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Municipal, Industrial, and Hazardous Waste

Jonathan M. Links, PhD
Johns Hopkins University

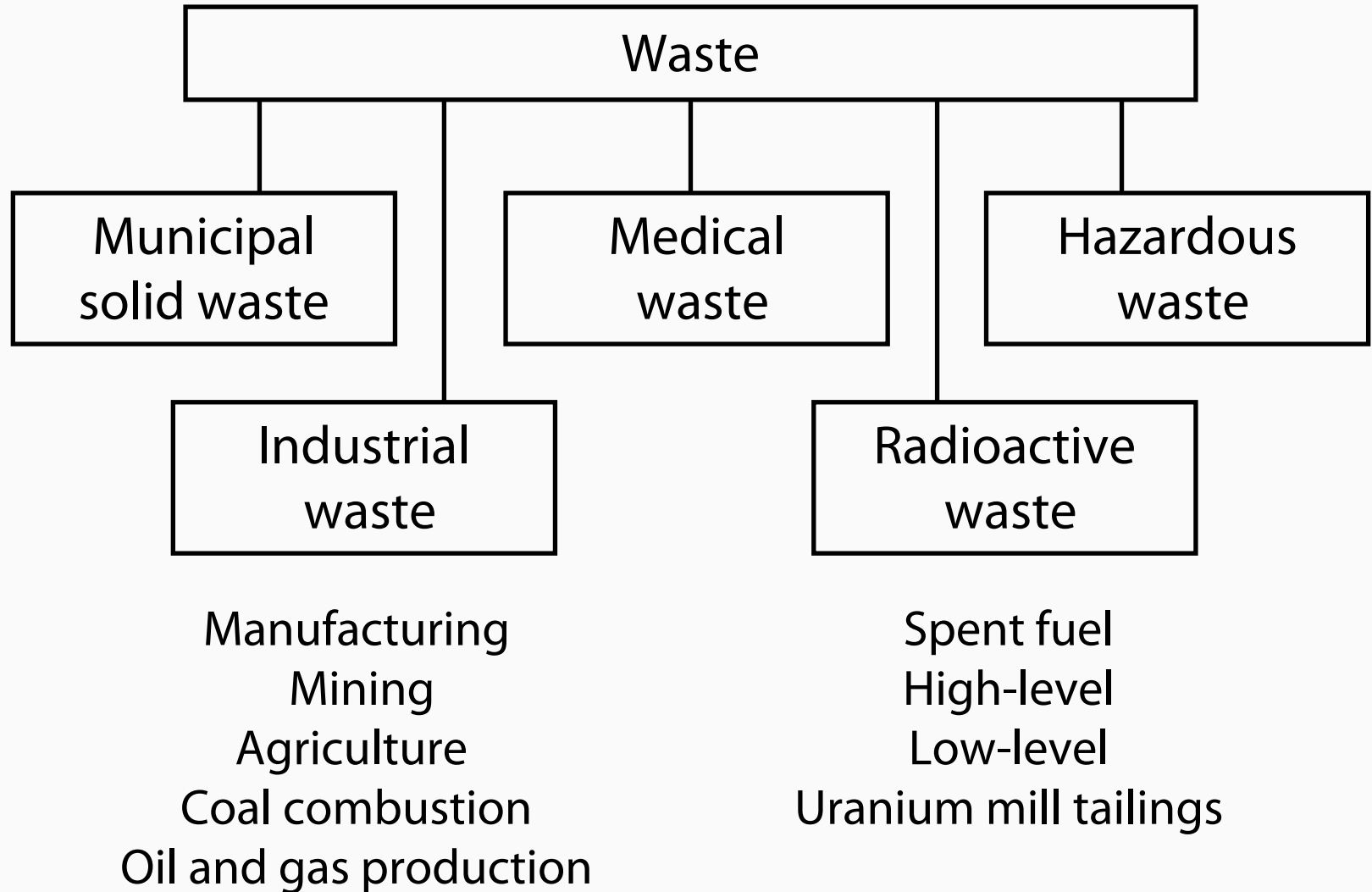


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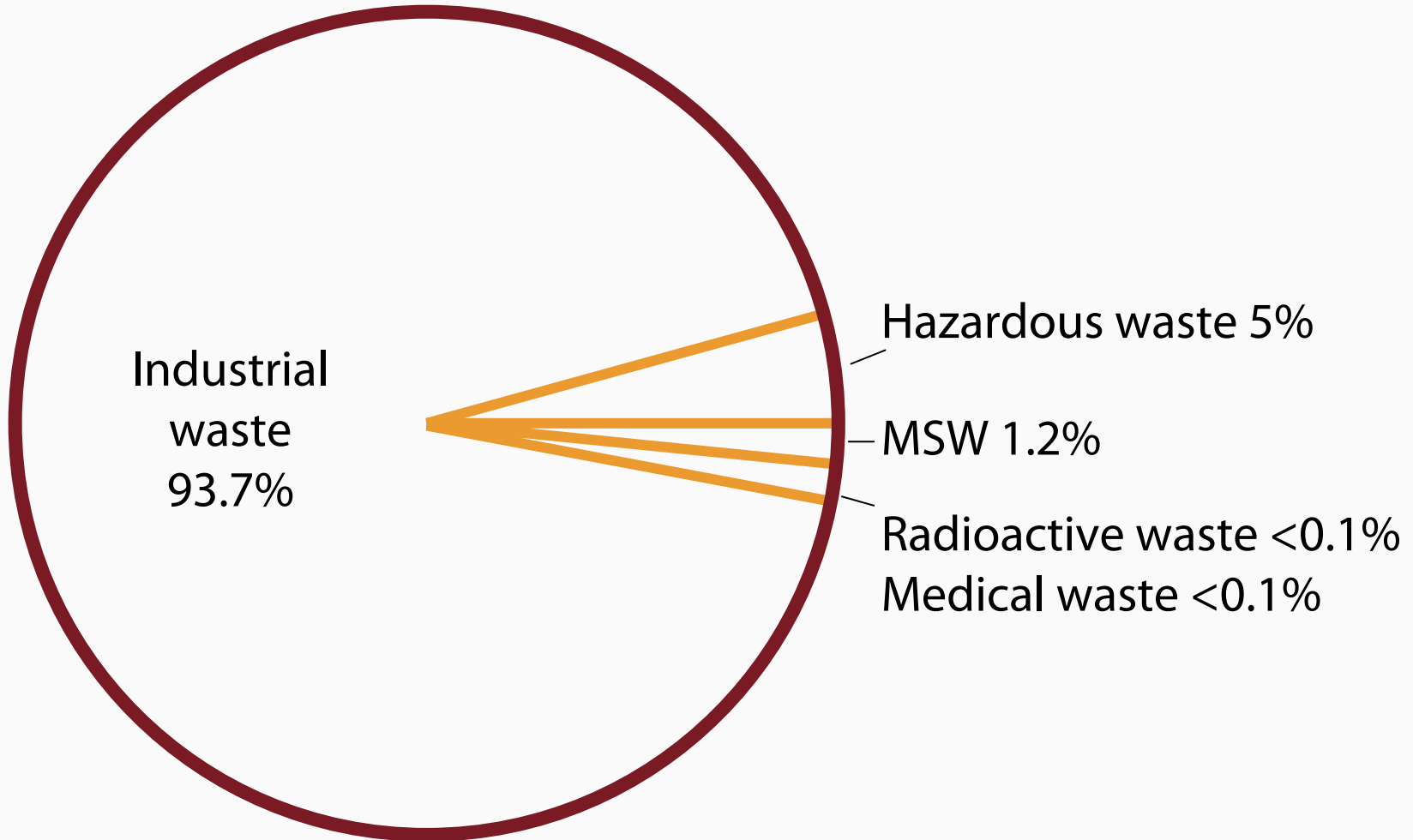
Section A

Types of Waste and Waste Management

Types of Waste



The Universe of Waste

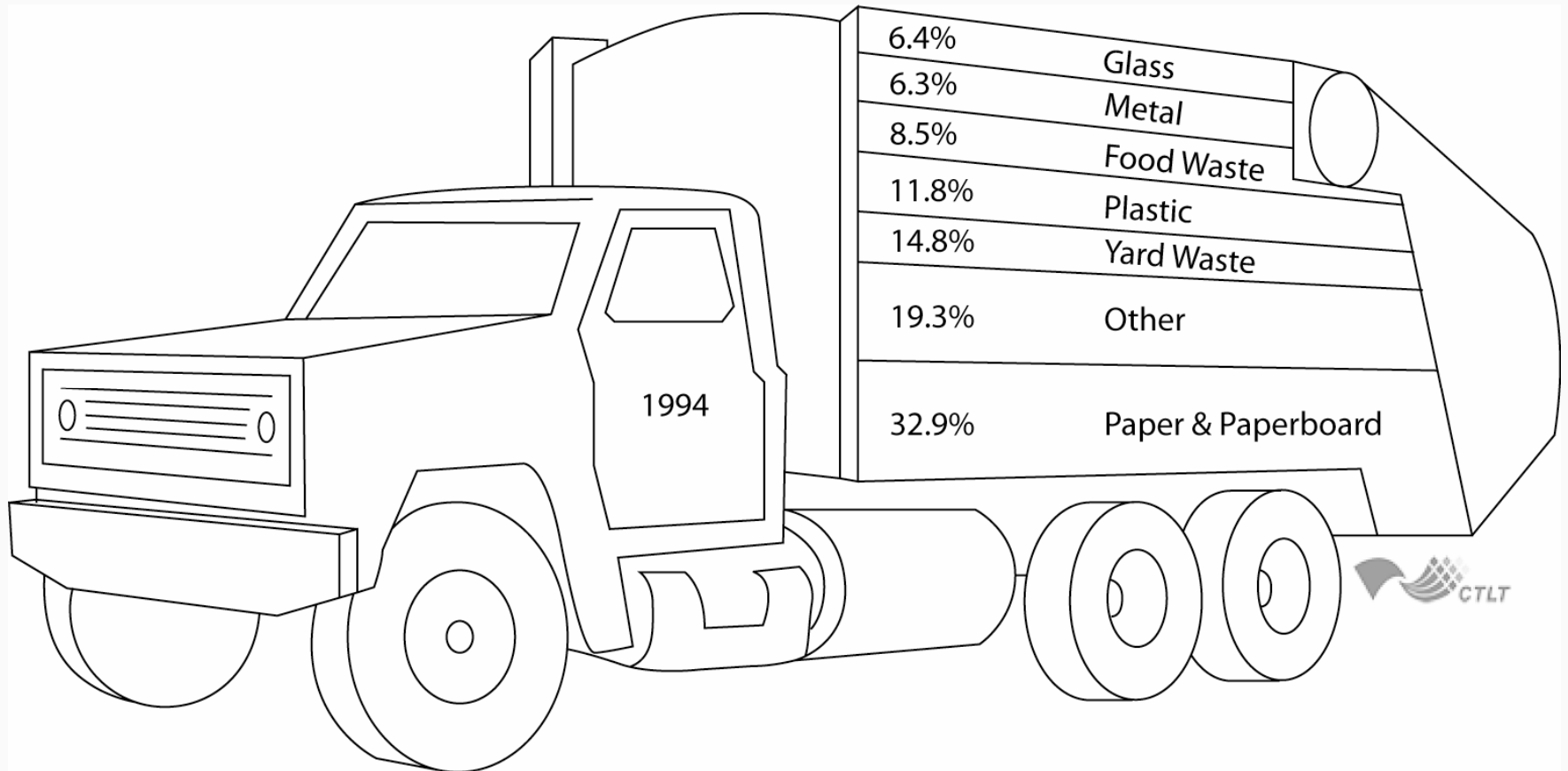


Waste Categories and Generated Amounts (1990 Data)

Source	Amount (x 10 ⁶ tons/year)	Per capita (lbs/day)
Municipal	164	4.7
Industrial	13,000	285
Hazardous	196	4.3
Medical	0.5	1 oz
Other		
Sewage sludge	300	6.3
Dredged material	400	
Animal waste	1,325*	

