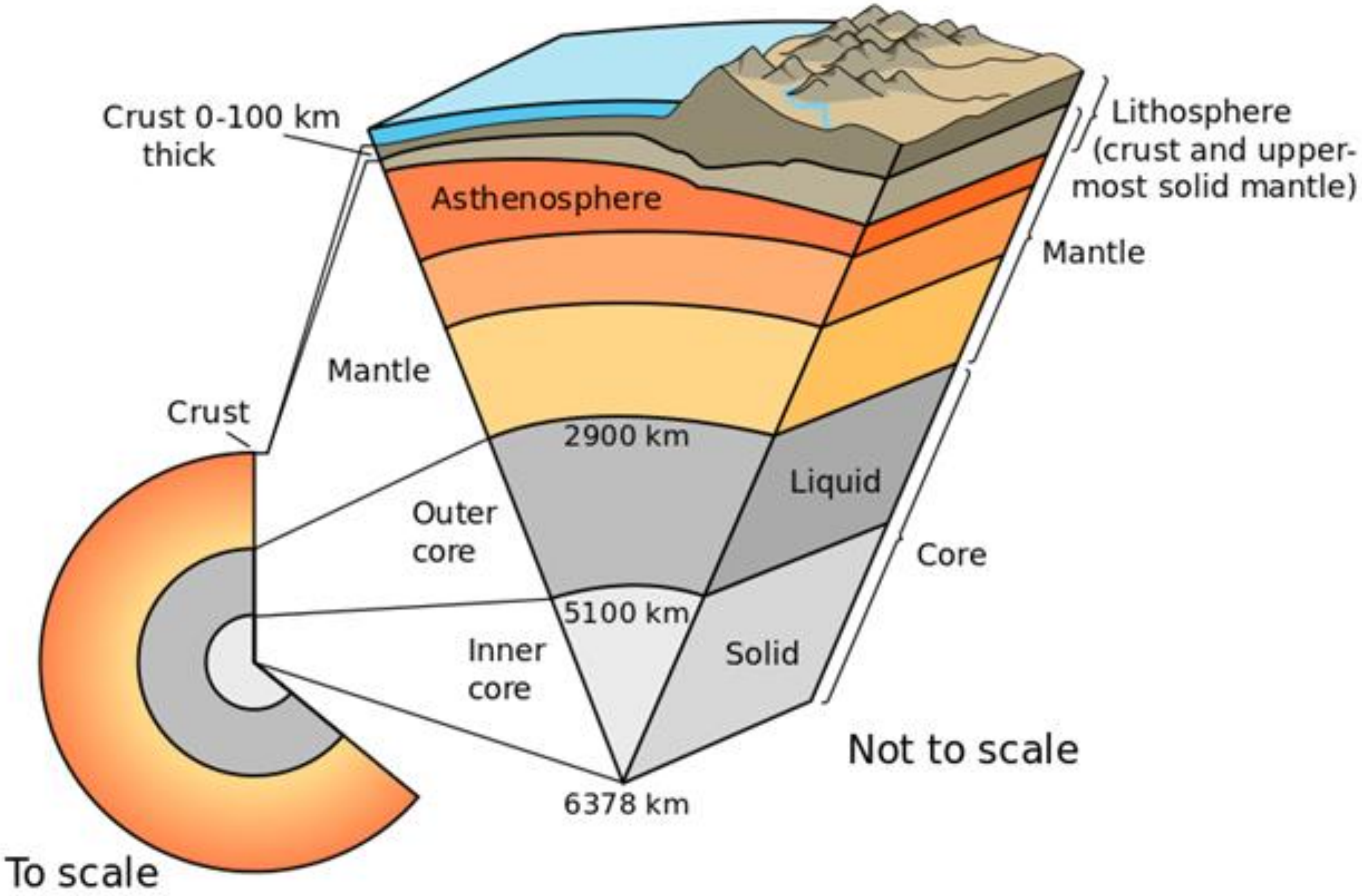
Module 4

- SOIL POLLUTION AND SOLID WASTE MANAGEMENT

Lithosphere



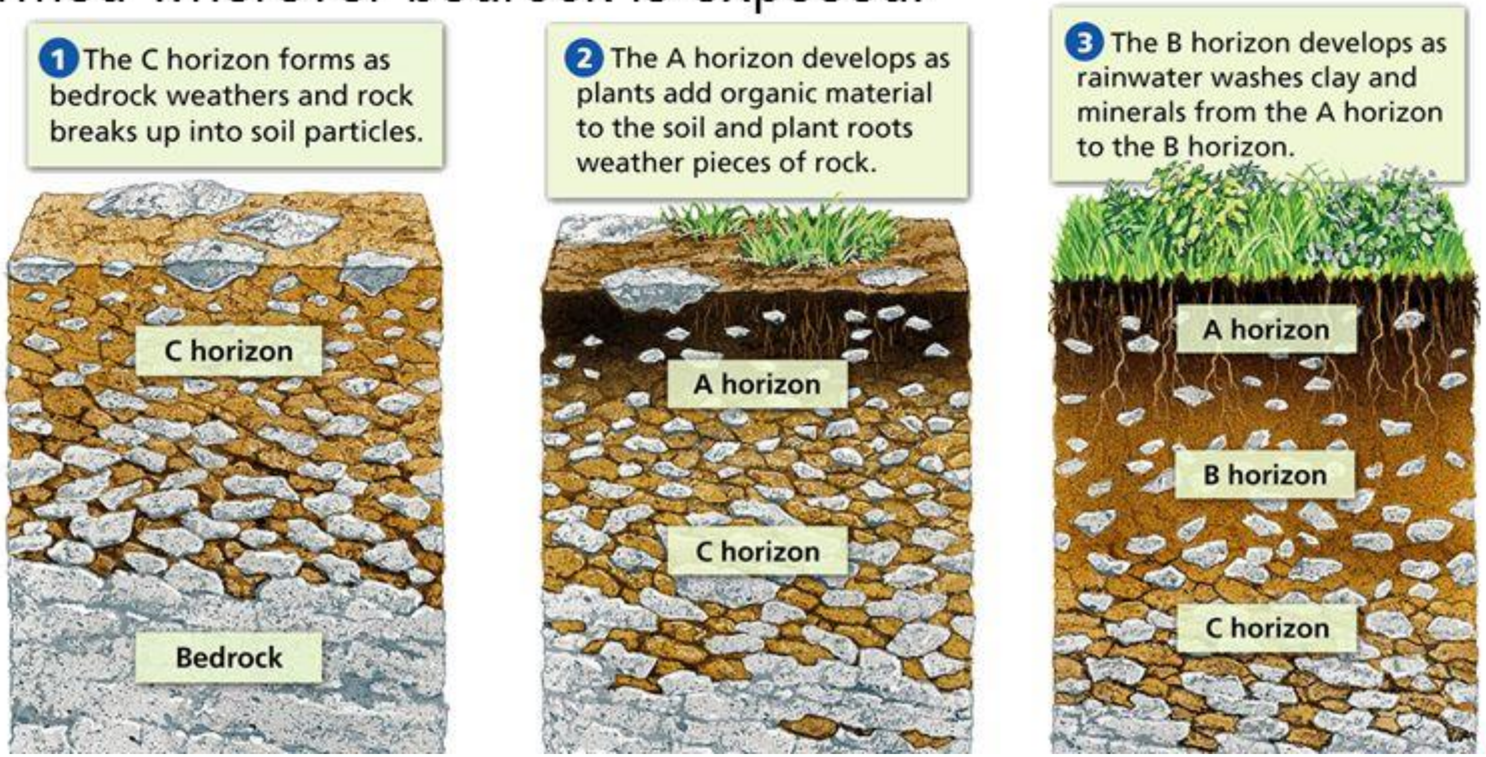
Soil Properties

Soil is the mixture of minerals, organic matter, gases, liquids, and the countless organisms that together support life on Earth.

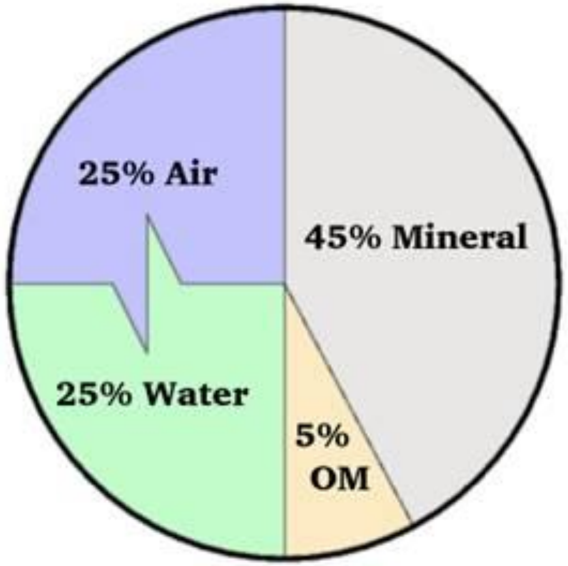
Weathering and Soil Formation - How Soil Forms

The Process of Soil Formation

Soil forms as rock is broken down by weathering and mixes with other materials on the surface. Soil is constantly being formed wherever bedrock is exposed.



Components of Soil



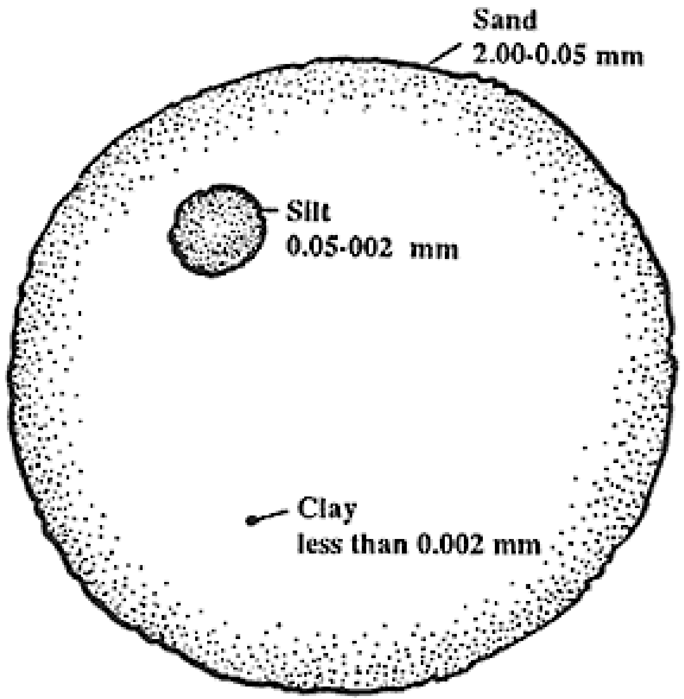
- **The basic components of soil are minerals, organic matter, water and air. The typical soil consists of approximately**
- **45% mineral,**
- **5% organic matter,**
- **20-30% water, and**
- **20-30% air.**
- soil minerals and organic matter hold and store nutrients,
- soil water is what readily provides nutrients for plant uptake.
- Soil air, supports microorganisms that live in the soil need air to undergo the biological processes that release additional nutrients into the soil.

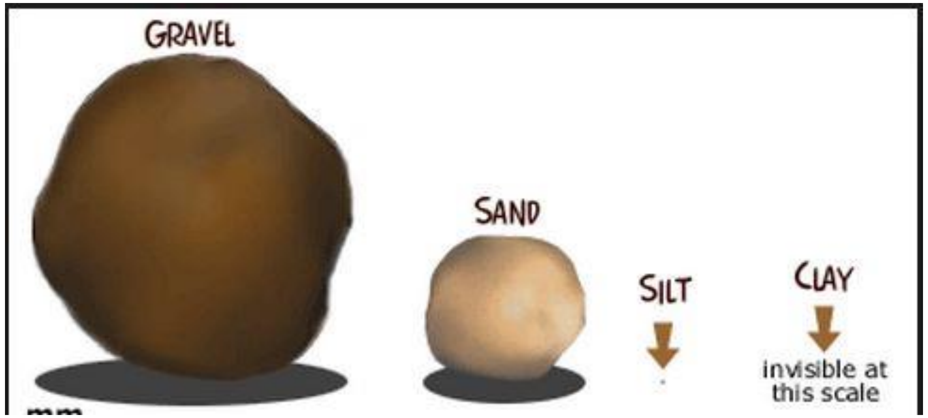
Soil Minerals

- Soil minerals play a vital role in soil fertility and these minerals vary greatly in size and chemical composition.
- **FINE EARTH FRACTION**
- The fine earth fraction includes any particle less than 2.0 mm (.078 inches) and is divided into three classes of size: sand, silt, or clay.
- **COARSE FRACTION**
- The coarse fraction of soil includes any soil particles greater than 2mm. The coarse fraction includes boulders, stones, gravels, and coarse sands. These are rocky fragments and are generally a combination of more than one type of mineral.

The Fine Earth Fraction

	Size	Texture	Characteristics
Sand	2.0 mm -0.05 mm	gritty	Sand is visible to eyes normally, consists of particles with low surface area, and permits excessive drainage.
Silt	0.05 mm - 0.002 mm	buttery	Silt is not visible to eyes normally and increases the water holding capacity of soil.
Clay	< 0.002 mm	sticky	Clay has a high surface area, high water holding capacity, many small pores, and possesses charged surfaces to attract and hold nutrients.





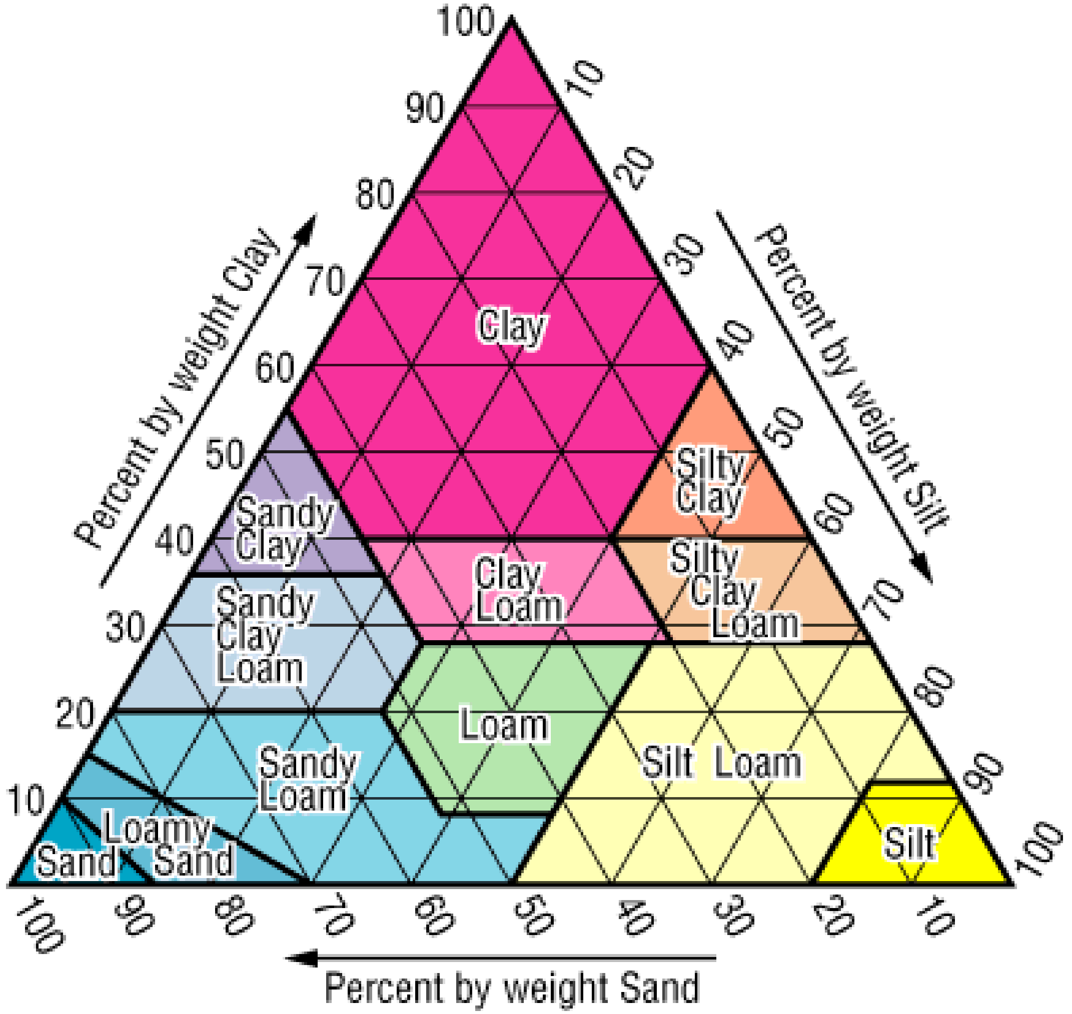
Texture

Soil texture refers to the weight proportion (relative proportion by weight percentage of sand, silt, and clay) of the mineral **soil** separates for particles less than two millimeters (mm) as determined from a laboratory particle-size distribution.

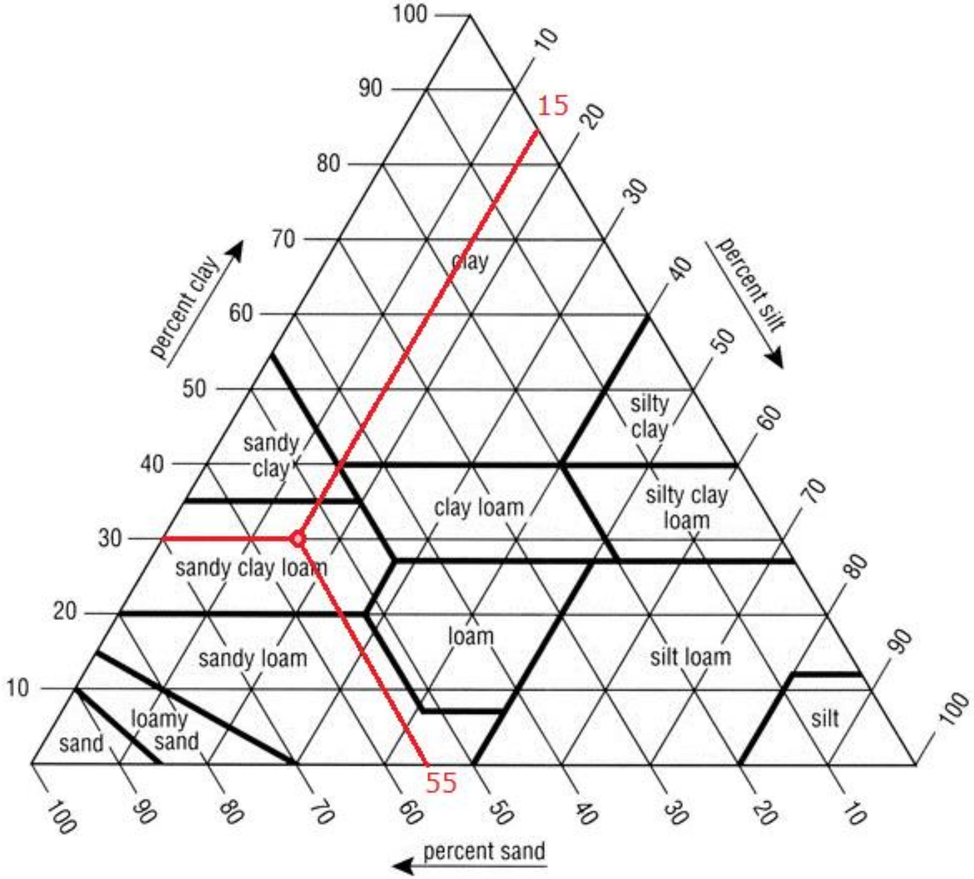
Soil texture is an **important soil** characteristic that influences storm water infiltration rates. The textural class of a **soil** is determined by the percentage of sand, silt, and clay. **Soils** can be classified as one of four major textural classes: (1) sands; (2) silts; (3) loams; and (4) clays.

Textural Triangle.

The **soil textural** class is a grouping of **soils** based upon these relative proportions. **Soils** with the finest **texture** are called clay **soils**, while **soils** with the coarsest **texture** are called sands.



Example: Classify a soil sample that is 30% clay, 15% silt, and 55% sand. First locate 30% on the clay axis, and draw a line horizontally from left to right. Next, locate 15% on the silt axis, and draw a line going down diagonally to the left. Finally, locate 55% on the sand axis, and draw a line going up diagonally to the left. The intersection is in a region called Sandy Clay Loam.



Soil Minerals and Mineral Composition

Typical soil parent mineral materials are:

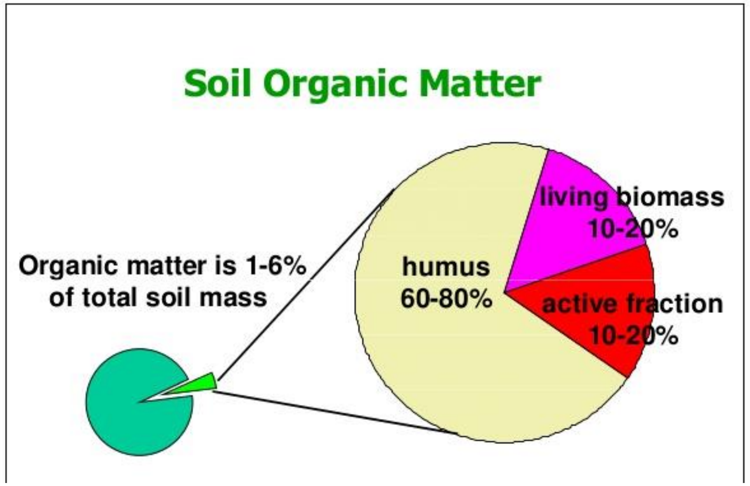
- Quartz: SiO_2,
- Calcite: $CaCO_3$,
- Feldspar: $KAlSi_3O_8$,
- Mica (biotite): $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$

Important Minerals and Weathered Materials of Basalt Rock

Primary Minerals of Basalt Rock	•Plagioclase Feldspar •Olivine •Augite Others: magnetite, apatite, ilmenite
Secondary Minerals	•Smectite, such as montmorillonite (less weathered) •Kaolin, such as halloysite (more weathered)
Iron Oxides	•Hematite •Goethite •Magnetite •Maghemite •Lepidocrosite •Ferrihydride
Aluminum Oxide	•Gibbsite
Amorphous Minerals	•Allophane •Imogolite

Soil Organic Matter

- Soil organic matter includes all organic (or carbon-containing) substances within the soil.
- Soil organic matter includes:
  - Living organisms (soil biomass)
  - The remains of microorganisms that once inhabited the soil
  - The remains of plants and animals
  - Organic compounds that have been decomposed within the soil and, over thousands of years, reduced to complex and relatively stable substances commonly called humus.

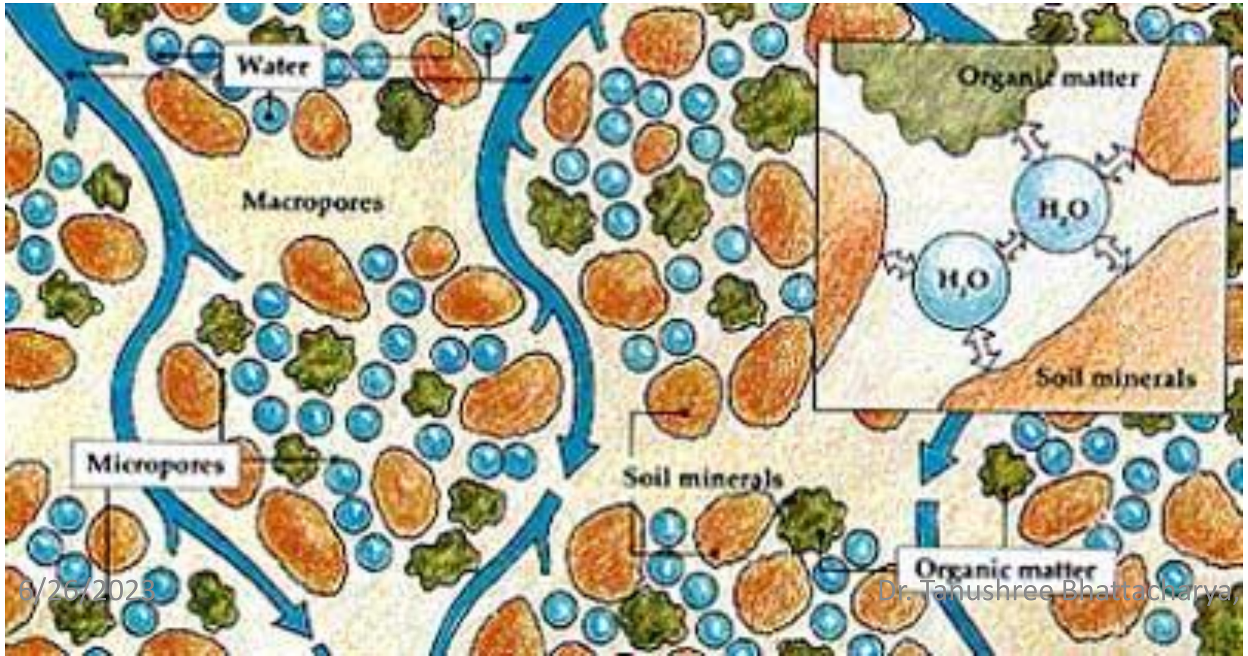


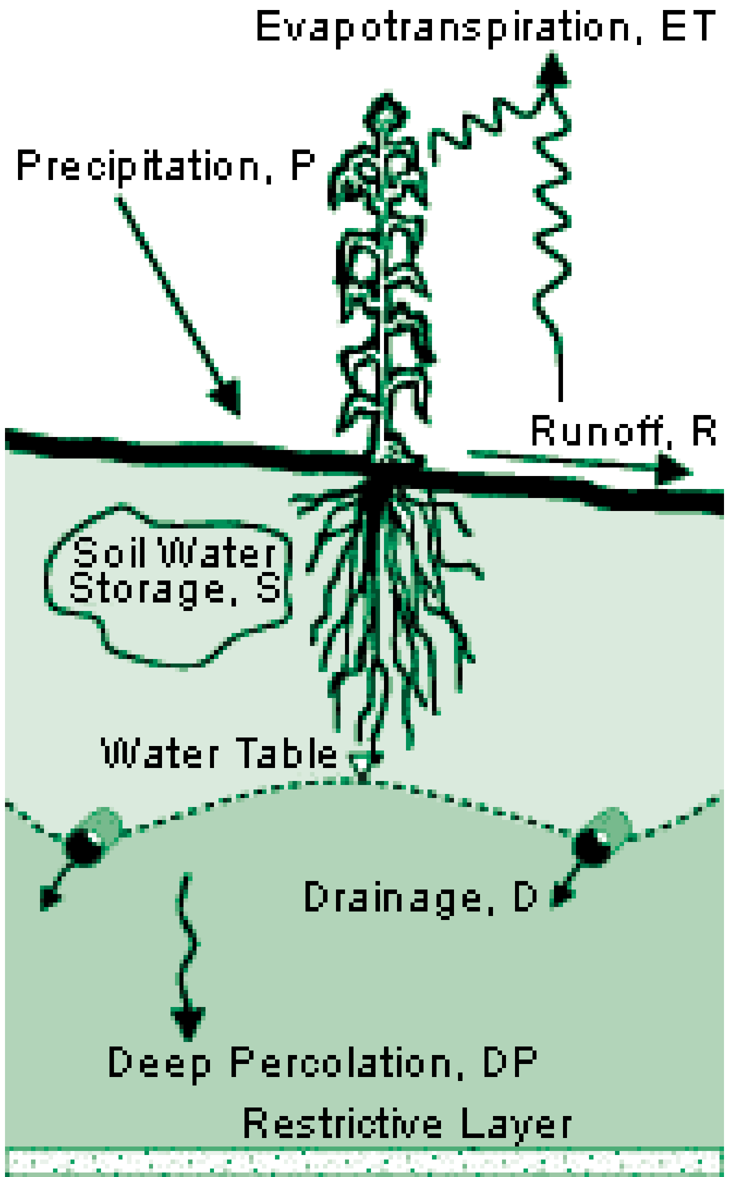
Important Functions of Organic Matter

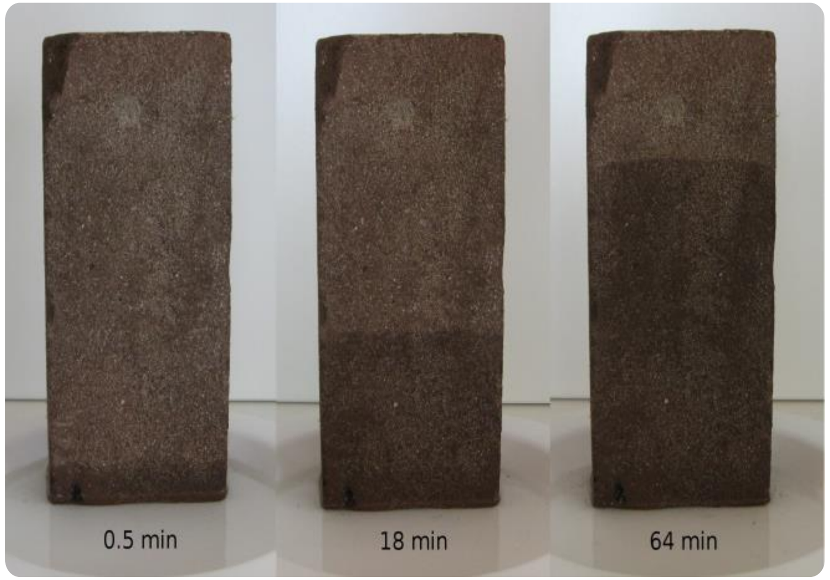
- Acts as a binding agent for mineral particles.
  - This is responsible for producing friable (easily crumbled) surface soils.
- Increases the amount of water that a soil may hold.
- Provides food for organisms that inhabit the soil.
- Humus is an integral component of organic matter because it is fairly stable and resistant to further decomposition.
  - Humus is brown or black and gives soils its dark color.
  - Like clay particles, humus is an important source of plant nutrients.

