

# ENVIRONMENT

*THE SCIENCE BEHIND THE STORIES*  
Jay Withgott • Scott Brennan


## Ch 22

### Waste Management

Part 2: Environmental Issues  
the Search for Solutions

[Waste Management Video](#)


PowerPoint® Slides prepared by  
Jay Withgott and Heidi Marcum



Third Edition

### This lecture will help you understand:

- The types of waste we generate
- Approaches to managing waste
- The scale of the waste dilemma
- Conventional waste disposal methods
- Ways to reduce waste
- Industrial solid waste management
- Issues in managing hazardous waste



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

### Central Case: Transforming New York's Fresh Kills Landfill


- The largest landfill in the world, it closed in 2001
- Staten Island residents viewed the landfill as an eyesore and civic blemish
- It was briefly reopened to bury rubble from the World Trade Center after the September 11, 2001, attack
- New York plans to transform the landfill into a world-class public park



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

### Approaches to waste management

- **Waste** = any unwanted material or substance that results from human activity or process
- **Municipal solid waste** = non-liquid waste that comes from homes, institutions, and small businesses
- **Industrial solid waste** = waste from production of consumer goods, mining, agriculture, and petroleum extraction and refining
- **Hazardous waste** = solid or liquid waste that is toxic, chemically reactive, flammable, or corrosive
- **Wastewater** = water used in a household, business, or industry, as well as polluted runoff from our streets and storm drains



Skip

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Aims in managing waste

- Three main components of waste management:
  - Minimizing the amount of waste we generate (**source reduction**)
  - Recovering waste materials and finding ways to recycle them
  - Disposing of waste safely and effectively



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Ways to reduce waste that enters waste stream

- **Waste stream** = flow of waste as it moves from its sources toward disposal destinations
  - More efficient use of materials, consume less, buy goods with less packaging, reusing goods
- **Recovery (recycling, composting)** = next best strategy in waste management
  - **Recycling** = sends used goods to manufacture new goods
  - **Composting** = recovery of organic waste



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Patterns in the municipal solid waste stream vary

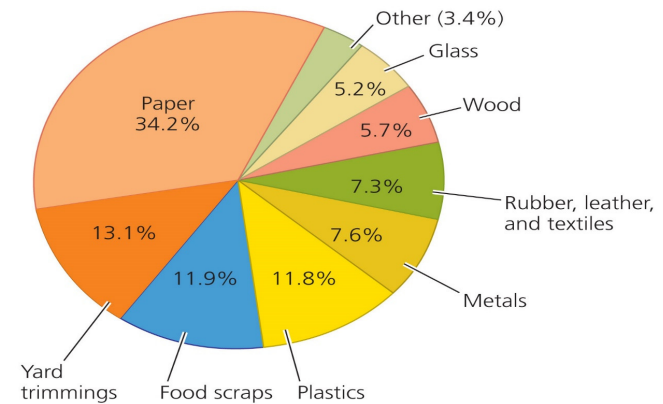


- Municipal solid waste is also referred to as *trash* or *garbage*
- In the U.S., paper, yard debris, food scraps, and plastics are the principal components of municipal solid waste
  - paper is the largest component of solid waste
- In developing countries, food scraps are the primary contributor



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## The U.S. municipal solid waste stream

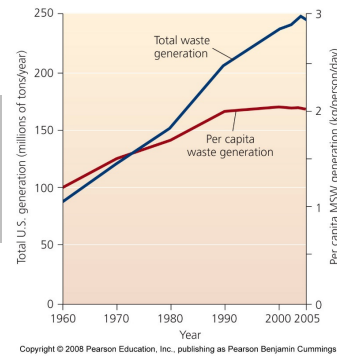


Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Waste generation is rising in the U.S.