*Nationwide, 130 times more animal waste than human waste

Municipal Solid Waste



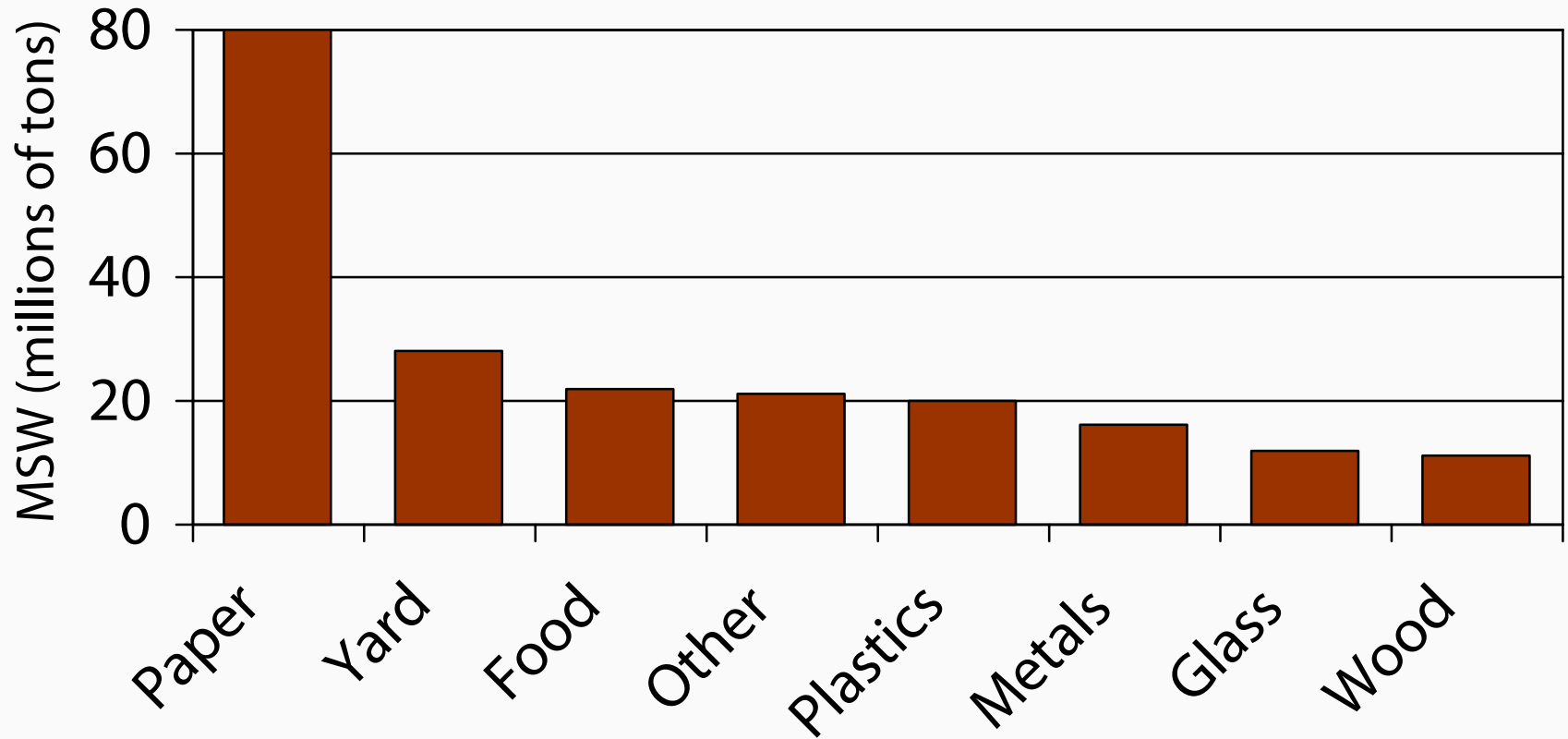
Sources and Examples of MSW

Sources	Examples of products
Residential , including single- and multiple-family houses	Nondurable paper items (magazines, newspapers, advertising flyers), plastic and glass bottles, aluminum and steel cans, packaging, food wastes, yard wastes
Institutional , including schools, hospitals, prisons, and nursing homes	Food wastes, paper (classrooms and offices), disposable tableware, napkins, paper towels from restrooms and yard trimmings

More Sources and Examples of MSW

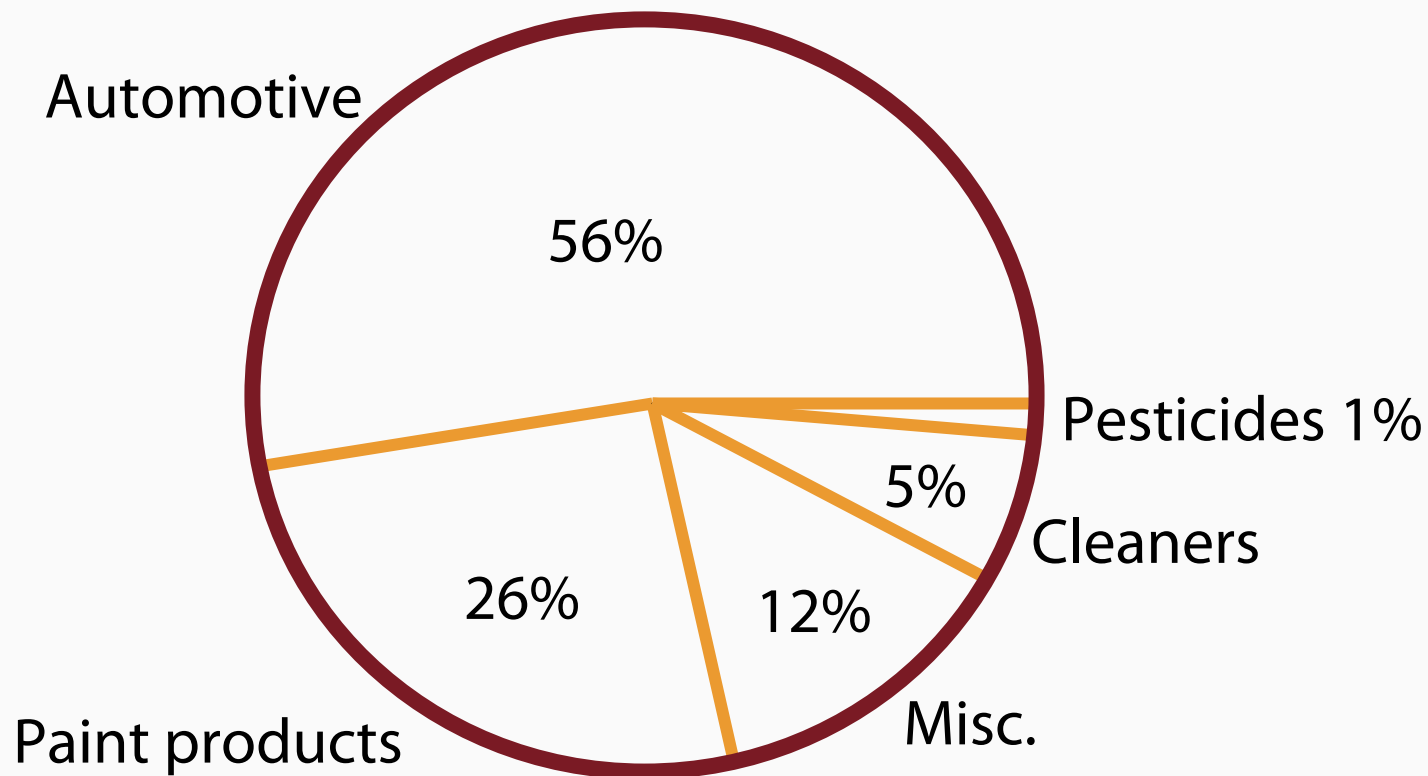
Sources	Examples of products
Commercial , including restaurants, office buildings, and stores	Food wastes, paper products from offices, restrooms and serving tables, disposable tableware, corrugated and paperboard products, yard wastes
Industrial packaging and administrative wastes	Wooden pallets, office paper, corrugated and paperboard products, plastic film and food wastes (from cafeterias)

