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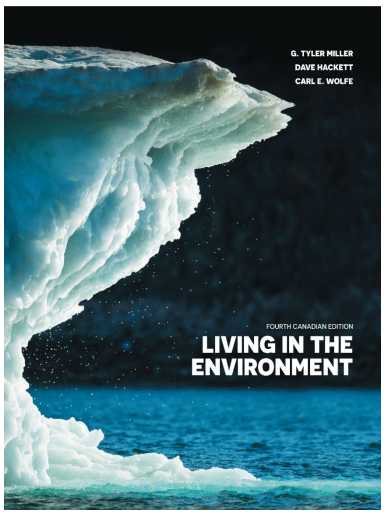


prepared by

Ian Dawe

Chapter 24

Solid and Hazardous Waste

Key Concepts

Solid waste – types and amounts

Methods to reduce waste

Industrial ecology

Methods of dealing with wastes

How is hazardous waste regulated?

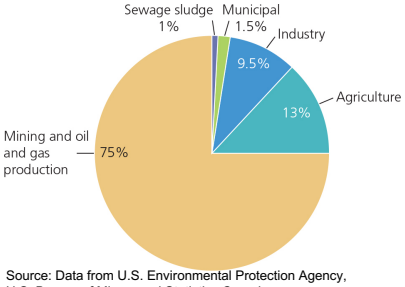
Transitions to a low-waste society

Case Study: Waste Production in North America

One-third of all global waste comes from less than 5% of the global population.

Municipal solid waste

- Increased 3x from 1960–2005
- Per capita increase of 70% from 1960–1990



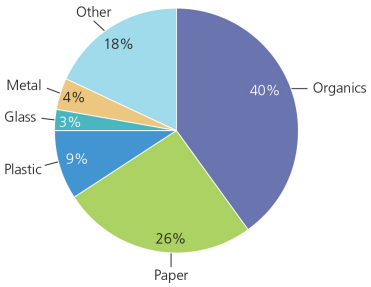
Source: Data from U.S. Environmental Protection Agency, U.S. Bureau of Mines, and Statistics Canada.

Garbage: Municipal Solid Waste

Per person, 777 kg of garbage is produced

Waste management costs $2.6 billion

E-waste growing rapidly (725 000 tonnes)



Source: Statistics Canada

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What Does It Mean to Live in a High-Waste Society?

Wasting valuable resources

- North Americans spend more $ on *trash bags* than 90 other countries spend on *everything*
- Each year, we throw away
  - 670 000 tonnes of edible food
  - 186 billion pieces of junk mail
  - 50 million computers
  - Enough diapers to go from the Earth to the moon and back seven times

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Producing Less Waste

Waste Management

– High-waste approach

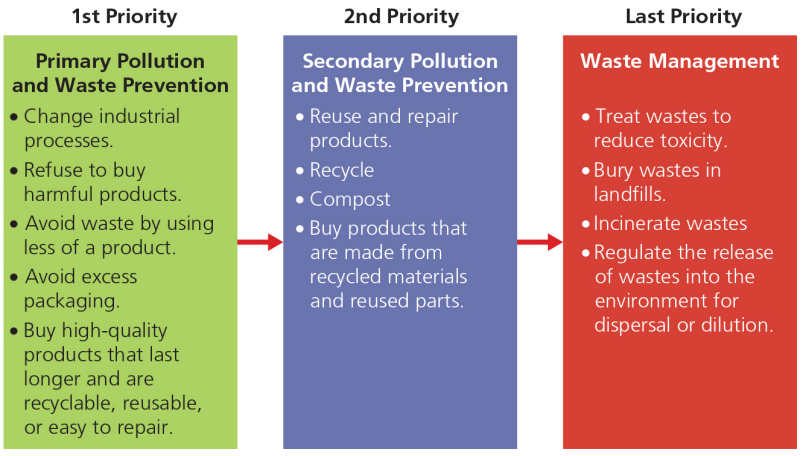
– Burying, burning, shipping

Waste Reduction

– Low-waste approach

– Refuse, reduce, reuse, recycle, rethink, and recover

Priorities in Waste Reduction



How Can We Reduce Solid Waste?