Soil water and its importance

- The presence of water is essential for plants and organisms in the soil.
- Water is necessary for the weathering of soil.
- Soil water is the medium from which all plant nutrients are assimilated by plants. Soil water contains dissolved organic and inorganic substances and transports dissolved nutrients, such as nitrogen, phosphorus, potassium, and calcium, to the plant roots for absorption.







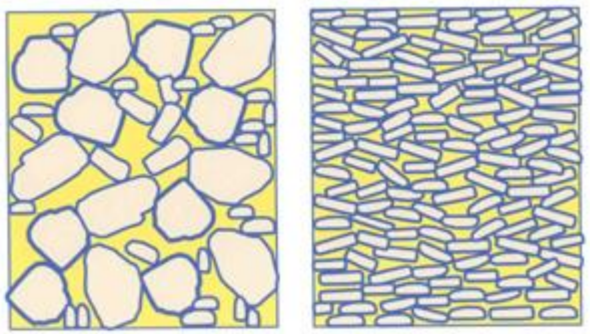
Soil water holding capacity

- Water molecules behave in two ways:
  - Cohesion Force: Because of cohesion forces, water molecules are attracted to one another.
  - Adhesion Force: This force is responsible for the attraction between water and solid surfaces.
- Water also exhibits a property of surface tension:
  - water surfaces behave like expandable films. This phenomenon is what makes it possible for certain insects to walk along water surfaces.
- Capillary Action:
  - Capillary action, also referred to as capillary motion or capillarity, is a combination of cohesion/adhesion and surface tension forces.

Pore Space

Pore space is a function of soil texture, structure and the activity of beneficial soil organisms. Water coats the solid particles and fills the smaller pore spaces. Air fills the larger pore spaces.

Comparative pore space.



Left soil with large pore space. Right soil lacking large pore space.

The quantities of large and small pore spaces directly affect plant growth. On fine-texture, clayey and/or compacted soils, a lack of large pore spaces restricts water and air infiltration and movement, thus limiting root growth and the activity of beneficial soil organisms. On sandy soils, the lack of small pore space limits the soil's ability to hold water and nutrients.

Soil Air

Soil aeration influences the availability of many nutrients.

•Since plant roots require water and oxygen (from the air in pore spaces), maintaining the balance between root and aeration and soil water availability is a critical aspect of managing crop plants.

- ❖ The oxygen is critical because it allows for respiration of both plant roots and soil organisms.
- ❖ Other natural soil gases are atmospheric methane and radon.
- ❖ Some environmental contaminants below ground produce gas which diffuses through the soil such as from landfill wastes, mining activities, and contamination by petroleum hydrocarbons which produce volatile organic compounds.

Component	Soil air (%)	Atmosphere (%)
N_2	79.2	79.0
O_2	20.6	20.9
CO_2	0.25	0.03

Source: Russel, E. J., and Appleyard, A. 1915. The atmosphere of the soil, its composition and causes of variation. *J. Agr. Sci.* 7:1–48.

Element	Symbol	mg/kg	percent
Nitrogen	N	15,000	1.5
Potassium	K	10,000	1.0
Calcium	Ca	5,000	0.5
Magnesium	Mg	2,000	0.2
Phosphorus	P	2,000	0.2
Sulfur	S	1,000	0.1
Chlorine	Cl	100	--
Iron	Fe	100	--
Boron	B	20	--
Manganese	Mn	50	--
Zinc	Zn	20	--
Copper	Cu	6	--
Molybdenum	Mo	0.1	--
Nickel	Ni	0.1	--

Soil Micro and macronutrients

Macronutrients: **N**, **K**, **Ca**, **Mg**, **P**, and **S**, and Micronutrients: **Cl**, **Fe**, **B**, **Mn**, **Zn**, **Cu**, **Mo**, and **Ni**

Industrial Sources of Chemical contamination

- Pesticide manufacturing industries include chemicals used as insecticides, herbicides, fungicides, rodent poisons and some other kinds of poisons.
- Sewage biosolids/sludge and fly ash, may result in the addition of heavy metals and PBTs (persistent, bioaccumulative, toxic chemicals) to soils.
- Products made from cement kiln dust may also contain heavy metals and dioxins.
- Phosphate fertilizers are known to contain some cadmium (from the rock phosphate), and manures are sometimes relatively high in copper or zinc.
- Lead Paint and High Traffic Areas
- Petroleum spills: can result in elevated levels of contaminants such as benzene, toluene, and xylene in the soil.
- Treated Lumber: Arsenic, in the form of chromated copper arsenate or CCA, has been used in wood preservatives to make pressure-treated lumber

- Furniture Refinishing: Some chemical strippers used in furniture refinishing contain methylene chloride and other solvents, including toluene and methanol.
- Landfi lls / Garbage Dumps:
- Fires: The intentional or accidental burning of materials can produce and release PAHs, dioxins or other chemicals into soils
- Automobile or Machine Repair: Many possible contaminants could be associated with these activities, including petroleum products, PAHs (particularly from motor oil), solvents like trichloroethylene (TCE), used tyres and rubber products, metals (used engine oil may contain chromium, lead, molybdenum, or nickel from engine wear), or used batteries (which may release lead or mercury)

Distribution of Soil contaminants

- Some organic (carbon-based) contaminants can undergo chemical changes or degrade into products that may be more or less toxic than the original compound.
- chemical elements (such as metals) cannot break down, but their characteristics may change so that they can be more or less easily taken up by plants or animals.
- Different contaminants vary in their tendency to:
  - End up in water held in the soil or in the underlying groundwater (by leaching through the soil);
  - Volatilize (evaporate) into the air; or (eg: alpha benzo pyrene $C_{20}H_{12}$)
  - Bind tightly to the soil.

Factors affecting distribution of contaminants in soil

- ♦ Soil mineralogy and clay content (soil texture);
- ♦ pH (acidity) of the soil;
- ♦ Amount of organic matter in the soil;
- ♦ Moisture levels;
- ♦ Presence of other chemicals.

Fate of nutrients in soil

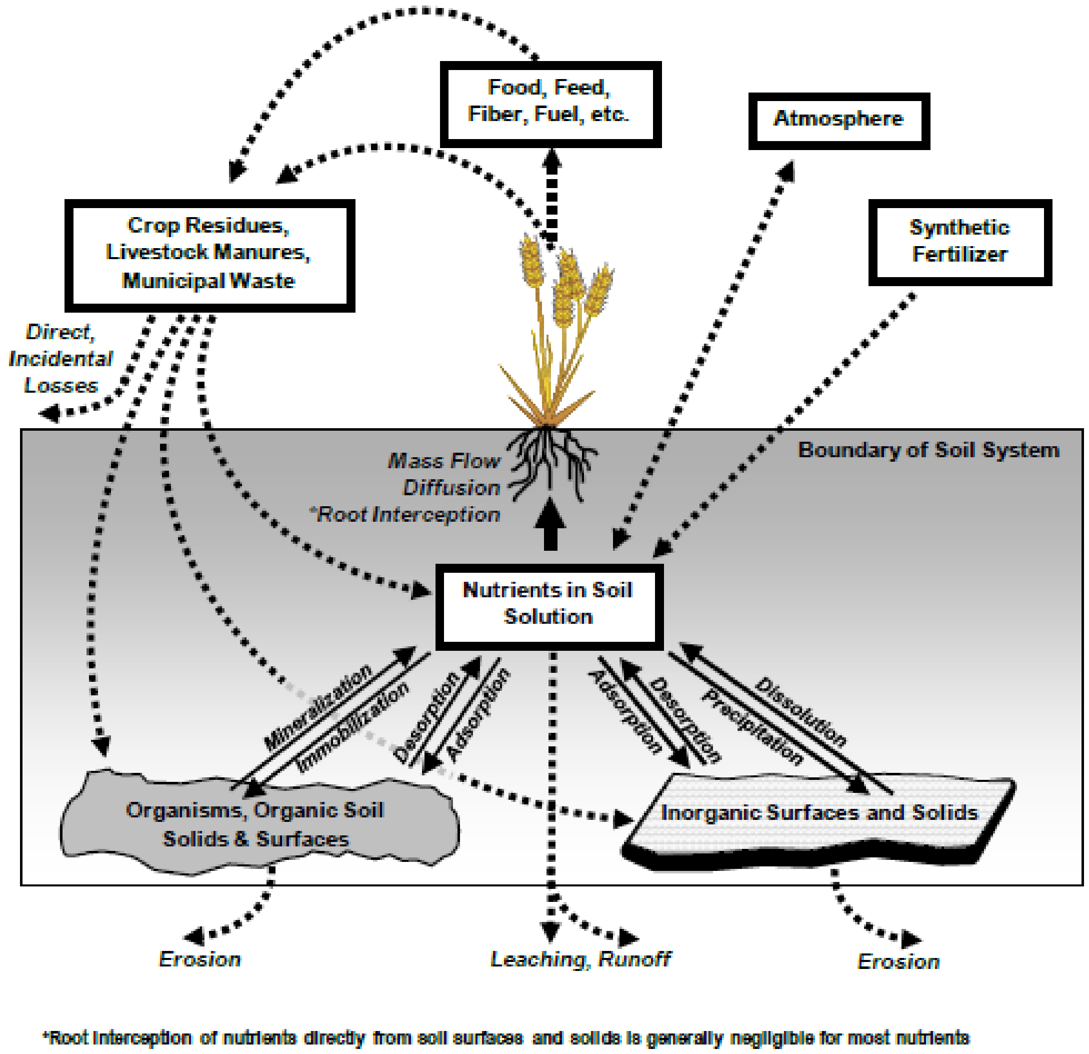
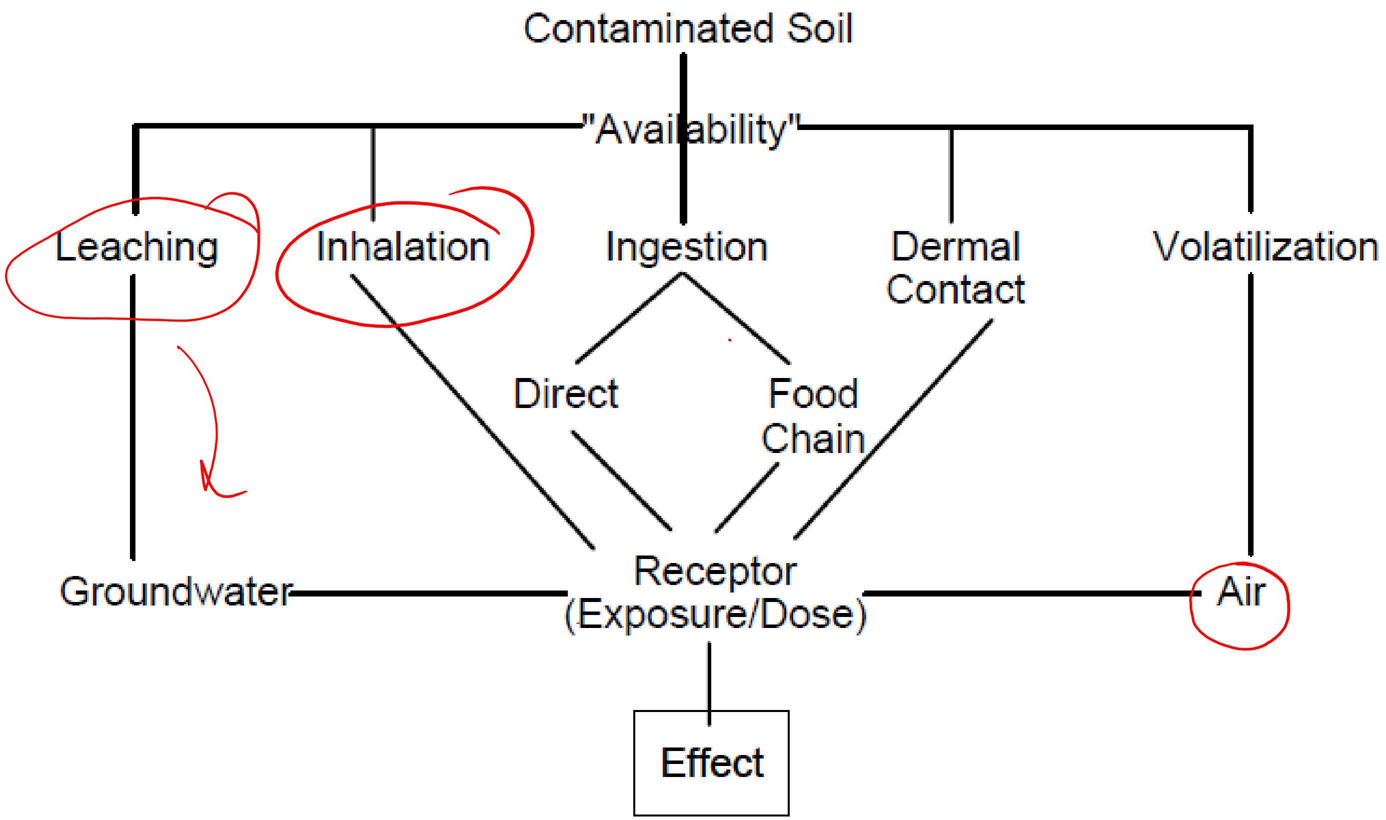


Figure 2 | The nutrient cycle. Dashed lines represent nutrient gains or losses in the soil system; solid lines represent internal transformations within the soil system.

Ecological effects of Soil contamination

- Elevated levels of soil contaminants can negatively affect plant vigor, animal health, microbial processes, and overall soil health.
- Some contaminants may change plants' metabolic processes and reduce yields or cause visible damage to crops.
- Even relatively low concentrations of certain contaminants can alter soil chemistry and impact organisms that depend on the soil or plants for their nutrition and habitat.
- ***For example, legume plants are able to fix nitrogen in the soil through a symbiotic relationship with Rhizobium bacteria in their root nodules. However, these bacteria are sensitive to zinc contamination, which can disrupt the nitrogen fixation process.***

Importance of availability in determination of risk



Exposure Routes for Human Health

Various routes of exposure by which a soil-bound chemical can meet a receptor. These exposure routes include:

Diseases Caused Due To Soil Pollution

Malaria
If water is contaminated by polluted soil or vice versa, then sludge is formed. The protozoa in the sludge causes malaria. How? Mosquitoes breed in stagnant water, act as carriers of these protozoan germs and infect humans, causing a widespread outbreak of malaria. This impact of polluted soil occurs in areas where rainfall is heavy and where sewage water gets mixed with the soil.

Cholera and Dysentery
When polluted soil seeps into ground water, it contaminates reservoirs of drinking water as well. So there an outbreak of water-borne diseases like cholera and dysentery.

Skin and Stomach Infections
Soil can enter the body if it collects in one's fingernails. Green leafy vegetables and underground vegetables (the main part of the plant grows below the soil) can have residue and particles of soil struck to them. If washed improperly (or not at all), the soil will enter the human body. Germs present in this ingested soil can cause amoebiosis or acute stomach infection.

- **Brain and Nerve Damage**
- Children can be exposed to the harmful effects of soil pollution in places like playgrounds and parks, where lead-contaminated soil has been proven to cause brain and neuromuscular development problems.
- **Soil pollution affects neuromuscular development in children.**
- **Cancer**

Most pesticides and fertilizers contain benzene, chromium and other chemicals, which are carcinogens (chemicals that cause cancer). Consumption of such contaminated crops decreases the production of red blood cells, white blood cells and antibodies in the blood, thus affecting the body's immunity.

Kidney and Liver Disease

When chemicals like mercury and cyclodienes are present in the soil, they enter a living being's body through food grown on such soil. These persistent pollutants can cause irreparable damage to the kidneys and liver

Control measures of soil pollution

- Soil erosion can be controlled by a variety of forestry and farm practices. Ex: Planting trees on barren slopes Contour cultivation and strip cropping may be practiced instead of shifting cultivation Terracing and building diversion channels may be undertaken. Reducing deforestation and substituting chemical manures by animal wastes also helps arrest soil erosion in the long term.
- Proper dumping of unwanted materials: Excess wastes by man and animals pose a disposal problem. Open dumping is the most commonly practiced technique. Nowadays, controlled tipping is followed for solid waste disposal. The surface so obtained is used for housing or sports field.
- Production of natural fertilizers: Bio-pesticides should be used in place of toxic chemical pesticides. Organic fertilizers should be used in place of synthesized chemical fertilizers. Ex: Organic wastes in animal dung may be used to prepare compost manure instead of throwing them wastefully and polluting the soil.
- Proper hygienic condition: People should be trained regarding sanitary habits. Ex: Lavatories should be equipped with quick and effective disposal methods.
- Public awareness: Informal and formal public awareness programs should be imparted to educate people on health hazards by environmental education. Ex: Mass media, Educational institutions and voluntary agencies can achieve this.
- Recycling and Reuse of wastes: To minimize soil pollution, the wastes such as paper, plastics, metals, glasses, organics, petroleum products and industrial effluents etc should be recycled and reused. Ex: Industrial wastes should be properly treated at source. Integrated waste treatment methods should be adopted.
- Ban on Toxic chemicals: Ban should be imposed on chemicals and pesticides like DDT, BHC, etc which are fatal to plants and animals. Nuclear explosions and improper disposal of radioactive wastes should be banned.

What are Wastes?

Waste (also known as **rubbish**, **trash**, **refuse**, **garbage**, **junk**, **litter**, and **ort**) is unwanted or useless materials. In biology, waste is any of the many unwanted substances or toxins that are expelled from living organisms, metabolic waste; such as urea and sweat.

Basel Convention Definition of Wastes (22nd March, 1989)

"substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of the law"

<u>Disposal means</u>

"any operation which may lead to resource recovery, recycling, reclamation, direct re-use or alternative uses (Annex IVB of the Basel convention)"

Kinds of Wastes

Solid wastes: wastes in solid forms, domestic, commercial and industrial wastes

- Examples: *plastics, Styrofoam containers, bottles, cans, papers, scrap iron, and other trash*

Liquid Wastes: wastes in liquid form

- Examples: *domestic washings, chemicals, oils, wastewater from ponds, manufacturing industries and other sources*

Classification of Wastes according to their Properties

Bio-degradable

can be degraded (paper, wood, fruits and others)

Non-biodegradable

cannot be degraded (plastics, bottles, old machines,cans, styrofoam containers and others)

Classification of Wastes according to their Effects on Human Health and the Environment

Hazardous wastes

Substances unsafe to use commercially, industrially, agriculturally, or economically and have any of the following properties- ignitability, corrosivity, reactivity & toxicity.

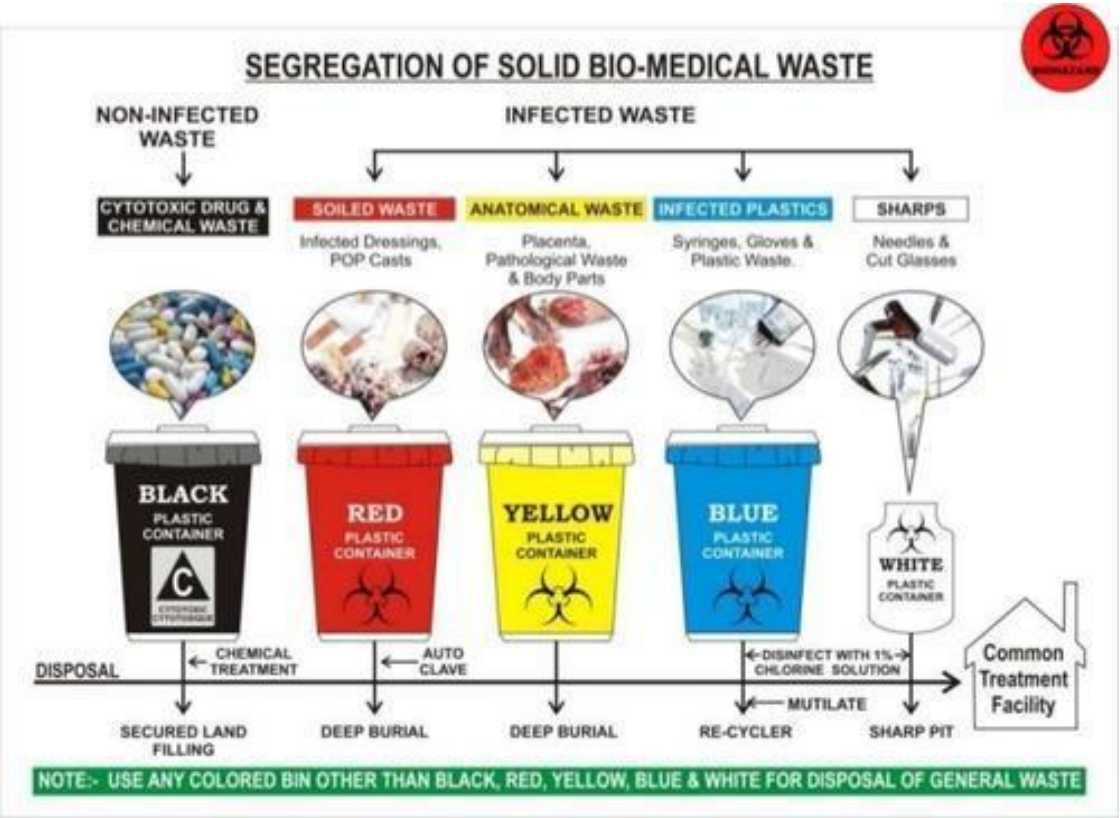
Non-hazardous

Substances safe to use commercially, industrially, agriculturally, or economically and do not have any of those properties mentioned above. These substances usually create disposal problems.

Classification of wastes according to their origin and type

- **Municipal Solid wastes:** Solid wastes that include household garbage, rubbish, construction & demolition debris, sanitation residues, packaging materials, trade refuges etc. are managed by any municipality.
- **Bio-medical wastes:** Solid or liquid wastes including containers, intermediate or end products generated during diagnosis, treatment & research activities of medical sciences.
- **Industrial wastes:** Liquid and solid wastes that are generated by manufacturing & processing units of various industries like chemical, petroleum, coal, metal gas, sanitary & paper etc.
- **Agricultural wastes:** Wastes generated from farming activities. These substances are mostly biodegradable.
- **Fishery wastes:** Wastes generated due to fishery activities. These are extensively found in coastal & estuarine areas.
- **Radioactive wastes:** Waste containing radioactive materials. Usually these are byproducts of nuclear processes. Sometimes industries that are not directly involved in nuclear activities, may also produce some radioactive wastes, e.g. radio-isotopes, chemical sludge etc.
- **E-wastes:** Electronic wastes generated from any modern establishments. They may be described as discarded electrical or electronic devices. Some electronic scrap components, such as CRTs, may contain contaminants such as Pb, Cd, Be or brominated flame retardants.

Biomedical waste



CATEGORIES OF BIO MEDICAL WASTE

OPTION	WASTE CATEGORY	TREATMENT & DISPOSAL
Category No. 1	Human Anatomical Waste	Incineration / deep burial
Category No. 2	Animal Waste	Incineration / deep burial
Category No. 3	Microbiology & Biotechnology Waste	Local autoclaving / microwaving / incineration
Category No. 4	Waste Sharps	Disinfection by chemical treatmet / atoclaving / microwaving and mutilation / shredding
Category No. 5	Discarded Medicines and Cytoxic drugs	Incineration / destruction and drugs disposal in secured landfills
Category No. 6	Solid Waste	Incineration / autoclaving / microwaving
Category No. 7	Solid Waste	Disinfection by chemical treatment / autoclaving / microwaving and mutilation / shredding
Category No. 8	Liquid Waste	Disinfection by chemical treatment and discharge into drains.
Category No. 9	Incineration Ash	Disposal in municipal landfill
Category No. 10	Chemical Waste	Chemical treatment and discharge into drains for liquids and secured land for solids

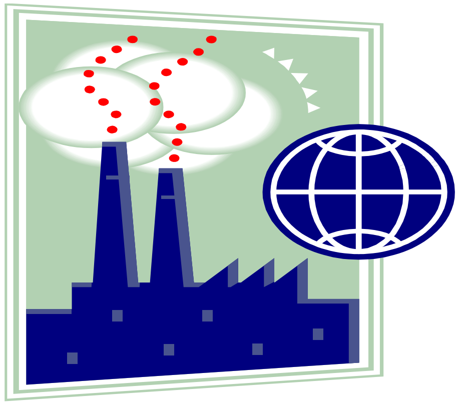
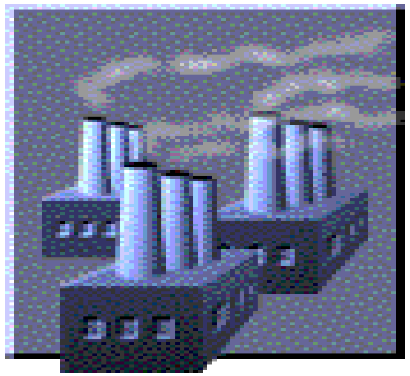
Source: Bio-medical Waste Management Rules, 1998, Schedule I.

