

Energy & Environmental Engineering

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Module 2

- **ENVIRONMENTAL POLLUTION (10 hours)**
- Water, air, soil, noise, thermal and radioactive, marine pollution: sources, effects and engineering control strategies. Drinking water quality and standards, Ambient air and noise quality standards



LAND POLLUTION

- **Land pollution** is the degradation of Earth's land surfaces often caused by human activities and their misuse of land resources. It occurs when waste is not disposed properly.
- disposal of urban and industrial wastes, exploitation of minerals, and improper use of soil by inadequate agricultural practices are a few factors.
- Urbanization and industrialization are major causes of land pollution.
- The Industrial Revolution set a series of events into motion which destroyed natural habitats and polluted the environment, causing diseases in both humans and other species of animals.

Land Pollution Comprises Of

○ Solid Waste

○ Soil Pollution



Soil pollution

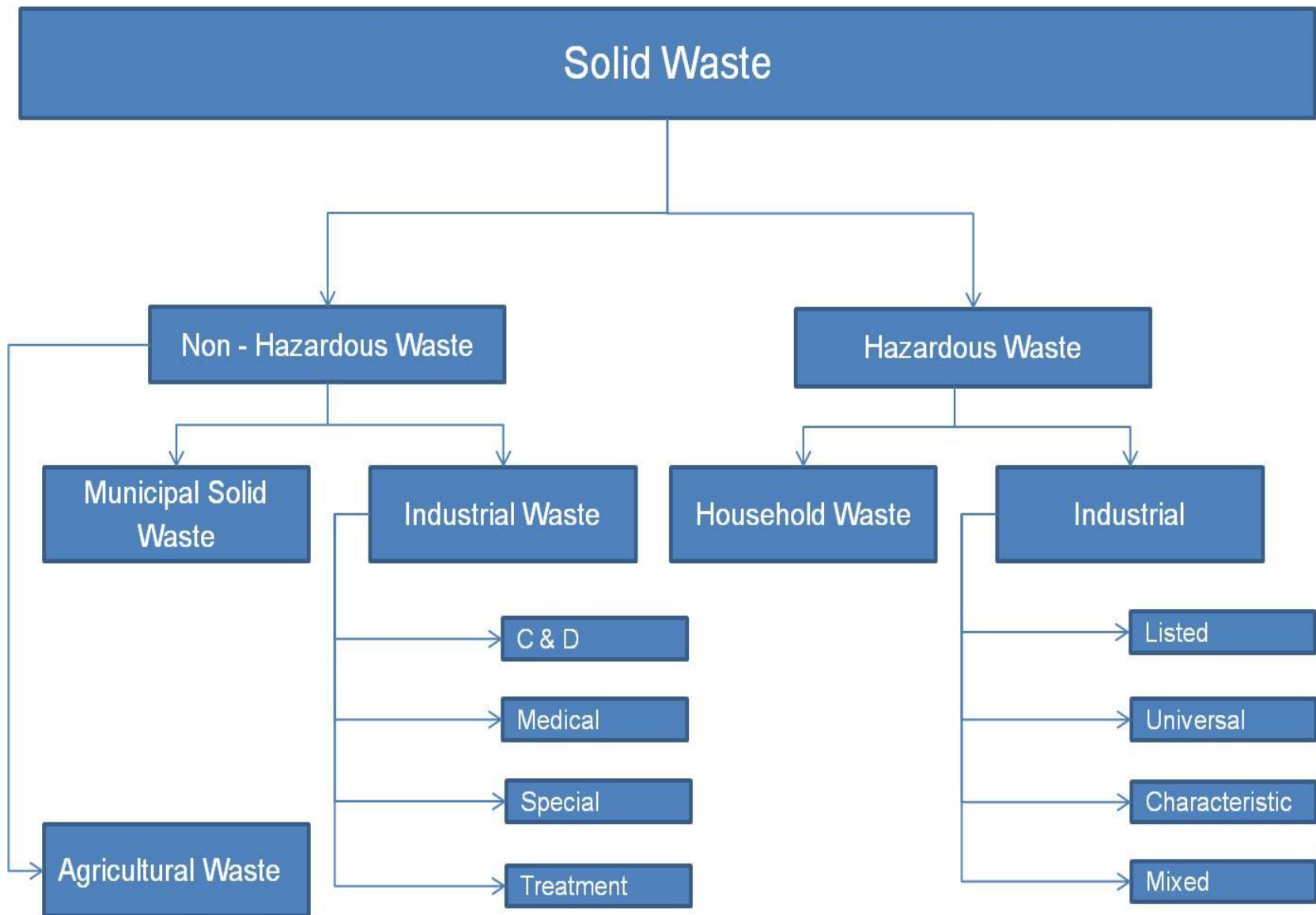
It is caused by the presence of xenobiotic (human-made) chemicals or other alteration in the natural soil environment.

Caused due to

- Underground storage tanks
- Application of pesticides
- Percolation of contaminated surface water to subsurface strata
- Oil spillage and fuel dumping
- Waste dumping

What is meant by Solid Waste?

- Dry refuse or solid material rejected by the society
- Racks, pieces of broken furniture, plastic material, food waste etc.
- Solid wastes are generated from various domestic, commercial and industrial activities which are classified as municipal wastes, industrial wastes and hazardous waste
 - Municipal solid waste
 - Industrial solid waste
 - Hazardous solid waste







Three main components of Refuse

Garbage (Food wastes) : Decomposing organic matter such as vegetable, fruits and food material.

- 0.1 kg/head/day
- These wastes are best suited for biodegradation

Rubbish : Combustible and Non combustible solid waste (mostly inorganic)

- Average of 0.25 kg/day
- Includes glass, metal , leather , textiles, paper, plastics , building materials

Ashes and residue products are the remains after combustion

- Other types of solid wastes include street sweeping, animal dung and dead animals

Municipal Solid waste- Classification

Component	Description
Food wastes	Garbage (vegetable residue), fruits, animals etc Decomposition is rapid
Rubbish	Combustible (paper, cardboard, textile, rubber, leather, wood, furniture, garden trimming etc) and non combustible solid waste (glass, crockery, tin canes, aluminium cans, ferrous non ferrous metals, construction wastes)
Ashes and residues	Burning residue of wood, coal and other combustible waste. Burnt & partially burnt material
Demolition & construction waste	Construction, remodelling, repairing (dirt, stone, concrete, bricks, plaster)
Special wastes	Street sweeping, roadside litter, catch basin debris, dead animals, abandoned vehicles
Treatment plant waste	Solid & semi solid wastes from water, waste water/ industrial waste watertreatment facilities

Sources & Composition of MSW

Composition of MSW

Compostable / Bio-degradable = 30% - 55%
matter (can be converted into manure)

Inert material = 40% - 45% (to go to landfill)