Major Material Components of MSW by Weight, 1996

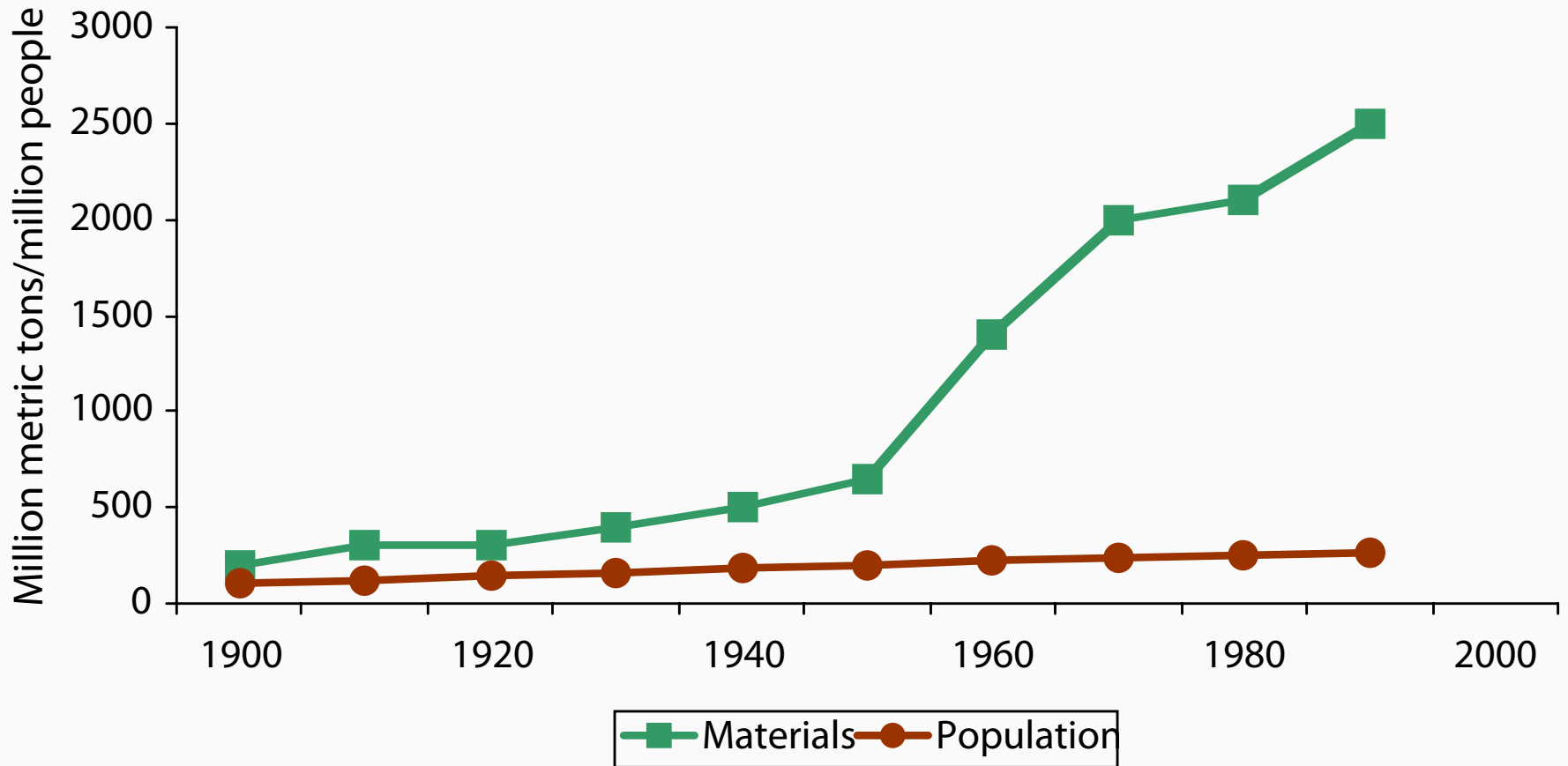


Sources of Household Hazardous Waste

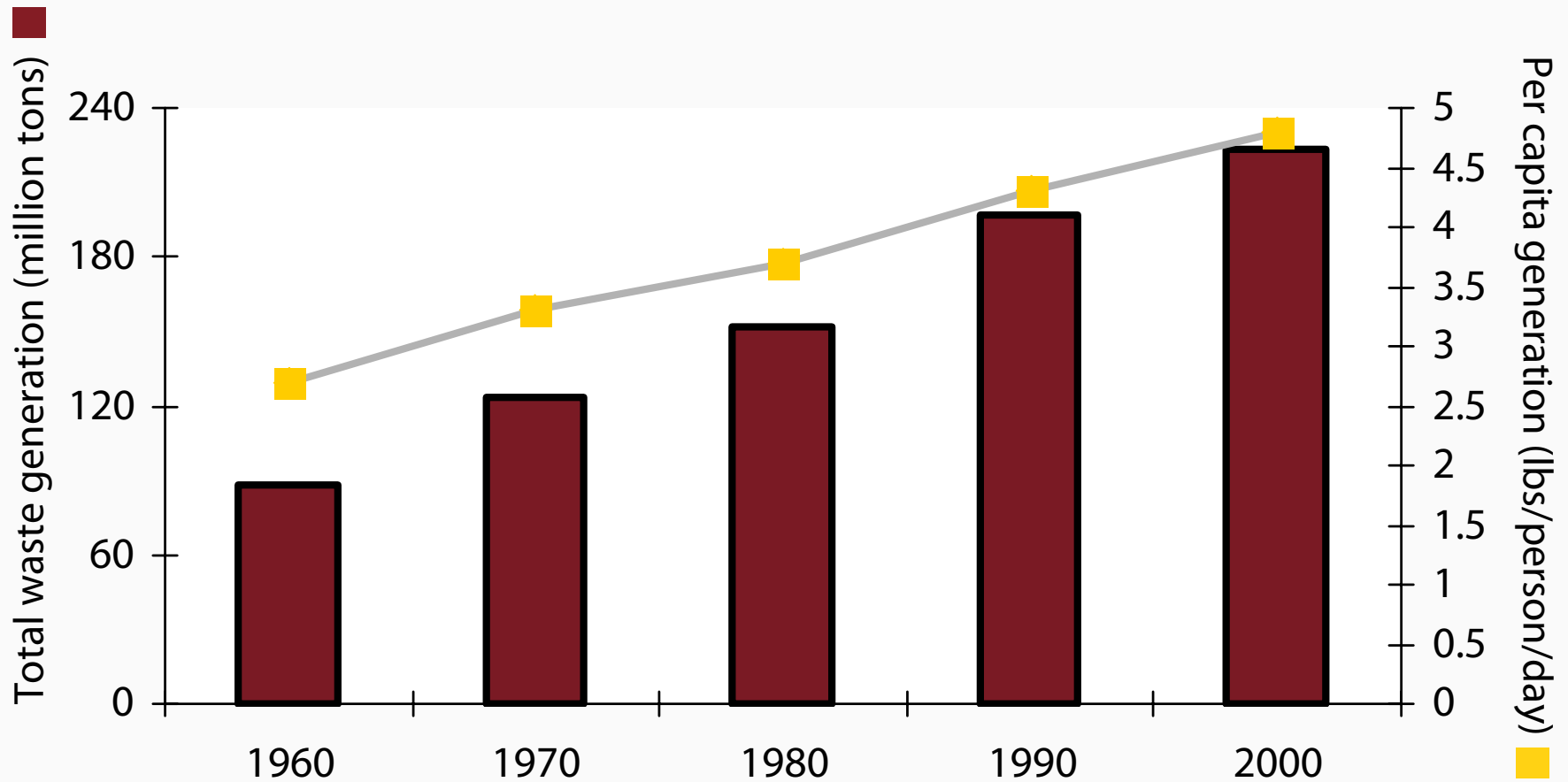
- Household hazardous waste: approximately 0.5% of refuse weight



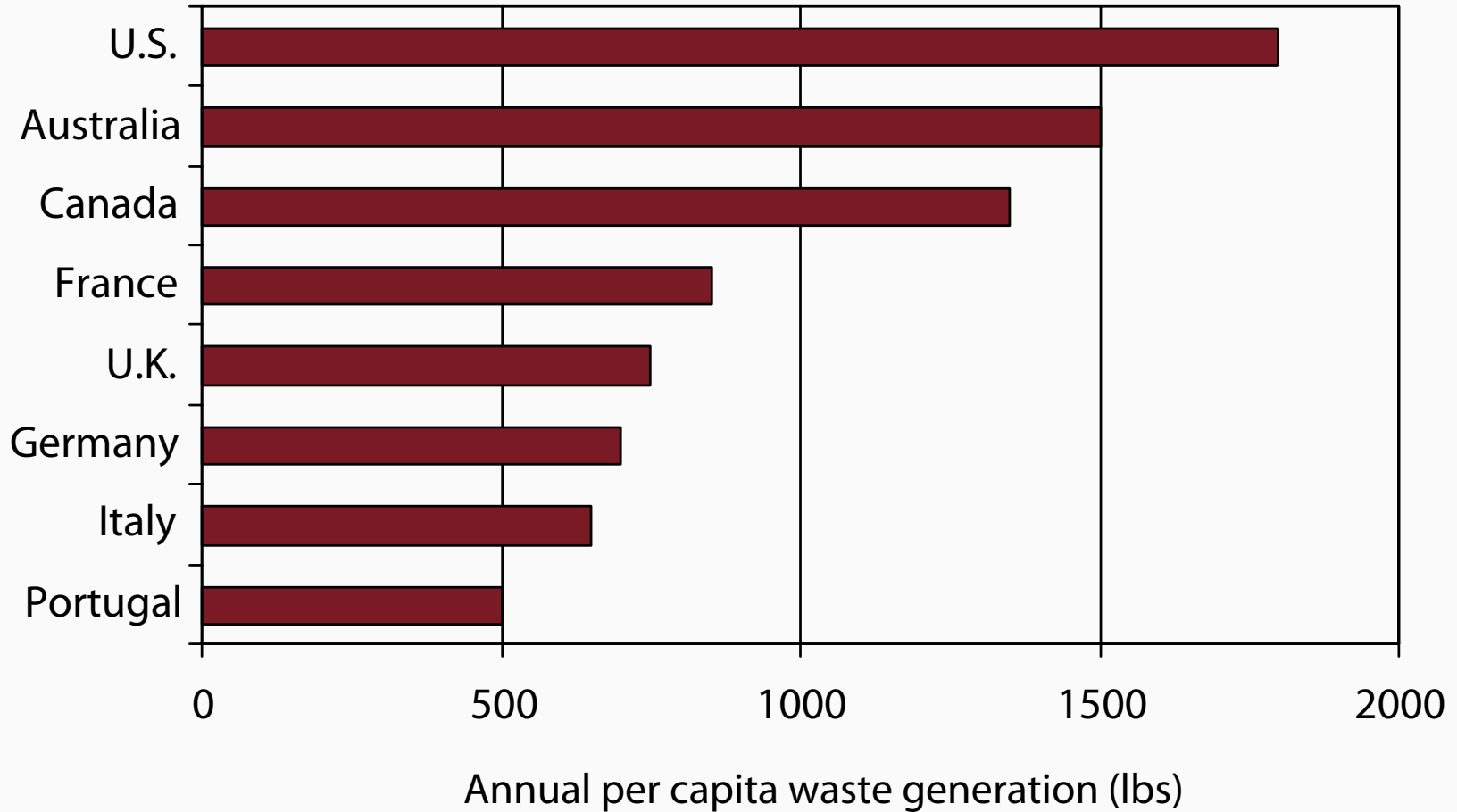
U.S. Material Consumption and Population Growth



Waste Generation Rates, 1960–2000



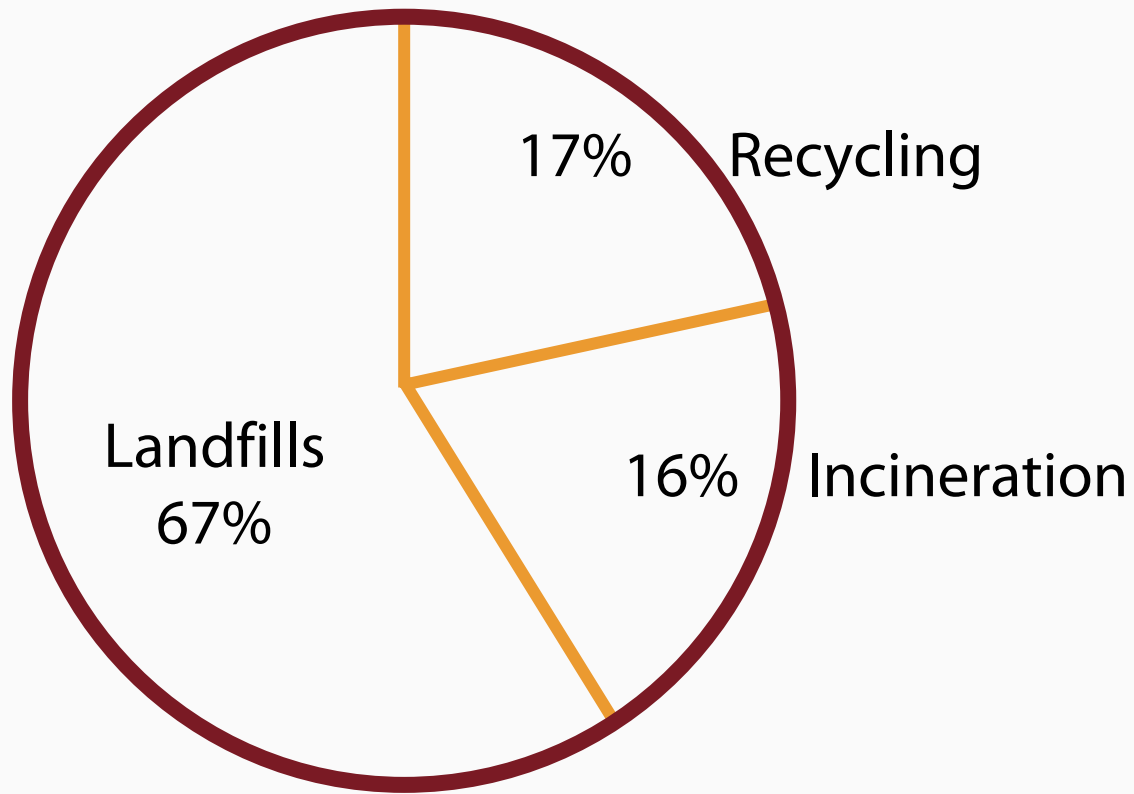
Annual Municipal Waste Generation per Person



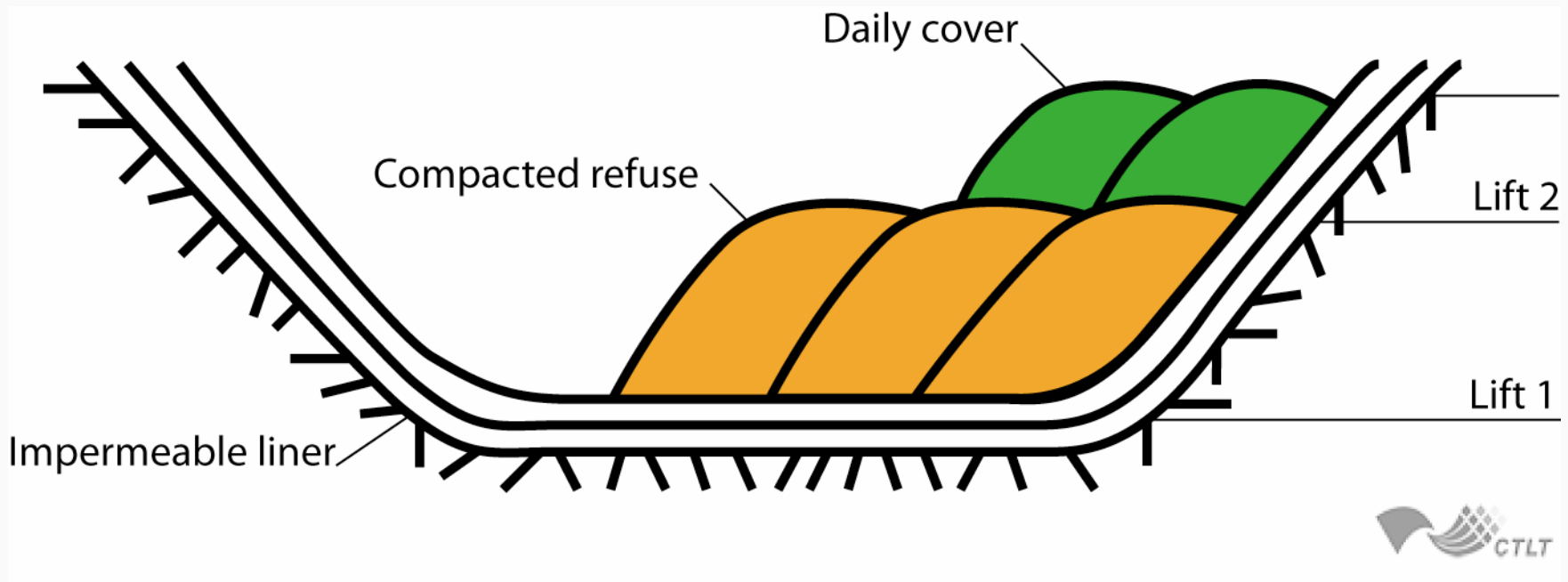
Causes for Increased Waste Generation

- Demographic changes
- Degree of urbanization
- Consumer preference
- Demand for convenience ahead of the environment
- Little economic incentive for Americans to reduce waste

How MSW Is Managed in the U.S.