*In the U.S., since 1960, waste generation has increased by 2.8 times*



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Waste generation is rising in all nations

- Consumption is greatly increasing in developing nations
- Wealthy consumers often discard items that can still be used



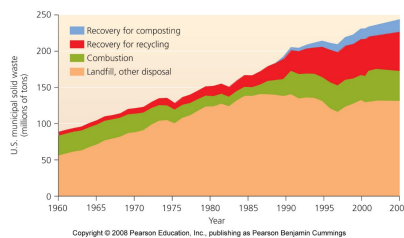
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Improved disposal methods

- Historically people dumped their garbage wherever it suited them
  - Open dumping and burning still occur throughout the world
- Most industrialized nations now bury waste in lined and covered landfills or burn it in incineration facilities
  - In the U.S., recycling is decreasing pressure on landfills



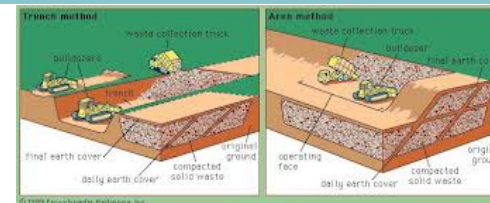
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Sanitary landfills are regulated

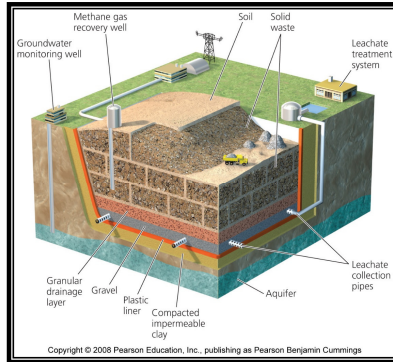
- **Sanitary landfills** = waste buried in the ground or piled in large, engineered mounds
  - Must meet national standards set by the EPA under the Resource Conservation and Recovery Act (RCRA) of 1976
  - Waste is partially decomposed by bacteria and compresses
  - Layered with soil to reduce odor, speed decomposition, reduce infestation by pets
  - When a landfill is closed, it must be capped and maintained



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## A typical sanitary landfill

To protect against environmental contamination, landfills must be located away from wetlands, earthquake-prone faults, and 20 ft above water table

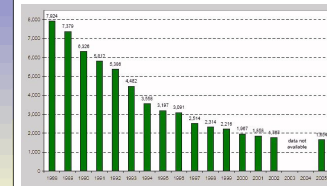
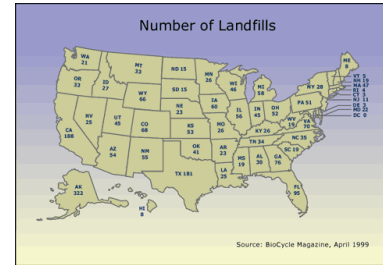


animation

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Landfills can be transformed after closure

- Thousands of landfills lie abandoned
- U.S. had nearly 8,000 landfills
  - Today there are fewer than 1,700
- Growing cities converted closed landfills into public parks



Source: BioCycle Magazine, April 1999

## Landfills have drawbacks

- Experts believe that leachate will eventually escape
- It is hard to find places suitable for landfills
  - The Not-In-My-Backyard (NIMBY) syndrome
- The “Garbage barge” case
  - In 1987, Islip, New York’s landfills were full, and a barge traveled to empty the waste in North Carolina, which rejected the load
  - It returned to Queens to incinerate the waste, after a 9,700 km (6,000 mile) journey



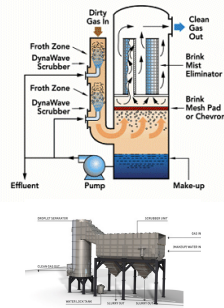
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

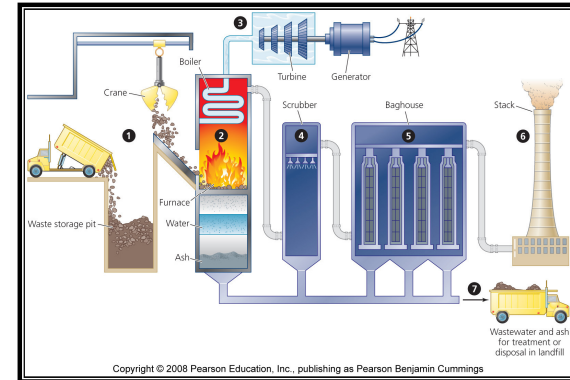
### Incinerating trash reduces landfill pressure