Biomedical waste management

- Who deals with Bio-medical wastes in India?
- Central Pollution Control Board has been following up with all SPCBs/PCCs to ensure effective management of biomedical waste in States/UTs.
- Collection and disposal
- The collection and disposal is treated and disposed as per the specified methods of disposal prescribed under Schedule I of the Rules.
- Bio-medical waste generated from the hospitals shall be treated and disposed by Common Bio-medical Waste Treatment and Disposal Facility.
- In case there is no common facility in the reach of a healthcare facility, then such healthcare facility should install captive treatment and disposal facility.
- There are 200 authorized Common Bio-medical Waste Treatment and Disposal Facilities (CBWTFs) in 28 States for environmentally safe disposal of biomedical waste.
- Remaining 7 States namely Goa, Andaman Nicobar, Arunachal Pradesh, Lakshadweep, Mizoram, Nagaland and Sikkim do not have CBWTFs.
- Categorization
- As informed by CPCB and as per Bio-medical Waste Management Rules, 2016, Bio-medical waste is required to be segregated in 4 color coded waste categories.
- Common methods of treatment and disposal of bio-medical waste are by incineration/plasma pyrolysis/deep-burial for Yellow Category waste;
- Autoclaving/microwaving/chemical disinfection for Red Category waste;
- Sterilization and shredding, disinfection followed by burial in concrete pit/recycling through foundry/encapsulation for White Category sharps waste; and
- Washing, disinfection followed by recycling for Blue Category glass waste.

Sources of Wastes


Households

Commerce and Industry

MAGNITUDE OF PROBLEM: Indian scenario

- **Per capita waste generation increasing by 1.3% per annum**
- **With urban population increasing between 3 – 3.5% per annum**
- **Yearly increase in waste generation is around 5% annually**
- **India produces more than 42.0 million tons of municipal solid waste annually.**
- **Per capita generation of waste varies from 200 gm to 600 gm per capita / day. Average generation rate at 0.4 kg per capita per day in 0.1 million plus towns.**

MSW GENERATION FROM THE METROPOLITANS OF INDIA

State/Union Territory	City	Urban Population in Lakhs (2001)	MSW generated (MT/day)
Andhra Pradesh	Hyderabad	3829753	957
Andhra Pradesh	Visakhapatnam	982904	246
Bihar	Patna	1961532	588
Delhi	New Delhi	350000	272
Delhi	Delhi	13363471	6000
Gujarat	Ahmedabad	4215497	1265
Gujarat	Surat City	2433835	730
Gujarat	Vadodara	1491045	447
Karnataka	Bangalore	1304008	326
Kerala	Kochi	275225	69
Maharashtra	Mumbai	11914398	7500
Maharashtra	Nagpur	2040175	700
Maharashtra	Pune	2540000	1000
Madhya Pradesh	Bhopal	1482718	445
Madhya Pradesh	Indore	1550880	465
Punjab	Ludhiana	1429709	500
Rajasthan	Jaipur	1870771	561
Tamil Nadu	Chennai	4343645	1086
Tamil Nadu	Coimbatore	1501373	375
Tamil Nadu	Madurai	1233083	308
Uttar Pradesh	Kanpur	2725207	954
Uttar Pradesh	Lucknow	2262369	792
Uttar Pradesh	Varanasi	1250039	438
West Bengal	Kolkata	4572876	1143
Grand Total	-	70924513	27167

Solid Waste in India

- 7.2 million tonnes of hazardous waste
- One Sq km of additional landfill area every-year
- Rs 1600 crore for treatment & disposal of these wastes
- In addition to this industries discharge about 150 million tonnes of high volume low hazard waste every year, which is mostly dumped on open low lying land areas.

Growth of Solid Waste In India

- Waste is growing by leaps & bounds
- In 1981-91, population of Mumbai increased from 8.2 million to 12.3 million
- During the same period, municipal solid waste has grown from 3200 tonnes to 5355 tonne, an increase of 67%
- City like Bangalore produces 2000 tonnes of waste per annum.
- Waste collection is very low for all Indian cities.

IMPACTS OF WASTE IF NOT MANAGED WISELY

- Affects our health
- Affects our socio-economic conditions
- Affects our coastal and marine environment
- Affects our climate

- GHGs are accumulating in Earth's atmosphere as a result of human activities, causing global mean surface air temperature and subsurface ocean temperature to rise.

- Rising global temperatures are expected to raise sea levels and change precipitation and other local climate conditions.

- Changing regional climates could alter forests, crop yields, and water supplies.

- This could also affect human health, animals, and many types of ecosystems.

- Deserts might expand into existing rangelands, and features of some of our national parks might be permanently altered.

IMPACTS OF WASTE…

- **Some countries are expected to become warmer, although sulfates might limit warming in some areas.**

- **Scientists are unable to determine which parts of those countries will become wetter or drier, but there is likely to be an overall trend toward increased precipitation and evaporation, more intense rainstorms, and drier soils.**

- **Whether rainfall increases, or decreases cannot be reliably projected for specific areas.**

Impacts of waste….

- **Activities that have altered the chemical composition of the atmosphere:**

- **Buildup of GHGs primarily carbon dioxide (CO_2) methane (CH_4), and nitrous oxide (N_20).**

- **$C0_2$ is released to the atmosphere by the burning of fossil fuels, wood and wood products, and solid waste.**

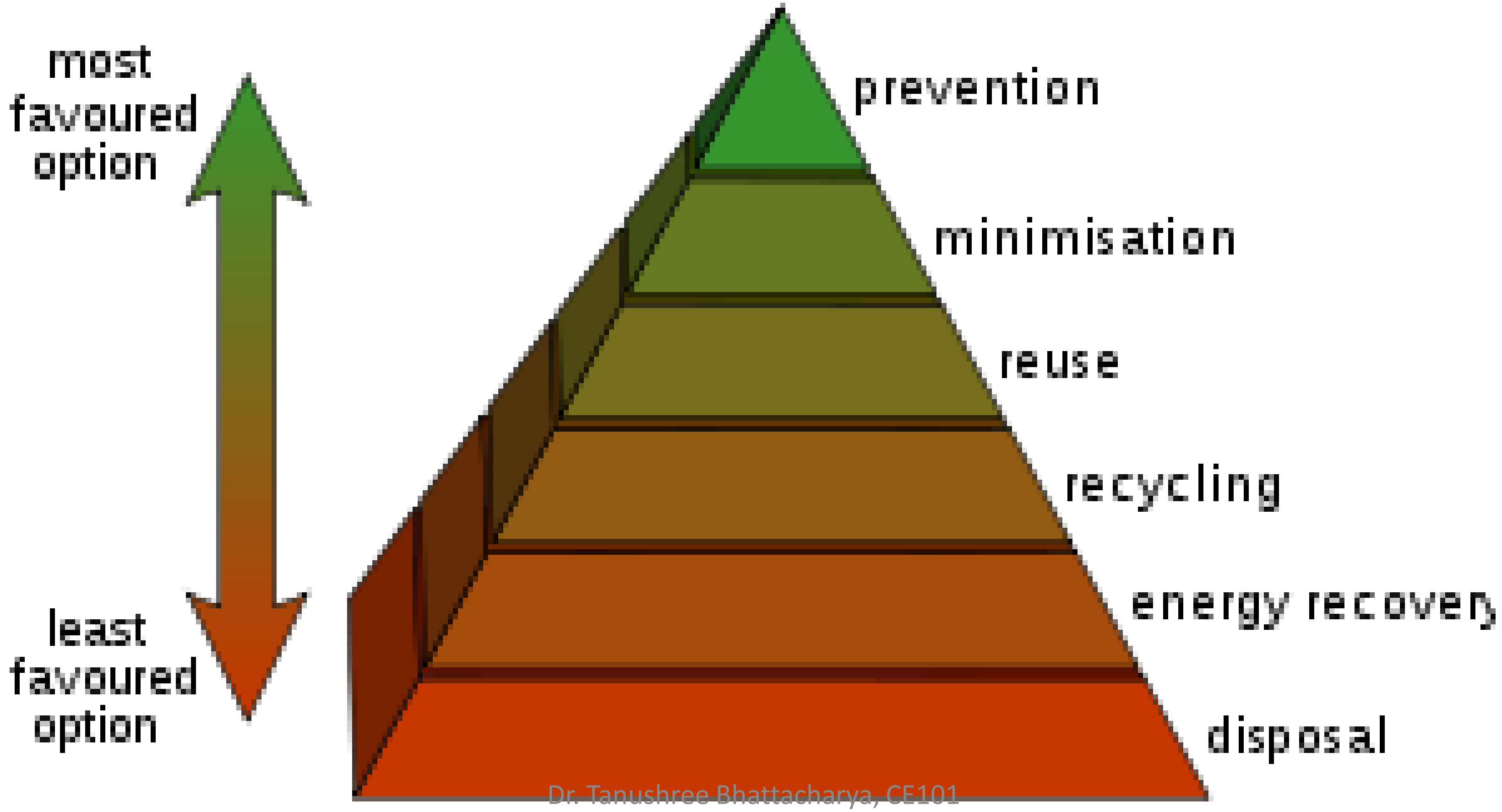
- **CH_4 is emitted from the decomposition of organic wastes in landfills, the raising of livestock, and the production and transport of coal, natural gas, and oil.**

- **$N0_2$ is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels. In 1977, the US emitted about one-fifth of total global GHGs.**

Waste hierarchy

Waste hierarchy refers to 3 Rs

Reduce, Reuse, Recycle



Useful options

- Resource recovery
- Composting
- Vermicomposting

- Energy recovery
- Incineration
- Pyrolysis
- Gasification
- Bio-methanation or anaerobic digestion

WASTE MANAGEMENT 3R CONCEPT

- The **waste hierarchy** refers to the 3 (or 4) R's of **reduce, reuse, recycle, (recovery)** which classify waste management strategies according to their desirability.
- The R's are meant to be a hierarchy, in order of importance. However in Europe the waste hierarchy has 5 steps: reduce, reuse, recycle, recovery, and disposal.
- **The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.**

Some waste management experts have recently incorporated a additional R: "Re-think", that effective system of waste management may need an entirely new way of looking at waste.

- *Source reduction* involves efforts to reduce hazardous waste and other materials by modifying industrial production.
- Source reduction methods involve changes in manufacturing technology, raw material inputs, and product formulation.
- At times, the term "pollution prevention" may refer to source reduction.

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REDUCE

Waste minimisation is the process and the policy of reducing the amount of waste produced by a person or a society.

Waste minimisation involves efforts to minimise resource and energy use during manufacture. For the same commercial output, usually the fewer materials are used, the less waste is produced.

Waste minimisation usually requires knowledge of the production process, cradle-to-grave (now *cradle-to-cradle*) analysis - the tracking of materials from their extraction to their return to earth (start a new cycle) and detailed knowledge of the composition of the waste.

The main sources of waste vary from country to country. In the UK, most waste comes from the construction and demolition of buildings, followed by mining, industry and commerce. Household waste constitutes a relatively small proportion of all waste.

In the waste hierarchy, the most effective approaches to managing waste are at the top. In contrast to waste minimisation, waste management focuses on processing waste after it is created, concentrating on re-use, recycling, and waste-to-energy conversion.

REDUCE

In industries, using more efficient manufacturing processes and better materials will generally reduce the production of waste. The application of waste minimisation techniques has led to the development of innovative and commercially successful replacement products. Waste minimisation has proven benefits to industry and the wider environment.

Waste minimisation often requires investment, which is usually compensated by the savings. However, waste reduction in one part of the production process may create waste production in another part.

There are government incentives for waste minimisation, which focus on the environmental benefits of adopting waste minimisation strategies.

REDUCE

RESOURCE OPTIMISATION - Minimising the amount of waste produced by organisations or individuals goes hand-in-hand with optimising their use of raw materials. For example, a dressmaker may arrange pattern pieces on a length of fabric in a particular way to enable the garment to be cut out from the smallest area of fabric.

REUSE OF SCRAPS MATERIAL - Scraps can be immediately re-incorporated at the beginning of the manufacturing line so that they do not become a waste product. Many industries routinely do this; for example, paper mills return any damaged rolls to the beginning of the production line, and in the manufacture of plastic items, off-cuts and scrap are re-incorporated into new products.

IMPROVED QUALITY CONTROL AND PROCESS MONITORING - Steps can be taken to ensure that the number of reject batches is kept to a minimum. This is achieved by increasing the frequency of inspection and the number of points of inspection. For example, installing automated continuous monitoring equipment can help to identify production problems at an early stage.

WASTE EXCHANGES - This is where the waste product of one process becomes the raw material for a second process. Waste exchanges represent another way of reducing waste disposal volumes for waste that cannot be eliminated.

SHIP TO POINT OF USE - This involves making deliveries of incoming raw materials or components direct to the point where they are assembled or used in the manufacturing process to minimise handling and the use of protective wrappings or enclosures.

REUSE

To reuse is to use an item more than once. This includes conventional reuse where the item is used again for the same function, and new-life reuse where it is used for a different function. In contrast, recycling is the breaking down of the used item into raw materials which are used to make new items.

By taking useful products and exchanging them, without reprocessing, reuse help save time, money, energy, and resources. In broader economic terms, reuse offers quality products to people and organizations with limited means, while generating jobs and business activity that contribute to the economy.

Historically, financial motivation was one of the main drivers of reuse. In the developing world this driver can lead to very high levels of reuse,

However rising wages and consequent consumer demand for the convenience of disposable products has made the reuse of low value items such as packaging uneconomic in richer countries, leading to the demise of many reuse programs.

Current environmental awareness is gradually changing attitudes and regulations, such as the new packaging regulations, are gradually beginning to reverse the situation.

One example of conventional reuse is the doorstep delivery of milk in refillable bottles; other examples include the retreading of tires and the use of returnable/reusable plastic boxes, shipping containers, instead of single-use corrugated (*rievots*) fiberboard boxes.

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An electric wire reel reused as a center table in a Rio de Janeiro fair

Tires, bottles and cans as building materials

RECYCLING


Publicity photo for US aluminium salvage campaign in 1942

Recycling and rubbish bin in a railway station, Germany

Early sorting of recyclable materials: glass and plastic bottles in Poland

Sign at Tamil Nandi, India

ENVIRONMENTAL EFFECTS OF RECYCLING

Material	Energy savings	Air pollution savings
Aluminium	95 %	95 %
Cardboard	24 %	—
Glass	5 - 30 %	20 %
Paper	40 %	73 %
Plastics	70 %	—
Steel	60 %	—

CATEGORIES OF WASTE DISPOSAL

1. **DILUTE AND DISPERSE**

(ATTENUATION)

→

Throw it in the river / lake / sea

Burn it

Basically this involves spreading trash thinly over a large area to minimize its impact

Works for sewage, some waste chemicals, when land-disposal is not available

[Plastic in Pacific]

2. CONCENTRATE AND CONTAIN

(ISOLATION)

→ Waste dumps, landfills

Historically, that's how most of the solid waste gets treated

Impacts of waste on health

- Chemical poisoning through chemical inhalation
- Uncollected waste can obstruct the storm water runoff resulting in flood
- Low birth weight
- Cancer
- Congenital malformations
- Neurological disease

Impacts of waste on health

- Nausea and vomiting
- Increase in hospitalization of diabetic residents living near hazard waste sites.
- Mercury toxicity from eating fish with high levels of mercury.

Effects of waste on animals and aquatics life

INCREASE IN MERCURY LEVEL IN FISH DUE TO DISPOSAL OF MERCURY IN THE RIVERS.

PLASTIC FOUND IN OCEANS INGESTED BY BIRDS.

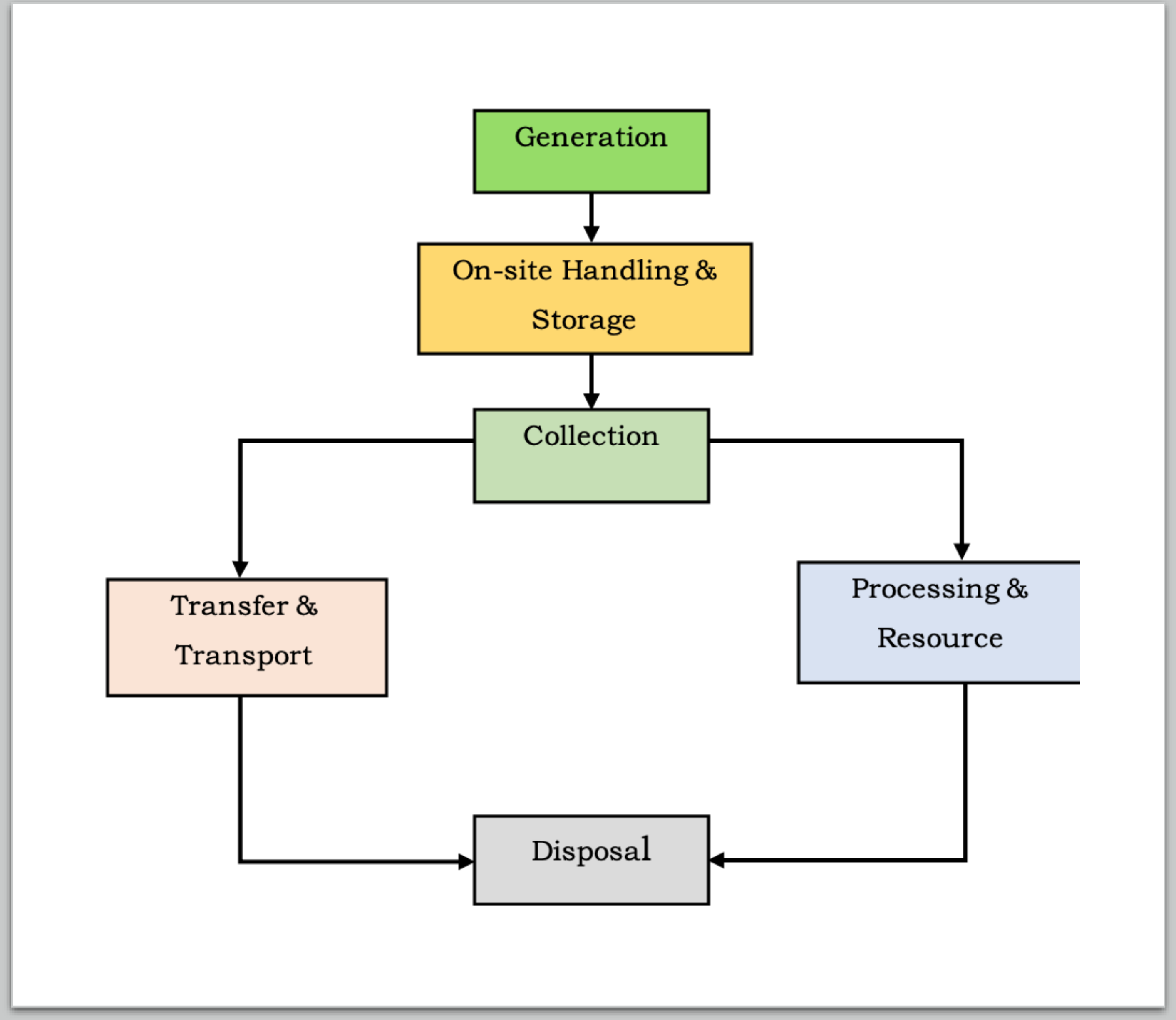
RESULTED IN HIGH ALGAL POPULATION IN RIVERS AND SEA.

DEGRADES WATER AND SOIL QUALITY.

Impacts of waste on Environment

- Waste breaks down in landfills to form methane, a potent greenhouse gas
- Change in climate and destruction of ozone layer due to waste biodegradable
- Littering, due to waste pollutions, illegal dumping, Leaching: is a process by which solid waste enter soil and ground water and contaminating them.

It is estimated that food wasted by the US and Europe could feed the world three times over. Food waste contributes to excess consumption of freshwater and fossil fuels which, along with methane and CO_2 emissions from decomposing food, impacts global climate change. Every tonne of food waste prevented has the potential to save 4.2 tonnes of CO_2 equivalent. If we all stop wasting food that could have been eaten, the CO_2 impact would be the equivalent of taking one in four cars off the road.



Functional elements of solid waste management

Waste collection

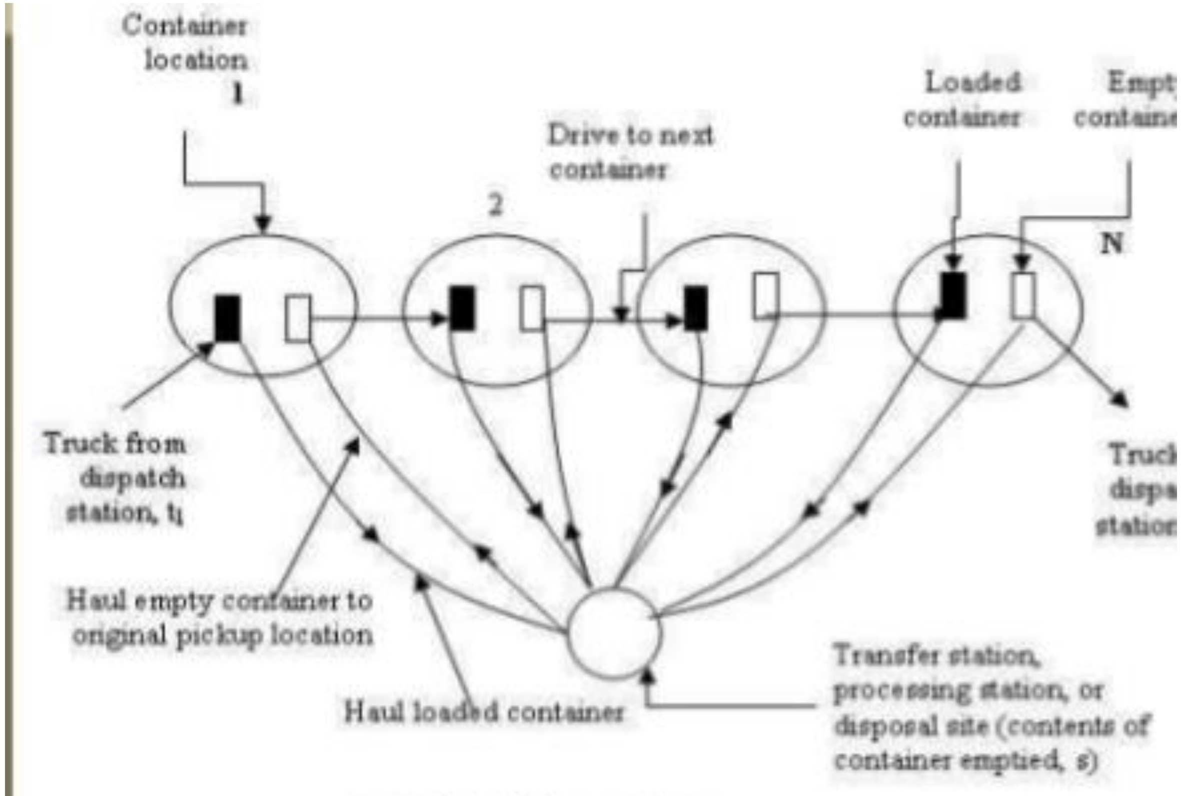
Types of Collection Systems

- Based on the mode of operation, collection systems are classified into two categories: **hauled-container systems and stationary-container systems.**

HCS

Hauled Container Systems

- **Collection system in which the containers used for the storage of waste are hauled to the processing, transfer, or disposal site, emptied, and returned to either their original location or some other location are defined as hauled-container system.**
- **There are two main types of container Tilt-frame Container, and Trash-Trailer.** The collector is responsible for driving the vehicles, loading full container and unloading empty containers, and emptying the contents of the container at the disposal site. In some cases, for safety reasons, both a driver and helper are used.

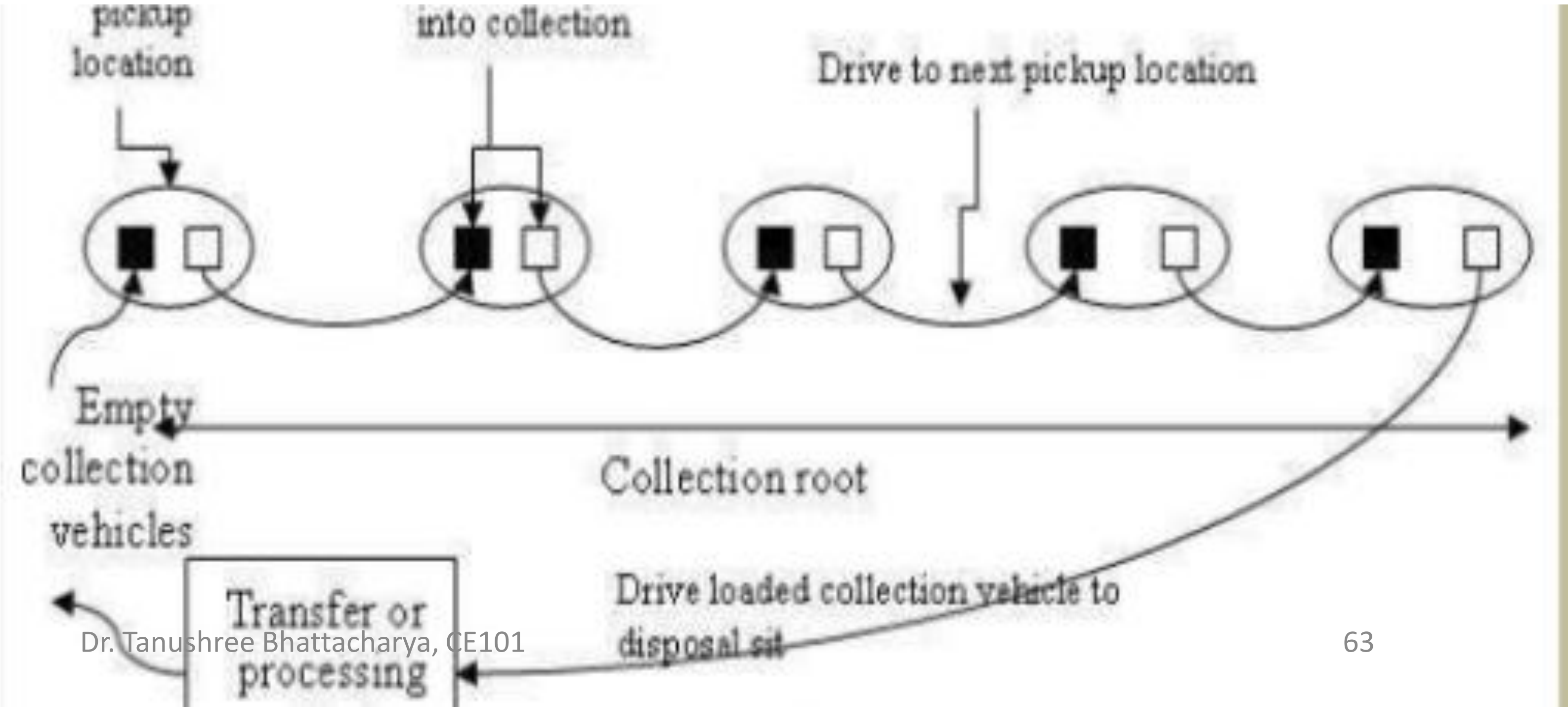


(a) Hauled container.