Arrangement of Cells in a Sanitary Landfill



Unlined Landfills and Groundwater Contamination

- Groundwater contamination as a result of unlined landfill disposal

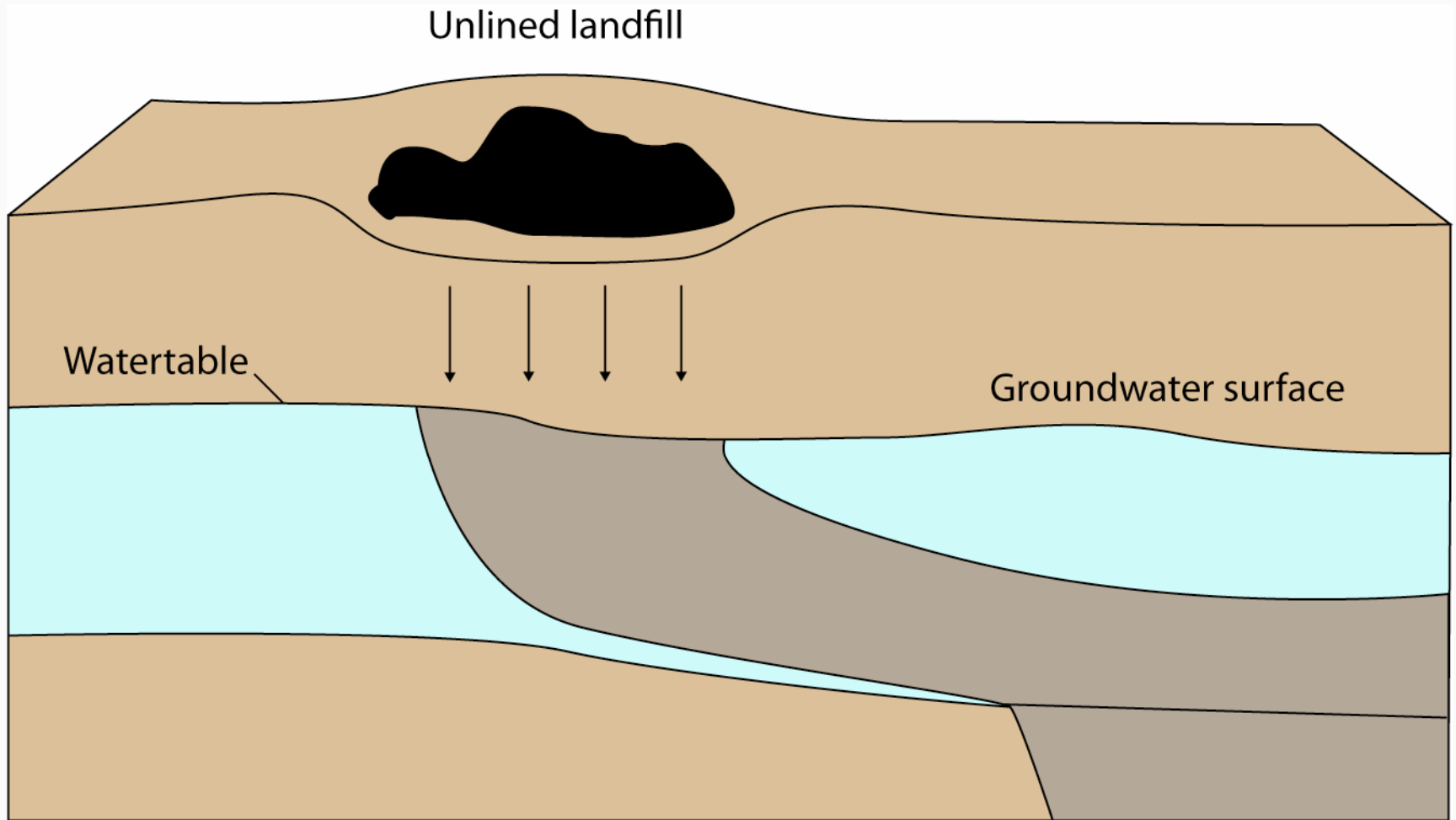
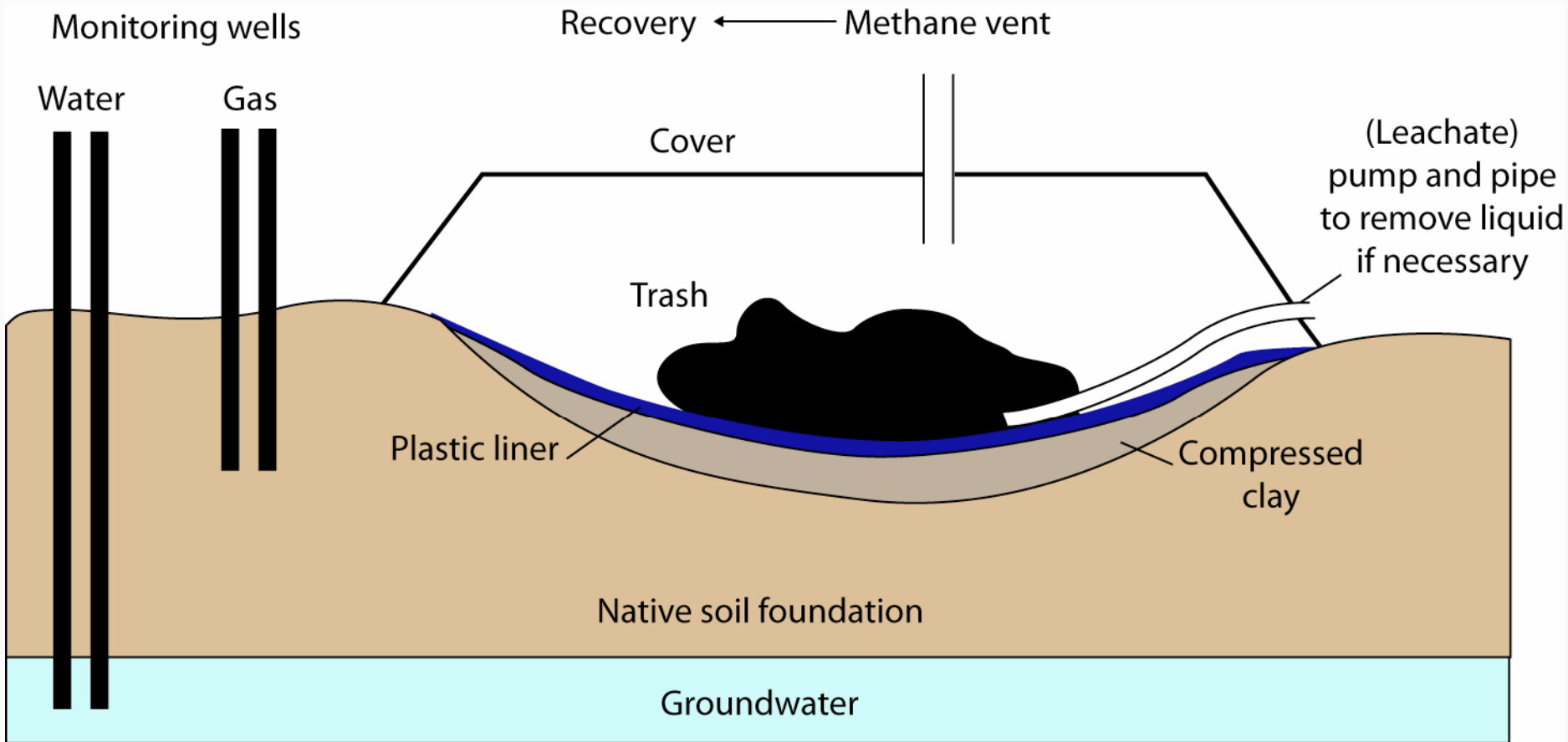
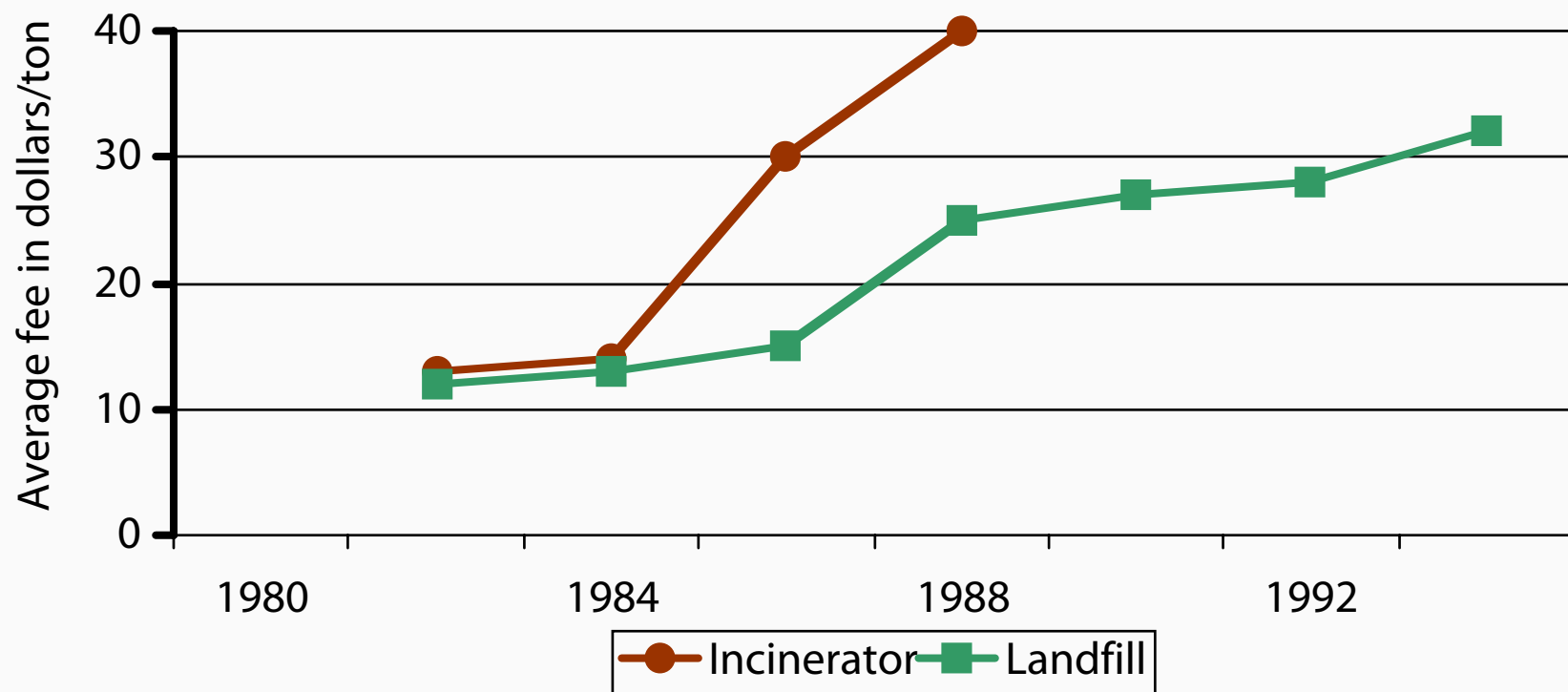


Diagram of a Sanitary Landfill

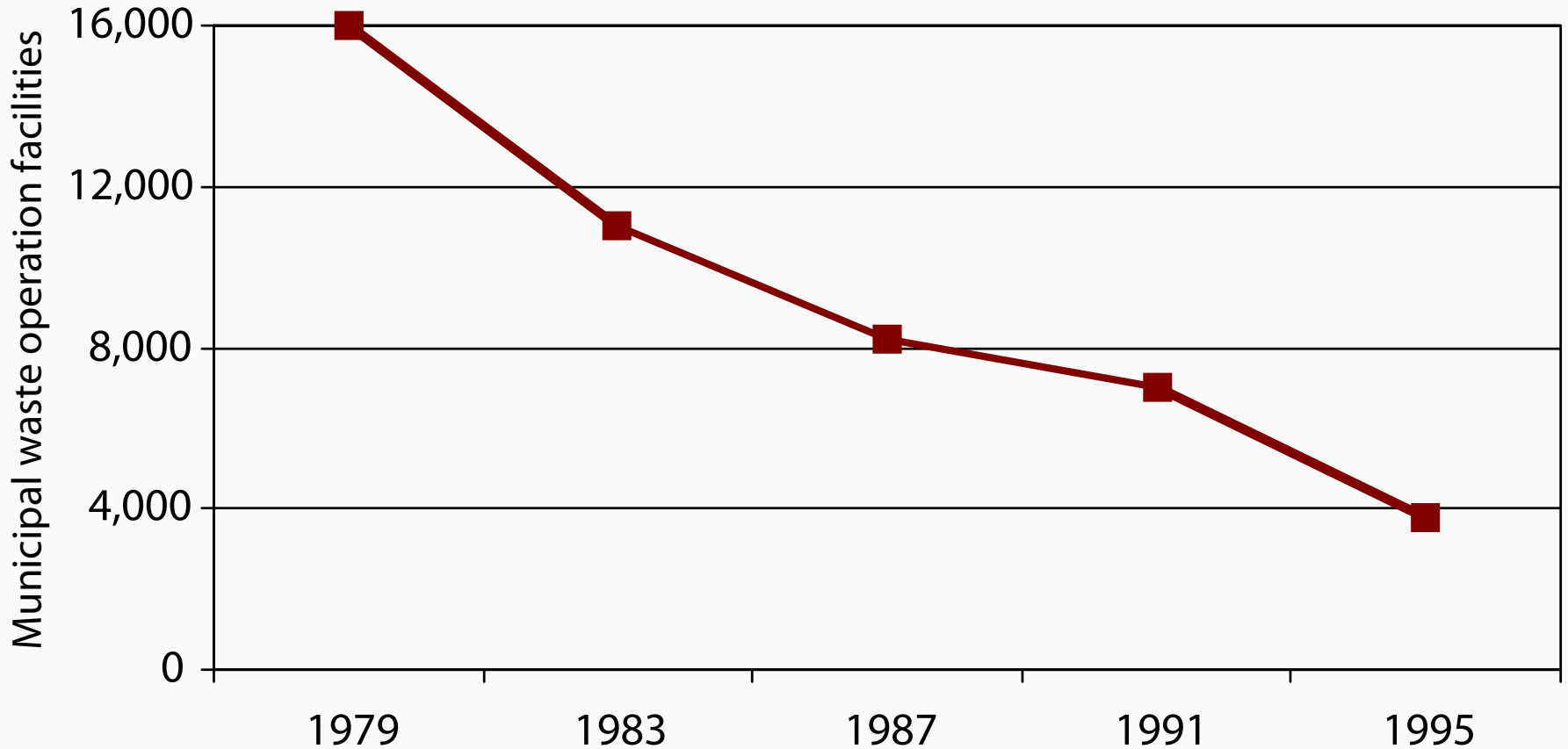


Change in Waste Disposal Tipping Fees



The Land Filling Crisis

- Changes in the number of municipal waste operating facilities (U.S.)