- **Incineration** = a controlled process in which mixed garbage is burned at very high temperatures
- Incineration in specially constructed facilities can be an improvement over open-air burning of trash
  - But, the remaining ash must be disposed of in a hazardous waste landfill
- **Scrubbers** = chemically treat the gases produced in combustion to remove hazardous components and neutralize acidic gases



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

### A typical solid waste incinerator

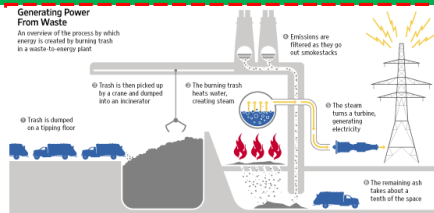


Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

### Many incinerators create energy

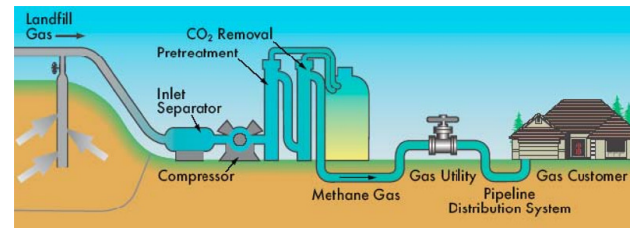
- Incineration is used to reduce the volume of waste and generate electricity
- **Waste-to-energy facilities (WTE)** = use the heat produced by waste combustion to create electricity
  - They can process nearly 100,000 tons of waste per day
- Companies contract with communities to guarantee a minimum amount of garbage
  - Long-term commitments interfere with the communities' later efforts to reduce waste



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

### Landfills can produce gas for energy

- Bacteria can decompose waste in an oxygen-deficient environment
- **Landfill gas** = a mix of gases that consists of roughly half methane
  - Can be collected, processed, and used like natural gas



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Reducing waste is a better option

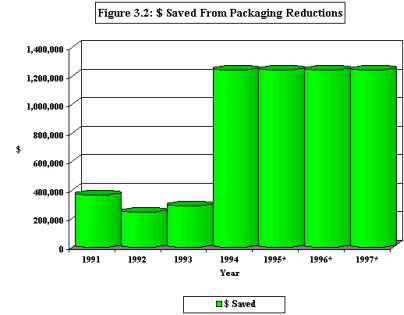
- **Source reduction** = preventing waste generation in the first place
  - Avoids costs of disposal and recycling
  - Helps conserve resources
  - Minimizes pollution
  - Can save consumers and businesses money



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Waste can be reduced by manufacturers

- Choose minimally packaged goods
- Buy unwrapped fruits and vegetables
- Buy in bulk
- Use packaging that is more recyclable
- Reduce the size or weight of goods



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Governments fight waste and litter

- Major source of litter and waste: plastic grocery bags
  - Grocery bags can take centuries to decompose
  - Choke and entangle wildlife
  - Litters the landscape
- Many governments, federal state and local, have banned *non-biodegradable* bags



Plastic Bag Journey

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Reuse is one main strategy for waste reduction

- To save waste, items can be used again or durable goods used instead of disposable ones
- People can donate items to resale centers such as Goodwill Industries and the Salvation Army



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Composting recovers organic waste

- **Composting** = the conversion of organic waste into mulch or humus through natural biological processes of decomposition
- Home composting:
  - Homeholders place waste into composting piles
  - Heat from microbial action builds in the interior and decomposition proceeds
  - Earthworms, bacteria, soil mite, sow bugs, and other organisms convert waste into high-quality compost



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Municipal composting programs

- Divert food and yard waste from the waste stream to central composting facilities
  - Reduces landfill waste
  - Encourages soil biodiversity
  - Reduces the need for chemical fertilizers



