



CHAPTER 21: SOLID AND HAZARDOUS WASTE

APES 2013

1

ELECTRONIC WASTE

- Also known as e-waste
- Fastest growing solid waste problem
- Each year, Americans throw out 155 million cell phones, 48 million computers, as well as millions of TVs, iPods, and other electronic products
- Most end up in landfills or incinerators even though these materials include high-quality plastics, aluminum, copper, nickel, platinum, silver, and gold.
- Source of hazardous pollutants like PVC, flame retardants, lead, and mercury which contaminate air, surface water, groundwater, and soil
- 70% of e-waste is shipped to China. The rest goes to India and poor African countries

2

BASICS OF WASTE

- In nature, there is no waste. The waste of organisms becomes the nutrients for others.
- Humans produce huge amounts of waste that go unused and pollute the environment
- We will always produce waste (law of conservation of matter), but the amount can be reduced.

3

WASTE

- Solid Waste - any unwanted or discarded material that is not a liquid or gas
- Industrial solid waste - produced by mines, agriculture, and industries
- Municipal solid waste (MSW) - solid waste produced by homes and workplaces
 - In developed countries, MSW is either put in landfills or burned in incinerators.
 - In developing countries, it ends up in open dumps.
- Hazardous waste (toxic waste) - threatens human health or the environment because it is poisonous, dangerously chemically reactive, corrosive, or flammable (organic compounds and toxic heavy metals)

4

NUCLEAR WASTE

- Produced by nuclear power plants and nuclear weapons facilities
- Must be stored for 10,000 to 240,000 years

5

What Harmful Chemicals Are in Your Home?

Cleaning

- Disinfectants
- Drain, toilet, and window cleaners
- Spot removers
- Septic tank cleaners



Paint Products

- Paints, stains, varnishes, and lacquers
- Paint thinners, solvents, and strippers
- Wood preservatives
- Artist paints and inks



General

- Dry-cell batteries (mercury and cadmium)
- Glues and cements



Gardening

- Pesticides
- Weed killers
- Ant and rodent killers
- Flea powders

Automotive

- Gasoline
- Used motor oil
- Antifreeze
- Battery acid
- Brake and transmission fluid

Fig. 21-2

6

UNITED STATES SOLID WASTE

- U.S. leads the world in producing solid waste
- 4.6% of the world's population but produces about 33% of solid waste
- 98.5% of U.S. waste is industrial from mining (76%), agriculture (13%), and industry (9.5%)
- For every one pound of electronics produced about 8,000 pounds of waste were produced

7

U.S. MSW

- 1.5% of total waste
- Paper and cardboard (37%), yard waste (12%), food waste (11%), plastics (11%), metals (8%)
- Yearly MSW could fill bumper-to-bumper convoy of trucks that circles the earth almost eight times

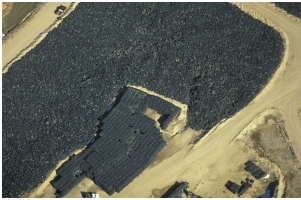


Fig. 21-4

8

NEW YORK CITY

- Per person trash output has actually gone down.
- 1999 NYC passed a mandatory recycling law
 - Had a law like this from 1896-1914
- 1st major city to run out of landfill space
- Since then it has been transporting its MSW to New Jersey and Pennsylvania

9

DEALING WITH WASTE

- Waste management - reduce the environmental impact of MSW without reducing the amount of waste produced
- Waste reduction - much less waste and pollution are produced
- Integrated waste management - variety of strategies for both waste reduction and waste management