Sanitary Landfill: Federal Legislation Provisions

- Landfills may not be sited on floodplains, wetlands, earthquake zones, unstable land, or airports (birds at site are hazard to aircraft)
- Landfills must have liners
- Landfills must have a leachate collection system
- Landfill operators must monitor groundwater for many specified toxic chemicals
- Landfill operators must meet financial assurance criteria that monitoring continues for 30 years after closure of the landfill

Why Are New Landfill Sites Not Being Established?

- Public opposition
 - **NIMBY:** Not in my backyard
 - **LULU:** Locally unwanted land use
 - **NIMEY:** Not in my election year
 - **NIMTOO:** Not in my term of office
 - **BANANA:** Build absolutely nothing anywhere near anyone
 - **NOPE:** Not on planet earth
- Rising costs
- EPA regulations

Does MSW Degrade in a Landfill?

- Minimal
- Designed to prevent generation of **leachate**
 - Liquid containing dissolved solids and toxics that results from precipitation percolating down through the waste and contaminating groundwater
- Oxygen, critical for degradation, has been eliminated by compaction
- “Biodegradable” advertised products

The Lasting Litter Chart

Bottle	1,000,000 years
Plastic 6-pack holder	450 years
Aluminum can	200–400 years
Tin can	80–100 years
Plastic container	20–30 years
Disposable diaper	10–20 years
Woolen cap	12 months
Cotton rag	1–5 months
Banana/orange peel	3–6 weeks
Paper	2–4 weeks

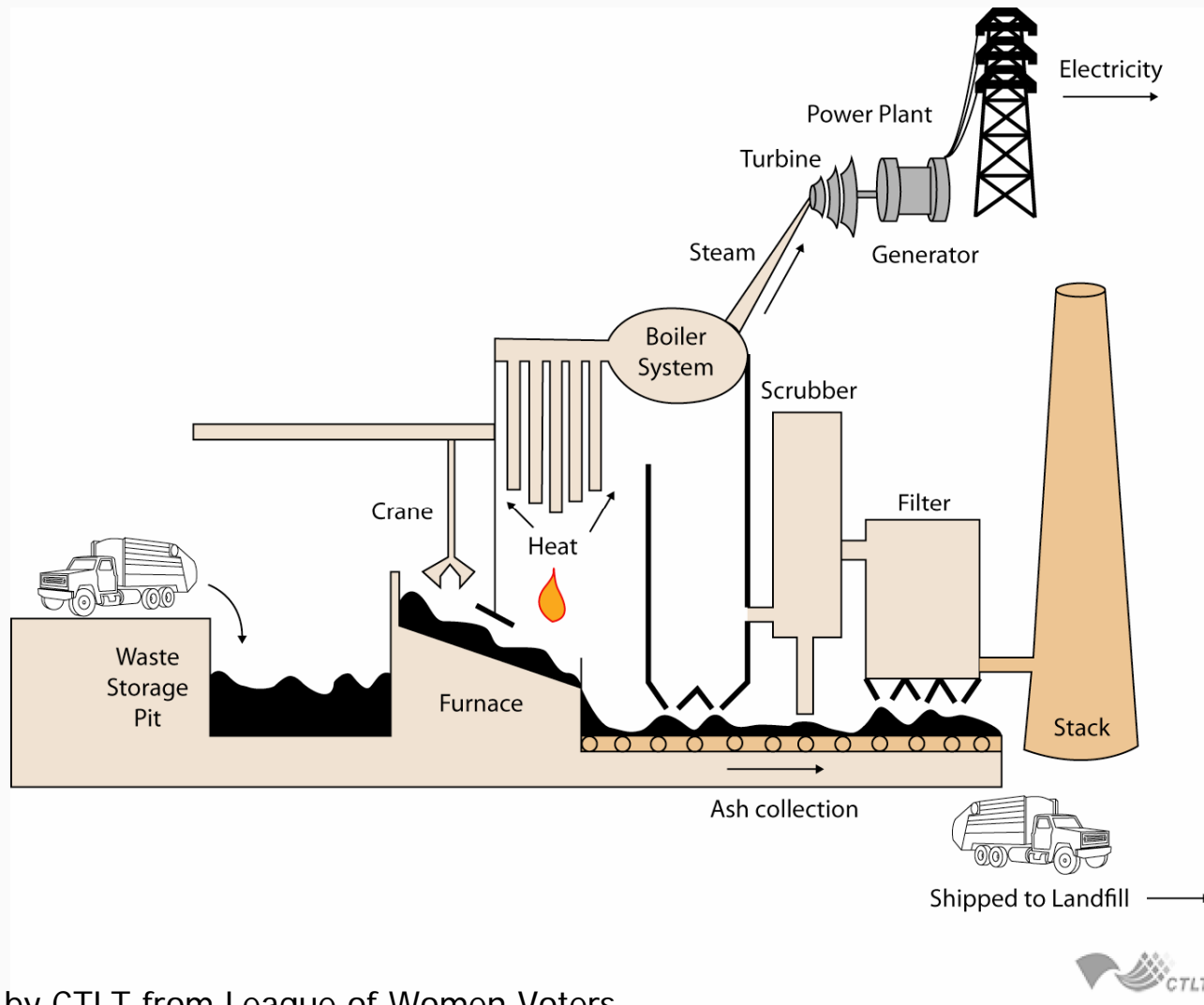
Typical Sanitary Landfill Leachate Composition

Component	Value
BOD ₅	20,000 mg/L
Ammonia nitrogen	500 mg/L
Chlorine	2,000 mg/L
Total iron	500 mg/L
Zinc	50 mg/L
Lead	2 mg/L
PCBs	1.5 µg/L
pH	6.0

- Reduces waste to solid residues, gases, and water vapor
- Process reduces waste volume by 80–90%
- Solid residues need further disposal (landfilling)
- Emissions have to be closely monitored and controlled
- Economic considerations
 - Incineration costs about \$125,000 per ton (cost is affected by plant capacity)
 - Typical plant capacity is about 1,000 tons per day

Waste-to-Energy Plant with Pollution Control System

- Mass burn waste-to-energy plant with pollution control system



Why Recycle?

- Resource conservation
 - Recycling reduces pressure on renewable and non-renewable resources
- Energy conservation
 - Recycling consumes 50–90% less energy than manufacturing the same item from virgin material
- Pollution abatement
 - Reduces level of pollutant emissions

Benefits Derived from Using Secondary Materials

- Environmental benefits derived from substituting secondary materials for virgin resources

Reduction of:	Aluminum	Steel	Paper	Glass
Energy use	90–97%	47–74%	23–74%	4–32%
Air pollution	95%	85%	74%	20%
Water pollution	97%	76%	35%	—
Mining waste	—	97%	—	80%
Water use	—	40%	58%	50%

Reasons More MSW Isn't Recycled: Attitudes

- Attitudes
 - Convenience, conditioned by advertising; throwaway attitude toward waste; not valued as a resource; out of sight, out of mind
 - Some people just don't care

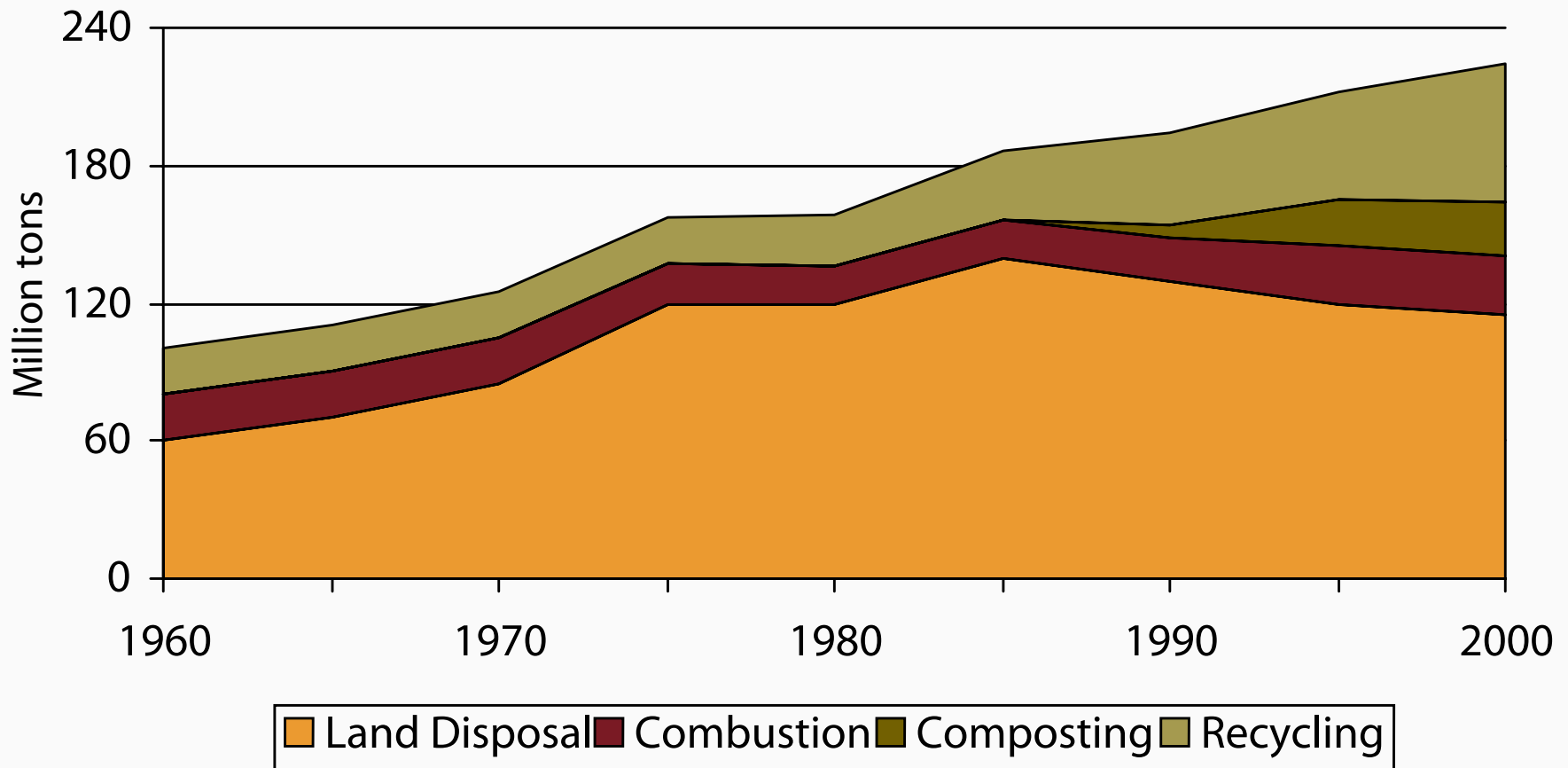
Reasons More MSW Isn't Recycled: Economic

- Economic
 - Public policy hinders recycling effort
 - Expense of sorting, transportation
 - Plastic virgin material less expensive than producing recycled material

Reasons More MSW Isn't Recycled: Market

- Market
 - Environmental cost is not reflected in market price
 - ▶ We must internalize the environmental costs
 - ▶ **We must include environmental cost in commodity pricing**

Trends in Waste Generation, Recovery, and Disposal



- Source reduction
 - Minimize the amount of waste being generated
 - Use less material per product
 - Make products last longer
 - Abandon the planned obsolescence approach
 - Front-end approach to waste management
- Reuse
 - Repeated use of items prior to disposal
 - Repair the item