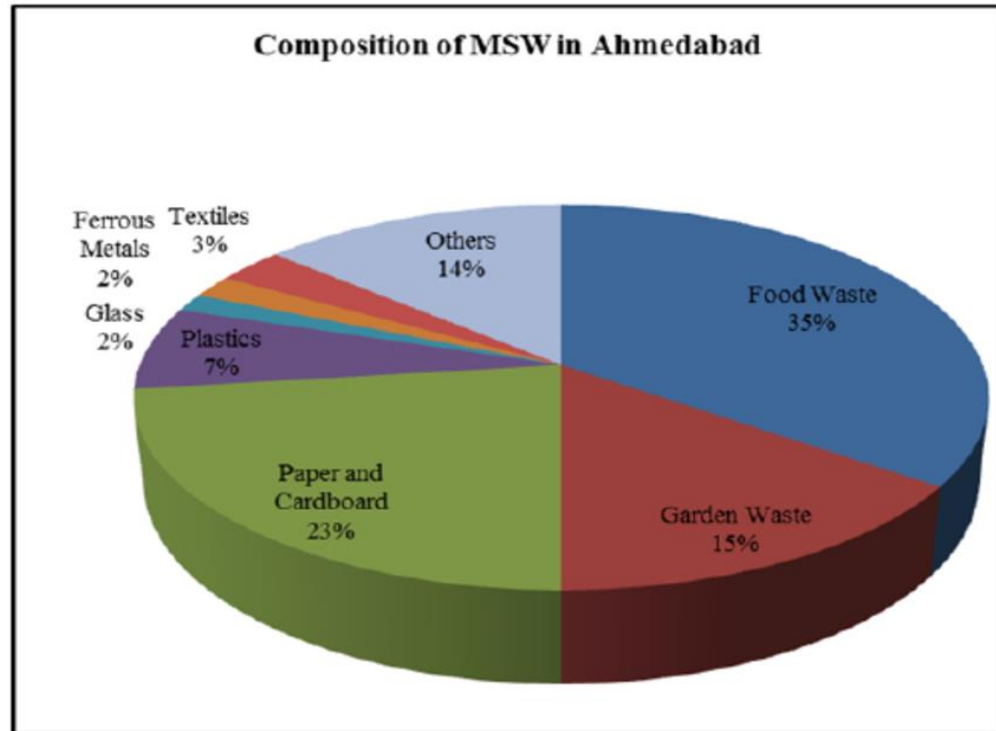
Recyclable materials = 5% - 10%
(Recycling)

These percentages vary from city to city depending on food habits



Source: www.ncrpb.nic.in (Master Plan Preparation for Solid Waste Management)

- Paper
- Yard trimmings
- Food waste
- Plastic
- Rubber
- Wood
- Metals



- How do we find the composition- source specific approach and material flow methodology

Properties of solid waste

- Physical properties

Density –Depends on composition of wastes (higher in organic waste and lower in commercial waste) Overall bulk density calculated for waste having materials of different densities

Particle size and distribution –Difficult to characterize because of waste heterogeneity

Moisture content –Weight loss (%) when a sample of solid waste is dried to a constant weight at a temperature of 100-150°C

Dry weight = Total weight –Moisture content

Evaluation of SW

Ultimate analysis

- ❑ Defined as the total elemental analysis to determine % of elements (C, H, O, N, S) present in waste
- ❑ Used to characterize the chemical composition of organic fraction of waste –assess the stability of the waste as a fuel

Proximate analysis of MSW

- More specific compared to ultimate analysis
- Determines (moisture, volatile matter, ash, fixed carbon)
- Assess capability of MSW as fuel

Heating value of waste

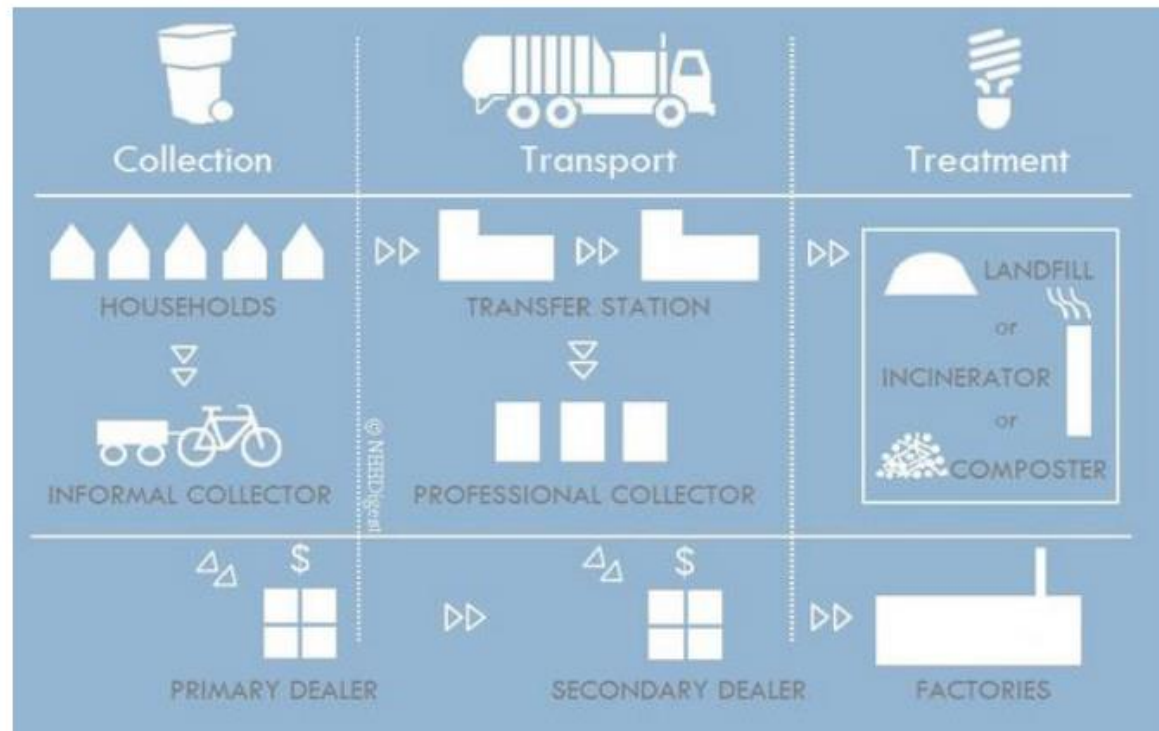
- Heat value of waste is energy released when waste is burned
- Heat value directly proportional to carbon content of waste; inversely proportional to ash and moisture content
- Heat value calculated using:
 - Dulong formula
 - Modified Dulong formula
 - Khan equation
- C/N ratio: Ratio of carbon to nitrogen in waste (preferred range –20 to 35)
- Heat of combustion: estimated by combusting samples in a boiler and measuring heat output/ using lab scale bomb calorimeter/ ultimate analysis