SCS

Stationary-Container System (SCS)

- **Collection systems in which the containers used for the storage of wastes remain at the point of waste generation, except when moved for collection are defined as stationary-container systems.** There are two main types of stationary-container system:
- **(1) Those in which self-loading compactors are used and**
- **(2) Those in which manual loaded vehicles are used.**



Equations to calculate time requirement

Hauled Containers

- An empty storage container (known as a drop-off box) is hauled to the storage site to replace the container that is full of waste, which is then hauled to the processing point, transfer station or disposal site
- The time required per trip

  $T_{hcs} = (PT_{hcs} + q + m + nx)$ (4.1)

  Where,

  T = time per trip for hauled-container system, h/trip hcs

  PT_{hcs}= pick-up time per trip for hauled-container system, h/trip

  q = at-site time per trip, h/trip

  m = empirical haul constant, h/km

  n = empirical haul constant, h/km

  x = round-trip haul distance, km/trip

Stationary Container System

$$Tscs = \frac{(Pscs + s + a + bx)}{(1-w)}$$

- The only difference between Thcs & Tscs is Pick up time.
- For Stationary Container System pick up time is

$Pscs = C_t (Uc) + (n_p - 1) (dbc)$ where

C_t = number of container emptied per trip, container / trip

Uc = Ave. unloading time per container for SCS, h/container

np = Number of container pick up locations, locations/trip

dbc = Ave. time spent driving b/w containers locations, h/location

Collection vehicles

- Primary collection
- Secondary collection

Robust vehicles

No. of collection vehicle needed

Number of collection vehicles needed for a community may be determined from below equation:

$$N = \frac{S*F}{X*W}$$

Where:

N = Number of collection vehicles needed.

S = Total number of customers serviced.

F = Collection frequency, number of collections per week.

X = Number of customers a single truck can service per day.

W = Number of workdays per week.

Calculate the number of collection vehicles a community would need if it has 4000 services (customers) that are to be collected once per week during working days in a city in Iraq. (Realistically, most trucks can service only about 200 to 300 customers before the truck is full and a trip to the landfill is necessary).

Solution

1) Given:

N = Number of collection vehicles needed

S = Total number of customers serviced = 4000

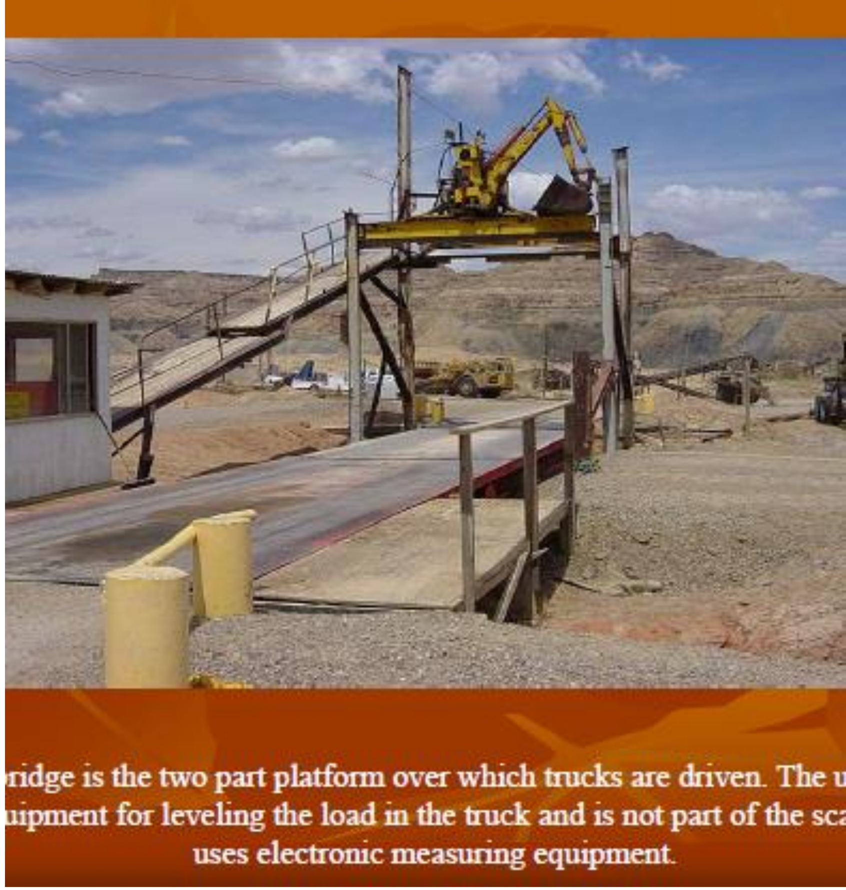
F = Collection frequency, number of collections per week = 1

X = Number of customers a single truck can service per day (A single truck can service 300 customers in a single day and still have time to take the full loads to the landfill) = 300.

2) W = Number of workdays per week (The town wants to collect on Saturday, Sunday, Monday, and Tuesdays leaving Wednesdays for special projects and truck maintenance) = 4 days.

3) Thus: N = SF/XW = (4000 *1)/(300*4) = 3.3

4) The community will need four trucks.



TRANSFER AND TRANSPORT

Collection Services For Solid Wastes

- **Municipal Collection Service**
- **Although a variety of collection services are available the three most common are curb, alley and backyard collection**. Curb collection has gained popularity because labour costs for collection can be minimized. In the future, it appears that the use of large container which can be emptied mechanically with an articulated container pickup mechanism will be the most common method used for the collection of municipal wastes.
- **Curb Service. The house owner is responsible for placing the solid waste containers at the curb on the scheduled day. The workmen come, collect and empty the container and put back at the curb**. The house owner is required to take back the empty containers from the curb to his house.
- **Alley Service. The containers are placed at the alley line from where they are picked up by workmen from refuse vehicle who deposit back the empty container**.

Curb Service

Alley Service

Kerbside / Alley Collection Method:

Collection , segregation at site

Collection, Segregation and Storage at the Site of Collection

- **The best way would have been the segregation of waste at the generation point. Segregation means collecting it in different bins, or plastic bags**. The domestic waste can be broadly separated as reusable (paper, plastic, metal etc.), and non reusable. **The non reusable may have organic matter like kitchen waste or inorganic matter like dust, dirt etc. The organic matter is liable to decomposition (putrescible) and thus requires immediate attention.**

Collection, Segregation and Storage at the Site of Collection

- **This separated waste should be regularly collected by the worker directly from the houses at some well defined time**. Then it should be transported in (covered vehicles)to some waste collection depots for utilization/transportation to different sites. **The organic waste can be used for the production of biogas or for the extraction of energy, incineration (controlled burning or making organic compost, and vermi-composting.**

Transfer and transport

- A transfer station is a building or processing site for the temporary deposition of waste. Transfer stations are often used as places where local waste collection vehicles will deposit their waste cargo prior to loading into larger vehicles.
- Typical activities at the waste transfer station involved the unloading of garbage trucks, pre-screening and removal of inappropriate items such as automobile batteries, compacting and then reloading onto larger vehicles, including trucks, trains and barges to their final destination.

Types of transfer station

Simple transfer station.

Mechanically loaded transfer station.

Badly managed transfer station can lead to environmental problems

Key Benefits of transfer stations

- The transfer station is a key component of cost-effective solid waste transportation. By transferring waste from local collection vehicles onto larger trailers or other transport modes such as barge and rail, the cost of transportation to distant disposal sites can be significantly reduced, freeing collection-specific vehicles and crews to devote their time to actual collection activities. Here are some of the main benefits:
- Provides fuel savings, reduction in road wear and less air pollution due to fewer vehicles being on the road
- Provides a trash and recyclable material drop-off location for citizens
- Reduces total traffic congestion in the community by transferring it onto larger vehicles
- Reduces total truck traffic and improves safety at the landfill or waste-to-energy facility
- Provides the opportunity to screen incoming trash for such purposes as removing hazardous waste or recovering recyclables

Planning the route for waste collection vehicles

For any urban location, there is likely to be a number of transfer stations distributed around the town. The waste will need collecting from all these stations as well as directly from businesses, institutions and some households. In most locations, there is only one site for final treatment and disposal, to which the waste must be transported, and this is usually situated at the edge of the town. It is important to plan the routes for the waste collection vehicle (or vehicles) to make the best use of the resources available. This keeps costs down and gives people the best-possible service. Route planning is a complex operation, but the basic process consists of three stages:

1. Identifying the pickup points and the likely amounts of waste to be collected from each point.
2. Grouping pickup points to form ‘collection rounds’ that can be served by a single collection vehicle.
3. Planning the route of each collection round taking account of the distance travelled, traffic levels and safety to the public and the waste collectors.

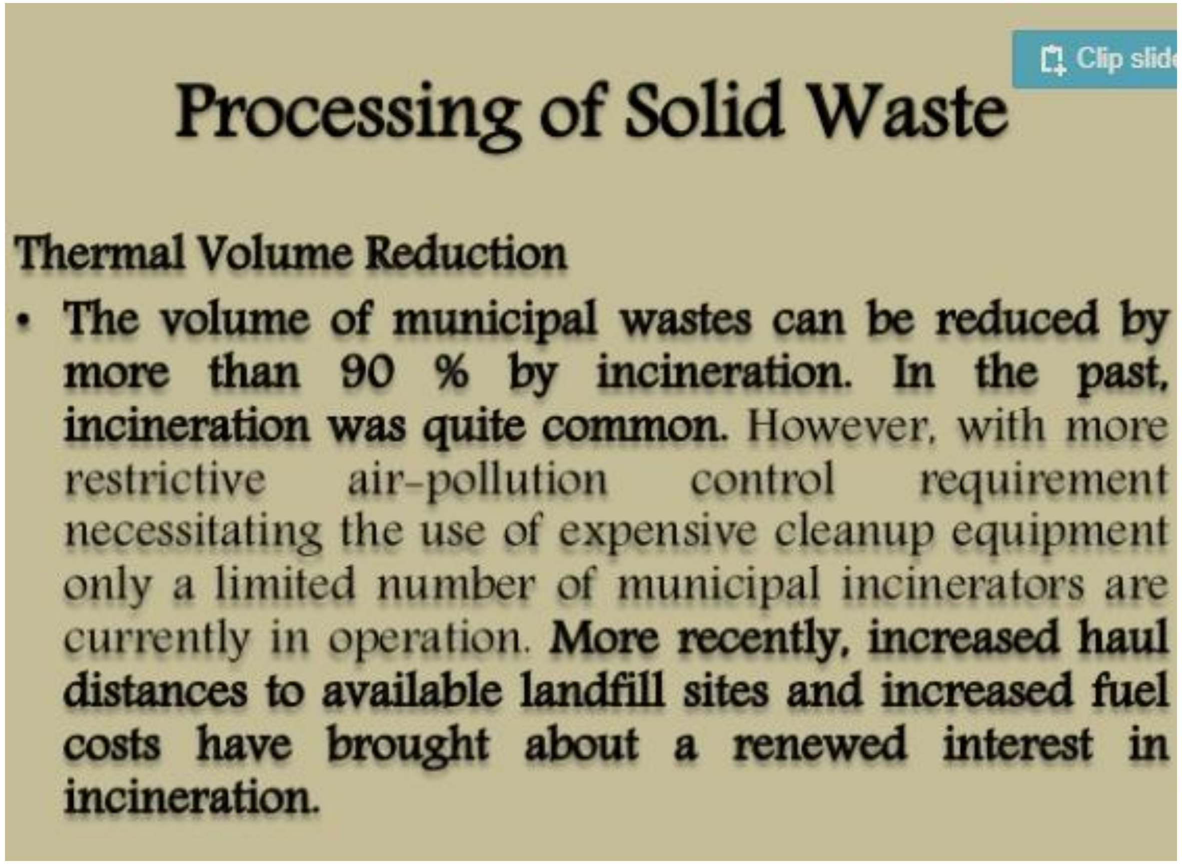
PROCESSING

Processing of Solid Waste

- Processing techniques are used in solid waste management systems to **(1) improve the efficiency of solid-Waste disposal systems (2) To recover Resources and (3) To prepare materials for the recovery of conversion products and energy**.
- **Mechanical Volume Reduction**
- **Mechanical Volume Reduction is perhaps the most important factor in development and operation of solid-waste management systems. Vehicles equipped with compaction mechanisms are used for the collection of most municipal solid wastes.** To increase the life of landfills, wastes are compacted. Paper for recycling is baled for shipping to processing centres.

Mechanical Volume Reduction

INCINERATION



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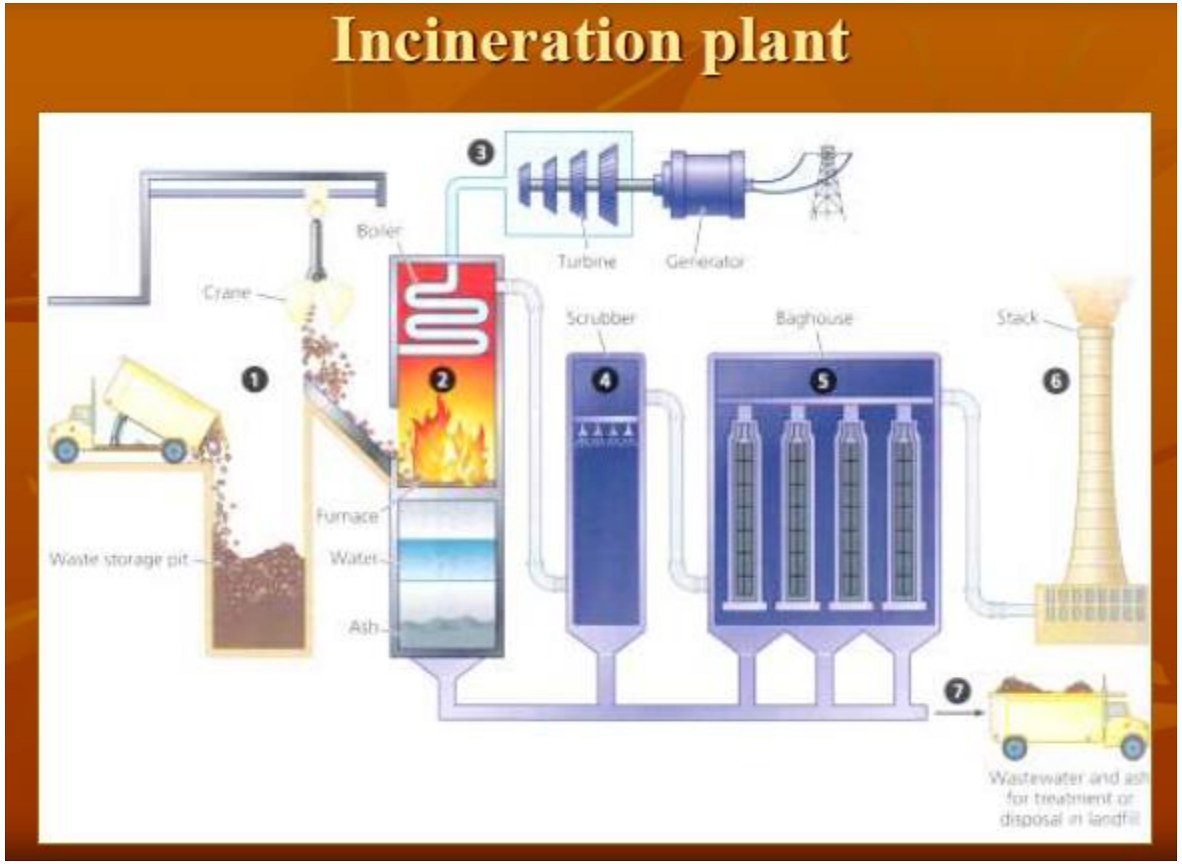
Processing of Solid Waste

Thermal Volume Reduction

- **The volume of municipal wastes can be reduced by more than 90 % by incineration. In the past, incineration was quite common.** However, with more restrictive air-pollution control requirement necessitating the use of expensive cleanup equipment only a limited number of municipal incinerators are currently in operation. **More recently, increased haul distances to available landfill sites and increased fuel costs have brought about a renewed interest in incineration.**



Advantages and disadvantages of incineration

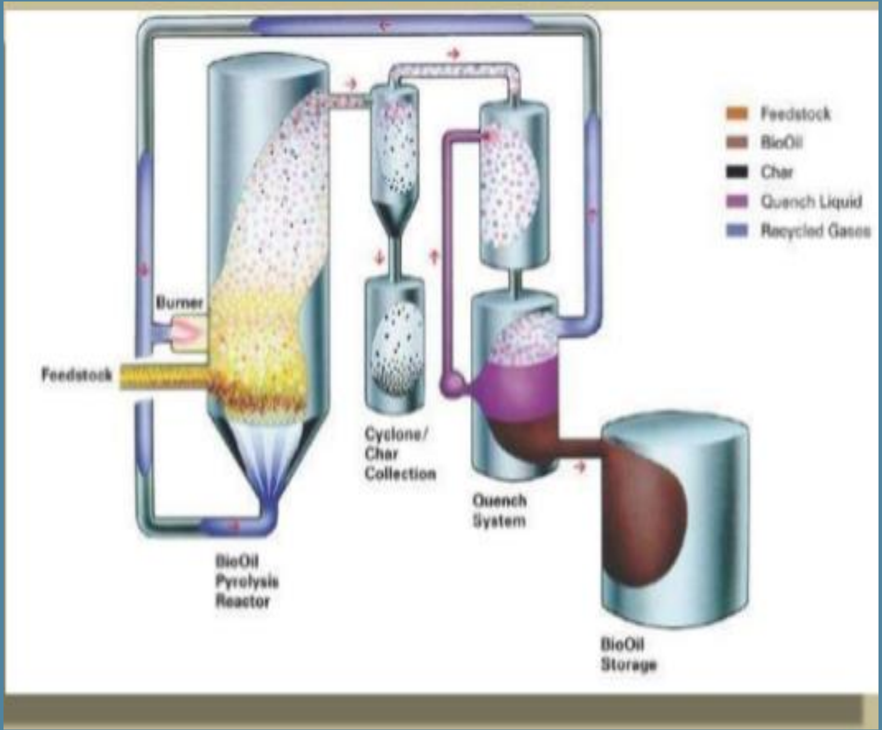
ADVANTAGES

- Minimum of land is needed compared to other disposal methods.
- The weight of the waste is reduced to 25% of the initial value.
- No risk of polluting local streams and ground waters as in landfills.
- Incineration plants can be located close to residential areas.
- Gases are used to generate power.

DISADVANTAGES

- Expensive
- Required skilled labour.
- The chemicals that would be released into the air could be strong pollutants and may destroy ozone layer (major disadvantage).
- high energy requirement.

PYROLYSIS



Pyrolysis

- It is defined as heating the solid waste at very high temperature in absence of air.
- Pyrolysis is carried out at a temperature between 500 ^{0} C to 1000 ^{0}C to produce three component streams.
- Gas: It is a mixture of combustible gases such as hydrogen, carbon dioxide, methane, carbon mono-oxide and some hydrocarbons.
- Liquid: It contains tar, pitch, light oil, and low boiling organic chemicals like acetic acid, acetone, methanol etc.
- Char: It consists of elemental carbon along with inert material in the waste feed.
- The char liquid and gases have high calorific values.
- It has been observed that even after supplying the heat necessary for pyrolysis, certain amount of excess heat still remains which can be commercially exploited.

COMPOSTING

Compost

Compost is organic matter that has been decomposed and recycled as a fertilizer and soil amendment. Compost is a key ingredient in organic farming. At its most essential, the process of composting requires simply piling up waste outdoors and waiting for the materials to break down from anywhere between 5-6 weeks or even more.

Modern, methodical composting is a multi-step, closely monitored process with measured inputs of water, air and carbon- and nitrogen-rich materials. The decomposition process is aided by shredding the plant matter, adding water and ensuring proper aeration by regularly turning the mixture. Worms and fungi further break up the material.

Aerobic bacteria manage the chemical process by converting the inputs into heat, carbon dioxide and ammonium. The ammonium is further converted by bacteria into plant-nourishing nitrites and nitrates through the process of nitrification.

Compost can be rich in nutrients. It is used in gardens, landscaping, and agriculture. The compost itself is beneficial for the land in many ways, including as a soil conditioner, a fertilizer, addition of vital humus or humic acids, and as a natural pesticide for soil.

In ecosystems, compost is useful for erosion control, land and stream reclamation, wetland construction, and as landfill cover. Organic ingredients intended for composting can alternatively be used to generate biogas through anaerobic digestion.

Anaerobic digestion is fast overtaking composting in some parts of the world including central Europe as a primary means of downcycling waste organic matter.

COMPOSTING


Composting
Composting organisms require four equally important things to work effectively:
Carbon — for energy; the microbial oxidation of carbon produces the heat, if included at suggested levels.
High carbon materials tend to be brown and dry.
Nitrogen — to grow and reproduce more organisms to oxidize the carbon.
High nitrogen materials tend to be green (or colorful, such as fruits and vegetables) and wet.[7]
Oxygen — for oxidizing the carbon, the decomposition process.
Water — in the right amounts to maintain activity without causing anaerobic conditions.
ost pile that is steaming with the
ted by thermophilic microorganisms.

INDORE METHOD FOR COMPOSTING

Indore Method of Composting

- **Indore Method of Composting:**
- In this method solid waste night soil and animal dung etc. are placed in brick lined pits 3 m x 3 m x 1 m deep in alternate layers of 7.5 to 10 cm height, till the total height becomes 1.5 m. Chemical insecticides are added to prevent fly breeding. The material is turned regularly for a period of **about 8 to 12 weeks and then stored on ground for 4 to 6 weeks. In about 6 to 8 turnings and period of 4 months time compost becomes ready for use as manure.** Insecticide used in Indore method was DDT but now because of very high half life of DDT in nature other suitable insecticide is recommended, e.g. Gamaxine.

Bangalore Method

- The solid waste is stabilized anaerobically. Earthen trenches of size 10 x 1.5 x 1.5 m deep are filled up in alternate layers of solid waste and night soil/cow dung. The material is converse with 15 cm earthen layer and left for biodegradation. **In about 4-5 months the compost becomes ready to use, normally a city produces 200 to 250 kg/capita/year of refuse** and 8 to 10 kg / capita/year of night soil.

Vermicomposting

- Vermicompost (vermi-compost) is the product of the decomposition process using various species of worms, usually red wigglers, white worms, and other earthworms, to create a mixture of decomposing vegetable or food waste, bedding materials, and vermicast.

Earthworms consume biomass and excrete it in digested form called worm casts/Black gold.

The casts are rich in nutrients, growth promoting substances, beneficial soil micro flora

Biological advantages	In many soils, these play major role in converting large pieces of organic matter into rich humus and thus improving soil fertility
Burrowing activities	The earthworm is of great value in keeping soil structure open, creating multitude of channels that allow processes of both aeration and drainage to occur
Earthworm castings	In home garden, the presence of earthworm castings provide 5 to 11 times more nitrogen, phosphorous, and potassium as the surrounding soil
Secretions in intestinal tracts of earthworms	This help in making nutrients more concentrated as well as readily available for plant uptake including micro nutrients


Red earthworm is preferred because of its high multiplication rate and thereby converts the organic matter into vermicompost within 45-50 days.
Since it is a surface feeder it converts organic materials into vermicompost from top.


Species of earthworms
Eisenia foetida (Red earthworm), *Eudrilus eugeniae* (night crawler), *Perionyx excavatus* etc.

Methods of vermicomposting

- *Bed method :*

  Composting is done on the pucca / kachcha floor by making bed (6x2x2 feet size) of organic mixture. This method is easy to maintain and to practice

- *Pit method:*

  Composting is done in the cemented pits of size 5x5x3 feet. The unit is covered with thatch grass or any other locally available materials. This method is not preferred due to poor aeration, water logging at bottom, and more cost of production.

Phases of Vermicomposting

Phase 1	:	Processing involving collection of wastes, shredding, mechanical separation of the metal, glass and ceramics and storage of organic wastes.
Phase 2	:	Pre digestion of organic waste for twenty days by heaping the material along with cattle dung slurry. This process partially digests the material and fit for earthworm consumption. Cattle dung and biogas slurry may be used after drying. Wet dung should not be used for vermicompost production.
Phase 3	:	Preparation of earthworm bed. A concrete base is required to put the waste for vermicompost preparation. Loose soil will allow the worms to go into soil and also while watering, all the dissolvable nutrients go into the soil along with water.
Phase 4	:	Collection of earthworm after vermicompost collection. Sieving the composted material to separate fully composted material. The partially composted material will be again put into vermicompost bed.
Phase 5	:	Storing the vermicompost in proper place to maintain moisture and allow the beneficial microorganisms to grow.

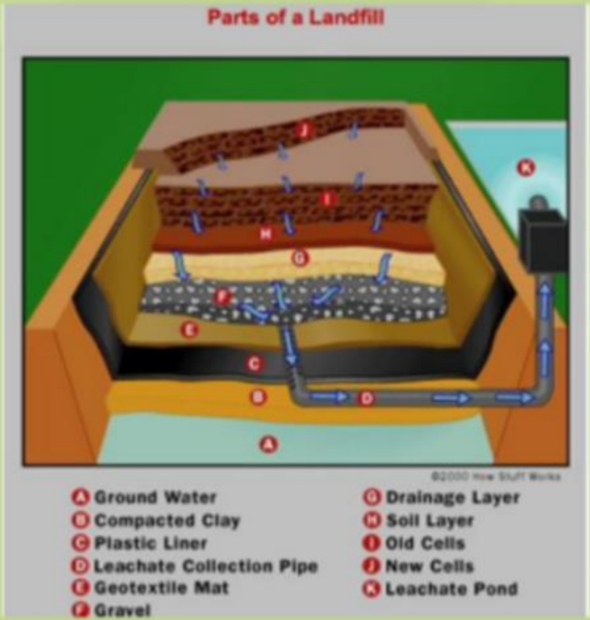
DISPOSAL-LANDFILLING

What is a Sanitary Landfill

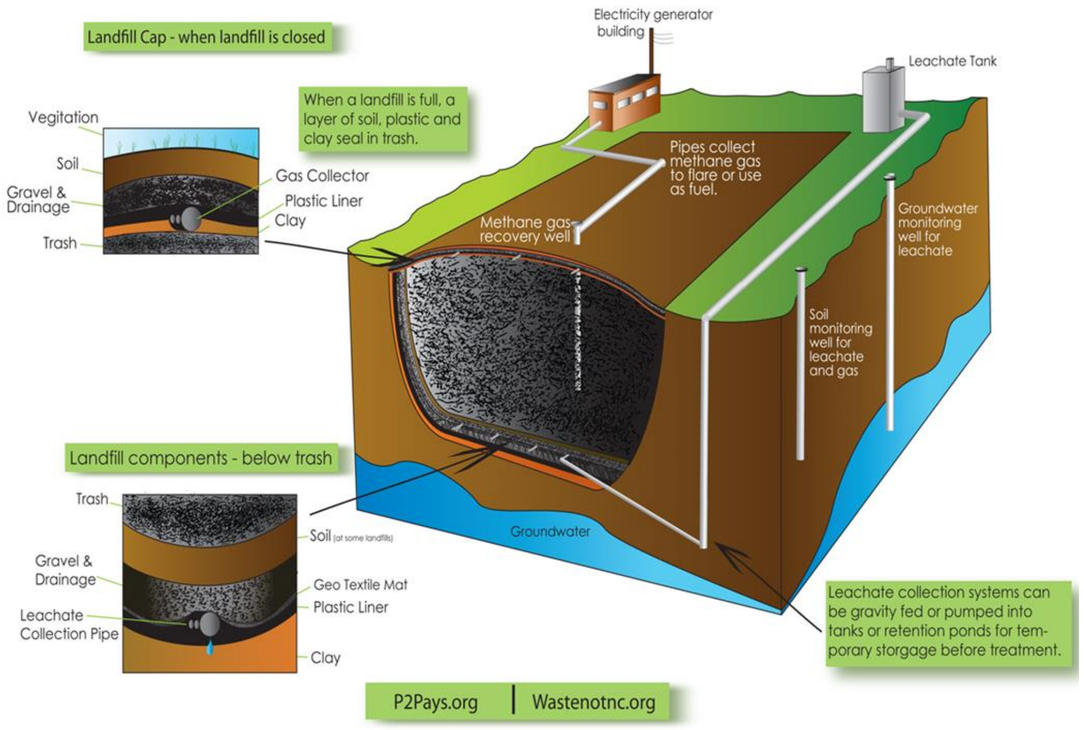
- A sanitary land fill is a waste disposal location where layers of compressed garbage is covered with layers of earth. When the facility reaches the end of its life and is full, a cap is used to close the top of site. Sanitary land fills are among the most popular methods for disposing of waste, although they have some serious disadvantages.