MSW Management Hierarchy

- Municipal waste management hierarchy ranked in order of increasing impact on the environment
 - Source reduction
 - Reuse
 - Recycling
 - Incineration with energy recovery
 - Incineration without energy recovery
 - Landfill



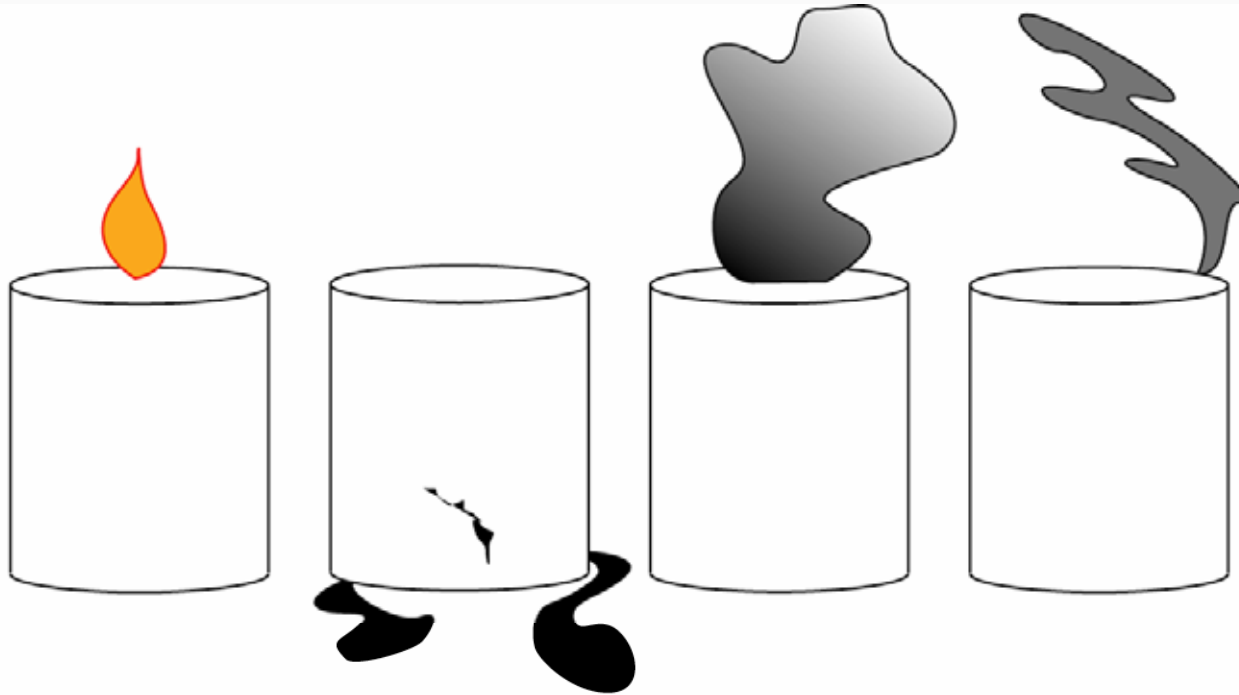
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Section B

Hazardous Waste

- Legal designation for certain wastes that require special handling because they present a serious threat to human health and the environment if mismanaged

Hazardous Waste



Ignitable

Corrosive

Reactive

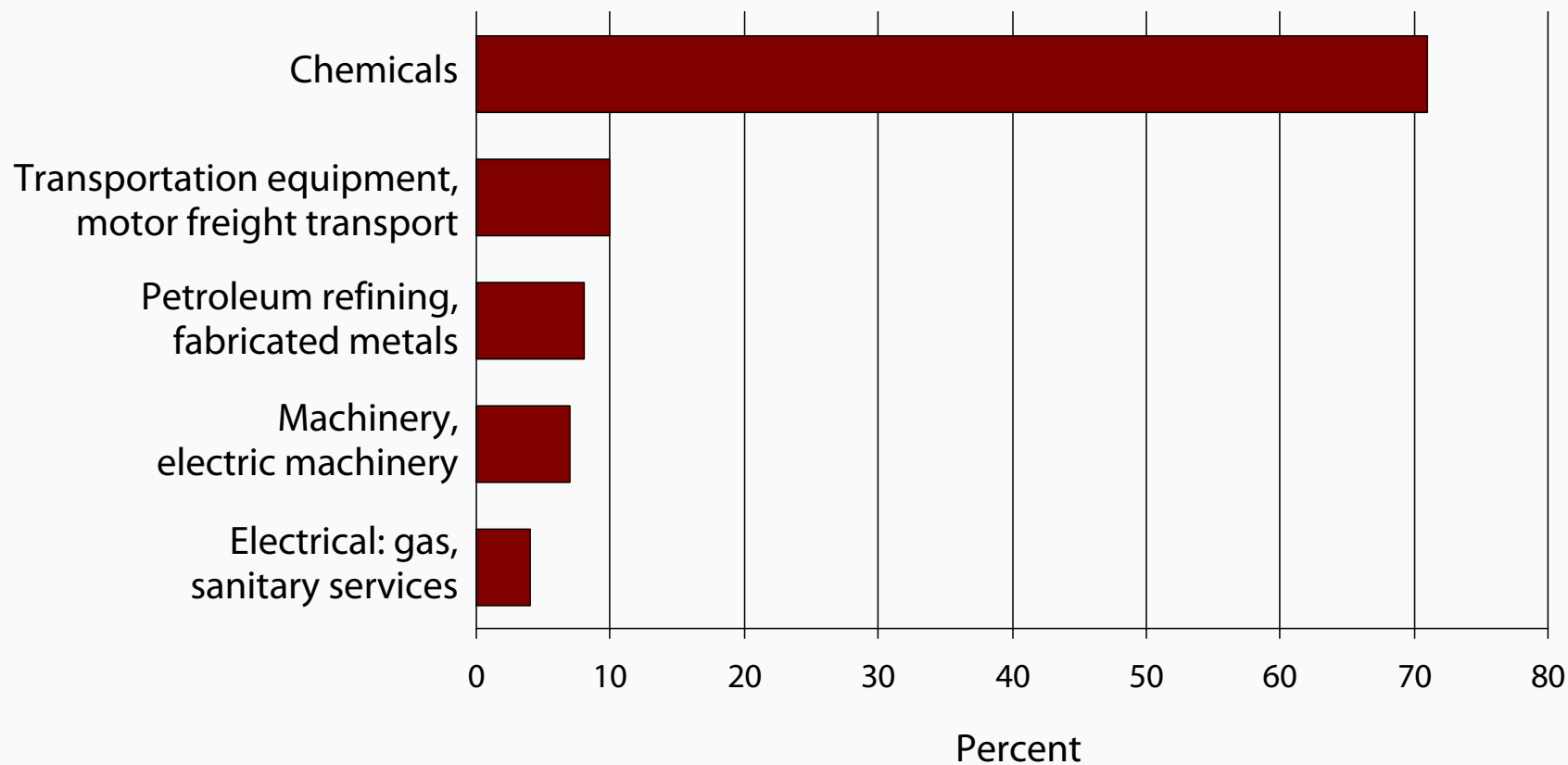
Toxic



Hazardous Waste Characteristics

- Ignitability
 - Substances that catch fire with a flash point of 140 degrees Fahrenheit or less
- Corrosivity
 - Substances that corrode storage tanks (pH <2 or >12.5)
- Reactivity
 - Substances that are chemically unstable and may explode or generate poisonous gases (cyanide and sulfide)
- Toxicity
 - Substances that are injurious to health when ingested or inhaled (e.g., chlorine, ammonia, pesticides, formaldehyde)

Hazardous Waste Sources in the U.S.



The “Toxic Soup” of Hazardous Waste

What

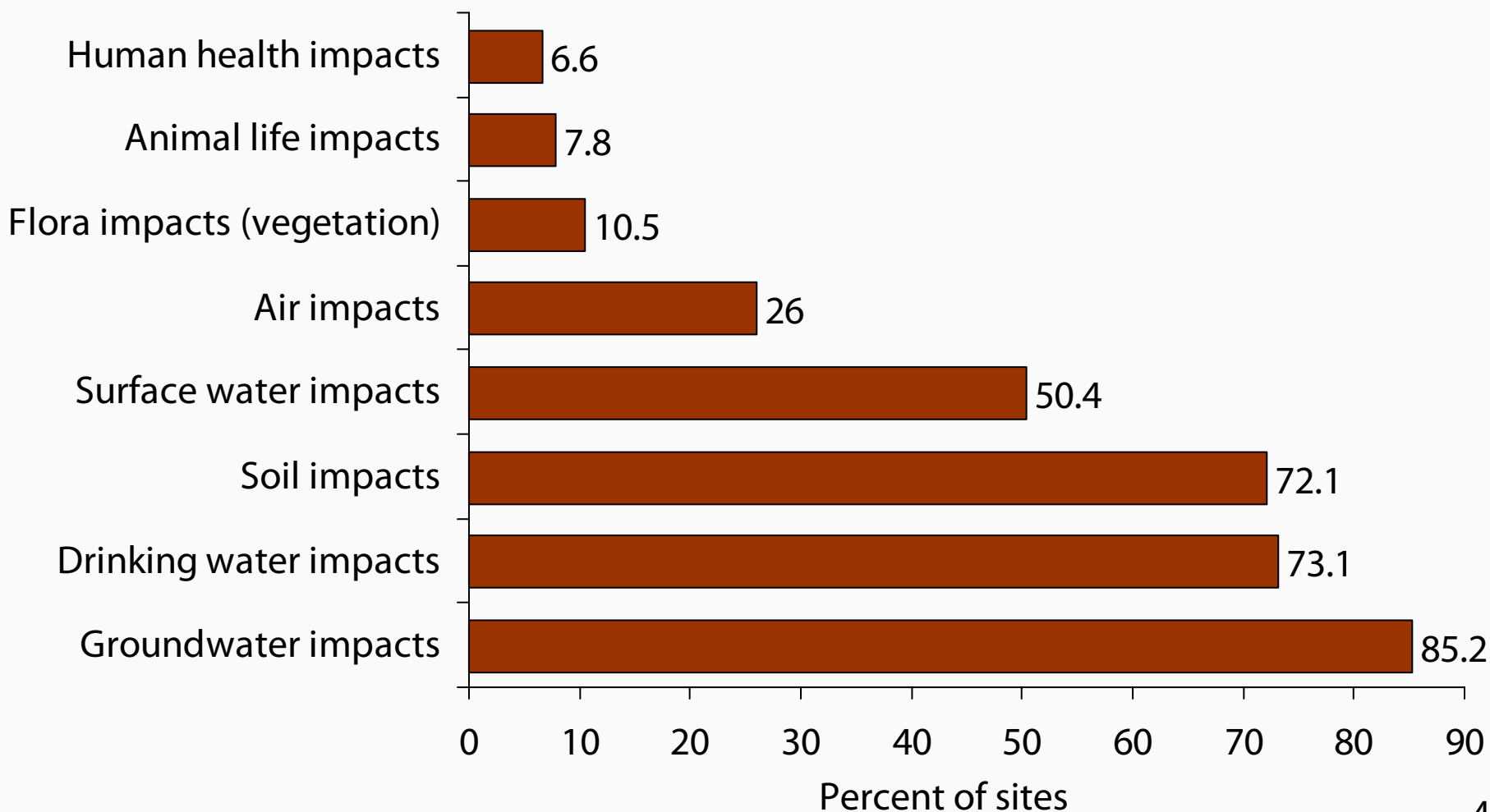
- Heavy metals
- Solvents
- Organic chemicals
- Municipal waste
- Inorganic waste
- Pesticides
- Paints and oil wastes
- Sludges

How much

- Between 300 and 700 million tons per year
- 90% is wastewater (which is dilute but contains enough regulated materials)

Potential Threats That Led to Listing on the NPL

- Potential threats to the environment that led to listing on the National Priorities List (NPL)