Key components of solid waste management

- Solid waste management can be divided into five key components:

- ☐ Generation
- ☐ Storage
- ☐ Collection
- ☐ Transportation
- ☐ Disposal

Steps in management of solid waste



Source: Municipal Solid Waste Management in China – An infographic
www.needigest.com

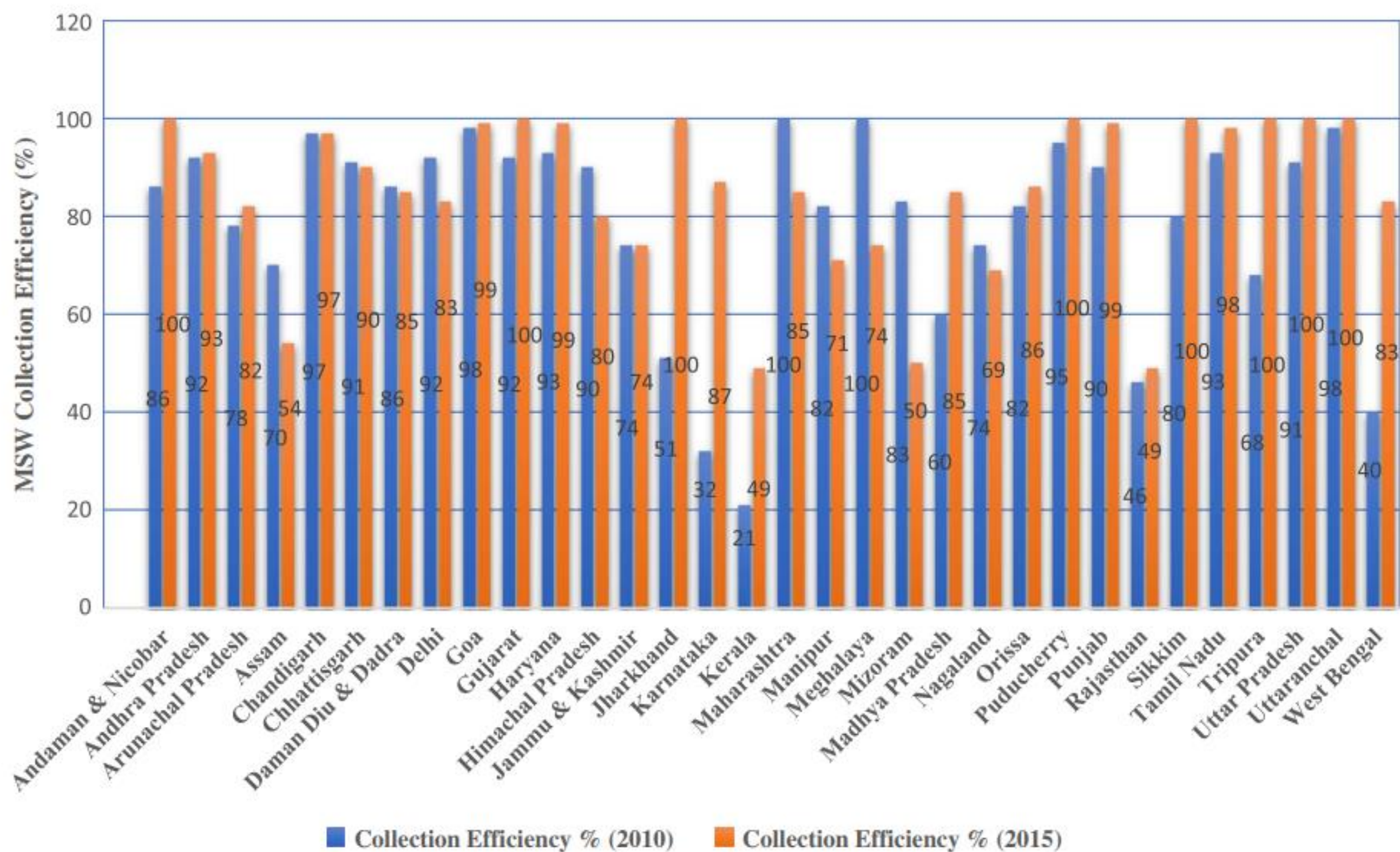


Fig. 1. MSW collection efficiency of selected Indian states. (Data from CPCB 2013; MNRE 2016.)

<https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29EE.1943-7870.0001490>

Table 6. Current status of MSW management in India

Parameter	Status
House-to-house collection of waste	18 states (of 29)
Segregation of waste at the source	5 states (of 29)
Number of unsanitary landfill sites identified	1,285
Number of sanitary landfill sites constructed	95
Number of ULBs operating compost/ vermicompost facilities	553
Number of ULBs under construction compost/ vermicompost facilities	173
Number of operating pipe composting facilities	7,000
Number of operating RDF facilities	12
Number of operating biogas plants	645
Number of energy generation plants	11 (6 operational)
Waste generation	143,449 Mt/day
Waste collection	117,644 Mt/day (82%)
Waste treated	32,871 Mt/day (28%)

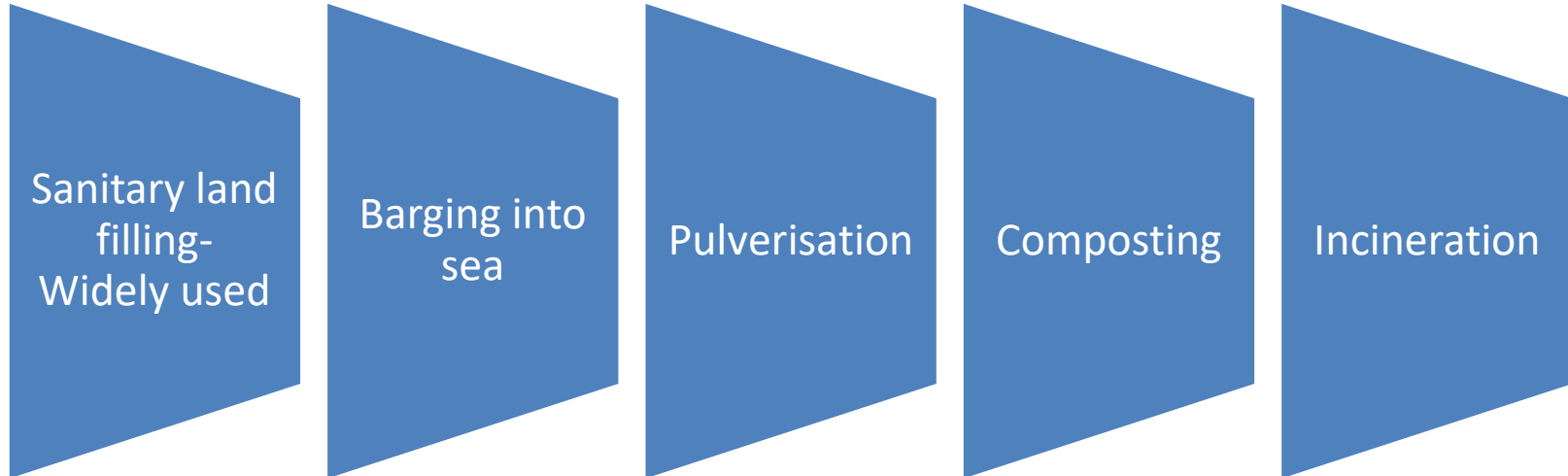
Source: Data from CPCB (2016).