Parts of a Sanitary Landfill

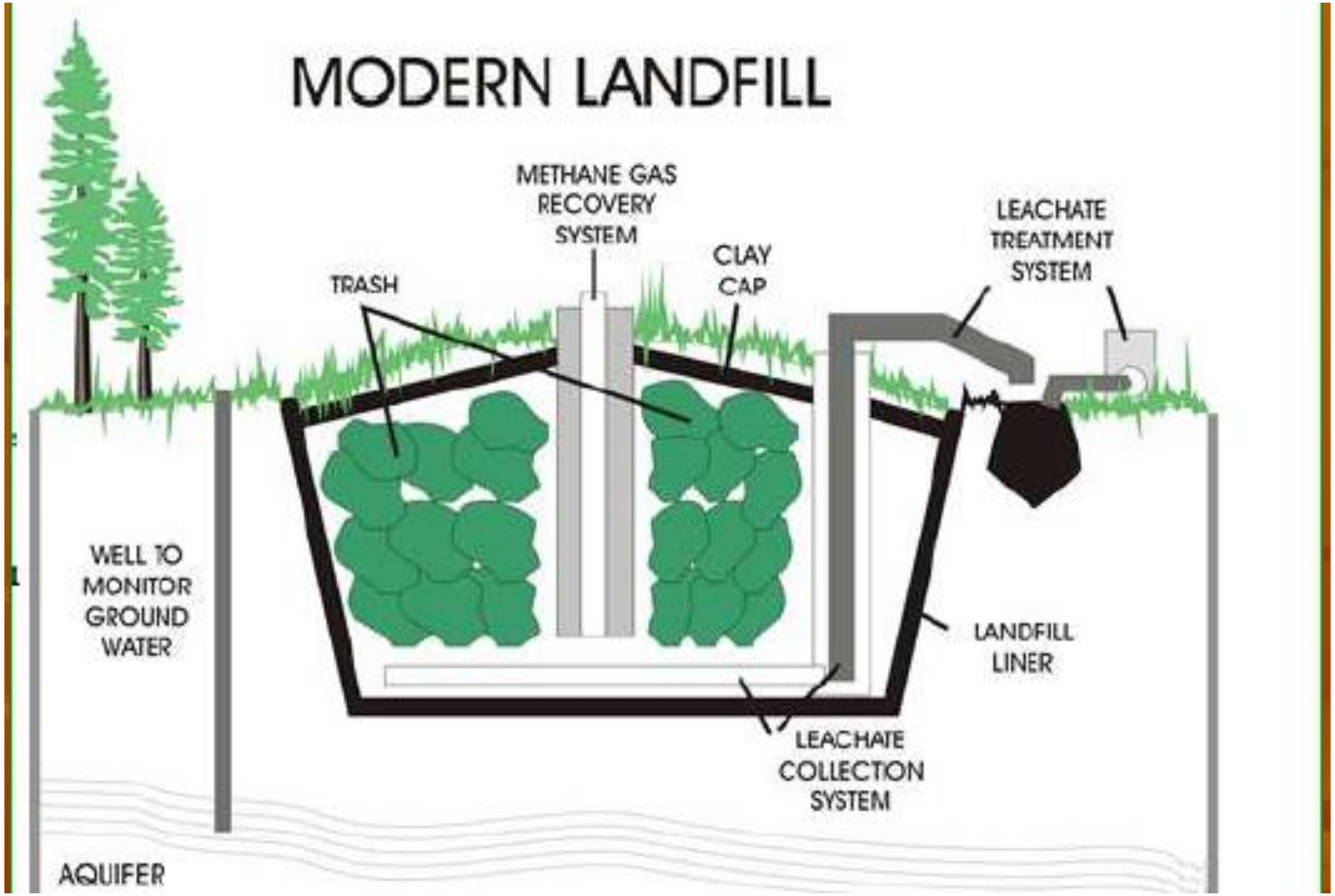
- **Bottom liner system** - separates trash and subsequent leachate from groundwater
- **Cells (old and new)** - where the trash is stored within the landfill
- **Storm water drainage system** - collects rain water that falls on the landfill
- **Leachate collection system** - collects water that has percolated through the landfill itself and contains contaminating substances (**leachate**)
- **Methane collection system** - collects methane gas that is formed during the breakdown of trash
- **Covering or cap** - seals off the top of the landfill



Parts of a Municipal Solid Waste Landfill



LANDFILL


MODERN LANDFILL
METHANE GAS RECOVERY SYSTEM
LEACHATE TREATMENT SYSTEM
CLAY CAP
TRASH
WELL TO MONITOR GROUND WATER
LANDFILL LINER
LEACHATE COLLECTION SYSTEM
AQUIFER

Stages of decomposition in landfills

- **Phase I**: Initial adjustment phase - This phase is associated with initial placement of solid waste and accumulation of moisture within landfills. An acclimation period (or initial lag time) is observed until sufficient moisture develops and supports an active microbial community. Preliminary changes in environmental components occur in order to create favourable conditions for biochemical decomposition.
- **Phase II**: Transition phase - In the transition phase, the field capacity is sometimes exceeded, and a transformation from an aerobic to anaerobic environment occurs, as evidenced by the depletion of oxygen trapped within a landfill media.
- **Phase III**: Acid formation phase - The continuous hydrolysis (solubilization) of solid waste, followed by the microbial conversion of biodegradable organic content results in the production of intermediate short chain carboxylic acids at high concentrations throughout this phase. A decrease in pH values is often observed. Viable biomass growth associated with the acid formers (acidogenic bacteria), and rapid consumption of substrate and nutrients are the predominant features of this phase. The leachate contains a high chemical oxygen demand (COD) that is attributable to carboxylic acids. Because these acids are biodegradable, **the highest BOD and COD concentrations in the leachate will be measured during this phase .**
- **Phase IV**: Methane fermentation phase - During Phase IV, intermediate acids are consumed by methanogenic bacteria and converted into methane and carbon dioxide. Sulphate and nitrate are reduced to sulphides and ammonia, respectively. The pH value is elevated, being controlled by the bicarbonate buffering system, and consequently supports the growth of methanogenic bacteria. Heavy metals are removed by complexation and precipitation. Carboxylic acid concentrations decrease **with corresponding decreases in the leachate COD and BOD.**
- **Phase V**: Maturation phase - During the final state of landfill stabilization, nutrients and available substrate become limiting, and the biological activity shifts to relative dormancy. Gas production drops dramatically and leachate strength stays steady at much lower concentrations. Reappearance of oxygen and oxidized species may be observed slowly. However, the slow degradation of resistant organic fractions. In this phase the BOD/COD is relatively low because dissolved organic matter that is degradable is consumed as rapidly as it is produced.

Major chemical reactions of different phases

Hydrolysis

- Equation 1 : $C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_2$

Fermentation/Acidogenesis

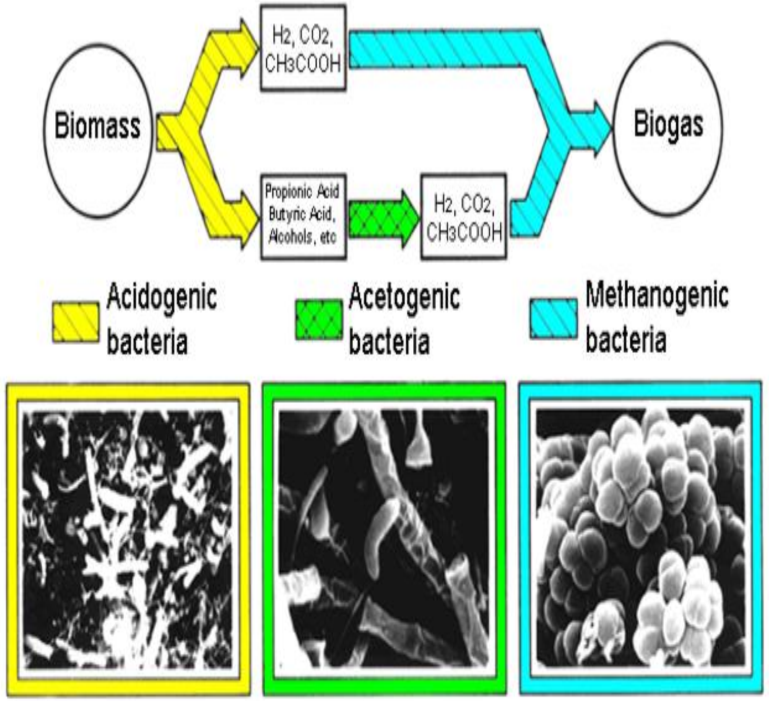
Equation 2 : $C_6H_{12}O_6 \leftrightarrow 2CH_3CH_2OH + 2CO_2$
Equation 3 : $C_6H_{12}O_6 + 2H_2 \leftrightarrow 2CH_3CH_2COOH + 2H_2O$
Equation 4 : $C_6H_{12}O_6 \rightarrow 3CH_3COOH$

Acetogenesis

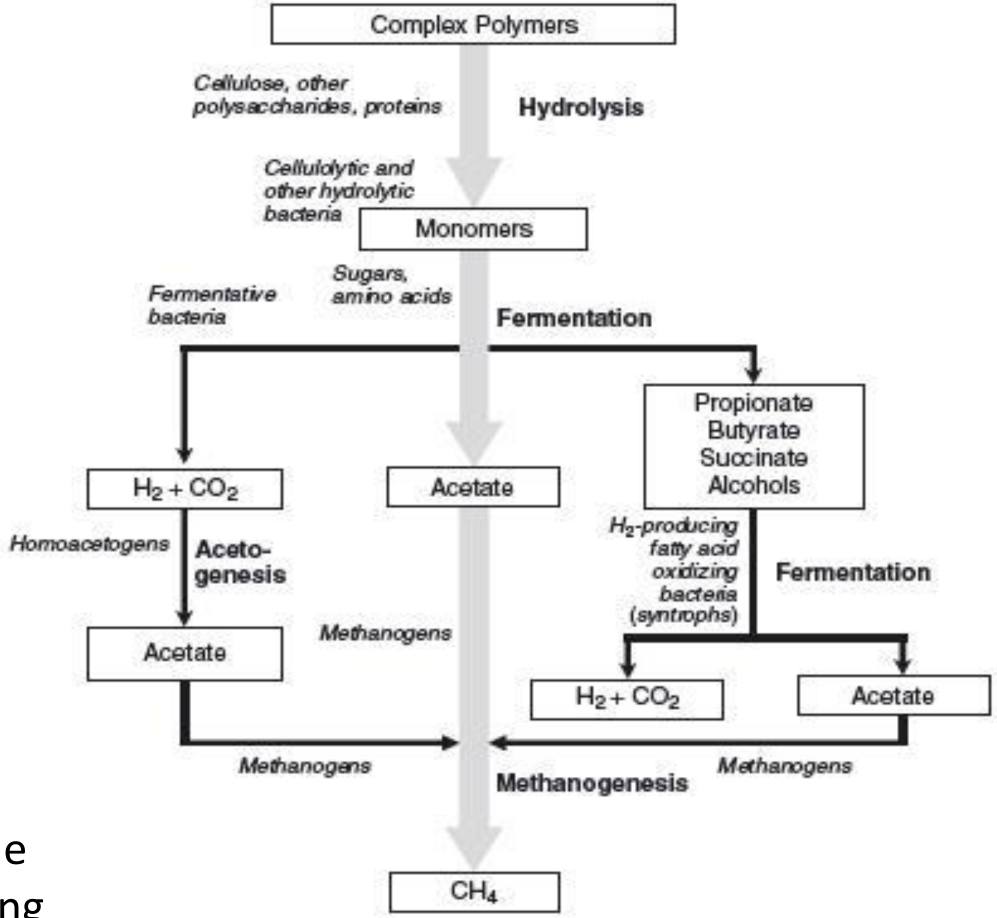
Equation 5 : $CH_3CH_2COO^{-} + 3H_2O \leftrightarrow CH_3COO^{-} + H^{+} + HCO_3^{-} + 3H_2$
Equation 6 : $C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2CO_2 + 4H_2$
Equation 7 : $CH_3CH_2OH + 2H_2O \leftrightarrow CH_3COO^{-} + 2H_2 + H^{+}$

Methanogenesis

Equation 8 : $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
Equation 9 : $2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$
Equation 10 : $CH_3COOH \rightarrow CH_4 + CO_2$

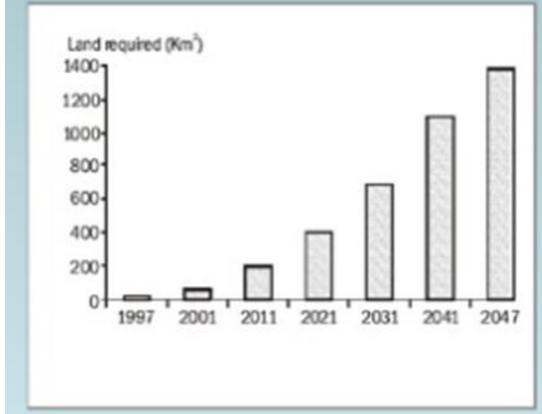


Schematic representation of the course of anaerobic methane generation from complex organic substances showing scanning electron micrographs of individual microorganisms involved

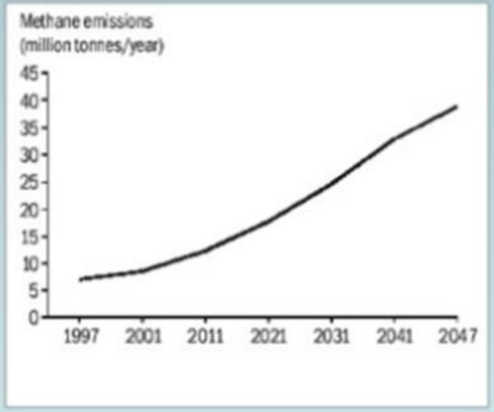


Overall process of anaerobic decomposition

Advantages and disadvantages



LAND REQUIRED FOR DISPOSAL OF MSW



EMMISION OF METHANE FROM LANDFILL

ADVANTAGES

- Landfill site is a cheap waste disposal option for the local council.
- Jobs will be created for local people.
- Lots of different types of waste can be disposed of by landfill in comparison to other waste disposal methods.
- The gases given off by the landfill site could be collected and used for generating power.

DISADVANTAGES

- The site will look ugly while it is being used for landfill.
- Dangerous gases are given off from landfill sites that cause local air pollution and contribute to global warming.
- Local streams could become polluted with toxins seeping through the ground from the landfill site.
- Once the site has been filled it might not be able to be used for redevelopment as it might be too polluted.

E-waste in India

- According to United Nations' "Global E-waste Monitor", 2017:

- Globally, 44.7 million metric tonnes of e-waste was generated in 2016 and only 20% was recycled through appropriate channels. China was the top e-waste producer in the world, generating 7.2 Mt.
- India generated about 2Mt of electronic waste in 2016. According to the report, India's electronics industry is one of the world's fastest growing industries and plays an "important role" in the domestic generation of e-waste. The report also highlighted the issue of imports of electronic waste to India from developed countries.

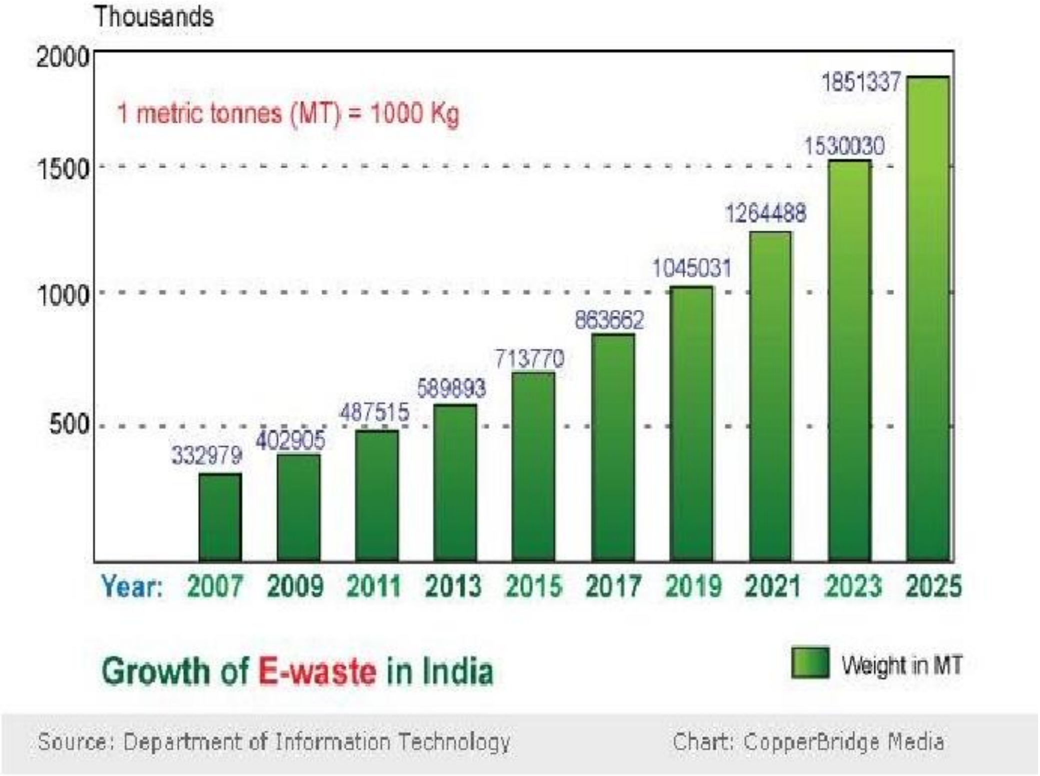


Fig. 1 Forecast of e-waste estimate in India[14]

E-waste in India

- India is ranked fifth in the world amongst top e-waste producing countries after the USA, China, Japan, and Germany and recycles less than 2 per cent of the total e-waste it produces annually formally.
- Since 2018, India generates more than two million tonnes of e-waste annually, and also imports huge amounts of e-waste from other countries around the world.
- Dumping in open dumpsites is a common sight which gives rise to issues such as groundwater contamination, poor health, and more.
- The Associated Chambers of Commerce and Industry of India (ASSOCHAM) and KPMG study, Electronic Waste Management in India identified that computer equipment account for almost 70 per cent of e-waste, followed by telecommunication equipment phones (12 per cent), electrical equipment (8 per cent), and medical equipment (7 per cent) with remaining from household e-waste.

The problem….

- E-waste collection, transportation, processing, and recycling is dominated by the informal sector. The sector is well networked and unregulated. Often, all the materials and value that could be potentially recovered is not recovered. In addition, there are serious issues regarding leakages of toxins into the environment and workers' safety and health.

- Seelampur in Delhi is the largest e-waste dismantling centre of India. Adults as well as children spend 8–10 hours daily extracting reusable components and precious metals like copper, gold and various functional parts from the devices. E-waste recyclers use processes such as open incineration and acid-leeching. This situation could be improved by creating awareness and improving the infrastructure of recycling units along with the prevalent policies. The majority of the e-waste collected in India is managed by an unorganized sector.

Impact on Human Health:
Pollutants, their sources and effects on human health (Table: 1)

Pollutant	Sources	Effect
Arsenic	Semiconductors, diodes, microwaves, LEDs, solar cells	Black-foot disease
Barium	Electron tubes, filler for plastic and rubber, lubricant additives	neurodegenerative diseases, lung diseases
Cadmium	Batteries, pigments, solder, alloys, circuit boards, computer batteries	Contain Carcinogens; causes Itai-Itai disease which affects kidneys and softens bones
Cobalt	Insulators	
Lead	Lead rechargeable batteries, solar, transistors, lithium batteries, PVC	chronic kidney disease, neurological problems
Lithium	Mobile telephones, batteries	
Mercury	Components in copper machines and steam irons; batteries in clocks and pocket calculators, switches, LCDs	Affects the central nervous system, kidneys and immune system; causes Minamata disease
PCBs (polychlorinated biphenyls)	Transformers, capacitors, softening agents for paint, glue, plastic	Cardiovascular diseases, neurobehavioral and immunological changes in children
Silver	Capacitors, switches (contacts), batteries, resistors	Inhalation of silver dust can cause respiratory problems
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances	Metal fume fever, respiratory diseases
Beryllium	Switch boards and printed circuit boards.	Carcinogenic and causes lung diseases.
Plastic	circuit boards, cabinets and cables	Contain carcinogens, harms reproductive, gastro-intestine and immune system
Chromium	Used to protect metal housings and plates in a computer from corrosion	

Opportunities of E-Waste Management in India

- The Ministry of Environment, Forest and Climate Change rolled out the E-Waste (Management) Rules in 2016 to reduce e-waste production and increase recycling. Under these rules, the government introduced EPR which makes producers liable to collect 30 per cent to 70 per cent (over seven years) of the e-waste they produce, said the study.
- E-waste is a rich source of metals such as gold, silver, and copper, which can be recovered and brought back into the production cycle. There is significant economic potential in the efficient recovery of valuable materials in e-waste and can provide income-generating opportunities for both individuals and enterprises. The E-Waste Management Rules, 2016 were amended by the government in March 2018 to facilitate and effectively implement the environmentally sound management of e-waste in India. The amended Rules revise the collection targets under the provision of EPR with effect from October 1, 2017. By way of revised targets and monitoring under the Central Pollution Control Board (CPCB), effective and improved management of e-waste would be ensured.

Some recent data…

- India collected just 10 per cent of the electronic waste (e-waste) estimated to have been generated in the country 2018-19 and 3.5 per cent of that in the generated in 2017-18, said a recent report by the Central Pollution Control Board.

- India generated 708,445 tonne e-waste in 2017-18 and 771,215 tonne the following fiscal, the report estimated. In 2019-20, the figure rose 32 per cent to 1,014,961 tonne.

- The figures have taken into account the 21 types of electrical and electronic equipments listed in the E-Waste Management Rules, 2016. These include discarded computer monitors, mobile phones, chargers, motherboards, headphones, television sets, among other appliances.

- The report published on December 18, 2020 mentioned that the collection targets for 2017-18 and 2018-19 based on the rules were 35,422 tonnes and 1,54,242 tonnes, respectively.

- The actual collection, however, was lower in both the years — 25,325 tonnes in 2017-18 and 78,281 tonnes in 2018-19.

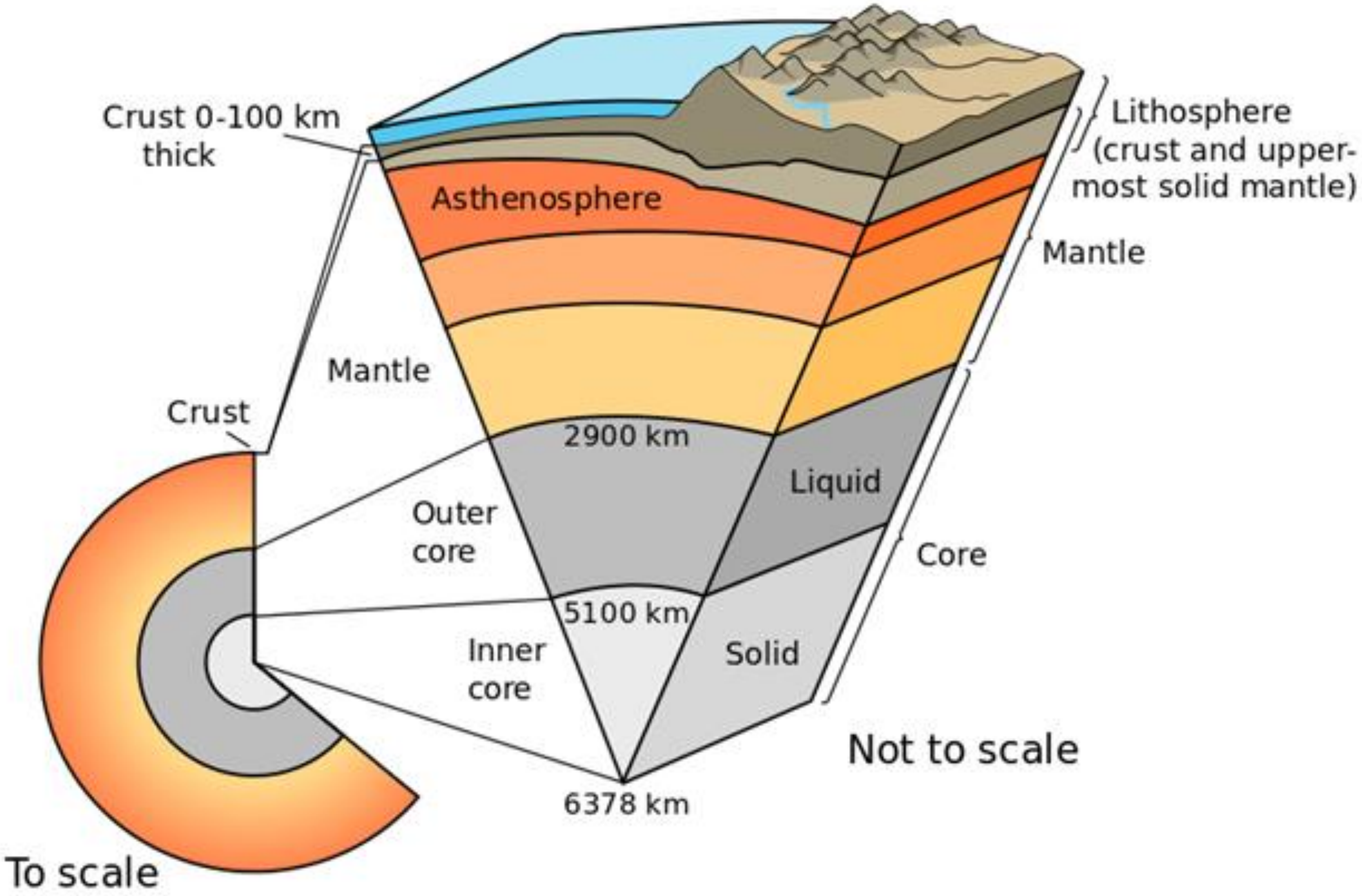
E-waste management

- Thanks

Module 4

- SOIL POLLUTION AND SOLID WASTE MANAGEMENT

Lithosphere

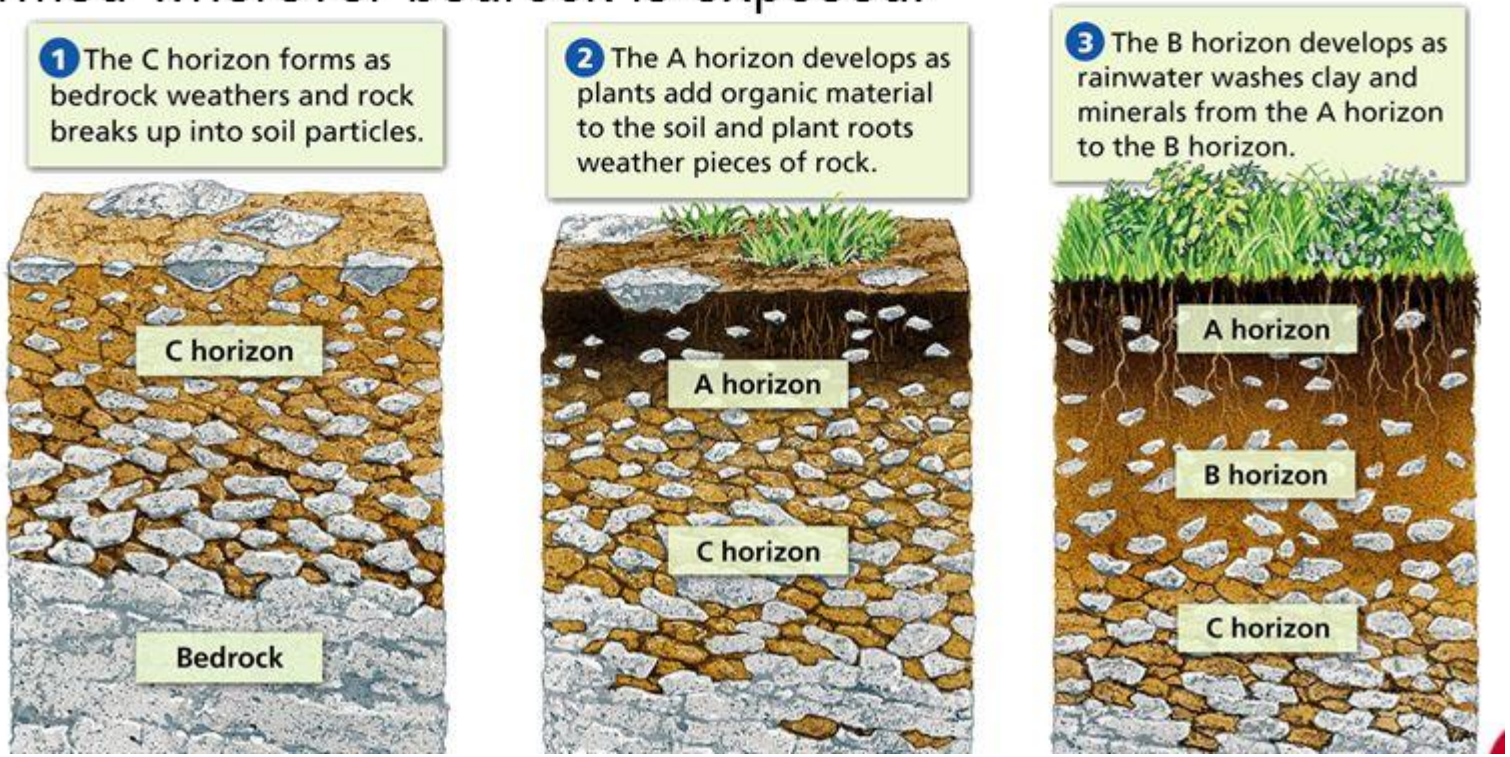


Soil is the mixture of minerals, organic matter, gases, liquids, and the countless organisms that together support life on Earth.