10

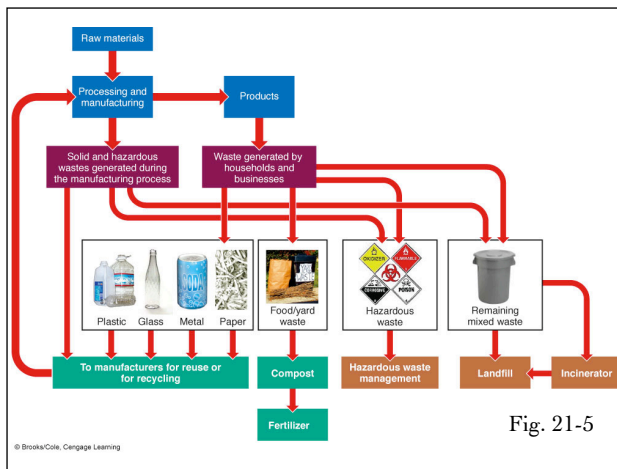


Fig. 21-5

11

INTEGRATED WASTE MANAGEMENT

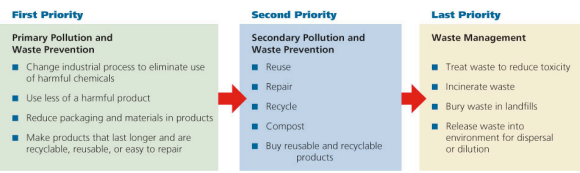


Fig. 21-6

12

REDUCE, REUSE, AND RECYCLE

Strategies:

- Redesign manufacturing processes and products to use less material and energy
- Redesign manufacturing processes to produce less waste and pollution
- Develop products that are easier to repair, reuse, remanufacture, compost, or recycle
- Eliminate or reduce unnecessary packaging
- Use fee-per-bag collection system
- Cradle to grave responsibility laws (think cradle to cradle)
- Restructure urban transportation systems

13

WHAT CAN YOU DO?

Solid Waste

- Follow the three Rs of resource use: Reduce, Reuse, and Recycle
- Ask yourself whether you really need a particular item, and refuse packaging where possible
- Rent, borrow, or barter goods and services when you can, buy secondhand, and donate or sell unused items
- Buy things that are reusable, recyclable, or compostable, and be sure to reuse, recycle, and compost them
- Avoid disposables, and do not use throwaway paper and plastic plates, cups, and eating utensils, and other disposable items when reusable or refillable versions are available
- Use e-mail or text-messaging in place of conventional paper mail
- Read newspapers and magazines online
- Buy products in bulk or concentrated form whenever possible

Fig. 21-7

14

WHAT CAN YOU DO?

Reuse

- Buy beverages in refillable glass containers instead of cans or throwaway bottles
- Use reusable plastic or metal lunchboxes
- Carry sandwiches and store food in the refrigerator in reusable containers instead of wrapping them in aluminum foil or plastic wrap
- Use rechargeable batteries and recycle them when their useful life is over
- Carry groceries and other items in a reusable basket, a canvas or string bag, or a small cart
- Use reusable sponges and washable cloth napkins, dish towels, and handkerchiefs instead of throwaway paper ones
- Buy used furniture, computers, cars, and other items instead of buying new
- Give away or sell items you no longer use

Fig. 21-9

15

TYPES OF RECYCLING

- Primary (closed-loop) - materials recycled into new products of the same type (ex. used aluminum cans into new aluminum cans)
- Secondary - waste materials converted into different products (ex. tires converted into rubberized road surfacing, newspapers into insulation)
- Materials-recovery facilities - send mixed wastes to a factory that sorts out the recyclable materials (more expensive, more pollutants produced)
- Source separation - consumers separate out materials (costs less, less pollution)
- Pay-as-you-throw (Fee-per-bag) - charges by amount of waste thrown away but does not charge for pick-up of recycled material

16

COMPOSTING

- Mimics nature's recycling of nutrients
- Allows decomposer bacteria to recycle yard trimmings, food scraps, and other organic wastes
- Resulting materials can be added to soil to supply plants with nutrients
- Large-scale composting - located carefully (odors monitored)



Fig. 21-10

17

RECYCLING PAPER

- In most countries paper is the dominant material of MSW
- Paper industry is the fifth most polluting and energy consuming industry in the world (3rd in U.S. and Canada)
- Paper is easy to recycle
 - Recycled paper uses 64% less energy, produces 35% less waste, and 74% less air pollution
 - U.S. recycles 56% of its paper (Denmark recycles 97%)
 - Even with our recycling rate, we still throw away more paper per year than is used in China.