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



## Recycling consists of three steps

- **Recycling** = collecting materials that can be broken down and reprocessed to manufacture new items
  - Recycling diverts 58 million tons of materials
- Step 1 : collection and processing of recyclable materials through curbside recycling or designated locations
  - **Materials recovery facilities (MRFs)** = workers and machines sort items, then clean, shred and prepare them for reprocessing



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## The second and third steps of recycling

- Step 2 is using recyclables to produce new products
- In step 3, consumers purchase goods made from recycled materials

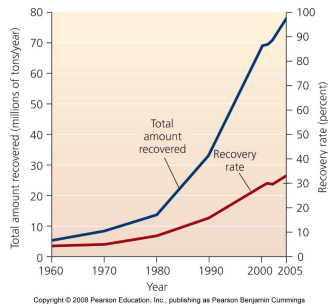


Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Recycling has grown rapidly and can expand



- The EPA calls the growth of recycling “one of the best environmental success stories of the late 20th century”
- Recycling rates vary widely, depending on the product
  - 67% of major appliances are recycled
  - Only 6% of plastics are recycled

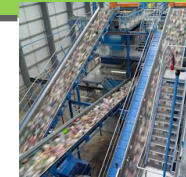
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

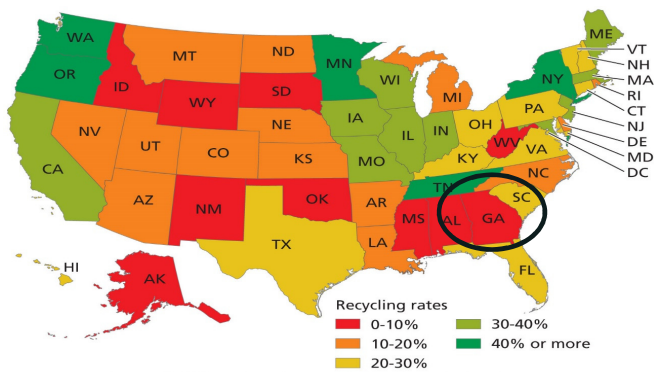
## Growth in recycling results from:

- A desire reduce waste output
- The public’s desire to expand recycling
- New technologies and markets make recycling more and more cost effective
- The more material that is recycled, the lower the price
- Not taken into account is the health and environmental effects of *not* recycling



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Recycling rates vary widely in the U.S.

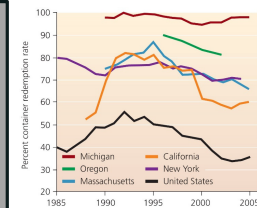


Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

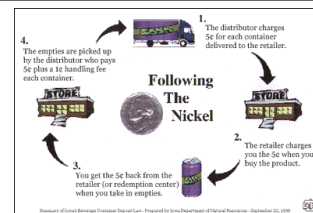
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Financial incentives can address waste

- **Pay-as-you-throw** approach = uses financial incentives to influence consumer behavior
  - The less waste a house generates the less it is charged for trash collection
- **Bottle bills** = consumers receive a refund for returning used bottles



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



## A Canadian city showcases reduction and recycling

- Edmonton, Alberta, has created one of the world's most advanced waste management programs
  - Waste: 35% landfilled, 15% is recycled, 50% is composted
  - 81% of the people participate in curbside recycling
- Produces 80,000 tons/year in its composting plant
- Its state-of-the-art MRF handles 30,000 - 40,000 tons of waste annually



(a) Composting facility, Edmonton, Alberta  
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



(b) Aeration building, Edmonton composting facility  
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

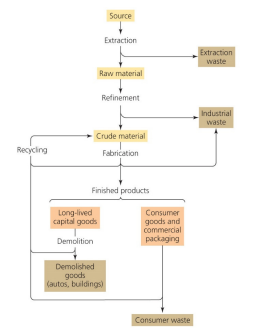
Skip

## Regulation and economics influence waste

- Most methods and strategies of waste disposal, reduction, and recycling are similar to municipal solid waste
- Regulation varies from state to state
  - In most cases, state and local regulations are less strict than federal rules
  - In many areas, industries are not required to have permits, install landfill liners or leachate collection systems, or monitor groundwater for contamination