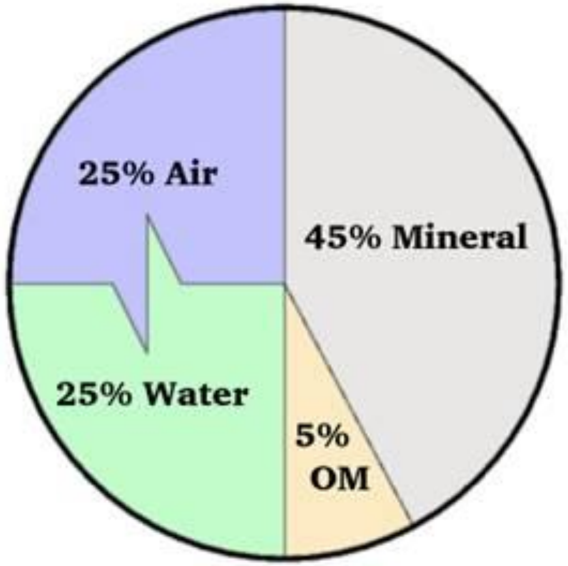
Weathering and Soil Formation - How Soil Forms

The Process of Soil Formation

Soil forms as rock is broken down by weathering and mixes with other materials on the surface. Soil is constantly being formed wherever bedrock is exposed.



Components of Soil



- **The basic components of soil are minerals, organic matter, water and air. The typical soil consists of approximately**
- **45% mineral,**
- **5% organic matter,**
- **20-30% water, and**
- **20-30% air.**
- soil minerals and organic matter hold and store nutrients,
- soil water is what readily provides nutrients for plant uptake.
- Soil air, supports microorganisms that live in the soil need air to undergo the biological processes that release additional nutrients into the soil.

Soil Properties

Soil colour

- **Soil color:** is one property that can be used to describe horizonation and soil morphology.
- The change in **soil color** with depth is directly related to a variety of processes that are occurring in the soil
- The soil color does not effect the behavior of the soils, but provides insights into **environmental conditions**, **formation processes**, and other **influences on the soil**.
- Used is used in **classifying soils**.

Soil colour

Soil color: does not affect the behavior and use of soil; however, it can indicate the composition of the soil and give clues to the conditions that the soil is subjected to. Soil can exhibit a wide range of colour; gray, black, white, reds, browns, yellows and under the right conditions green.

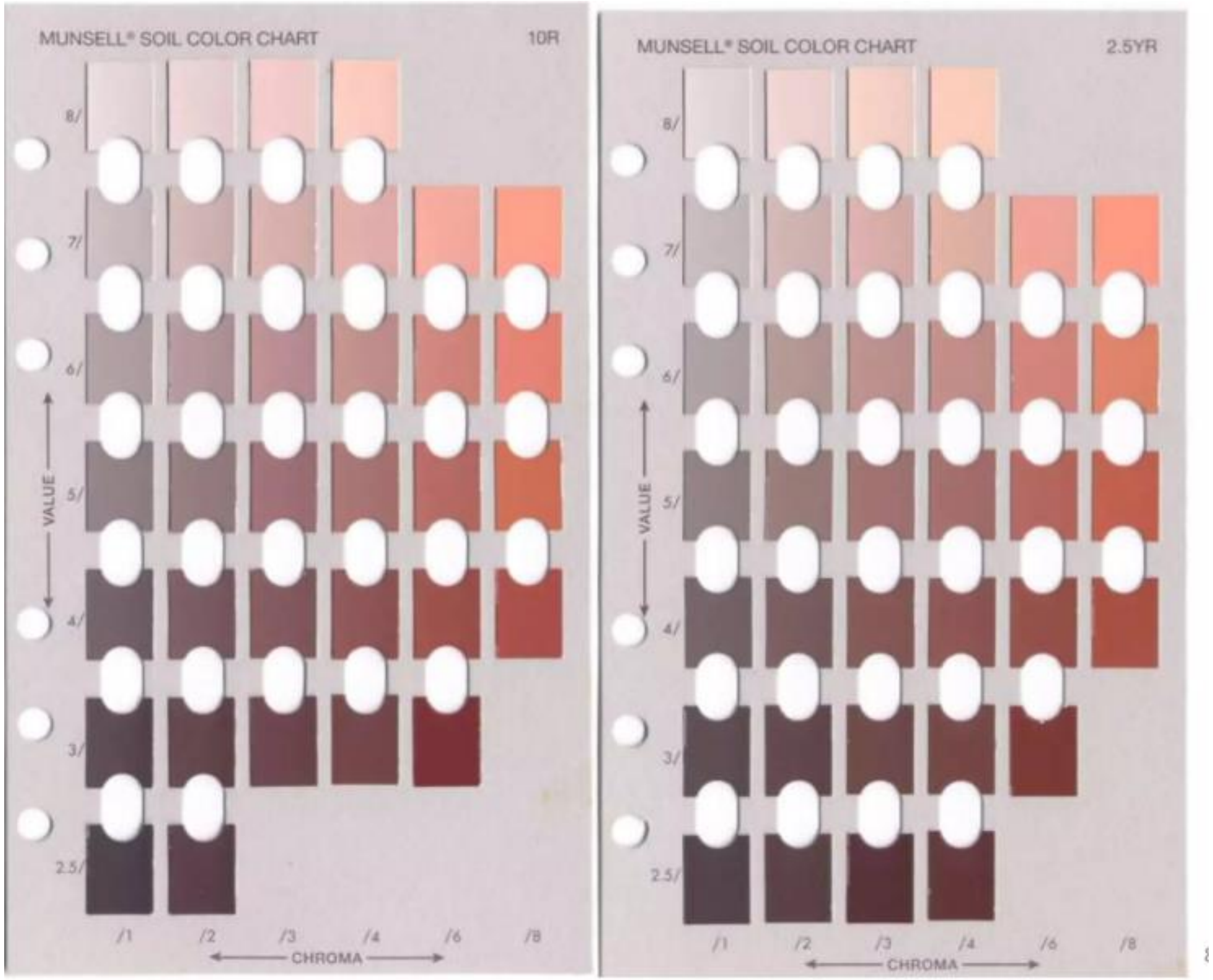
5

Classification of Soil colour

Soil colour is usually due to 3 main pigments:

- black—from organic matter
- red—from iron and **aluminium oxides**
- white—from silicates and salt.

Colour can be a useful indicator of some of the general properties of a soil, as well as some of the chemical processes that are occurring beneath the surface.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Soil Coloring

Material	Chemical Composition	Color
Manganese	Mn02	Purplish Black
Hematite	Fe203	Red
Geothite	FeOOH	Yellow
Hydrated Ferric Oxide	Fe(OH)3*nH20	Red Brown
Calcite	CaC03	Whitish
Glauconite	KMg(Fe,Al)(SiO3)6.3H2O	Greenish

Soil color is influenced by the amount of proteins present in the soil.

• Yellow or red soil indicates the presence of **iron oxides.**

• Dark brown or black colour in soil indicates that the soil has a high **organic matter** content.

•Wet soil will appear darker than **dry soil.**

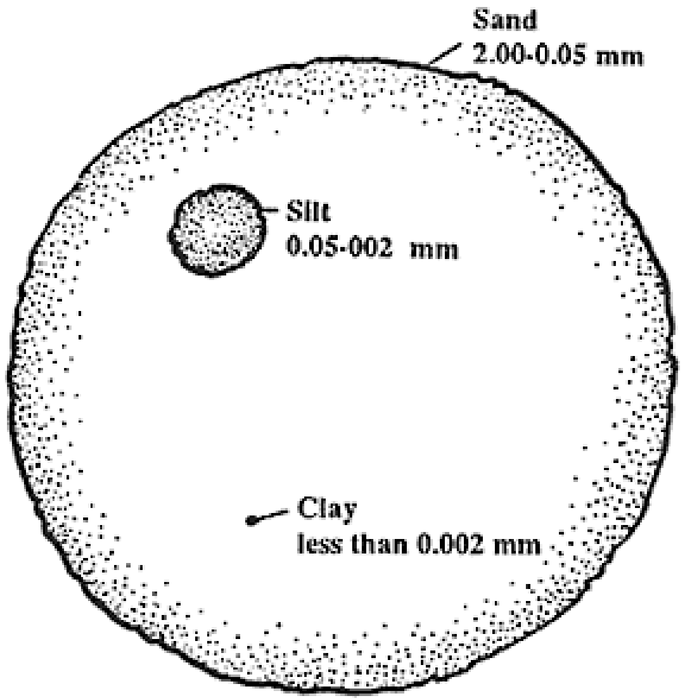
• The presence of water also affects soil color by affecting the oxidation rate. Soil that has a **high water** content will have less air in the soil, specifically less oxygen. In well drained (and therefore oxygen rich soils) red and brown colours caused by oxidation are more_common, as opposed to in wet (low oxygen) soils where the soil usually appears grey.

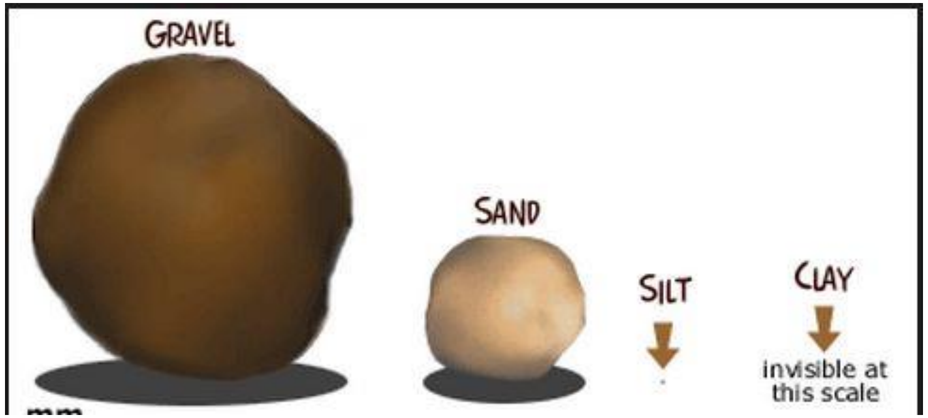
Soil Minerals

- Soil minerals play a vital role in soil fertility and these minerals vary greatly in size and chemical composition.
- **FINE EARTH FRACTION**
- The fine earth fraction includes any particle less than 2.0 mm (.078 inches) and is divided into three classes of size: sand, silt, or clay.
- **COARSE FRACTION**
- The coarse fraction of soil includes any soil particles greater than 2mm. The coarse fraction includes boulders, stones, gravels, and coarse sands. These are rocky fragments and are generally a combination of more than one type of mineral.

The Fine Earth Fraction

	Size	Texture	Characteristics
Sand	2.0 mm -0.05 mm	gritty	Sand is visible to eyes normally, consists of particles with low surface area, and permits excessive drainage.
Silt	0.05 mm - 0.002 mm	buttery	Silt is not visible to eyes normally and increases the water holding capacity of soil.
Clay	< 0.002 mm	sticky	Clay has a high surface area, high water holding capacity, many small pores, and possesses charged surfaces to attract and hold nutrients.





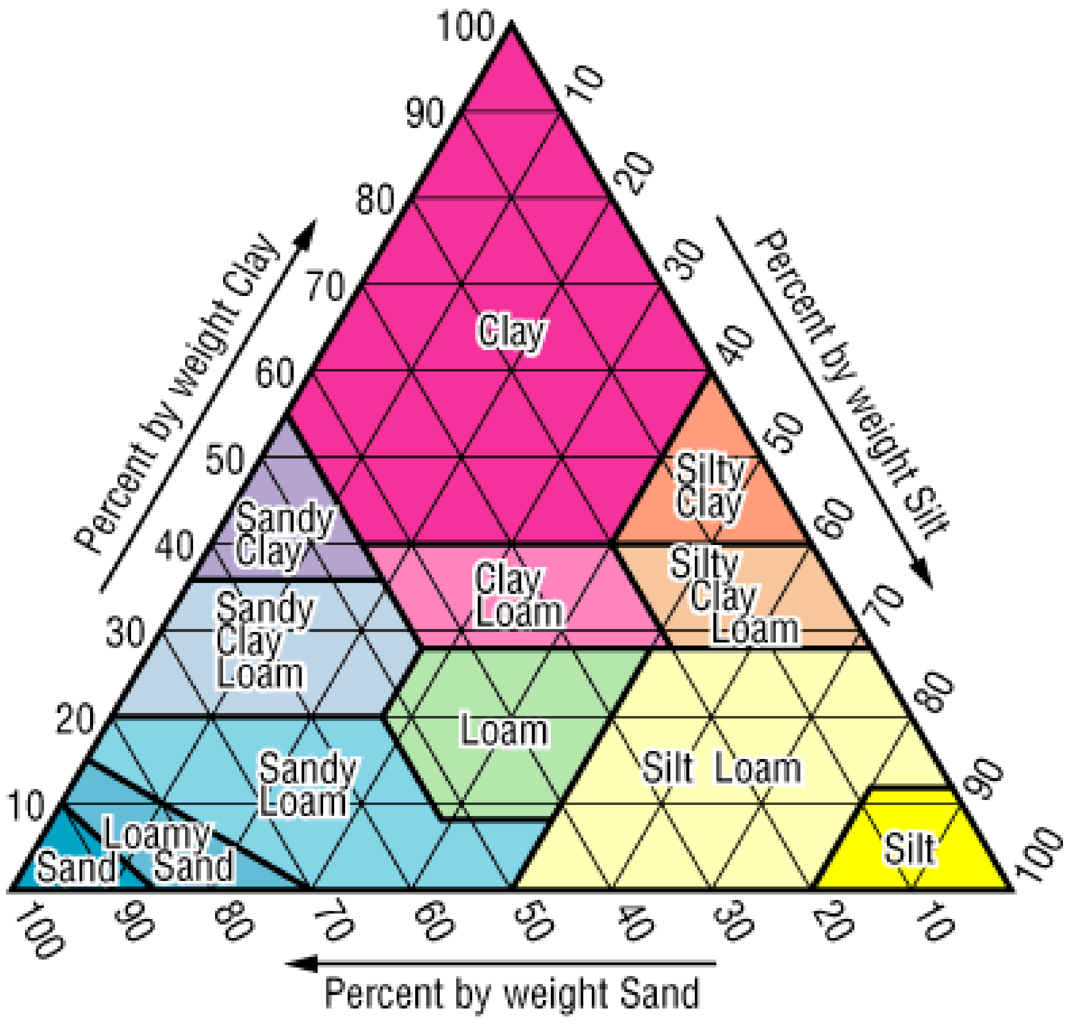
Texture

Soil texture refers to the weight proportion (relative proportion by weight percentage of sand, silt, and clay) of the mineral **soil** separates for particles less than two millimeters (mm) as determined from a laboratory particle-size distribution.

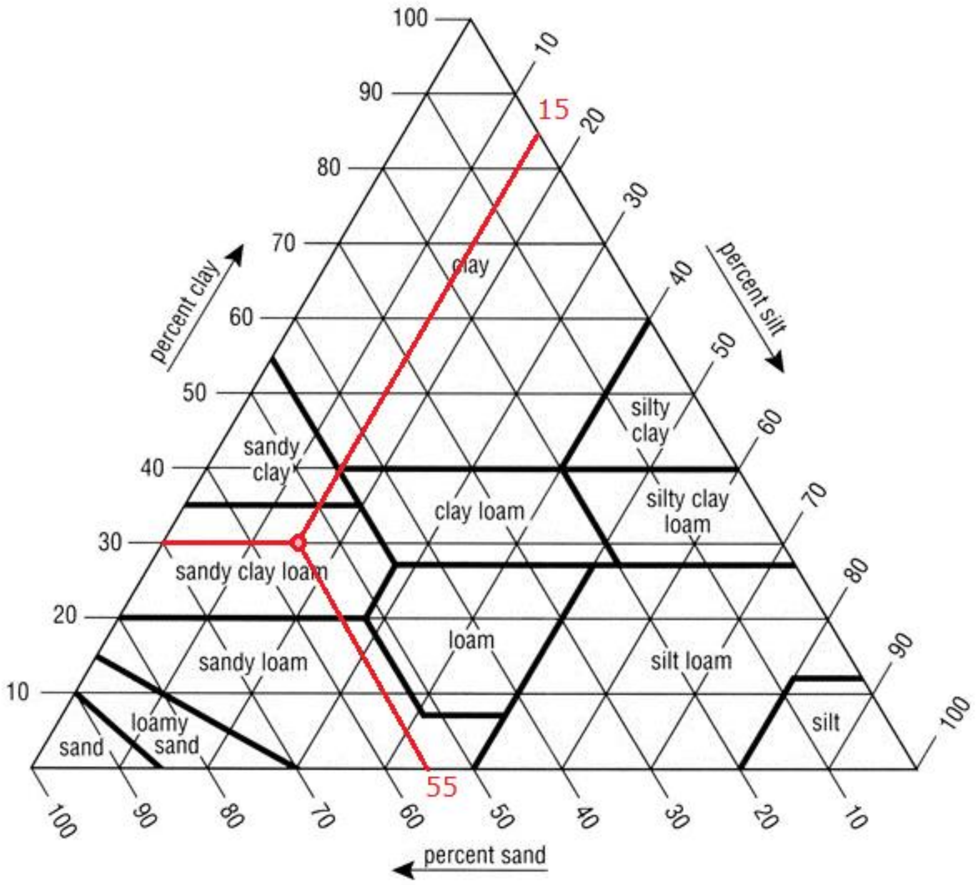
Soil texture is an **important soil** characteristic that influences storm water infiltration rates. The textural class of a **soil** is determined by the percentage of sand, silt, and clay. **Soils** can be classified as one of four major textural classes: (1) sands; (2) silts; (3) loams; and (4) clays.

Textural Triangle.

The **soil textural** class is a grouping of **soils** based upon these relative proportions. **Soils** with the finest **texture** are called clay **soils**, while **soils** with the coarsest **texture** are called sands.



Example: Classify a soil sample that is 30% clay, 15% silt, and 55% sand. First locate 30% on the clay axis, and draw a line horizontally from left to right. Next, locate 15% on the silt axis, and draw a line going down diagonally to the left. Finally, locate 55% on the sand axis, and draw a line going up diagonally to the left. The intersection is in a region called Sandy Clay Loam.



Soil Minerals and Mineral Composition

Typical soil parent mineral materials are:

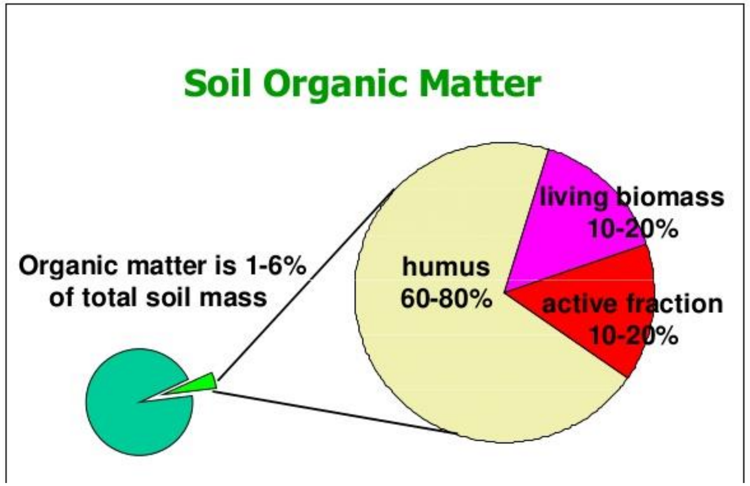
- Quartz: SiO_2,
- Calcite: $CaCO_3$,
- Feldspar: $KAlSi_3O_8$,
- Mica (biotite): $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$

Important Minerals and Weathered Materials of Basalt Rock

Primary Minerals of Basalt Rock	•Plagioclase Feldspar •Olivine •Augite Others: magnetite, apatite, ilmenite
Secondary Minerals	•Smectite, such as montmorillonite (less weathered) •Kaolin, such as halloysite (more weathered)
Iron Oxides	•Hematite •Goethite •Magnetite •Maghemite •Lepidocrosite •Ferrihydride
Aluminum Oxide	•Gibbsite
Amorphous Minerals	•Allophane •Imogolite

Soil Organic Matter

- Soil organic matter includes all organic (or carbon-containing) substances within the soil.
- Soil organic matter includes:
  - Living organisms (soil biomass)
  - The remains of microorganisms that once inhabited the soil
  - The remains of plants and animals
  - Organic compounds that have been decomposed within the soil and, over thousands of years, reduced to complex and relatively stable substances commonly called humus.

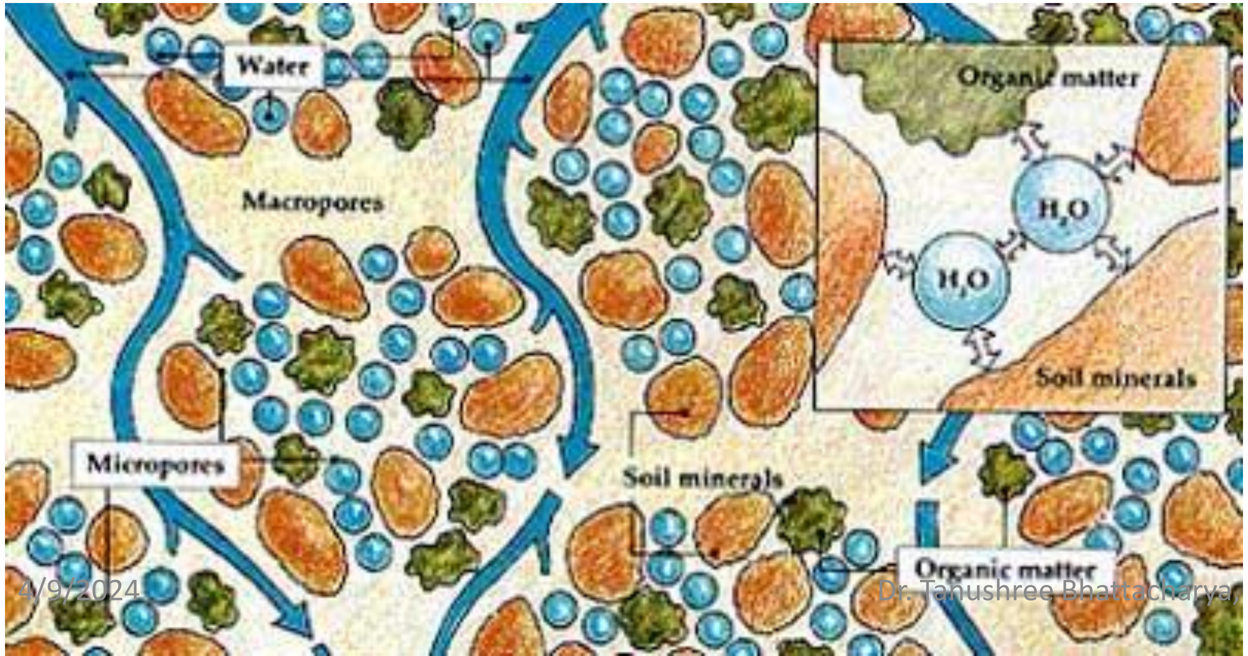


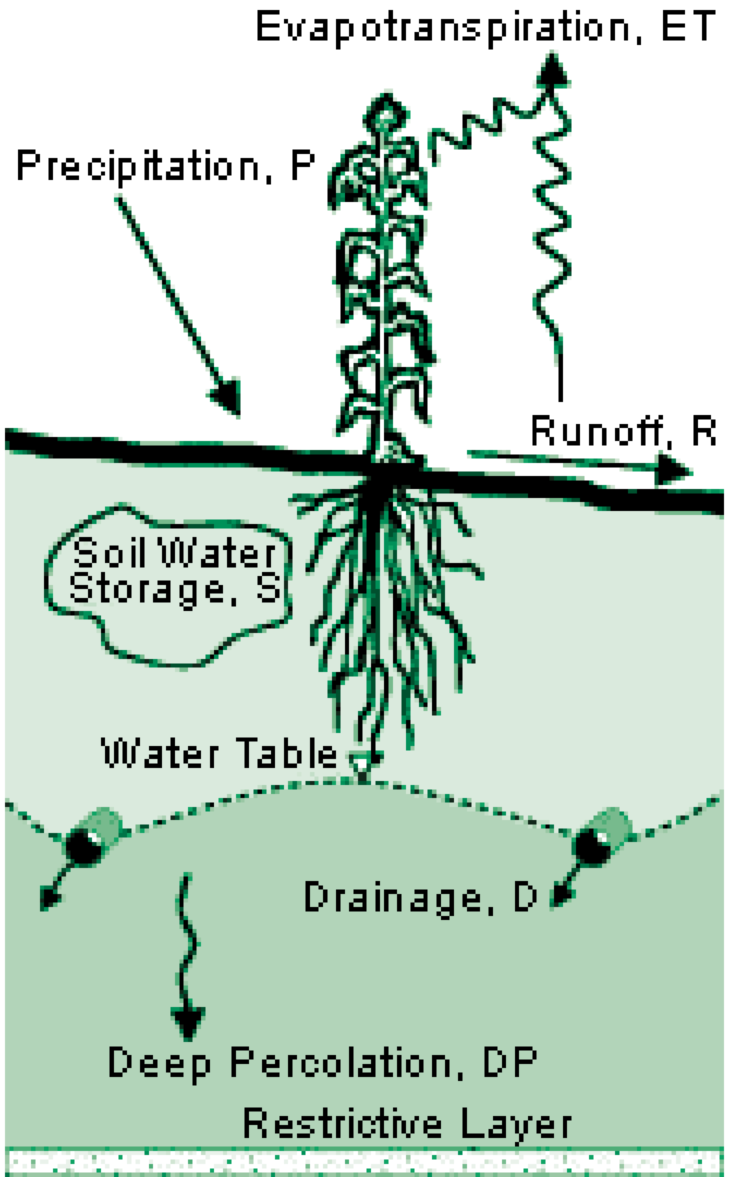
Important Functions of Organic Matter

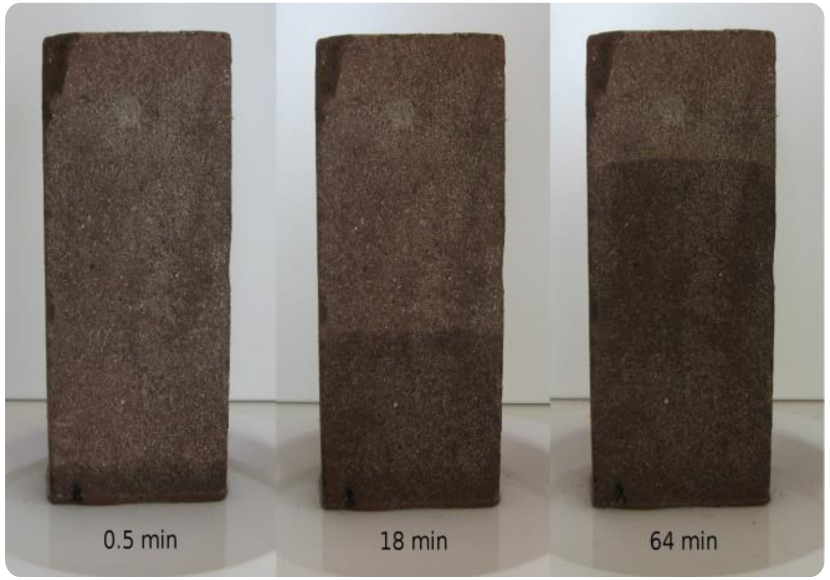
- Acts as a binding agent for mineral particles.
  - This is responsible for producing friable (easily crumbled) surface soils.
- Increases the amount of water that a soil may hold.
- Provides food for organisms that inhabit the soil.
- Humus is an integral component of organic matter because it is fairly stable and resistant to further decomposition.
  - Humus is brown or black and gives soils its dark color.
  - Like clay particles, humus is an important source of plant nutrients.