Consume less

Redesign manufacturing processes and products to

- Use less material and energy
- Produce less waste and pollution

Develop products easier to repair, reuse, remanufacture, compost, and recycle

Design products to last longer

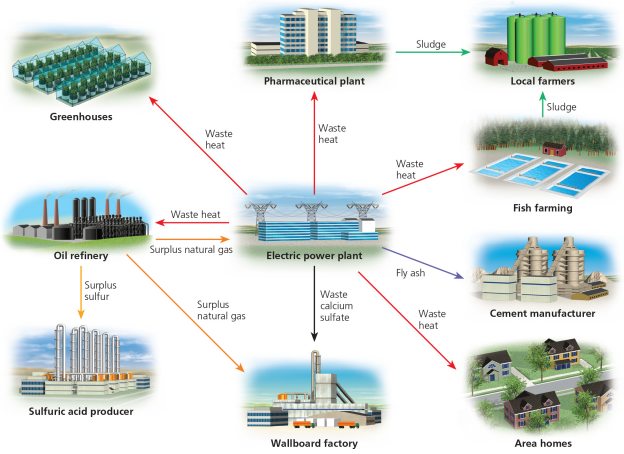
Eliminate or reduce unnecessary packaging

What Is Industrial Ecology?

Design industrial processes to mimic nature

- Recycle and reuse
- Resource exchange webs (like food webs)
- Biomimicry in innovation

Industrial Ecosystem



What Is a Service-Flow Economy?

Renting services instead of buying things

Companies makes more profit if they use minimum materials, product easy to maintain, repair, remanufacture, reuse, or recycle

Eco-Leasing

Renting the services that goods provide

Minimal ownership of physical goods

Reuse

- Reduces resource use
- Saves input energy and money
- Reduces pollution and waste
- Creates local jobs
- Design products for reuse
  - Shopping bags, food containers, shipping pallets, etc.

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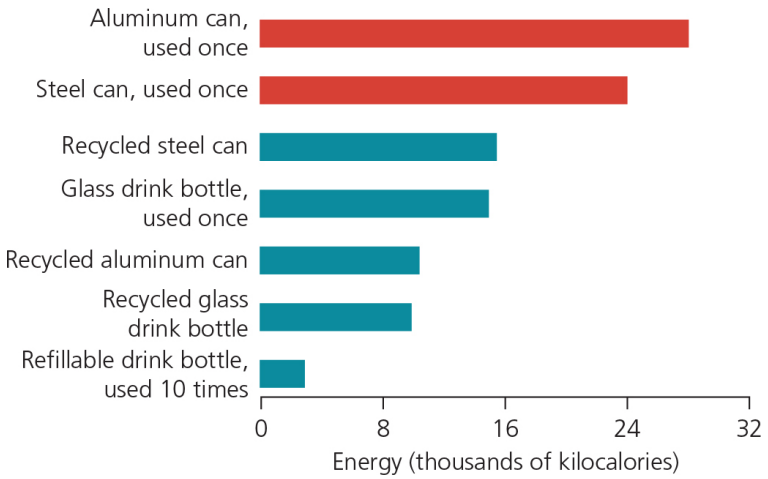
Energy Consumption of 350 mL Beverage Containers



Source: Data from Argonne National Laboratory.

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Recyling

Primary (**closed-loop**)
– Turn waste into same class of product
Secondary (**open-loop**)
– Downcycling

Pre-Consumer *vs*. **Post-Consumer**

Composting

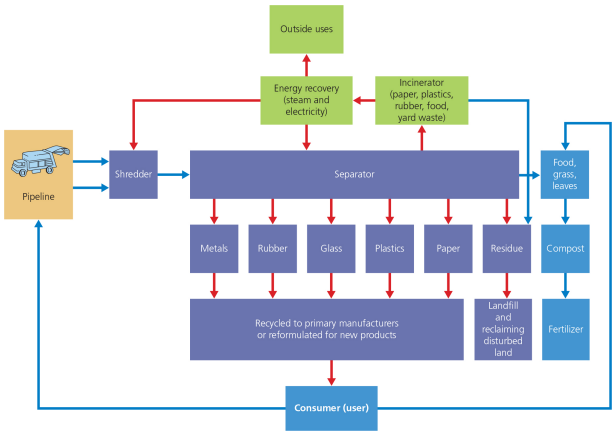
Recycling plant nutrients to soil

Of biodegradable wastes,
– Some European cities compost 85%
– North Americans only compost 5%

Large-scale *vs*. backyard *vs*. vermicompost

How Should We Recycle Solid Waste?

Option 1: Centralized recycling of mixed waste (MRF)



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How Should We Recycle Solid Waste?