18

RECYCLING PLASTICS

- ⊗ Currently only 4% of plastic (by weight) is recycled in the U.S.
- ⊗ Reasons for lack of recycling:
 - ⊗ Many plastics are difficult to isolate with different types in different layers
 - ⊗ Individual plastic items do not yield much resin
 - ⊗ Inflation-adjusted price of oil is low which incentivizes using new (virgin) plastics

19



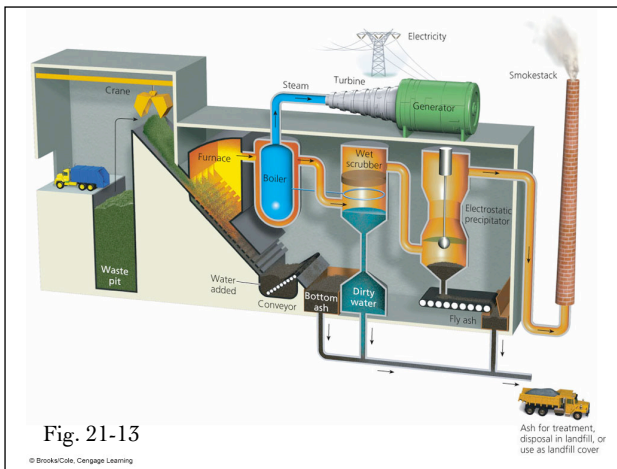
Fig. 21-12

20

BURNING SOLID WASTE

- ⊗ MSW is burned to heat water and produce electricity
- ⊗ Reduce amount of solid waste by 90%
- ⊗ Release many harmful chemicals into the air (particulates, carbon monoxide, toxic metals)
- ⊗ Add carbon dioxide to the atmosphere
- ⊗ Discourages reuse and recycling because large volumes are required to make it economically feasible

21



22

TRADE-OFFS

Incineration

Advantages	Disadvantages
<ul style="list-style-type: none"> Reduces trash volume Less need for landfills Low water pollution Concentrates hazardous substances into ash for burial Sale of energy reduces cost Modern controls reduce air pollution Some facilities recover and sell metals 	<ul style="list-style-type: none"> Expensive to build Costs more than short-distance hauling to landfills Difficult to site because of citizen opposition Some air pollution and CO₂ emissions Older or poorly managed facilities can release large amounts of air pollution Output approach that encourages waste production Can compete with recycling for burnable materials such as newspaper




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Fig. 21-14

23

BURYING WASTE

- ⊗ 54% of waste (by weight) is buried in landfills
- ⊗ Two types:
 - ⊗ Open dumps - fields or holes in the ground where garbage is dumped (rare in developed countries)
 - ⊗ Sanitary landfills - solid waste is spread into thin layers compacted and covered in clay or plastic foam (keeps material dry and prevents leakage)

24

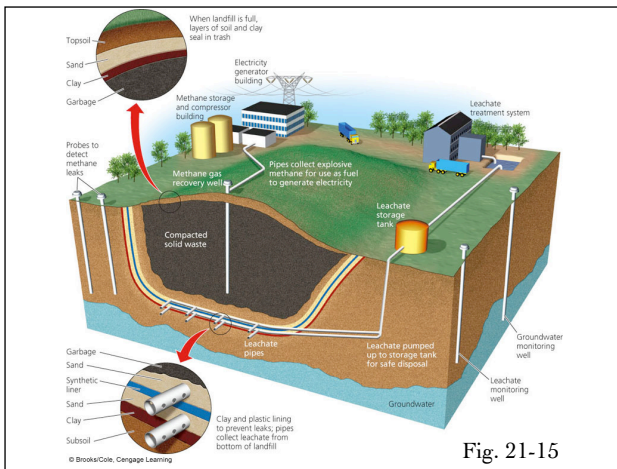


Fig. 21-15

25

TRADE-OFFS

Sanitary Landfills

<p>Advantages</p> <ul style="list-style-type: none"> No open burning Little odor Low groundwater pollution if sited properly Can be built quickly Low operating costs Can handle large amounts of waste Filled land can be used for other purposes No shortage of landfill space in many areas 	<p>Disadvantages</p> <ul style="list-style-type: none"> Noise and traffic Dust Air pollution from toxic gases and trucks Releases greenhouse gases (methane and CO₂) unless they are collected Slow decomposition of wastes Output approach that encourages waste production Eventually leaks and can contaminate groundwater
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Fig. 21-16