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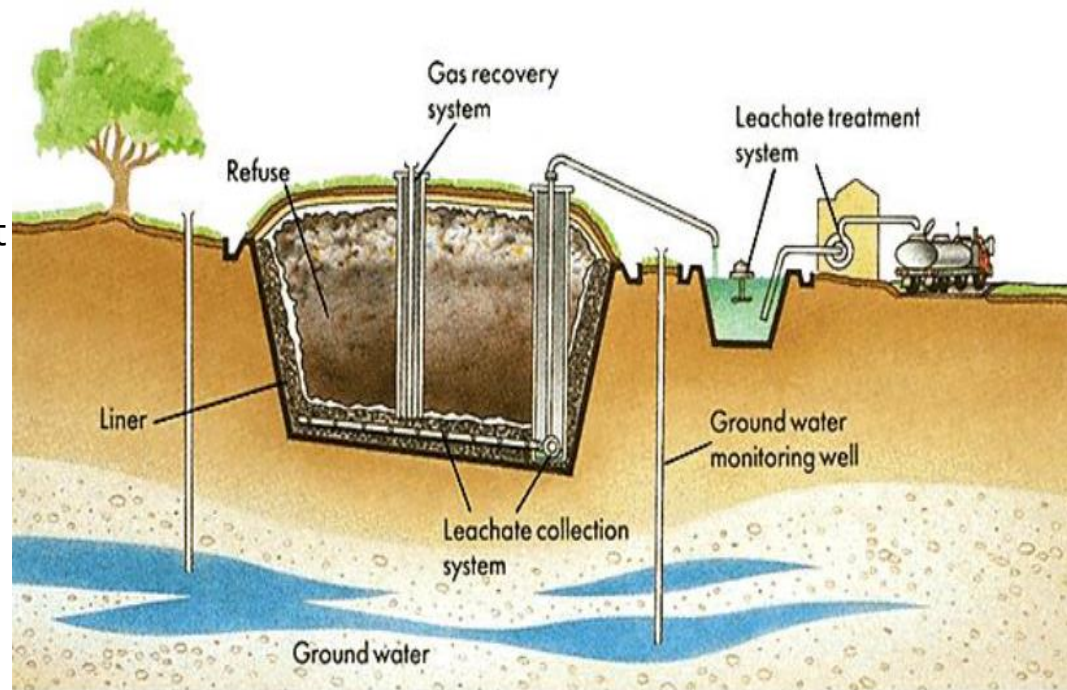
Disposal: The final stage of solid waste management is safe disposal where associated risks are minimized. There are four main methods for the disposal of solid waste:



Methods of Solid Waste Management

Sanitary Landfill- can be done in low lying areas

- Composite liner
- Landfill cover system- Soil cover to prevent odour
- Leachate generation and control: When rain water passes through MSW brownish water comes known as leachate. Very high BOD
- Landfill gas production –energy generation from capture of landfill gas- Major gas CH_4 , CO_2
- Closure- Once the land is filled it needs to be covered. Plantation etc can be done.
- Post-closure care activities- Ground water quality leachate quality regular checks.



Source: www.oocities.org

An evaluation of proposed sanitary landfill: Davao City

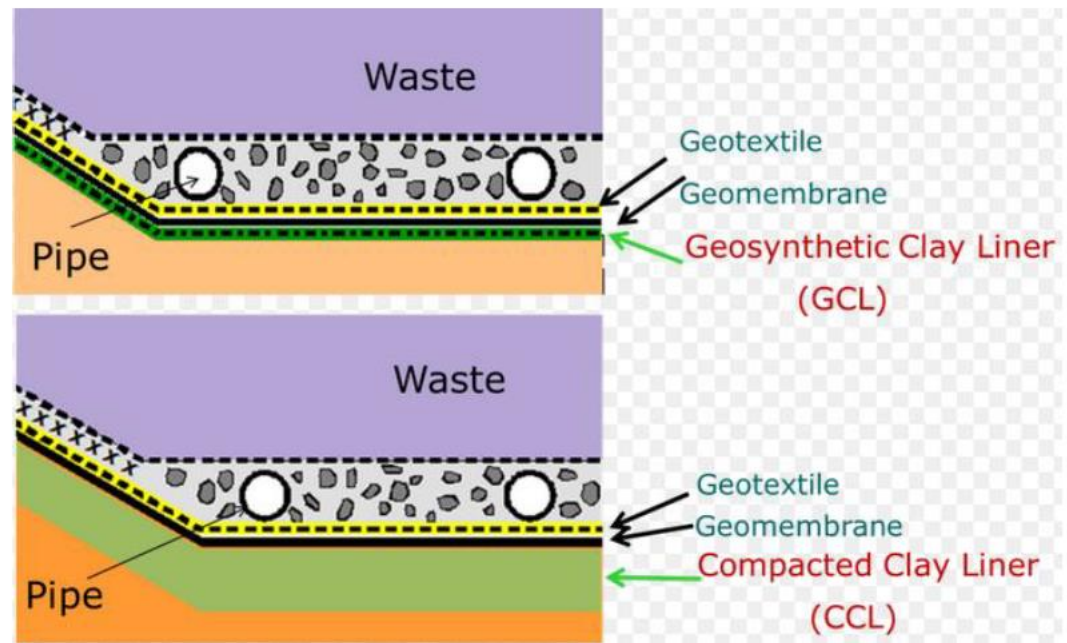
Methods of Solid Waste Management

Sanitary landfill

- ☐ Garbage is spread out in thin layers, compressed and covered with soil or plastic foam.
- ☐ bottom of the landfill - impervious liner which is usually made of several layers of thick plastic and clay.
- ☐ This liner protects the ground water from being contaminated because of leaching or percolation.
- ☐ When the landfill is full, it is covered with layers of sand, clay, top soil and gravel to prevent seepage of water.