Option 2: Separation at source

- Less air and water pollution
- Lower cost
- Uses less energy
- Provides more jobs
- Produces more valuable recyclables
- Education benefit but dependence on consumer

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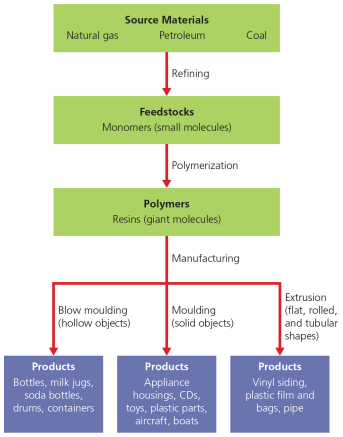
Case Study: Is It Feasible to Recycle Plastics?

Only 10% recycled

Challenges

- Difficult to isolate from mixed resins and stabilizers
- Low material yield
- Low primary resource cost



Source: Adapted from Society of the Plastics Industry

Why Do We Not Have More Reuse and Recycling?

Prices do not reflect the product **life-cycle.**

Higher tax breaks on resource extraction

Low **tipping fees**

Fluctuating demand

Minimal product stewardship

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Burning Solid Waste: Waste-to-Energy Incineration

Advantages

- Reduced trash volume
- Less need for landfills
- Low water pollution
- Quick and easy

Disadvantages

- High cost
- Air pollution (especially toxic dioxins)
- Produces a highly toxic ash
- Encourages waste production
- Discourages recycling and waste reduction

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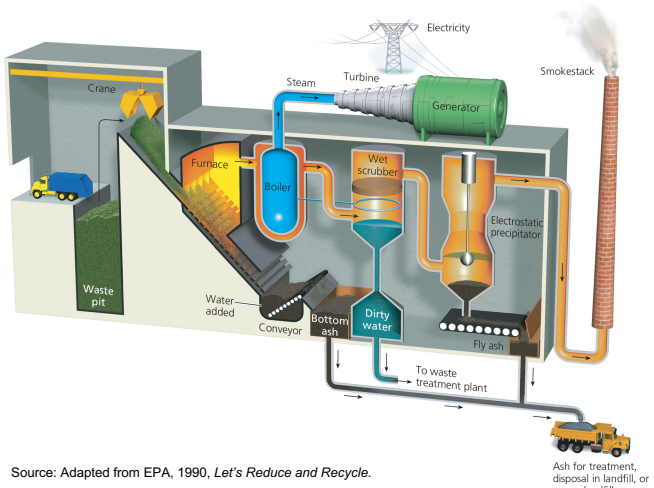
Waste-to-Energy Incinerator



Source: Adapted from EPA, 1990, *Let's Reduce and Recycle.*

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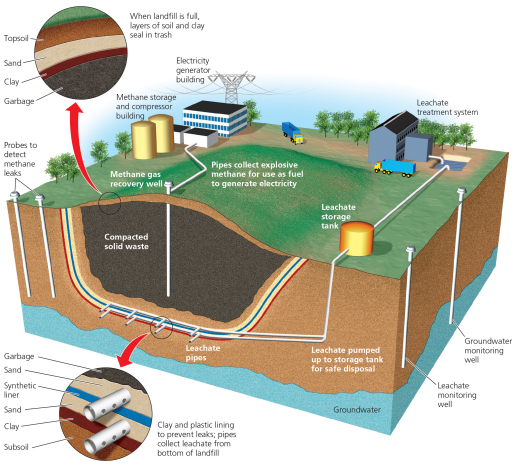
Burying Solid Wastes

Open dump (illegal in Canada)

Sanitary landfill
- Leachate collection
- Monitoring wells
- Landfill gases

Sanitary Landfill



Sanitary Landfills

Advantages

- No open burning
- Little odour
- 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

Disadvantages

- Noise and traffic
- Dust
- Air pollution from toxic gases and volatile organic compounds
- Releases greenhouse gases (methane and CO_2) unless they are collected
- Groundwater contamination
- Slow decomposition of wastes
- Discourages recycling and waste reduction
- Eventually leaks and can contaminate groundwater

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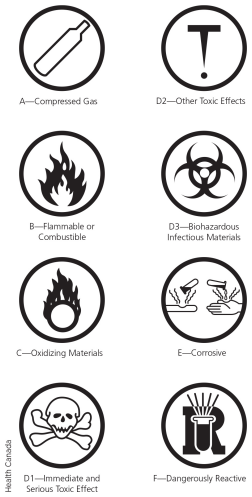
What Is Hazardous Waste?

Any discarded solid or liquid that has the potential to harm people

Workplace Hazardous Materials Information System (**WHMIS**)

- Labelling
- Training
- Information



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Hazardous Waste in Your Home

FIGURE 24-17 WHAT HARMFUL CHEMICALS ARE IN YOUR HOME?