Soil water and its importance

- The presence of water is essential for plants and organisms in the soil.
- Water is necessary for the weathering of soil.
- Soil water is the medium from which all plant nutrients are assimilated by plants. Soil water contains dissolved organic and inorganic substances and transports dissolved nutrients, such as nitrogen, phosphorus, potassium, and calcium, to the plant roots for absorption.







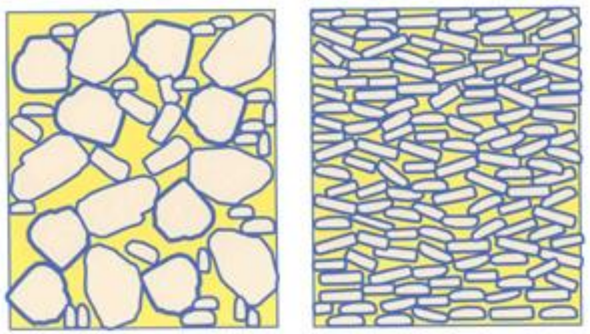
Soil water holding capacity

- Water molecules behave in two ways:
  - Cohesion Force: Because of cohesion forces, water molecules are attracted to one another.
  - Adhesion Force: This force is responsible for the attraction between water and solid surfaces.
- Water also exhibits a property of surface tension:
  - water surfaces behave like expandable films. This phenomenon is what makes it possible for certain insects to walk along water surfaces.
- Capillary Action:
  - Capillary action, also referred to as capillary motion or capillarity, is a combination of cohesion/adhesion and surface tension forces.

Pore Space

Pore space is a function of soil texture, structure and the activity of beneficial soil organisms. Water coats the solid particles and fills the smaller pore spaces. Air fills the larger pore spaces.

Comparative pore space.



Left soil with large pore space. Right soil lacking large pore space.

The quantities of large and small pore spaces directly affect plant growth. On fine-texture, clayey and/or compacted soils, a lack of large pore spaces restricts water and air infiltration and movement, thus limiting root growth and the activity of beneficial soil organisms. On sandy soils, the lack of small pore space limits the soil's ability to hold water and nutrients.

Soil Air

Soil aeration influences the availability of many nutrients.

•Since plant roots require water and oxygen (from the air in pore spaces), maintaining the balance between root and aeration and soil water availability is a critical aspect of managing crop plants.

- ❖ The oxygen is critical because it allows for respiration of both plant roots and soil organisms.
- ❖ Other natural soil gases are atmospheric methane and radon.
- ❖ Some environmental contaminants below ground produce gas which diffuses through the soil such as from landfill wastes, mining activities, and contamination by petroleum hydrocarbons which produce volatile organic compounds.

Component	Soil air (%)	Atmosphere (%)
N_2	79.2	79.0
O_2	20.6	20.9
CO_2	0.25	0.03

Source: Russel, E. J., and Appleyard, A. 1915. The atmosphere of the soil, its composition and causes of variation. *J. Agr. Sci.* 7:1–48.

Decomposition of biomass by soil microbes results in carbon loss as CO2 from the soil due to microbial respiration, while a small proportion of the original carbon is retained in the soil through the formation of humus, a product that often gives carbon-rich soils their characteristic dark color

Element	Symbol	mg/kg	percent
Nitrogen	N	15,000	1.5
Potassium	K	10,000	1.0
Calcium	Ca	5,000	0.5
Magnesium	Mg	2,000	0.2
Phosphorus	P	2,000	0.2
Sulfur	S	1,000	0.1
Chlorine	Cl	100	--
Iron	Fe	100	--
Boron	B	20	--
Manganese	Mn	50	--
Zinc	Zn	20	--
Copper	Cu	6	--
Molybdenum	Mo	0.1	--
Nickel	Ni	0.1	--

Soil Micro and macronutrients

Macronutrients: **N**, **K**, **Ca**, **Mg**, **P**, and **S**, and Micronutrients: **Cl**, **Fe**, **B**, **Mn**, **Zn**, **Cu**, **Mo**, and **Ni**

Industrial Sources of Chemical contamination

- Pesticide manufacturing industries include chemicals used as insecticides, herbicides, fungicides, rodent poisons and some other kinds of poisons.
- Sewage biosolids/sludge and fly ash, may result in the addition of heavy metals and PBTs (persistent, bioaccumulative, toxic chemicals) to soils.
- Products made from cement kiln dust may also contain heavy metals and dioxins.
- Phosphate fertilizers are known to contain some cadmium (from the rock phosphate), and manures are sometimes relatively high in copper or zinc.
- Lead Paint and High Traffic Areas
- Petroleum spills: can result in elevated levels of contaminants such as benzene, toluene, and xylene in the soil.
- Treated Lumber: Arsenic, in the form of chromated copper arsenate or CCA, has been used in wood preservatives to make pressure-treated lumber

- Furniture Refinishing: Some chemical strippers used in furniture refinishing contain methylene chloride and other solvents, including toluene and methanol.
- Landfills / Garbage Dumps:
- Fires: The intentional or accidental burning of materials can produce and release PAHs, dioxins or other chemicals into soils
- Automobile or Machine Repair: Many possible contaminants could be associated with these activities, including petroleum products, PAHs (particularly from motor oil), solvents like trichloroethylene (TCE), used tyres and rubber products, metals (used engine oil may contain chromium, lead, molybdenum, or nickel from engine wear), or used batteries (which may release lead or mercury)

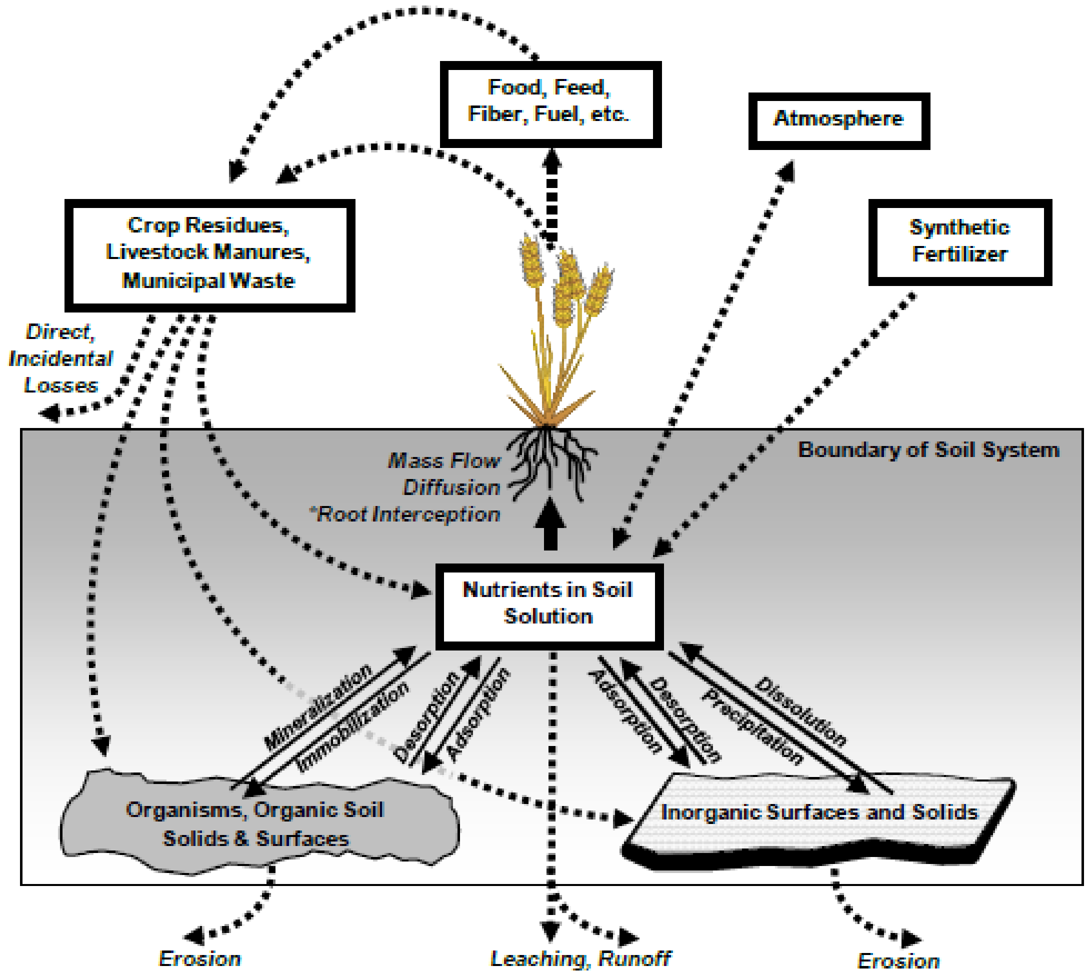
Distribution of Soil contaminants

- Some organic (carbon-based) contaminants can undergo chemical changes or degrade into products that may be more or less toxic than the original compound.
- chemical elements (such as metals) cannot break down, but their characteristics may change so that they can be more or less easily taken up by plants or animals.
- Different contaminants vary in their tendency to:
  - End up in water held in the soil or in the underlying groundwater (by leaching through the soil);
  - Volatilize (evaporate) into the air; or (eg: alpha benzo pyrene $C_{20}H_{12}$)
  - Bind tightly to the soil.

Factors affecting distribution of contaminants in soil

- ♦ Soil mineralogy and clay content (soil texture);
- ♦ pH (acidity) of the soil;
- ♦ Amount of organic matter in the soil;
- ♦ Moisture levels;
- ♦ Presence of other chemicals.

Fate of nutrients in soil



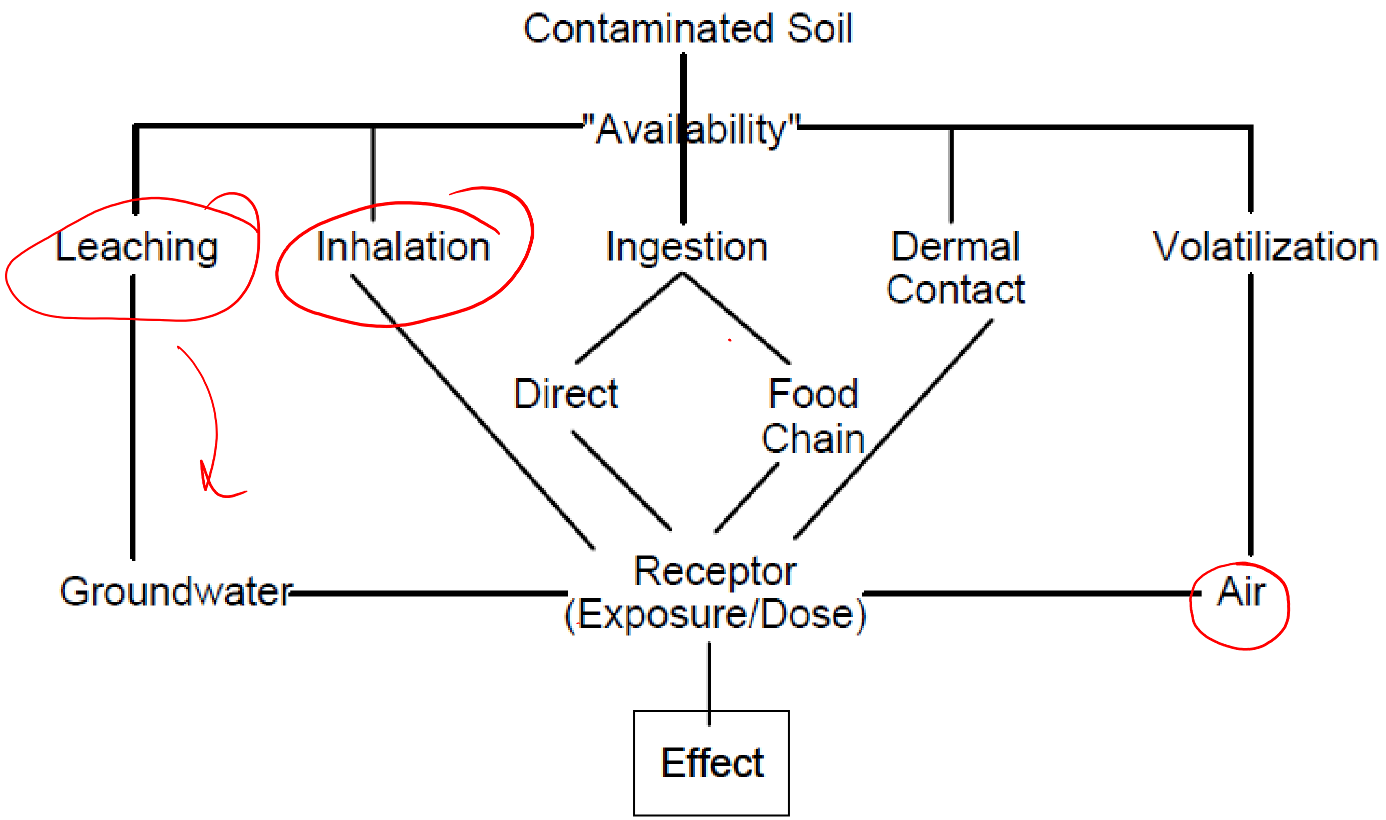
*Root interception of nutrients directly from soil surfaces and solids is generally negligible for most nutrients

Figure 2 | The nutrient cycle. Dashed lines represent nutrient gains or losses in the soil system; solid lines represent internal transformations within the soil system.

Ecological effects of Soil contamination

- Elevated levels of soil contaminants can negatively affect plant vigor, animal health, microbial processes, and overall soil health.
- Some contaminants may change plants' metabolic processes and reduce yields or cause visible damage to crops.
- Even relatively low concentrations of certain contaminants can alter soil chemistry and impact organisms that depend on the soil or plants for their nutrition and habitat.
- ***For example, legume plants are able to fix nitrogen in the soil through a symbiotic relationship with Rhizobium bacteria in their root nodules. However, these bacteria are sensitive to zinc contamination, which can disrupt the nitrogen fixation process.***

Importance of availability in determination of risk



Exposure Routes for Human Health

Various routes of exposure by which a soil-bound chemical can meet a receptor. These exposure routes include:

- Leaching to groundwater followed by ingestion of the groundwater;
- Direct inhalation;
- Soil ingestion;
- Dermal contact with the soil;
- Volatilization followed by inhalation of the air.

Diseases Caused Due To Soil Pollution

Malaria
If water is contaminated by polluted soil or vice versa, then sludge is formed. The protozoa in the sludge causes malaria. How? Mosquitoes breed in stagnant water, act as carriers of these protozoan germs and infect humans, causing a widespread outbreak of malaria. This impact of polluted soil occurs in areas where rainfall is heavy and where sewage water gets mixed with the soil.

Cholera and Dysentery
When polluted soil seeps into ground water, it contaminates reservoirs of drinking water as well. So there an outbreak of water-borne diseases like cholera and dysentery.

Skin and Stomach Infections
Soil can enter the body if it collects in one's fingernails. Green leafy vegetables and underground vegetables (the main part of the plant grows below the soil) can have residue and particles of soil struck to them. If washed improperly (or not at all), the soil will enter the human body. Germs present in this ingested soil can cause amoebiosis or acute stomach infection.

- **Brain and Nerve Damage**
- Children can be exposed to the harmful effects of soil pollution in places like playgrounds and parks, where lead-contaminated soil has been proven to cause brain and neuromuscular development problems.
- **Soil pollution affects neuromuscular development in children.**
- **Cancer**

Most pesticides and fertilizers contain benzene, chromium and other chemicals, which are carcinogens (chemicals that cause cancer). Consumption of such contaminated crops decreases the production of red blood cells, white blood cells and antibodies in the blood, thus affecting the body's immunity.

Kidney and Liver Disease

When chemicals like mercury and cyclodienes are present in the soil, they enter a living being's body through food grown on such soil. These persistent pollutants can cause irreparable damage to the kidneys and liver

Control measures of soil pollution

- Soil erosion can be controlled by a variety of forestry and farm practices. Ex: Planting trees on barren slopes Contour cultivation and strip cropping may be practiced instead of shifting cultivation Terracing and building diversion channels may be undertaken. Reducing deforestation and substituting chemical manures by animal wastes also helps arrest soil erosion in the long term.
- Proper dumping of unwanted materials: Excess wastes by man and animals pose a disposal problem. Open dumping is the most commonly practiced technique. Nowadays, controlled tipping is followed for solid waste disposal. The surface so obtained is used for housing or sports field.
- Production of natural fertilizers: Bio-pesticides should be used in place of toxic chemical pesticides. Organic fertilizers should be used in place of synthesized chemical fertilizers. Ex: Organic wastes in animal dung may be used to prepare compost manure instead of throwing them wastefully and polluting the soil.
- Proper hygienic condition: People should be trained regarding sanitary habits. Ex: Lavatories should be equipped with quick and effective disposal methods.
- Public awareness: Informal and formal public awareness programs should be imparted to educate people on health hazards by environmental education. Ex: Mass media, Educational institutions and voluntary agencies can achieve this.
- Recycling and Reuse of wastes: To minimize soil pollution, the wastes such as paper, plastics, metals, glasses, organics, petroleum products and industrial effluents etc should be recycled and reused. Ex: Industrial wastes should be properly treated at source. Integrated waste treatment methods should be adopted.
- Ban on Toxic chemicals: Ban should be imposed on chemicals and pesticides like DDT, BHC, etc which are fatal to plants and animals. Nuclear explosions and improper disposal of radioactive wastes should be banned.

What are Wastes?

Waste (also known as **rubbish**, **trash**, **refuse**, **garbage**, **junk**, **litter**, and **ort**) is unwanted or useless materials. In biology, waste is any of the many unwanted substances or toxins that are expelled from living organisms, metabolic waste; such as urea and sweat.

Basel Convention Definition of Wastes (22nd March, 1989)

"substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of the law"

Disposal means

"any operation which may lead to resource recovery, recycling, reclamation, direct re-use or alternative uses (Annex IVB of the Basel convention)"

Kinds of Wastes

Solid wastes: wastes in solid forms, domestic, commercial and industrial wastes

- Examples: *plastics, Styrofoam containers, bottles, cans, papers, scrap iron, and other trash*

Liquid Wastes: wastes in liquid form

- Examples: *domestic washings, chemicals, oils, wastewater from ponds, manufacturing industries and other sources*

Classification of Wastes according to their Properties

Bio-degradable

can be degraded (paper, wood, fruits and others)

Non-biodegradable

cannot be degraded (plastics, bottles, old machines,cans, styrofoam containers and others)

Classification of Wastes according to their Effects on Human Health and the Environment

Hazardous wastes

Substances unsafe to use commercially, industrially, agriculturally, or economically and have any of the following properties- ignitability, corrosivity, reactivity & toxicity.

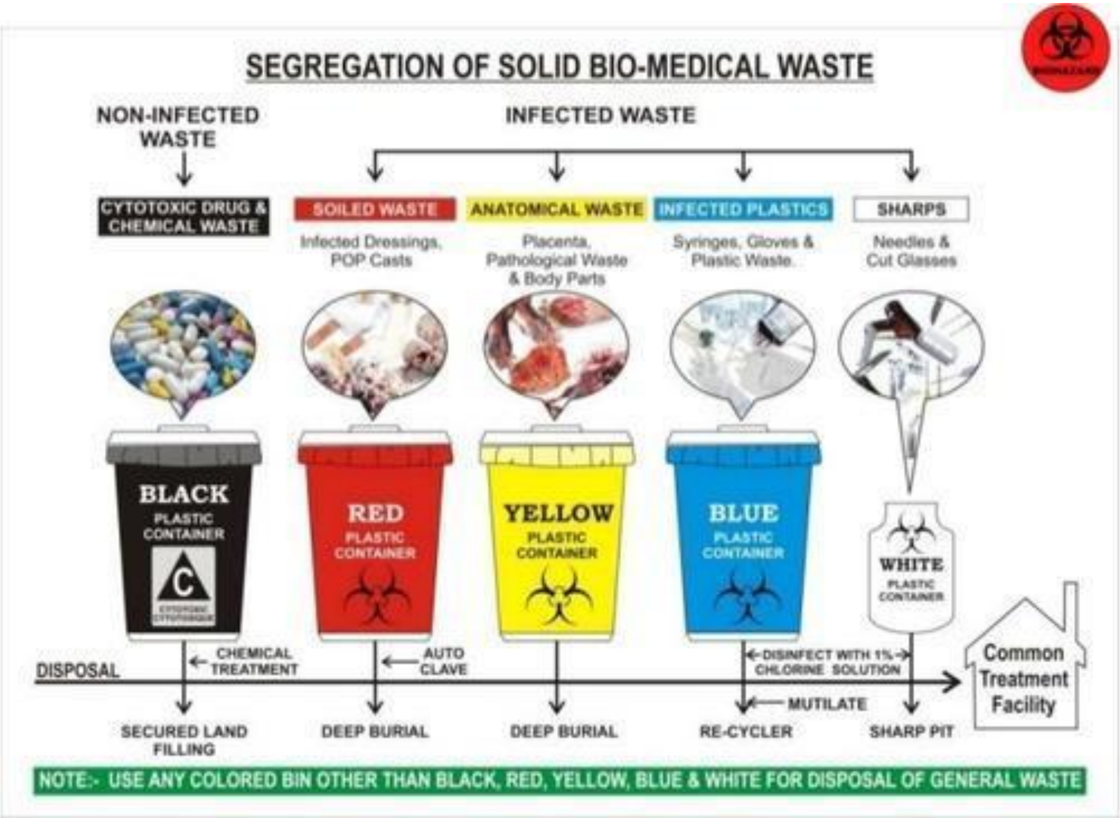
Non-hazardous

Substances safe to use commercially, industrially, agriculturally, or economically and do not have any of those properties mentioned above. These substances usually create disposal problems.

Classification of wastes according to their origin and type

- **Municipal Solid wastes:** Solid wastes that include household garbage, rubbish, construction & demolition debris, sanitation residues, packaging materials, trade refuges etc. are managed by any municipality.
- **Bio-medical wastes:** Solid or liquid wastes including containers, intermediate or end products generated during diagnosis, treatment & research activities of medical sciences.
- **Industrial wastes:** Liquid and solid wastes that are generated by manufacturing & processing units of various industries like chemical, petroleum, coal, metal gas, sanitary & paper etc.
- **Agricultural wastes:** Wastes generated from farming activities. These substances are mostly biodegradable.
- **Fishery wastes:** Wastes generated due to fishery activities. These are extensively found in coastal & estuarine areas.
- **Radioactive wastes:** Waste containing radioactive materials. Usually these are byproducts of nuclear processes. Sometimes industries that are not directly involved in nuclear activities, may also produce some radioactive wastes, e.g. radio-isotopes, chemical sludge etc.
- **E-wastes:** Electronic wastes generated from any modern establishments. They may be described as discarded electrical or electronic devices. Some electronic scrap components, such as CRTs, may contain contaminants such as Pb, Cd, Be or brominated flame retardants.

Biomedical waste



CATEGORIES OF BIO MEDICAL WASTE

OPTION	WASTE CATEGORY	TREATMENT & DISPOSAL
Category No. 1	Human Anatomical Waste	Incineration / deep burial
Category No. 2	Animal Waste	Incineration / deep burial
Category No. 3	Microbiology & Biotechnology Waste	Local autoclaving / microwaving / incineration
Category No. 4	Waste Sharps	Disinfection by chemical treatmet / atoclaving / microwaving and mutilation / shredding
Category No. 5	Discarded Medicines and Cytoxic drugs	Incineration / destruction and drugs disposal in secured landfills
Category No. 6	Solid Waste	Incineration / autoclaving / microwaving
Category No. 7	Solid Waste	Disinfection by chemical treatment / autoclaving / microwaving and mutilation / shredding
Category No. 8	Liquid Waste	Disinfection by chemical treatment and discharge into drains.
Category No. 9	Incineration Ash	Disposal in municipal landfill
Category No. 10	Chemical Waste	Chemical treatment and discharge into drains for liquids and secured land for solids

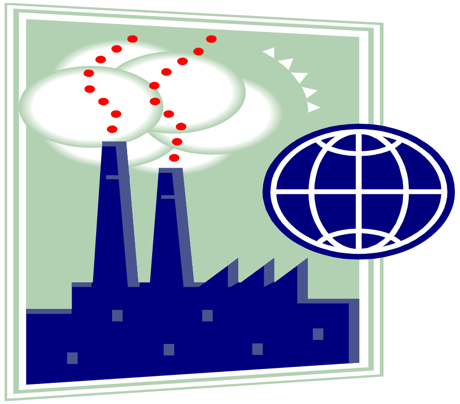
Source: Bio-medical Waste Management Rules, 1998, Schedule I.