Liner system

- Types of liner systems:
 - Single liner
 - Composite liner
 - Double liner

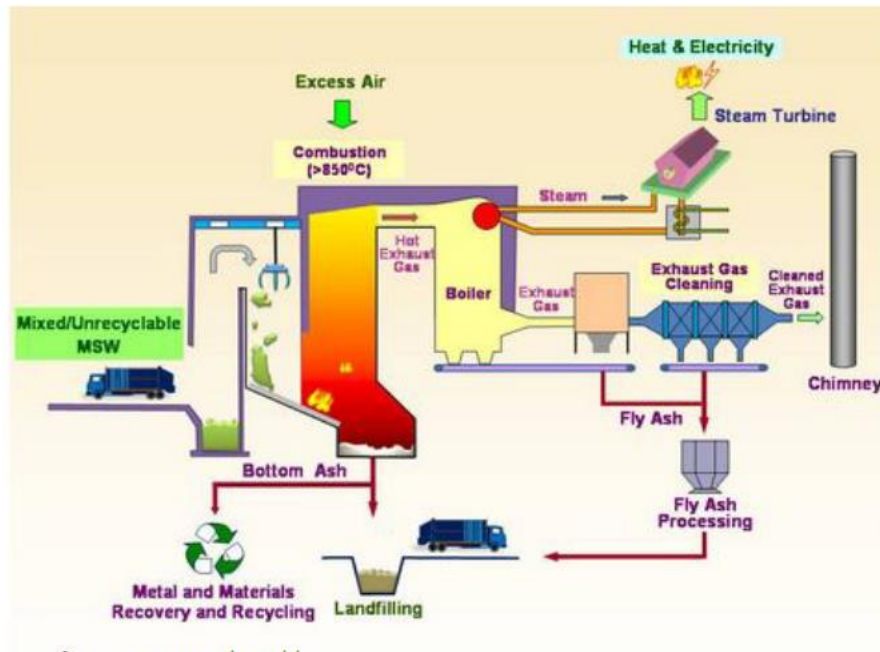


A typical composite liner system

Source: Landfill Barriers – Geoengineering Research Group
www.carleton.ca

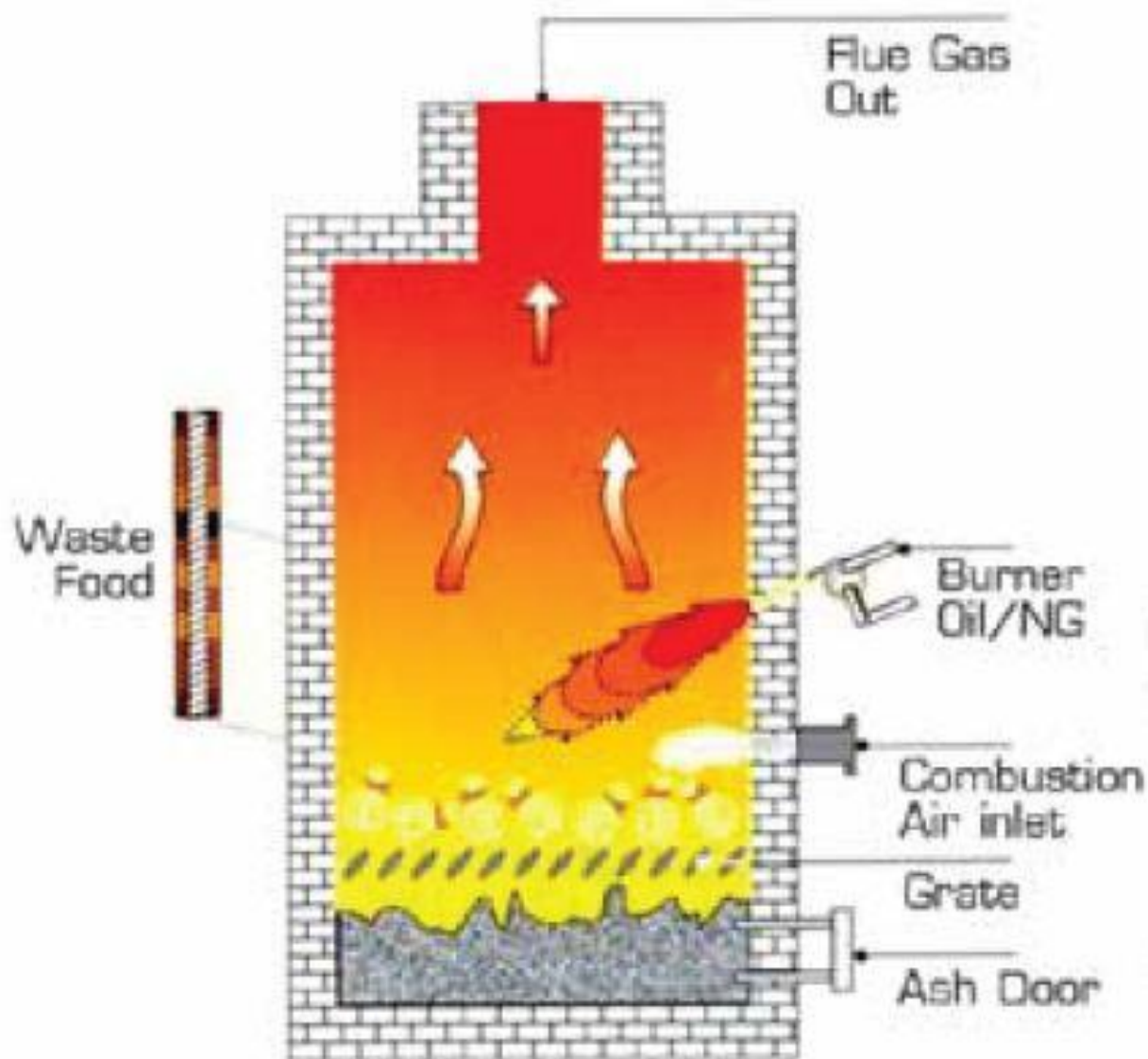
Methods of Solid Waste Management

Incineration of solid waste



Source: www.epd.gov.hk

- Energy derived from mass burning of MSW is poor compared to a fuel – due to high organic matter and moisture content
- Environmental considerations
 - Emission of gases (SO_x , NO_x , CO_2)
 - Heavy metals released through emission gases (Hg, Cd, Pb)
 - Odour
 - Dispersion of particulate matter



Incinerator

Methods of Solid Waste Management

Incineration:

pyrolysis

- Thermal pyrolysis/ destructive distillation: Burning in the absence of air.
- This usually occurs under pressure and at temperatures of up to 430 degrees Celsius.
- The solid wastes are changed into gasses, solid residue and small quantities of liquid
- 3 major components
- Gas- CH_4 , CO_2 , CO , etc
- Liquid- Tar
- Solid- Charcoal

