands of former military and industrial sites are contaminated with hazardous waste in the United States, Russia, and virtually every other nation on Earth.
    2. For most nations, dealing with these messes is simply too difficult, time-consuming, and expensive.
    3. Under the **Superfund** program, administered by the EPA, experts identify sites polluted with hazardous chemicals, take action to protect groundwater near these sites, and clean up the pollution.
    4. One objective is to charge the responsible parties for cleanup of the sites, but in many cases the responsible parties cannot be found or held liable.
    5. Once a Superfund site has been identified, the EPA determines whether the wastes are confined or are likely to spread, and how threatening the site is to humans or drinking water supplies.
    6. Sites are ranked according to the level of risk to human health, and cleanup proceeds as funds become available.
    7. Many sites are contaminated with chemicals we have no effective way to deal with, and cleanup involves trying to isolate the waste.
    8. Under a 1980 law, tax was placed on chemical raw materials. The funds generated from this tax, funded cleanup at Superfund sites. The Bush Administration and Congress allowed this law to expire. There are no funds available for site cleanup, so taxpayers are shouldering the costs completely. As a result, fewer sites are getting attention.

VI. Conclusion

A. Our societies have made great strides in addressing our waste problems.
B. The United States now diverts 30% of all solid waste from disposal into recycling.
C. Our consumption habits create more waste than ever.
D. Our waste management efforts are still marked by a number of difficult dilemmas.
E. The best hope lies in reducing our generation of waste by finding ways to reduce, reuse, and efficiently recycle materials and goods.