26

HAZARDOUS WASTE MANAGEMENT

<p>Produce Less Hazardous Waste</p> <ul style="list-style-type: none"> ■ Change industrial processes to reduce or eliminate hazardous waste production ■ Recycle and reuse hazardous waste 	<p>Convert to Less Hazardous or Nonhazardous Substances</p> <ul style="list-style-type: none"> ■ Natural decomposition ■ Incineration ■ Thermal treatment ■ Chemical, physical, and biological treatment ■ Dilution in air or water 	<p>Put in Perpetual Storage</p> <ul style="list-style-type: none"> ■ Landfill ■ Underground injection wells ■ Surface impoundments ■ Underground salt formations
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Fig. 21-17

27

DETOXIFYING HAZARDOUS WASTE

- ⊗ Physical methods - using charcoal or resins to filter out harmful solids and distilling liquid mixtures to separate out harmful chemicals
- ⊗ Chemical methods - convert hazardous chemicals to harmless or less harmful ones (ex. cyclodextrin to remove toxic materials like solvents and pesticides from contaminated soil and groundwater)
 - ⊗ After it makes its way through the ground or water, it can be pumped out, cleaned of the hazardous chemicals and reused.

28

DETOXIFYING HAZARDOUS WASTE

- ⊗ Nanomagnets - magnetic nanoparticles coated with certain compounds that remove various pollutants from water (ex. chitosan - made from the exoskeletons of shrimp and crabs used to remove oil from contaminated water)

29

BIOLOGICAL DETOXIFICATION METHODS

- ⊗ Bioremediation - bacteria and enzymes destroy toxic or hazardous substances or convert them to harmless compounds
- ⊗ Phytoremediation - using plants to absorb, filter, and remove contaminants from polluted soil and water

30

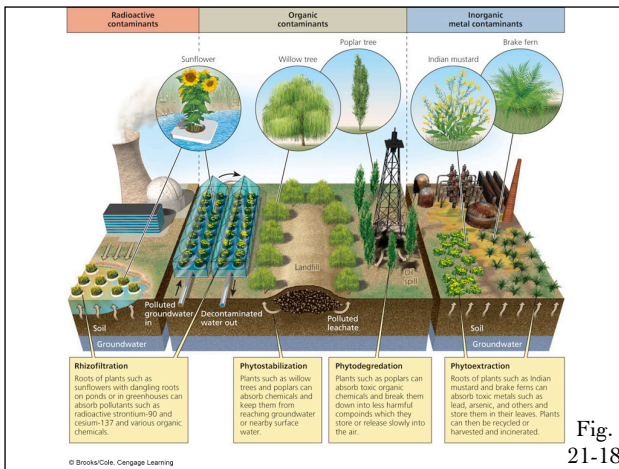


Fig. 21-18 31

TRADE-OFFS

Phytoremediation

Advantages	Disadvantages
Easy to establish	Slow (can take several growing seasons)
Inexpensive	Effective only at depth plant roots can reach
Can reduce material dumped into landfills	Some toxic organic chemicals may evaporate from plant leaves
Produces little air pollution compared to incineration	Some plants can become toxic to animals
Low energy use	

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Fig. 21-19 32

PLASMA ARC TORCH

- Incinerate hazardous waste at very high temperatures by passing electric current through a gas to create plasma (ionized gas)
- Converts hazardous waste into ions and atoms of hydrogen and carbon monoxide
- This fuel can be used to make fuels like hydrogen gas and methane

TRADE-OFFS

Plasma Arc

Advantages	Disadvantages
Small	High cost
Mobile. Easy to move to different sites	Produces CO ₂ and CO
Produces no toxic ash	Can release particulates and chlorine gas
	Can vaporize and release toxic metals and radioactive elements