Harmful chemicals are found in many homes. Make a survey to see which of these are in your home.

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

Paint
- Latex and oil-based paints
- Paint thinners, solvents, and strippers
- Stains, varnishes, and lacquers
- Wood preservatives
- Artist paints and inks

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

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

Automotive
- Gasoline
- Used motor oil
- Antifreeze
- Battery acid
- Solvents
- Brake and transmission fluids
- Rust inhibitor and rust remover

What To Do With Hazardous Waste?

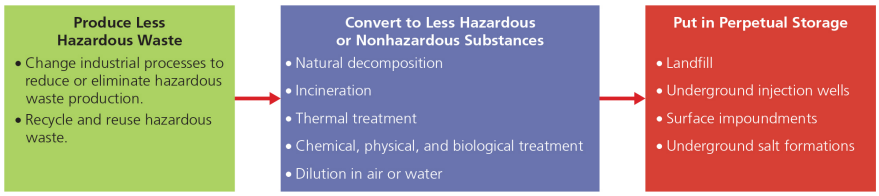
Management

- Output approach
- Burning or burying
- Expensive
- Pollution outputs

Reduction

- Input approach
- Reuse or recycle
- Consider non-hazardous alternatives

Priorities For Dealing With Hazardous Waste



Source: Data from U.S. National Academy of Sciences.

How Can We Remove or Detoxify Hazardous Waste?

Physical methods

– Distillation, filtration, precipitation

Chemical methods

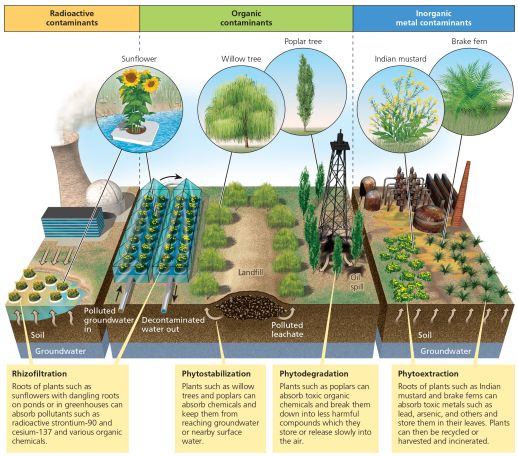
Bioremediation

– Using bacteria or enzymes

Phytoremediation

– Using plants or algae

Phytoremediation



Phytoremediation: Trade-offs

FIGURE 24-21 **TRADE-OFFS**

Phytoremediation

Advantages and disadvantages of using phytoremediation to remove or detoxify hazardous waste. Pick the single advantage and disadvantage that you think are the most important.

(Left: © Daryl Mulvihill/Alamy Stock Photo; (Right): © Quang nguyen vinh/Shutterstock

Advantages

- Easy to establish
- Inexpensive
- Can reduce material dumped into landfills
- Produces little air pollution compared to incineration
- Low energy use

Disadvantages

- Slow (can take several growing seasons)
- Effective only at the depth that plant roots can reach
- Possibility that toxic organic chemicals may evaporate from plant leaves
- Possibility that some plants become toxic to animals

Deep Underground Wells: Trade-offs

FIGURE 24-22 **TRADE-OFFS**

Deep Underground Wells

Advantages and disadvantages of injecting liquid hazardous wastes into deep underground wells. Pick the single advantage and disadvantage that you think are the most important.

(left): © TU studio/Shutterstock; (Right): © Roland Weihrauch/picture alliance/dpa/AP Images

Advantages

- Safe method if sites are chosen carefully
- Wastes retrievable if problems develop
- Easy to do
- Low cost

Disadvantages

- Leaks or spills at surface
- Leaks from corrosion of well casing
- Possibility of waste escaping into groundwater through existing fractures or during earthquakes
- Encourages waste production

Surface Impoundments: Trade-offs

FIGURE 24-23 **TRADE-OFFS**

Surface Impoundments

Advantages and disadvantages of storing liquid hazardous wastes in surface impoundments. Pick the single advantage and disadvantage that you think are the most important.