Skip

## Industrial solid waste



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

- U.S. industrial facilities generate 7.6 billion tons of waste
  - 97% is wastewater
- The federal government regulates municipal waste
- Industrial waste** = waste from factories, mining, agriculture, petroleum extraction, etc.
- Regulation varies from state to state



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

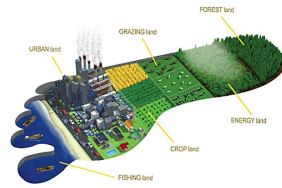
## Physical and economic efficiency

- Physical efficiency is not equal to economic efficiency
  - Often times it is cheaper to manufacture products or perform services quickly but messily
  - It can be cheaper to generate waste than to avoid waste
- The rising cost of waste disposal encourage industries to decrease waste and increase physical efficiency



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Industrial ecology

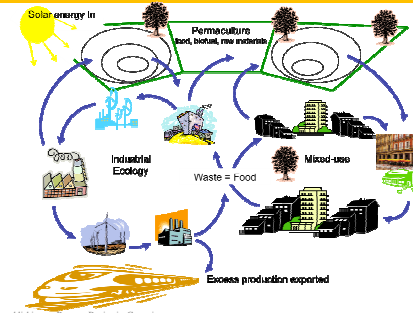


- **Industrial ecology** = redesigning industrial systems to reduce resource inputs and to minimize physical inefficiency while maximizing economic efficiency
  - Industrial systems should function like ecological systems, with little waste
- **Life cycle analysis** = examine the life cycle of a product and look for ways to make the process more ecologically efficient
  - Waste products can be used as raw materials
  - Eliminating environmentally harmful products and materials

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

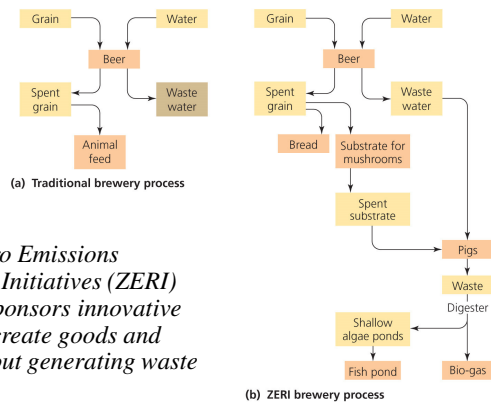
## Businesses are adopting industrial ecology

- Businesses are using industrial ecology to reduce waste and decrease their impact on health and the environment while saving money
  - American Airlines switched from hazardous to nonhazardous materials in its Chicago facility



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## An example of industrial ecology



*The Swiss Zero Emissions Research and Initiatives (ZERI) Foundation sponsors innovative projects that create goods and services without generating waste*

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Hazardous waste



- Hazardous waste is defined as:
- **Ignitable** = catches on fire easily (natural gas, alcohol)
- **Corrosive** = corrode metals in storage tanks or equipment
- **Reactive** = chemically unstable and readily react with other compounds
- **Toxic** = harm human health when they are inhaled, are ingested, or contact human skin

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Hazardous wastes have diverse sources

- Industry = produces the largest amount of hazardous waste
- Households = now the largest producer of hazardous waste
- Mining, Small businesses, Agriculture, Utilities, Building demolition

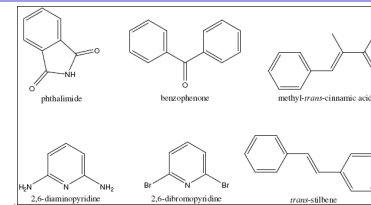


Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Organic compounds can be hazardous



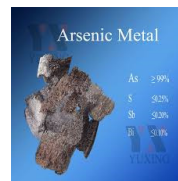
- Synthetic organic compounds = resist decomposition
  - Keep buildings from decaying, kill pests, and keep stored goods intact
  - Readily absorbed through the skin
  - They can act as mutagens, carcinogens, teratogens, and endocrine disruptors



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Heavy metals can be hazardous