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Fig. 21-20 33

HAZARDOUS WASTE STORAGE

- Burial or land storage should only be used as a third resort, even though it is the most widely used method.
- Deep-well disposal - liquid hazardous waste is pumped through a pipe into dry, porous rock formations far beneath aquifers
- Surface impoundments - ponds, pits, or lagoons with liners and hazardous wastes are stored
- Secure hazardous waste landfills - waste put into drums or other containers and buried in monitored sites

34



TRADE-OFFS
Deep-Well Disposal

Advantages

- Safe method if sites are chosen carefully
- Wastes can often be retrieved if problems develop
- Easy to do
- Low cost

Disadvantages

- Leaks or spills at surface
- Leaks from corrosion of well casing
- Existing fractures or earthquakes can allow wastes to escape into groundwater
- Output approach that encourages waste production

Fig. 21-23



TRADE-OFFS
Surface Impoundments

Advantages

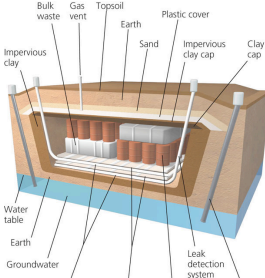
- Low construction costs
- Low operating costs
- Can be built quickly
- Wastes can often be retrieved if necessary
- Can store wastes indefinitely with secure double liners

Disadvantages

- Groundwater contamination from leaking liners (or no lining)
- Air pollution from volatile organic compounds
- Overflow from flooding
- Disruption and leakage from earthquakes
- Output approach that encourages waste production

Fig. 21-21

35



SECURE HAZARDOUS WASTE LANDFILL

WHAT CAN YOU DO?

Hazardous Waste

- Avoid using pesticides and other hazardous chemicals, or use them in the smallest amounts possible
- Use less harmful substances instead of commercial chemicals for most household cleaners. For example, use vinegar to polish metals, clean surfaces, and remove stains and mildew; baking soda to clean household utensils and to deodorize and remove stains; and borax to remove stains and mildew.
- Do not dispose of pesticides, paints, solvents, oil, antifreeze, or other hazardous chemicals by flushing them down the toilet, pouring them down the drain, burying them, throwing them into the garbage, or dumping them down storm drains. Instead, use hazardous waste disposal services available in many cities.

Fig. 21-24

Fig. 21-25

36

HAZARDOUS WASTE REGULATION

- Resource Conservation and Recovery Act (RCRA) - 5% of hazardous waste are regulated by this. EPA sets standards for management of several hazardous wastes. Those awarded permits must use cradle-to-grave systems.
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - Also known as Superfund program. Identifies sites where hazardous wastes have contaminated the environment and clean them up on a priority basis
 - 2008 - 1,240 sites on the list (It is estimated there should be closer to 10,000 sites on the list. The cost to clean up all sites would exceed \$1.7 trillion.)
 - Since 1980, 321 have been cleaned up enough to be removed from the list.

37

TOXIC RELEASE INVENTORY

- In 1984, Congress amended the Superfund Act to give citizens the right to know what toxic chemicals are being stored or released in their community (www.epa.gov/tri)
- Superfund law has made illegal dumping sites almost non-existent, made polluters pay for cleanup, made polluters reduce production of hazardous waste for fear of liability, and made recycling and reuse more prevalent.
- In 1995, Congress refused to renew a tax on oil and chemical companies that funds the Superfund law so now taxpayers foot the bill for cleaning up sites. (This has slowed the pace of cleanup.)

38

BROWNFIELDS

- Abandoned industrial and commercial sites contaminated with hazardous wastes
- Cleaned up and reborn as parks, nature reserves, athletic fields, eco-industrial parks, and neighborhoods
- By 2008, 42,000 brownfields have been redeveloped

39

ENVIRONMENTAL JUSTICE

- ⊗ Ideal whereby every person is entitled to protection from environmental hazards regardless of race, gender, age, national origin, income, social class, or political factor
- ⊗ Disproportionate numbers of hazardous sites are in areas where minorities are present and where poor people live.