Methods of Solid Waste Management

Pulverisation- Making into powder

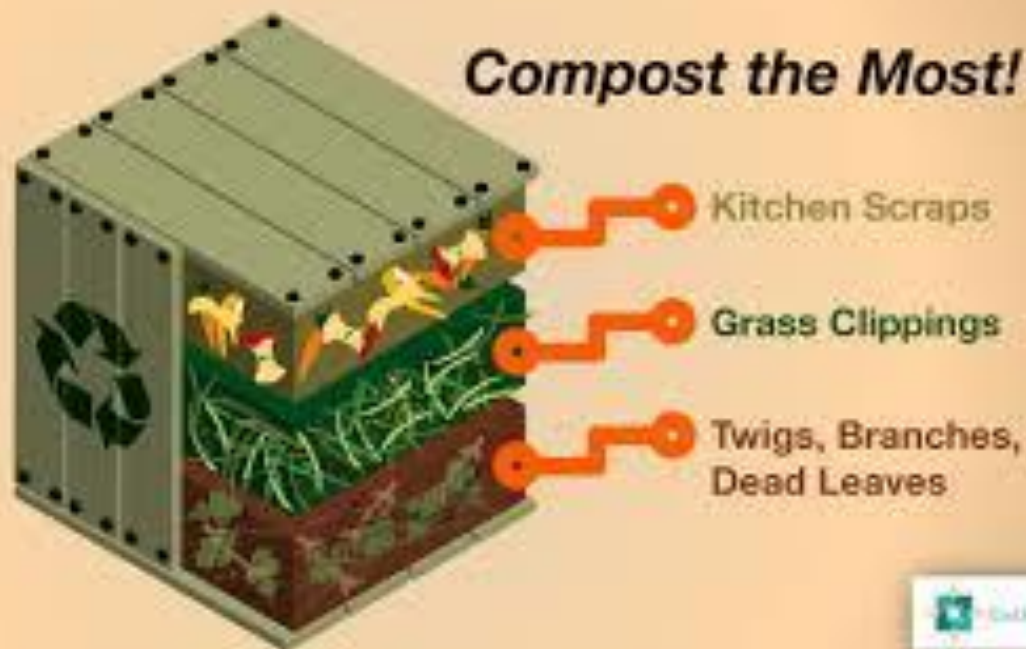
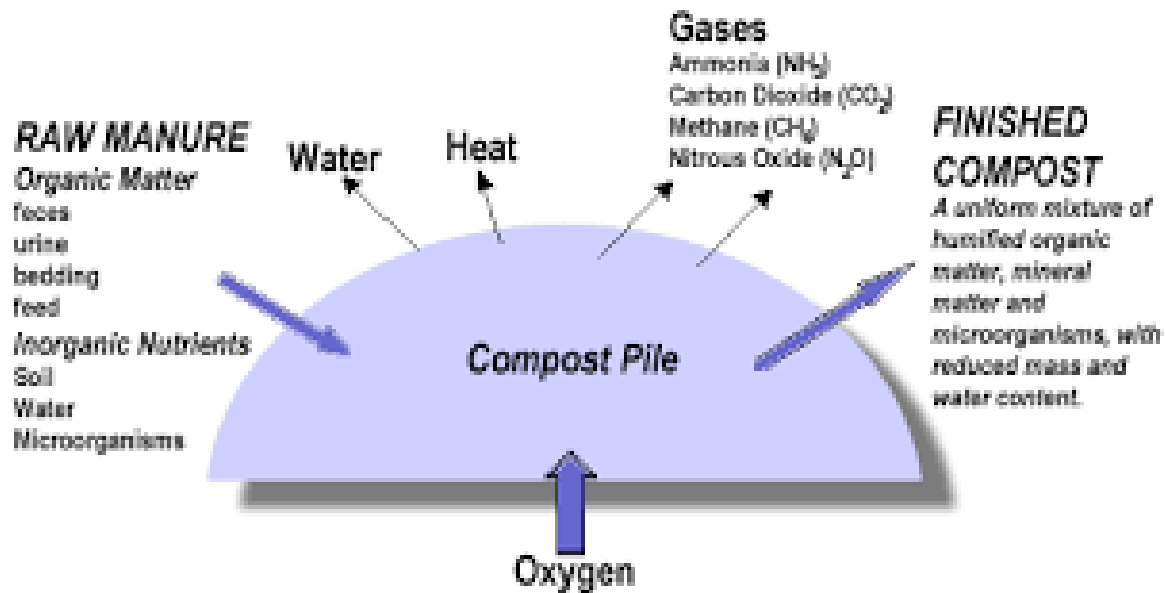
- ☐ Large material- decomposition occur slowly
- ☐ Shredders to reduce size and then sent to digesters
- ☐ Decomposition in digesters
- ☐ Artificial digesters maintaining temperature to improve decomposition

Compositing- Compost, humus, manure,

In India 2 methods

- 1) Bangalore method- anaerobic method- Under the ground, Slower process
- 2) Indore method- Aerobic method- kept above the ground, mixing at regular interval is needed to encourage aerobic condition, As aerobic its faster but unhygienic

Elutriation- Separate useful components (recyclable components)





Industrial waste

- Wastes from industrial activities and typically rubbish, ashes, demolition & construction waste, special waste, hazardous waste

Hazardous waste

- Waste that pose danger immediately or over a period of time to human, plant, animal life are classified as hazardous waste.
- Principle source- hospital waste & biological research
- Characteristics
 - Ignitability
 - Reactivity
 - Corrosivity
 - Toxicity
 - Flammability

USEPA has established four characteristic tests to determine whether a waste is hazardous or not.

Ignitability

- Wastes that pose a fire hazard during routine handling, storage, processing, transport, or disposal
- Examples – paint thinners and paint removing compounds, solvents used for cleaning parts and degreasing

Flammability

- Vapours of volatile organic compounds can ignite in the presence of a spark

Corrosivity

- Corrosive wastes occur at extreme pH
- $pH \leq 2.5, pH \geq 12.5$
- Liquid corrodes steel at a rate greater than 6.35 mm per year and at a temperature of 55°C
- Examples – battery acid, phenol wastes, acidic wastes from metal plating industries