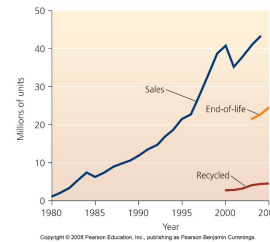
- Lead, chromium, mercury, arsenic, cadmium, tin, and copper
- Used widely in industry for wiring, electronics, metal plating, pigments, and dyes
- Heavy metals that are fat soluble and break down slowly can bioaccumulate and biomagnify



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## “E-waste” is a new and growing problem

- **Electronic waste (“e-waste”)** = waste involving electronic devices
  - Disposed of in landfills, but should be treated as hazardous waste



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Several steps precede disposal of hazardous waste

- For many years, hazardous waste was discarded without special treatment
  - Public did not know it was harmful to human health
  - Assumed the substances would disappear or be diluted in the environment
  - Since the 1980s, cities designate sites or special collection days to gather household hazardous waste



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

Skip

## Illegal dumping of hazardous waste

- Since hazardous waste disposal is costly
  - Industrial nations illegally dump in developing nations
  - Basel Convention, an international treaty, should prevent dumping but it still happens
- High costs of disposal encourages companies to invest in reducing their hazardous waste

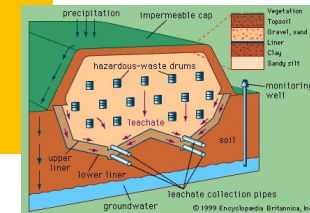
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Disposing of hazardous waste

- **Resource Conservation and Recovery Act (RCRA)** = states are required to manage hazardous waste
  - Large generators of hazardous waste must obtain permits and must be tracked “from cradle to grave”
  - Intended to prevent illegal dumping



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

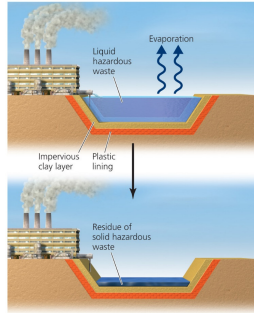
© 1999 Encyclopedia Britannica, Inc.

## Three disposal methods for hazardous waste

- These methods do nothing to lessen the hazards of the substances
  - But they help keep the substance isolated from people, wildlife, and ecosystems
- Landfills = must have several impervious liners and leachate removal systems
  - Standards are stricter than for ordinary sanitary landfills
  - Must be located far from aquifers

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Surface impoundments



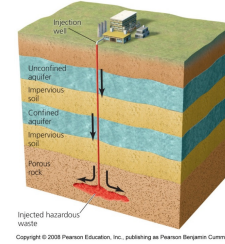
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

- **Surface impoundments** = store liquid hazardous waste
- Shallow depressions are lined with plastic and clay
- The underlying clay layer can crack and leak waste

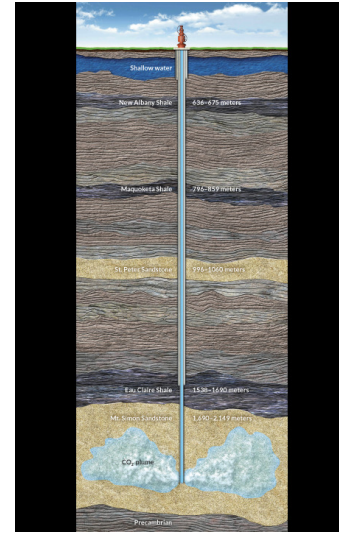
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Deep-well injection

- **Deep-well injection** = a well is drilled deep beneath the water table and waste is injected into it
  - A long-term disposal method
  - However, the wells become corroded and leak waste into soil