(Left): © Robert Brook/Alamy Stock Photo; (Right): © Jon Hollowa/The Stock Connection/Getty Images

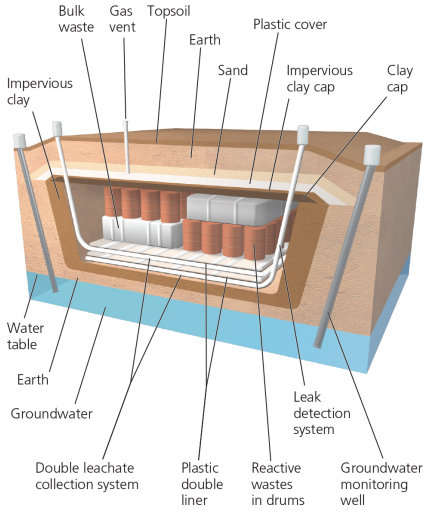
Advantages

- Low construction costs
- Low operating costs
- Can be built quickly
- Wastes retrievable 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
- Promotes waste production

Secure Hazardous Waste Landfills



Case Study: Lead

Key Problem: Lead poisoning in children

Sources

- Leaded gasoline (phased out by 1990 but took longer in developing countries)
- Lead paints
- Lead in plumbing

Case Study: Lead Poisoning Solutions

FIGURE 24-26 **SOLUTIONS**

Lead Poisoning

Ways to reduce exposure to lead

(Left: ©Ana Gram/Shutterstock; (Right): ©aureamar/Shutterstock

Prevention

- Phase out leaded gasoline worldwide.
- Phase out waste incineration.
- Test blood for lead by age 1.
- Ban lead solder in plumbing pipes, fixtures, and food cans.
- Ban lead glazing for ceramicware used to serve food.
- Ban candles with lead cores.

Control

- Sharply reduce lead emissions from old and new incinerators.
- Replace lead pipes and plumbing fixtures containing lead solder.
- Remove leaded paint and lead dust from older houses and apartments.
- Remove lead from TV sets and computer monitors before incineration or land disposal.
- Test for lead in existing ceramicware used to serve food.
- Test existing candles for lead.
- Wash fresh fruits and vegetables.

Case Study: Mercury

Key Problem: Aquatic contamination

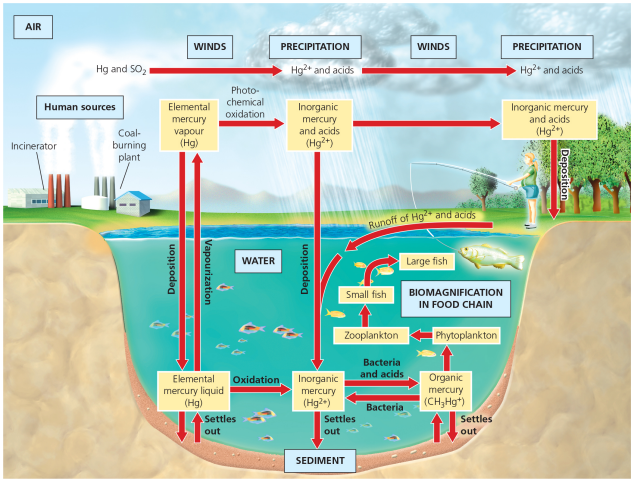
Sources

– Vapourized elemental Hg

– Inorganic particulate Hg^{2+} salts

– Organomercury compounds in fish

Case Study: Cycling of Mercury in Aquatic Environments



Case Study: Mercury Pollution Solutions

FIGURE 24-28 **SOLUTIONS**

Mercury Pollution

Ways to prevent or control inputs of mercury into the environment from human activities—mostly through coal-burning plants and incinerators. Which two of these solutions do you believe are the most important?

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Prevention

- Phase out waste incineration.
- Remove mercury from coal before it is burned.
- Convert coal to liquid or gaseous fuel.
- Switch from coal to natural gas and renewable energy resources such as wind, solar cells, and hydrogen.
- Phase out use of mercury in all products unless they are recycled.

Control

- Sharply reduce mercury emissions from coal- burning plants and incinerators.
- Tax each unit of mercury emitted by coal-burning plants and incinerators.
- Collect and recycle mercury-containing electric switches, relays, and dry-cell batteries.
- Require labels on all products containing mercury.

Case Study: Dioxins

Potentially highly toxic and persistent chlorinated hydrocarbons in contaminated food

Sources

- Waste incineration
- Fireplaces
- Coal-fired power plants
- Paper production
- Sewage sludge

Achieving a Low-Waste Society

Local grassroots action

International ban on 12 persistent organic pollutants (the dirty dozen)

Key Principles

- Everything is connected.
- There is no "away."
- Dilution is not the solution.
- Produce less pollutants, reuse, and recycle.

Conclusion

Societies produce waste.

The key is to manage that waste such that it doesn't harm ecosystems or populations.

Some waste is more toxic than others.

Reducing waste and better management are among the solutions.