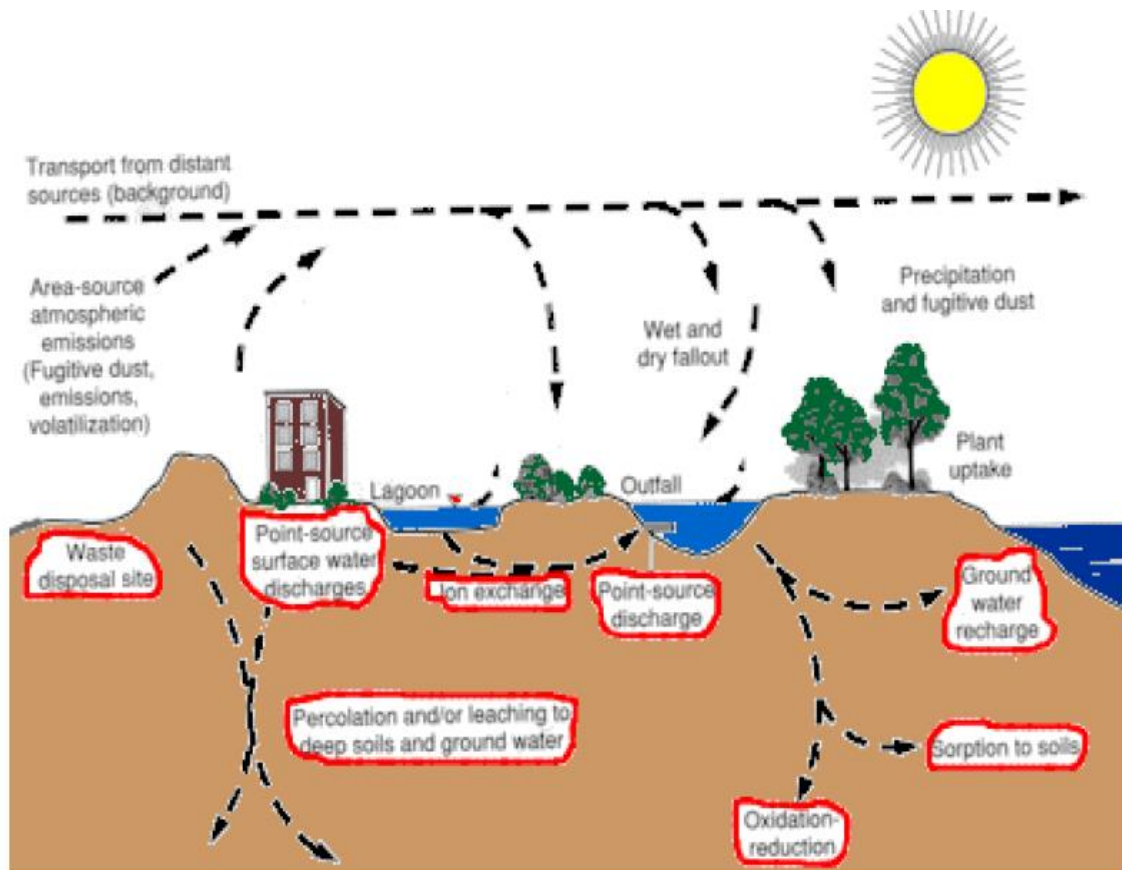
Reactivity

- Unstable waste
- Reacts violently with water
- When mixed with water, generates toxic gases/ vapours/ fumes
- Cyanide or sulphide bearing wastes
- Can pose sufficient danger to human health or environment

Toxicity

- Intent of test is to determine whether **toxic components** of waste could leach to groundwater and soil if exposed to acidic precipitation
- Examples – paint waste containing metals (Pb, Ag, Cd, Cr), mercury waste, oily wastes and sludge from petroleum industry, waste containing tetrachloroethylene

Properties of hazardous waste



Partitioning (movement) of hazardous waste from source to:

- Air (volatilization)
- Water (solubility)
- Soil (sorption)
- Biota (bioconcentration)

Source: www.geology.isu.edu

Health impact of hazardous waste

- A hazardous waste can have adverse health effects in any of the following scenarios:
- A large amount is released at once
- A small amount if released intermittently in the same location
- The substance does not get diluted
- The substance is very toxic
- Humans, plants and animals can come into contact with hazardous waste by either inhalation, ingestion, or dermal exposure.

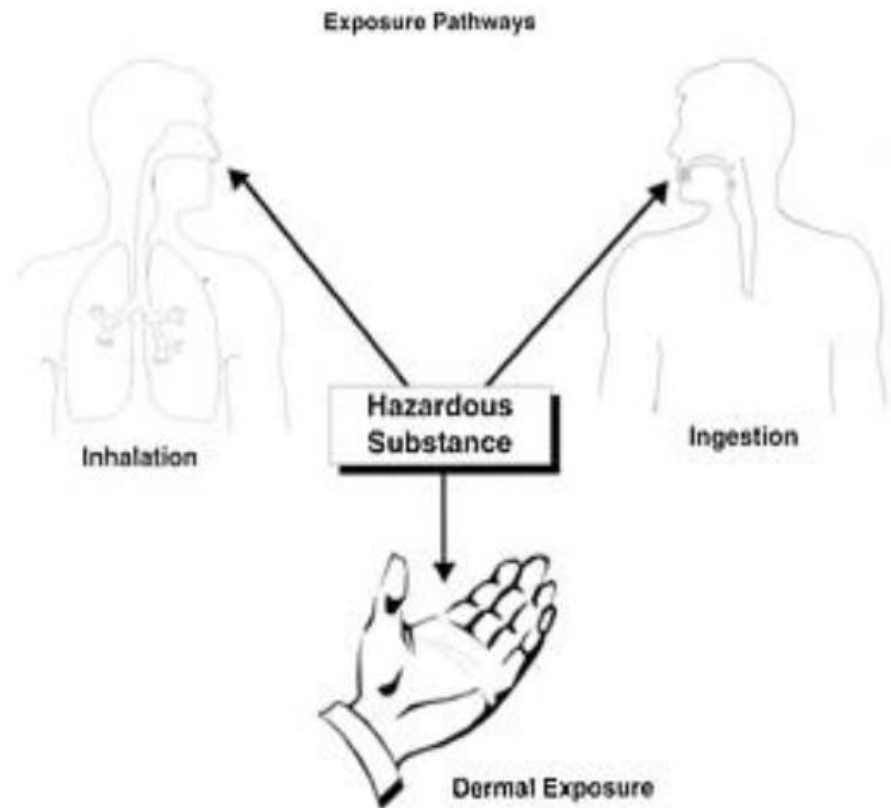
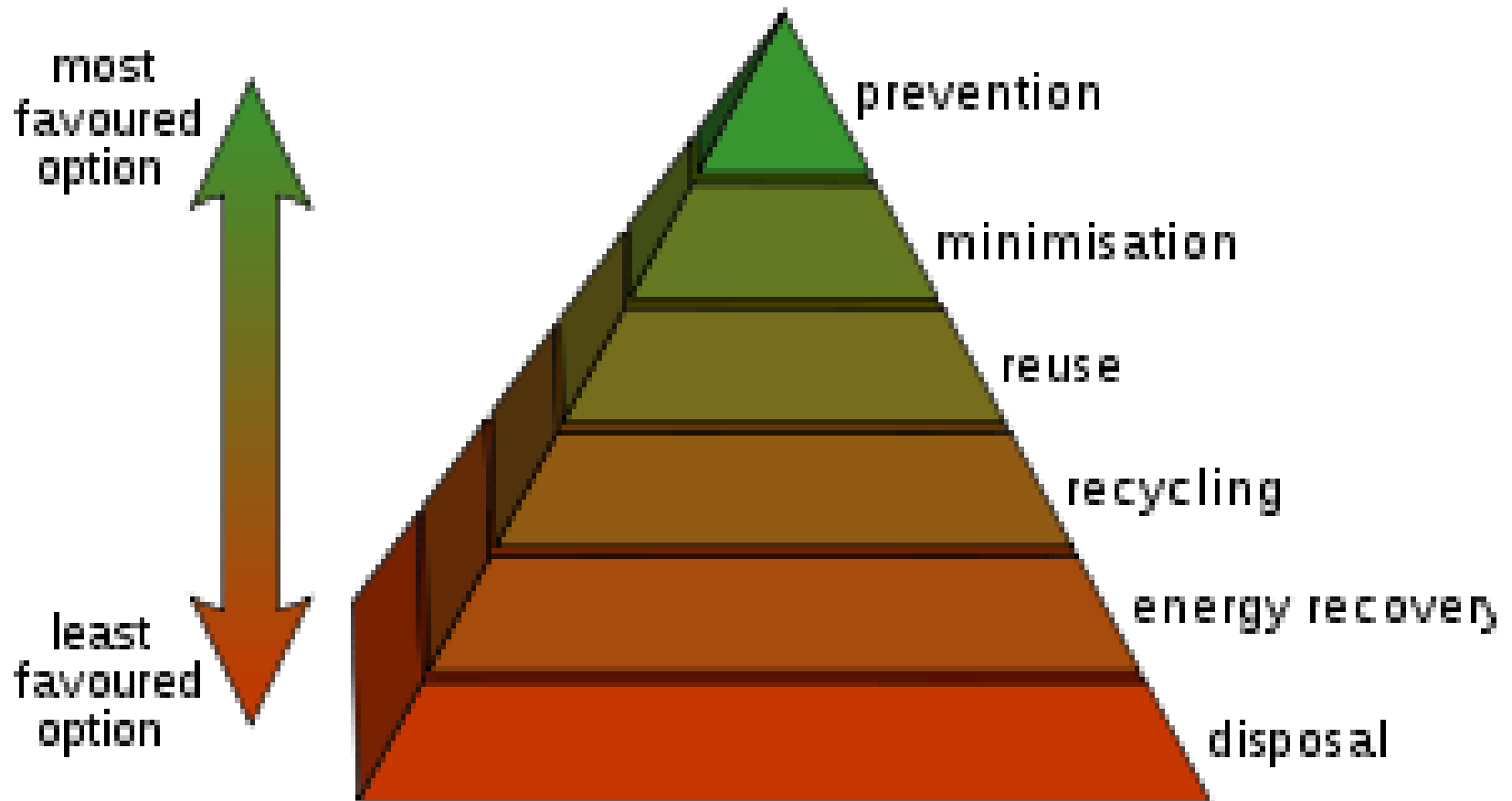