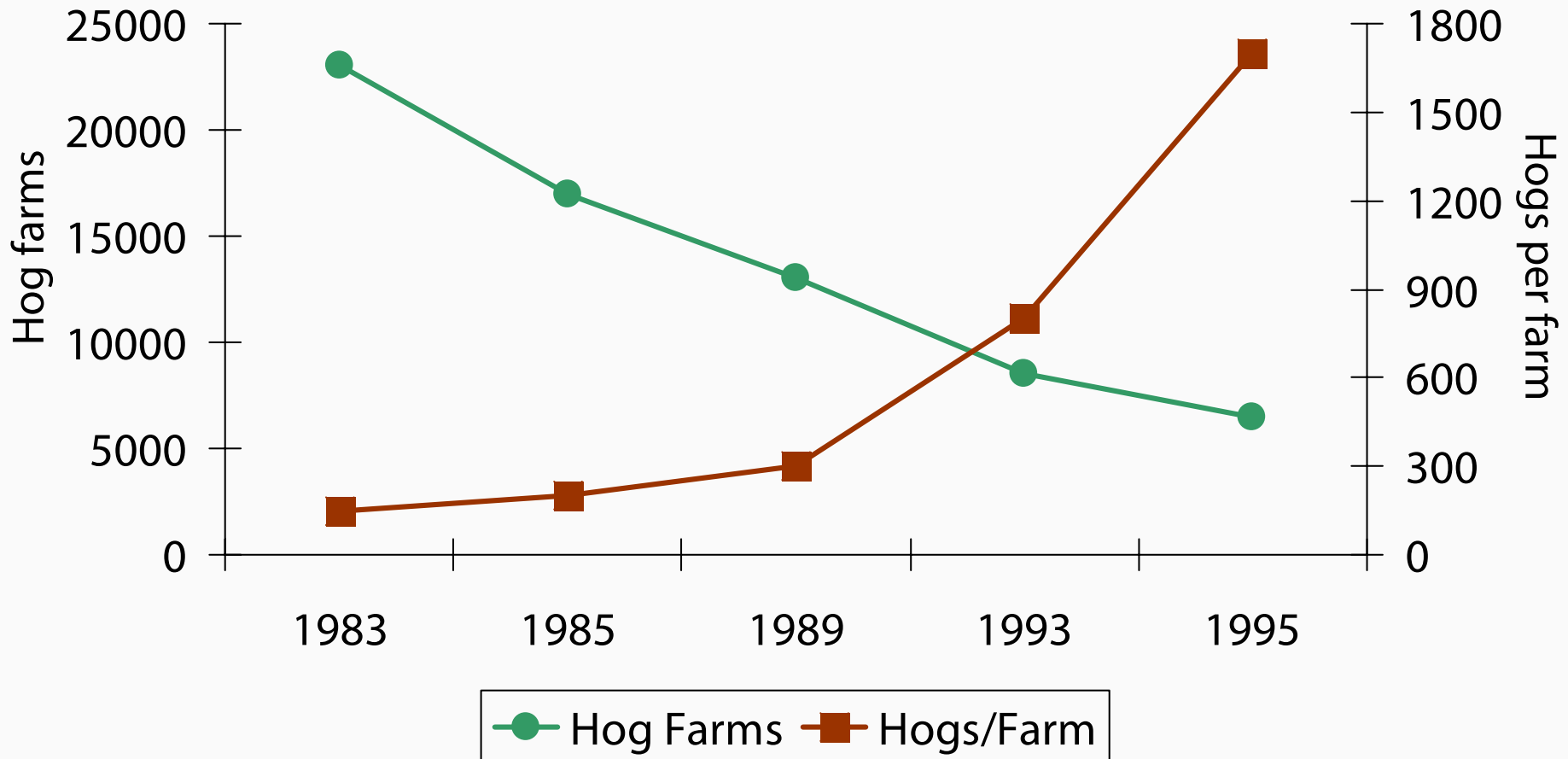


Livestock Production and Animal Waste Production

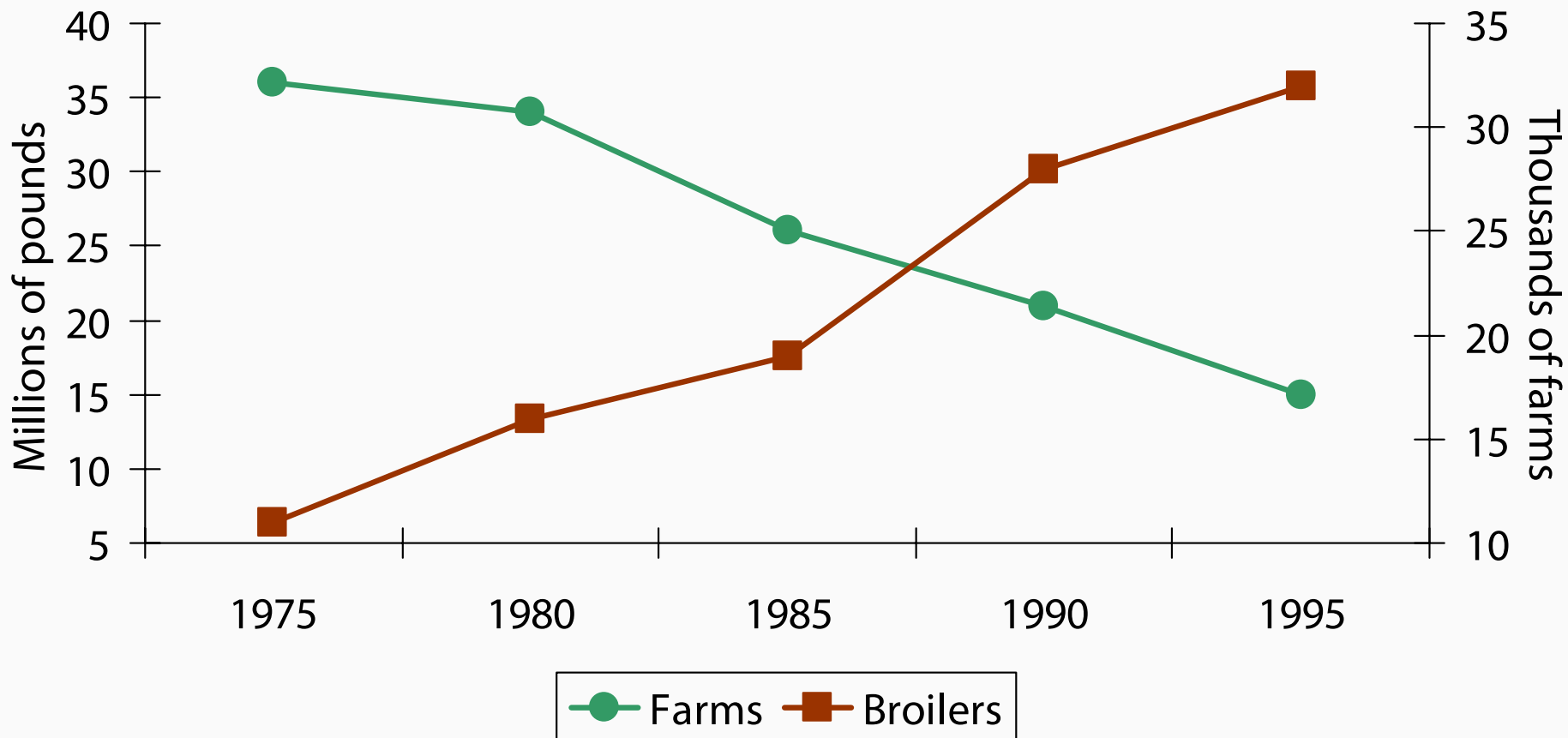
Animal	Production (x 10 ⁶ per year)	Solid manure (x 10 ⁶ tons per year)
Broilers	7,600	14.4
Turkeys	300	5.4
Hogs	103	116.4
Cattle (non-dairy)	58	1,229.2
		1,365.7
Concerns: (e.g., hogs)	Nitrogen Phosphorus Pathogens	29 lbs/year/hog 18 lbs/year/hog ?

Number of Hog Farms/Number of Hogs per Farm: NC

- Number of hog farms and average number of hogs per farm in North Carolina, 1983–1997



Broiler Numbers and Production Farms, 1975–1995



Environmental Impacts of Hog Farming

- Nutrient pollution of soil, rivers, and shorelines
 - Nitrogen and phosphorus
 - ▶ Stimulate algal growth leading to low dissolved-oxygen levels
- Air pollution
 - Nitrogen
- Contaminated groundwater and drinking wells
- Odor pollution
 - Ammonia

Potential Threats to Public Health

- Lists of recognized toxicants
- Lists of suspected toxicants
- Pathogens
- Antibiotic resistance
- Heavy metals in waste lagoons
- Greenhouse gases

- Comparison between municipal and hog farm waste treatment regulations
 - Municipalities are subject to strict waste control technologies
 - Hog farms are not
 - Municipalities must monitor their environmental performance
 - ▶ Hog farms have no obligation to monitor or report runoff, discharges, or groundwater contamination
 - ▶ Instead, they are inspected by state officials only two times per year

The U.S. Generates How Much Hazardous Waste?

- EPA estimates
 - 300–700 million tons per year
- ~ 90% (by weight) is wastewater
 - Used in industrial processes and becomes contaminated
 - Often is fairly dilute but contains enough regulated constituents to render it hazardous

The U.S. Generates How Much Hazardous Waste?

- ~ 10%
 - Inorganic solids (heavy metals, contaminated soil)
 - Organic liquids (solvents)
 - Sludges (treatment residues) from air- and water-pollution control devices

Hazardous Waste Generators

- 21,575 large-quantity generators
- 190,431 small-quantity generators
- 2,389 treatment, storage, and disposal facilities acting as waste generators

Uncontrolled Dumping of Hazardous Waste

- Contamination from uncontrolled dumping of hazardous waste
 - Chemical waste stored in barrels—either stocked on ground or buried—eventually corrode and leak, polluting surface water, soil, and groundwater
 - Liquid chemical waste dumped in an unlined lagoon from which contaminated water percolates through the solid and rock to the groundwater table
 - Liquid chemical waste illegally dumped in deserted fields or even along roads

“Top 20” Toxic Substances Found at NPL Sites

- “Top 20” most prominent toxic substances found at NPL sites (total list = 275)

Lead	Trichloroethylene
Arsenic	DDT
Mercury	Arachlor 1254
Benzene	Hexachlorobutadiene
Vinyl chloride	Arachlor 1260
Cadmium	DDE
PCBs	Arachlor 1242
Benzo(a)pyrene	Dibenzo(a,h)anthracene
Chloroform	Hexavalent chromium
Benzo(b)fluoranthene	Dieldrin

Health Effects of Selected Hazardous Substances

Chemical	Source	Health effect
DDT	Insecticide	Cancer; damages liver, embryo, bird eggs
BHC	Insecticide	Cancer, embryo damage
Benzene	Solvents, pharmaceuticals, detergent production	Headaches, nausea, loss of muscle coordination, leukemia, bone marrow damage
Vinyl chloride	Plastics production	Lung and liver cancer, depresses CNS, suspected embryotoxin

Health Effects of More Selected Hazardous Substances

Chemical	Source	Health effect
Dioxin	Herbicides, waste incineration	Cancer, birth defects, skin disease
PCBs	Electronics, hydraulic fluid, fluorescent lights	Skin damage, GI damage, possible carcinogen
Lead	Paint, gasoline	Neurotoxic; causes headaches, irritability, mental impairment in children; damages brain, liver, and kidneys
Cadmium	Zinc processing, batteries, fertilizer processing	Cancer in animals, damage to liver and kidneys

Persons at Potential Risk

- EPA:
 - ~ 73 million live within a four-mile radius of an NPL site
- ATSDR (Agency for Toxic Substances and Disease Registry):
 - ~ 11 million live within one mile of an NPL site
 - 1.3 million children under six years old live within one mile

- Problems
 - Residence near HWS does not necessarily translate to actual exposure to substance released from site
 - In many cases, no clearly established exposure pathway leads from source to population
 - Often, a community assumes exposure and a subsequent health hazard where neither exposure nor risk exists
 - A complex issue that requires examination of each site for its own characteristics

- The NRC (1991) conducted a comprehensive review of the published literature on public health implications of hazardous waste sites
- The review concluded that ***“the overall impact of hazardous wastes in the U.S. environment is unknown because of limitations in identifying, assessing, or ranking hazardous waste exposures and their potential effects on human health.”***