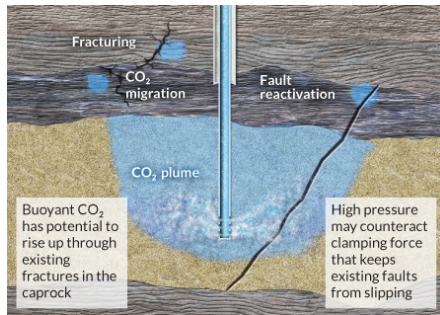


Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings



## Deep-well Injection

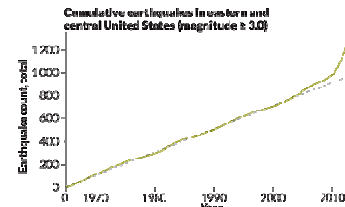
Pressure Concerns



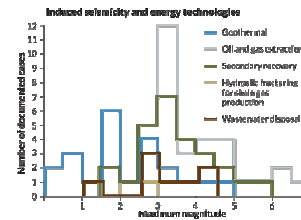
Down deep, where CO<sub>2</sub> is injected, high pressure spreads far beyond the injected fluid. As pressure rises, rock grains are pushed apart. This has potential to cause unwanted mechanical changes, including escape of CO<sub>2</sub> (through existing or new fractures or leaky faults) as well as quakes due to fault failure.

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Deep-well Injection



After decades of a steady earthquake rate (dotted line) in the central and eastern United States, activity began to rise in about 2009 and jumped to five times the normal rate by 2013, probably due to human activity.

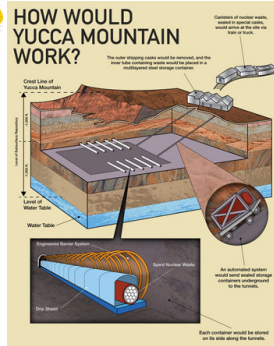


Several energy technologies have caused quakes of varying magnitudes; oil and gas extraction has caused the most quakes and highest magnitudes. Little data (two events around a magnitude 1) exist on the seismic impact of CO<sub>2</sub> injection.

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Radioactive waste is especially hazardous

- Radioactive waste is particularly dangerous and persistent
- Yucca Mountain in Nevada is now designated as the single-site repository for all U.S. nuclear waste
- The Waste Isolation Pilot Plant (WIPP) is the world's first underground repository for transuranic waste from nuclear weapons development



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Contaminated sites are being slowly cleaned up

- Globally, thousands of former military and industrial sites are contaminated with hazardous waste
- **Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (1980) (Superfund)**
  - Established a federal program to clean up U.S. sites polluted with hazardous waste
  - Experts identify polluted sites, take action to protect groundwater near these sites, and clean up the pollution



Around 1,400 Superfund sites listed in the US.

EPA

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Superfund



- **Brownfields** = lands whose reuse or development are complicated by the presence of hazardous materials
- Two events spurred creation of Superfund legislation
  - In *Love Canal*, Niagara Falls, New York, families were evacuated after buried toxic chemicals rose to the surface, contaminating homes and an elementary school



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## The Superfund process

- Once a Superfund site is identified, EPA scientists evaluate:
  - How close the site is to human habitation
  - Whether wastes are currently confined or likely to spread
  - Whether the site threatens drinking water supplies

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

## Superfund: harmful sites

- Harmful sites are:
  - Placed on the EPA's National Priority List
  - Ranked according to the level of risk to human health that they pose
  - Cleaned up on a site-by-site basis as funds are available
- The EPA is required to hold public hearings and inform area residents of its findings and to receive feedback

Copyright © 2009 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Who pays for cleanup?

- CERCLA operates under the **polluter pays principle** = polluting parties were to be charged for cleanup
  - However, the responsible parties often can't be found
  - A trust fund was established by a federal tax on petroleum and chemical industries
  - The fund is bankrupt, and neither the Bush administration nor Congress has moved to restore it, so taxpayers now pay all costs of cleanup
  - Fewer cleanups are being completed
  - An average cleanup costs \$25 million and takes 12 - 15 years

Copyright © 2009 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

## Conclusion

- Our societies have made great strides in addressing our waste problems
- Modern methods of waste management are far safer for people and gentler on the environment
- Recycling and composting are growing rapidly
- Our prodigious consumption had created more waste than ever before
- Finding ways to reduce, reuse and efficiently recycle the materials and goods that we use stands as a key challenge for the new century

Copyright © 2009 Pearson Education, Inc., publishing as Pearson Benjamin Cummings