Fig. 14: Exposure pathways

Source: www.epa.gov Superfund for Students

Waste hierarchy

Waste hierarchy refers to 3 Rs
Reduce, Reuse, Recycle



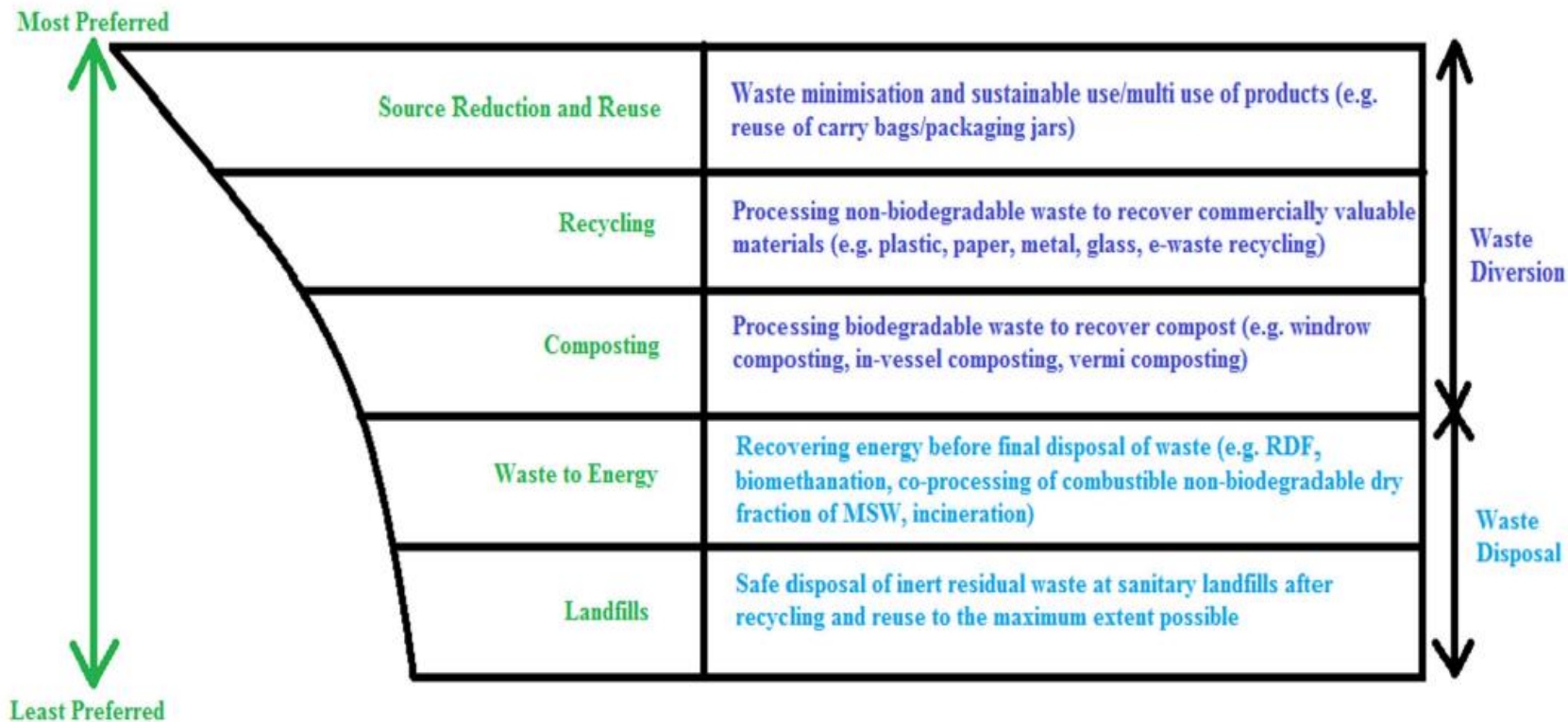


Fig. 3. Integrated solid waste management hierarchy. (Data from Agarwal et al. 2016; Chien Bong et al. 2017; CPHEEO 2016b; ERC 2015; McAllister 2015; Rathore et al. 2010.)

Waste

- Minimizing solid waste

- Minimizing packaging

- Recycleable

Paper, plastics, metals, glass, wood

- Reusable ?

Textiles, leather, rubber, metals, wood

- Compostable

Yard trimmings, food scraps (vegetable)