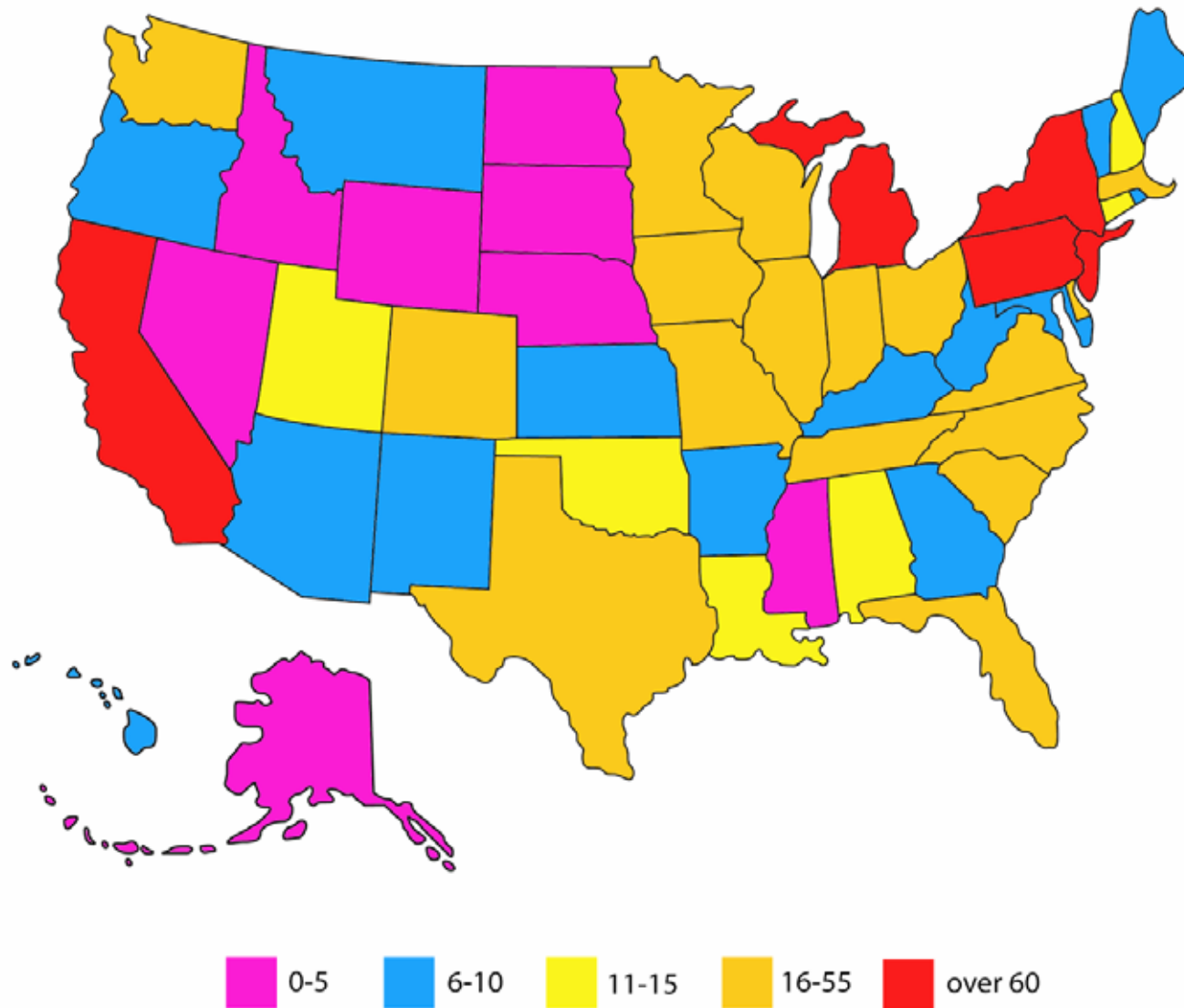
Cost of Cleanup

- Cost ranges depend on who does the estimates: The EPA, GAO, Office of Technology, industrial sector, etc.
- Non-federal
 - Between \$6 and \$12 million per site
 - 1991 EPA estimate: \$30 billion for all sites
- Federal sites
 - DOD: \$30 billion
 - DOE: \$240 billion
- All sites
 - ~ \$750 billion, with \$500 billion the lower estimate and \$1 trillion the upper estimate
 - Will require approximately 50 years of sustained effort

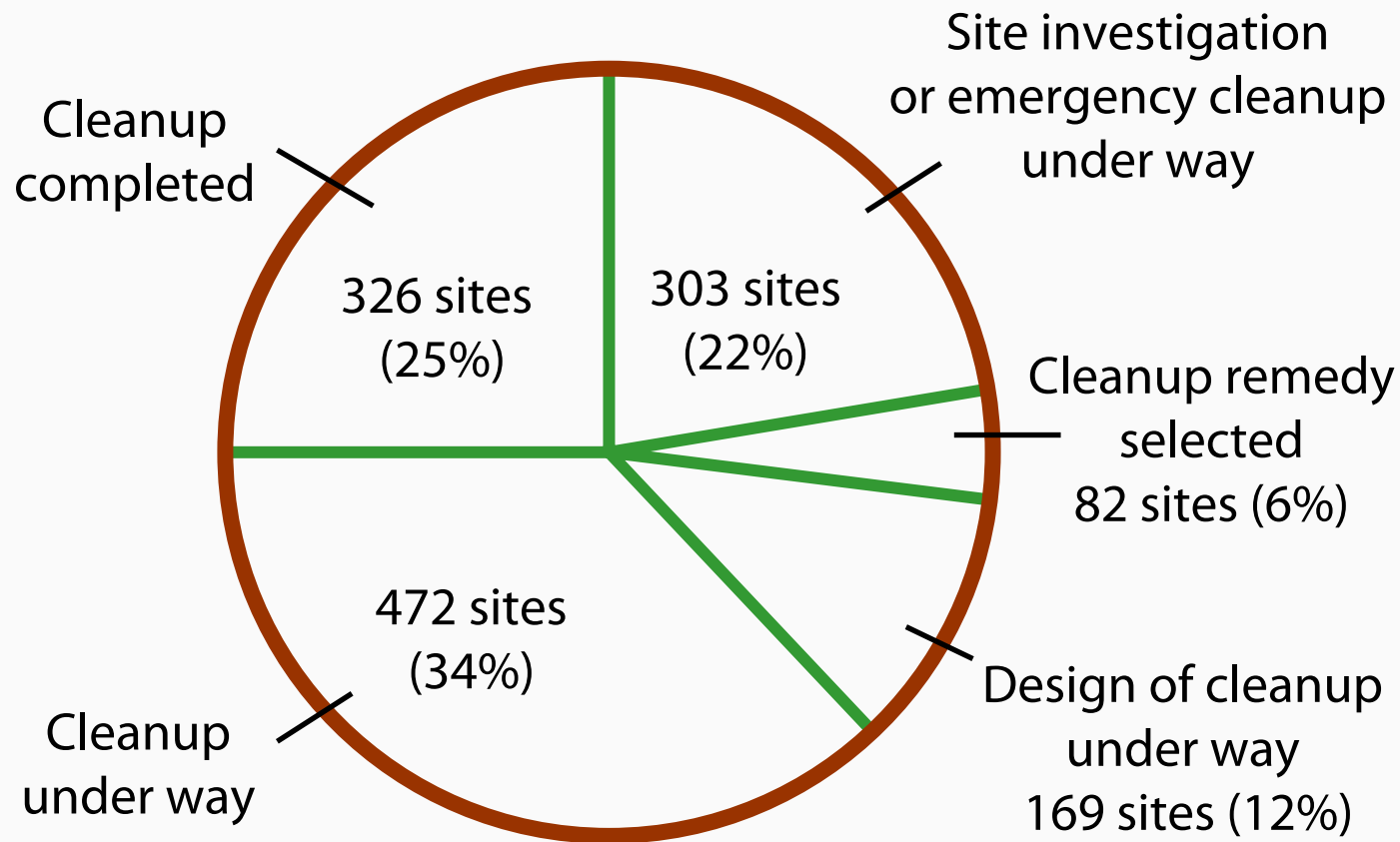
- Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
 - Cleanup existing disposal sites
 - ▶ How clean is clean enough?
 - Liability: “The polluter pays” principle
 - ▶ ~ 30% of Superfund paid for legal fees
 - Cost
 - ▶ Attempt to find the “potentially responsible party”
 - ▶ Government (taxpayer) continues to bear much of the financial burden

Location of NPL HWS

Total sites in U.S. 1,177



Cleanup Status of NPL Sites



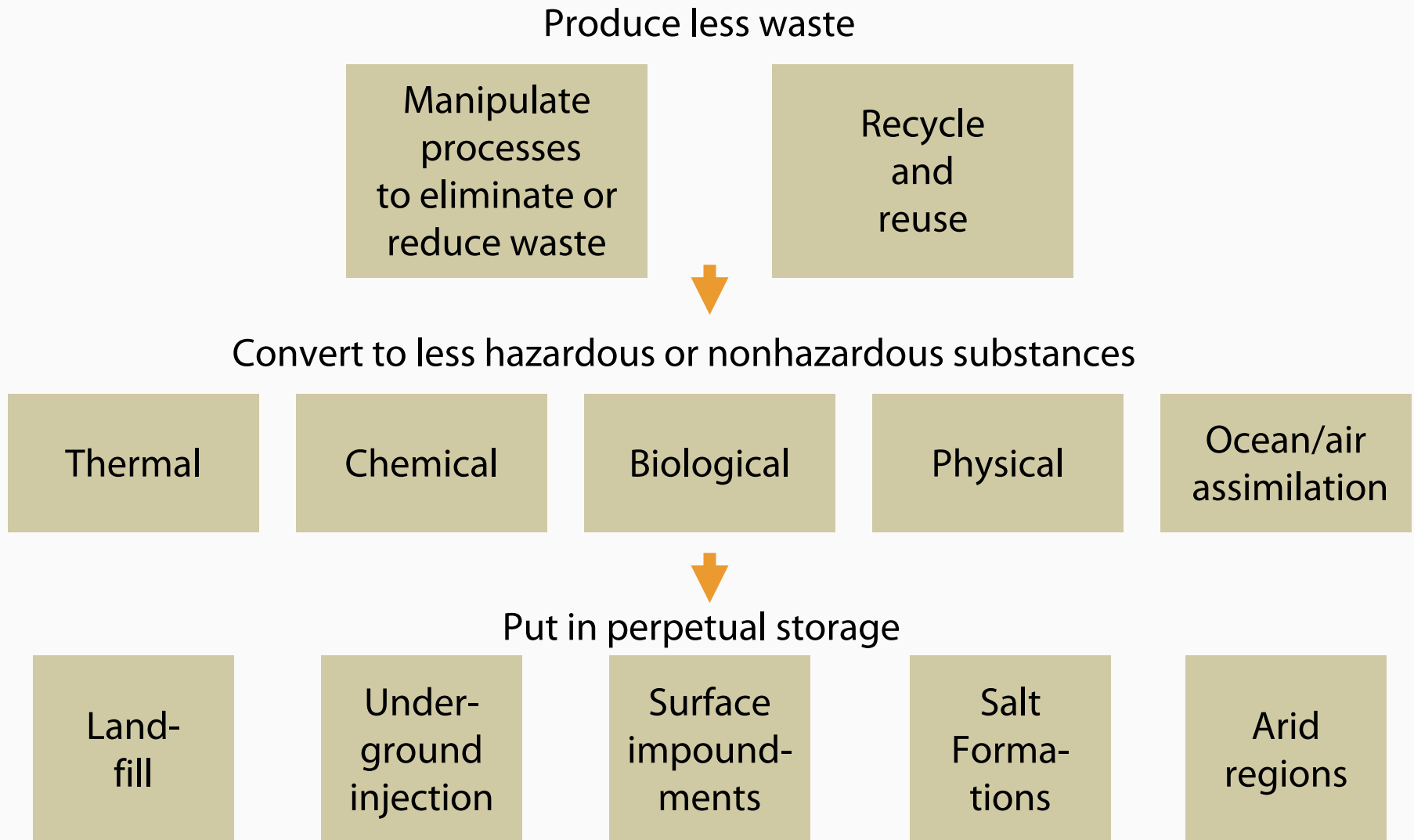
Question

- Are accidental toxic waste transportation accidents more of a public health threat than hazardous waste sites?
- School of thought
 - Probably more injuries are due to releases from these events than from waste sites proper

Transport of Hazardous Waste

- Modes of transport
 - 337,000 flatbed trucks
 - 130,000 cargo tanks
 - 115,000 railroad tank cars
 - 5,000 barges
 - 4,000 cargo loads for airplanes
- Moving about 10 million tons of hazardous waste per year
 - ~2,500 spills of 100 gallons or more per year

Hazardous Waste Management Options



Treatment, Disposal Technologies for Hazardous Waste

General approach	Specific technology
Physical/chemical	Neutralization Precipitation/separation Detoxification (chemical)
Biological	Aerobic reactor Anaerobic reactor Soil culture
Incineration	High temperature Medium temperature Co-incineration

Treatment, Disposal Technologies for Hazardous Waste

General approach	Specific technology
Immobilization	Chemical fixation Encapsulation Stabilization Solidification
Dumping	Landfill Deep underground Marine
Recycling	Gravity separation Filtration Distillation Chemical regeneration

Key Points: Types of Waste

- “Waste” includes municipal solid waste, industrial waste, hazardous waste, medical waste, and radioactive waste
 - Industrial waste accounts for 94% of all waste
- Animal waste is an important emerging source
- Municipal waste production is increasing, and landfills are decreasing
- Alternate management strategies, including recycling, reuse, and mass-to-energy conversion, are becoming important

Key Points: Hazardous Waste

- Hazardous wastes are classified by their ignitability, corrosivity, reactivity, and toxicity
- Hazardous waste sites are a potential threat mainly to groundwater and drinking water
- The main obstacles to progress include lack of money (e.g., Superfund), reluctance to accept responsibility, and incomplete science (e.g., epidemiologic studies)