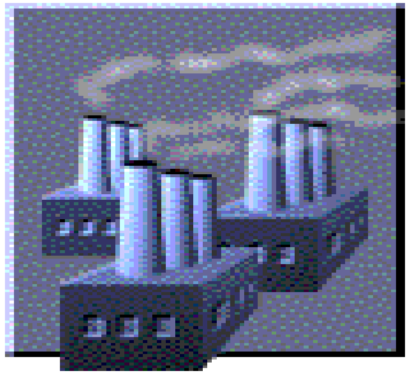
Biomedical waste management

- Who deals with Bio-medical wastes in India?
- Central Pollution Control Board has been following up with all SPCBs/PCCs to ensure effective management of biomedical waste in States/UTs.
- Collection and disposal
- The collection and disposal is treated and disposed as per the specified methods of disposal prescribed under Schedule I of the Rules.
- Bio-medical waste generated from the hospitals shall be treated and disposed by Common Bio-medical Waste Treatment and Disposal Facility.
- In case there is no common facility in the reach of a healthcare facility, then such healthcare facility should install captive treatment and disposal facility.
- There are 200 authorized Common Bio-medical Waste Treatment and Disposal Facilities (CBWTFs) in 28 States for environmentally safe disposal of biomedical waste.
- Remaining 7 States namely Goa, Andaman Nicobar, Arunachal Pradesh, Lakshadweep, Mizoram, Nagaland and Sikkim do not have CBWTFs.
- Categorization
- As informed by CPCB and as per Bio-medical Waste Management Rules, 2016, Bio-medical waste is required to be segregated in 4 color coded waste categories.
- Common methods of treatment and disposal of bio-medical waste are by incineration/plasma pyrolysis/deep-burial for Yellow Category waste;
- Autoclaving/microwaving/chemical disinfection for Red Category waste;
- Sterilization and shredding, disinfection followed by burial in concrete pit/recycling through foundry/encapsulation for White Category sharps waste; and
- Washing, disinfection followed by recycling for Blue Category glass waste.

Sources of Wastes

Households





Commerce and Industry

MAGNITUDE OF PROBLEM: Indian scenario

- **Per capita waste generation increasing by 1.3% per annum**
- **With urban population increasing between 3 – 3.5% per annum**
- **Yearly increase in waste generation is around 5% annually**
- **India produces more than 42.0 million tons of municipal solid waste annually.**
- **Per capita generation of waste varies from 200 gm to 600 gm per capita / day. Average generation rate at 0.4 kg per capita per day in 0.1 million plus towns.**

MSW GENERATION FROM THE METROPOLITANS OF INDIA

State/Union Territory	*City*	*Urban Population in Lakhs (2001)*	*MSW generated (MT/day)*
Andhra Pradesh	Hyderabad	3829753	957
Andhra Pradesh	Visakhapatnam	982904	246
Bihar	Patna	1961532	588
Delhi	New Delhi	350000	272
Delhi	Delhi	13363471	6000
Gujarat	Ahmedabad	4215497	1265
Gujarat	Surat City	2433835	730
Gujarat	Vadodara	1491045	447
Karnataka	Bangalore	1304008	326
Kerala	Kochi	275225	69
Maharashtra	Mumbai	11914398	7500
Maharashtra	Nagpur	2040175	700
Maharashtra	Pune	2540000	1000
Madhya Pradesh	Bhopal	1482718	445
Madhya Pradesh	Indore	1550880	465
Punjab	Ludhiana	1429709	500
Rajasthan	Jaipur	1870771	561
Tamil Nadu	Chennai	4343645	1086
Tamil Nadu	Coimbatore	1501373	375
Tamil Nadu	Madurai	1233083	308
Uttar Pradesh	Kanpur	2725207	954
Uttar Pradesh	Lucknow	2262369	792
Uttar Pradesh	Varanasi	1250039	438
West Bengal	Kolkata	4572876	1143
Grand Total	-	70924513	27167

Solid Waste in India

- 7.2 million tonnes of hazardous waste
- One Sq km of additional landfill area every-year
- Rs 1600 crore for treatment & disposal of these wastes
- In addition to this industries discharge about 150 million tonnes of high volume low hazard waste every year, which is mostly dumped on open low lying land areas.

Growth of Solid Waste In India

- Waste is growing by leaps & bounds
- In 1981-91, population of Mumbai increased from 8.2 million to 12.3 million
- During the same period, municipal solid waste has grown from 3200 tonnes to 5355 tonne, an increase of 67%
- City like Bangalore produces 2000 tonnes of waste per annum.
- Waste collection is very low for all Indian cities.

IMPACTS OF WASTE IF NOT MANAGED WISELY

- Affects our health
- Affects our socio-economic conditions
- Affects our coastal and marine environment
- Affects our climate

- GHGs are accumulating in Earth's atmosphere as a result of human activities, causing global mean surface air temperature and subsurface ocean temperature to rise.
- Rising global temperatures are expected to raise sea levels and change precipitation and other local climate conditions.
- Changing regional climates could alter forests, crop yields, and water supplies.
- This could also affect human health, animals, and many types of ecosystems.
- Deserts might expand into existing rangelands, and features of some of our national parks might be permanently altered.

IMPACTS OF WASTE…

- Some countries are expected to become warmer, although sulfates might limit warming in some areas.

- Scientists are unable to determine which parts of those countries will become wetter or drier, but there is likely to be an overall trend toward increased precipitation and evaporation, more intense rainstorms, and drier soils.

- Whether rainfall increases, or decreases cannot be reliably projected for specific areas.

Impacts of waste….

- **Activities that have altered the chemical composition of the atmosphere:**

- **Buildup of GHGs primarily carbon dioxide (CO_2) methane (CH_4), and nitrous oxide (N_20).**

- **$C0_2$ is released to the atmosphere by the burning of fossil fuels, wood and wood products, and solid waste.**

- **CH_4 is emitted from the decomposition of organic wastes in landfills, the raising of livestock, and the production and transport of coal, natural gas, and oil.**

- **$N0_2$ is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels. In 1977, the US emitted about one-fifth of total global GHGs.**

CATEGORIES OF WASTE DISPOSAL

1. **DILUTE AND DISPERSE**

(ATTENUATION)

→

Throw it in the river / lake / sea

Burn it

Basically this involves spreading trash thinly over a large area to minimize its impact

Works for sewage, some waste chemicals, when land-disposal is not available

[**Plastic in Pacific**]

2. CONCENTRATE AND CONTAIN

(ISOLATION)

→ Waste dumps, landfills

Historically, that’s how most of the solid waste gets treated

Impacts of waste on health

- Chemical poisoning through chemical inhalation
- Uncollected waste can obstruct the storm water runoff resulting in flood
- Low birth weight
- Cancer
- Congenital malformations
- Neurological disease

Impacts of waste on health

- Nausea and vomiting
- Increase in hospitalization of diabetic residents living near hazard waste sites.
- Mercury toxicity from eating fish with high levels of mercury.

Effects of waste on animals and aquatics life

INCREASE IN MERCURY LEVEL IN FISH DUE TO DISPOSAL OF MERCURY IN THE RIVERS.

PLASTIC FOUND IN OCEANS INGESTED BY BIRDS.

RESULTED IN HIGH ALGAL POPULATION IN RIVERS AND SEA.

DEGRADES WATER AND SOIL QUALITY.

Impacts of waste on Environment

- Waste breaks down in landfills to form methane, a potent greenhouse gas
- Change in climate and destruction of ozone layer due to waste biodegradable
- Littering, due to waste pollutions, illegal dumping, Leaching: is a process by which solid waste enter soil and ground water and contaminating them.

- **It is estimated that food wasted by the US and Europe could feed the world three times over. Food waste contributes to excess consumption of freshwater and fossil fuels which, along with methane and CO_2 emissions from decomposing food, impacts global climate change. Every tonne of food waste prevented has the potential to save 4.2 tonnes of CO_2 equivalent. If we all stop wasting food that could have been eaten, the CO_2 impact would be the equivalent of taking one in four cars off the road.**

Waste Characteristics

In order to identify the exact characteristics of municipal wastes, it is necessary that we analyse them using physical and chemical parameters.

Physical Characteristics

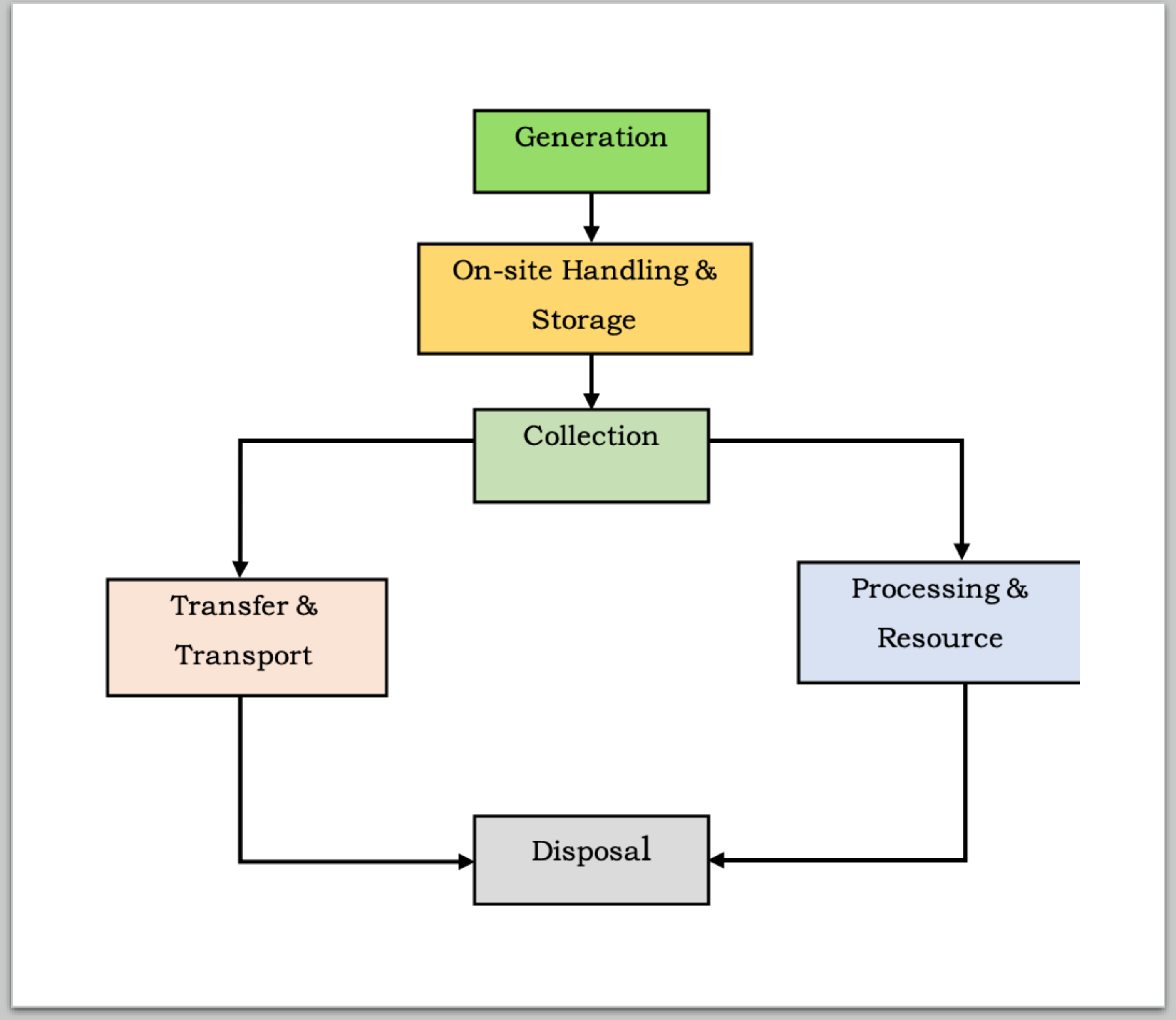
Chemical Characteristics

Chemical Characteristics

- Proximate analysis
- Fusing point of ash
- Ultimate analysis
- Energy content

Physical Characteristics

Density/Specific weight	Color
Moisture content	Voids
Particle size	Shape of components
Size distribution	Optical property
Field capacity	Magnetic properties
Compacted waste porosity	Electric properties



Functional elements of solid waste management

Waste collection

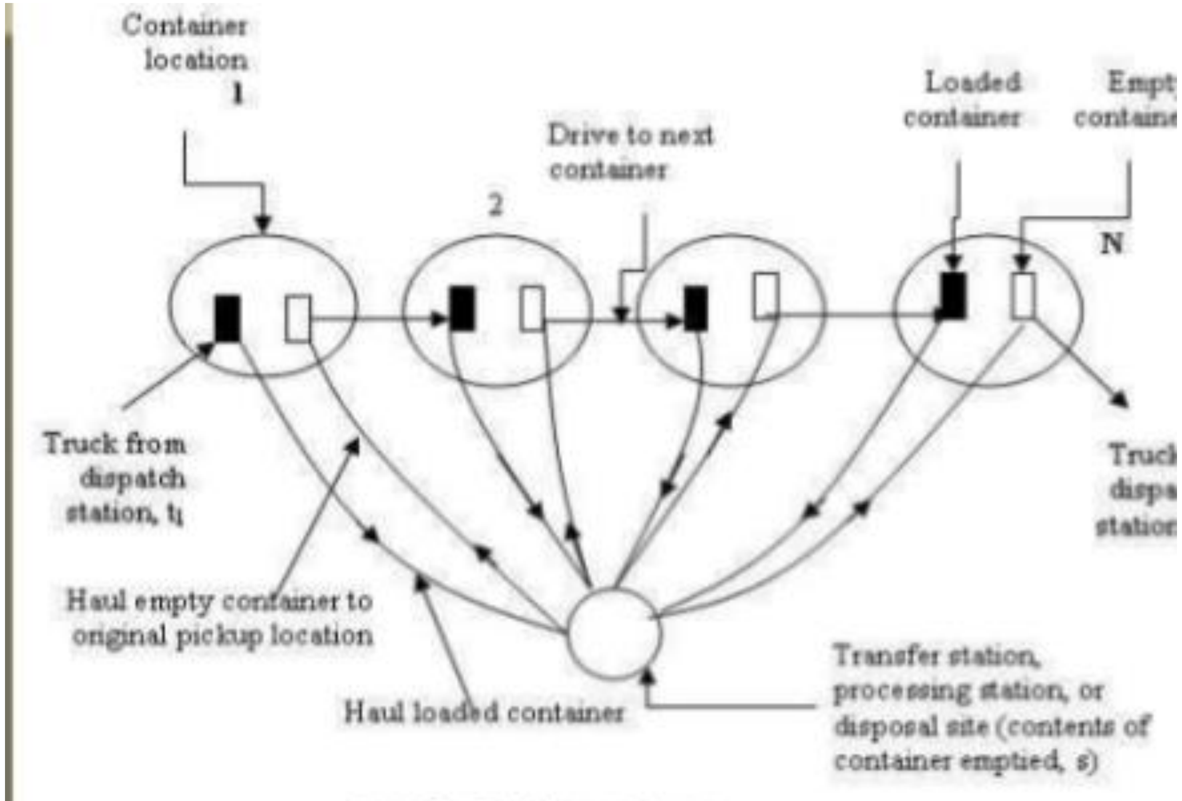
Types of Collection Systems

- Based on the mode of operation, collection systems are classified into two categories: **hauled-container systems and stationary-container systems.**

HCS

Hauled Container Systems

- **Collection system in which the containers used for the storage of waste are hauled to the processing, transfer, or disposal site, emptied, and returned to either their original location or some other location are defined as hauled-container system.**
- **There are two main types of container Tilt-frame Container, and Trash-Trailer.** The collector is responsible for driving the vehicles, loading full container and unloading empty containers, and emptying the contents of the container at the disposal site. In some cases, for safety reasons, both a driver and helper are used.

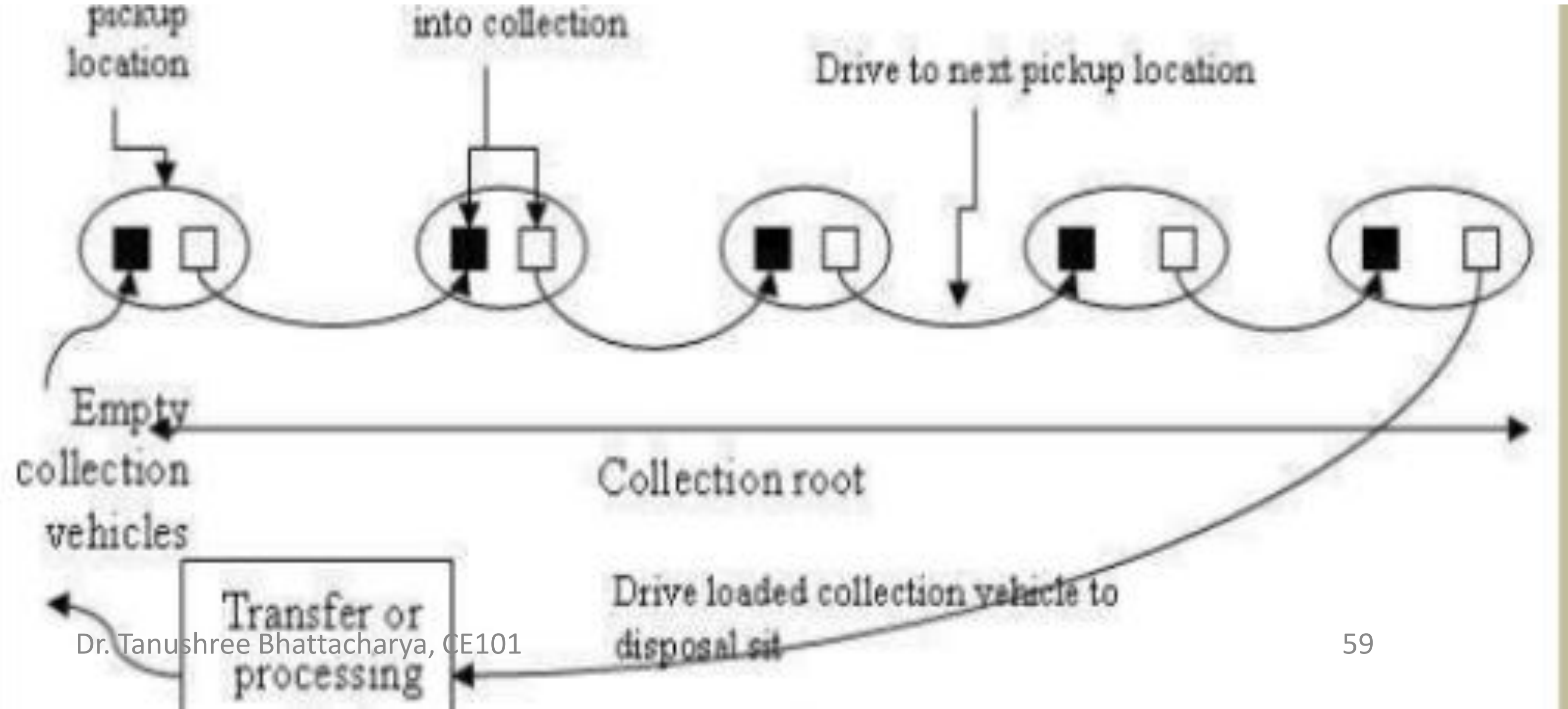


(a) Hauled container.

SCS

Stationary-Container System (SCS)

- **Collection systems in which the containers used for the storage of wastes remain at the point of waste generation, except when moved for collection are defined as stationary-container systems.** There are two main types of stationary-container system:
- **(1) Those in which self-loading compactors are used and**
- **(2) Those in which manual loaded vehicles are used.**



Equations to calculate time requirement

Hauled Containers

- An empty storage container (known as a drop-off box) is hauled to the storage site to replace the container that is full of waste, which is then hauled to the processing point, transfer station or disposal site
- The time required per trip

  $T_{hcs} = (PT_{hcs} + q + m + nx)$ (4.1)

  Where,

  T = time per trip for hauled-container system, h/trip hcs

  PT_{hcs}= pick-up time per trip for hauled-container system, h/trip

  q = at-site time per trip, h/trip

  m = empirical haul constant, h/km

  n = empirical haul constant, h/km

  x = round-trip haul distance, km/trip

Stationary Container System

$$Tscs = \frac{(Pscs + s + a + bx)}{(1-w)}$$

- ➢ The only difference between Thcs & Tscs is Pick up time.
- ➢ For Stationary Container System pick up time is

$$Pscs = C_t (Uc) + (n_p - 1)(dbc) \quad \text{where}$$

C_t = number of container emptied per trip, container / trip

Uc = Ave. unloading time per container for SCS, h/container

np = Number of container pick up locations, locations/trip

dbc = Ave. time spent driving b/w containers locations, h/location

Collection vehicles

- Primary collection
- Secondary collection

Robust vehicles



No. of collection vehicle needed

Number of collection vehicles needed for a community may be determined from below equation:

$$N = \frac{S*F}{X*W}$$

Where:

N = Number of collection vehicles needed.

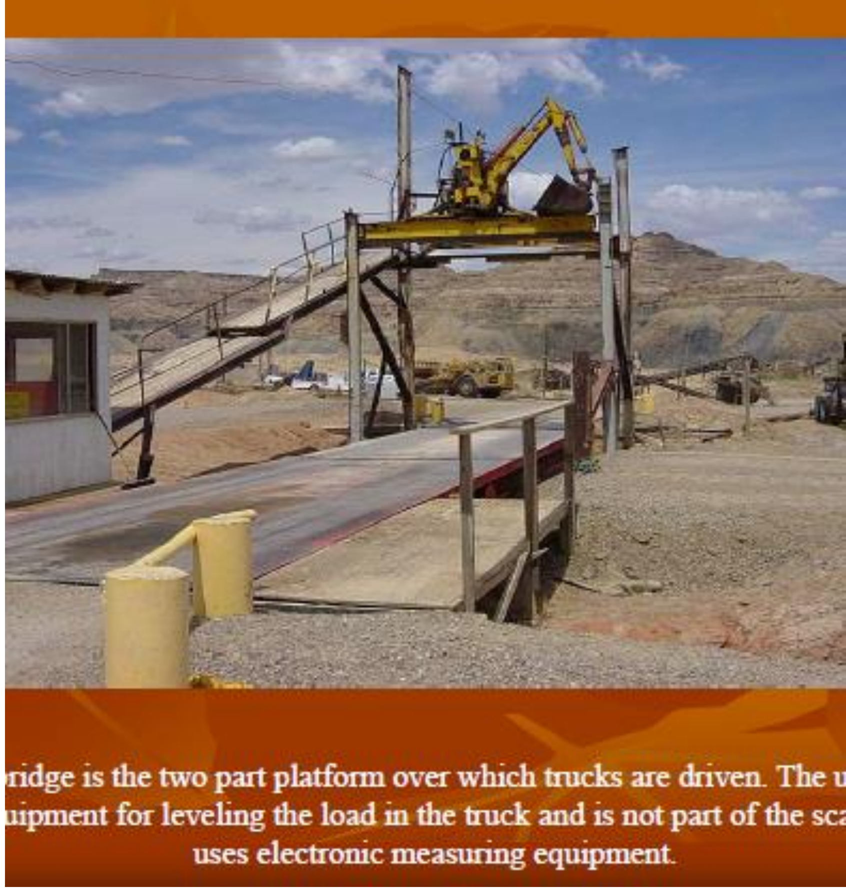
S = Total number of customers serviced.

F = Collection frequency, number of collections per week.

X = Number of customers a single truck can service per day.

W = Number of workdays per week.

Calculate the number of collection vehicles a community would need if it has 4000
services (customers) that are to be collected once per week during working days in
a city in Iraq. (Realistically, most trucks can service only about 200 to 300
customers before the truck is full and a trip to the landfill is necessary).
Solution
1) Given:
N = Number of collection vehicles needed
S = Total number of customers serviced = 4000
F = Collection frequency, number of collections per week = 1
X = Number of customers a single truck can service per day (A single truck can
service 300 customers in a single day and still have time to take the full loads to
the landfill) = 300.
2) W = Number of workdays per week (The town wants to collect on Saturday,
Sunday, Monday, and Tuesdays leaving Wednesdays for special projects and truck
maintenance) = 4 days.
3) Thus: N = SF/XW = (4000 *1)/(300*4) = 3.3
4) The community will need four trucks.



TRANSFER AND TRANSPORT

Collection Services For Solid Wastes

- **Municipal Collection Service**
- **Although a variety of collection services are available the three most common are curb, alley and backyard collection**. Curb collection has gained popularity because labour costs for collection can be minimized. In the future, it appears that the use of large container which can be emptied mechanically with an articulated container pickup mechanism will be the most common method used for the collection of municipal wastes.
- **Curb Service. The house owner is responsible for placing the solid waste containers at the curb on the scheduled day. The workmen come, collect and empty the container and put back at the curb**. The house owner is required to take back the empty containers from the curb to his house.
- **Alley Service. The containers are placed at the alley line from where they are picked up by workmen from refuse vehicle who deposit back the empty container**.

Curb Service

Alley Service

Kerbside / Alley Collection Method:

Collection , segregation at site

Collection, Segregation and Storage at the Site of Collection

- **The best way would have been the segregation of waste at the generation point. Segregation means collecting it in different bins, or plastic bags**. The domestic waste can be broadly separated as reusable (paper, plastic, metal etc.), and non reusable. **The non reusable may have organic matter like kitchen waste or inorganic matter like dust, dirt etc. The organic matter is liable to decomposition (putrescible) and thus requires immediate attention.**

Collection, Segregation and Storage at the Site of Collection

- **This separated waste should be regularly collected by the worker directly from the houses at some well defined time**. Then it should be transported in (covered vehicles)to some waste collection depots for utilization/transportation to different sites. **The organic waste can be used for the production of biogas or for the extraction of energy, incineration (controlled burning or making organic compost, and vermi-composting.**

Transfer and transport

- A transfer station is a building or processing site for the temporary deposition of waste. Transfer stations are often used as places where local waste collection vehicles will deposit their waste cargo prior to loading into larger vehicles.
- Typical activities at the waste transfer station involved the unloading of garbage trucks, pre-screening and removal of inappropriate items such as automobile batteries, compacting and then reloading onto larger vehicles, including trucks, trains and barges to their final destination.

Types of transfer station

Simple transfer station.

Mechanically loaded transfer station.

Badly managed transfer station can lead to environmental problems

Key Benefits of transfer stations

- The transfer station is a key component of cost-effective solid waste transportation. By transferring waste from local collection vehicles onto larger trailers or other transport modes such as barge and rail, the cost of transportation to distant disposal sites can be significantly reduced, freeing collection-specific vehicles and crews to devote their time to actual collection activities. Here are some of the main benefits:
- Provides fuel savings, reduction in road wear and less air pollution due to fewer vehicles being on the road
- Provides a trash and recyclable material drop-off location for citizens
- Reduces total traffic congestion in the community by transferring it onto larger vehicles
- Reduces total truck traffic and improves safety at the landfill or waste-to-energy facility
- Provides the opportunity to screen incoming trash for such purposes as removing hazardous waste or recovering recyclables

Planning the route for waste collection vehicles

For any urban location, there is likely to be a number of transfer stations distributed around the town. The waste will need collecting from all these stations as well as directly from businesses, institutions and some households. In most locations, there is only one site for final treatment and disposal, to which the waste must be transported, and this is usually situated at the edge of the town. It is important to plan the routes for the waste collection vehicle (or vehicles) to make the best use of the resources available. This keeps costs down and gives people the best-possible service. Route planning is a complex operation, but the basic process consists of three stages:

1. Identifying the pickup points and the likely amounts of waste to be collected from each point.
2. Grouping pickup points to form ‘collection rounds’ that can be served by a single collection vehicle.
3. Planning the route of each collection round taking account of the distance travelled, traffic levels and safety to the public and the waste collectors.

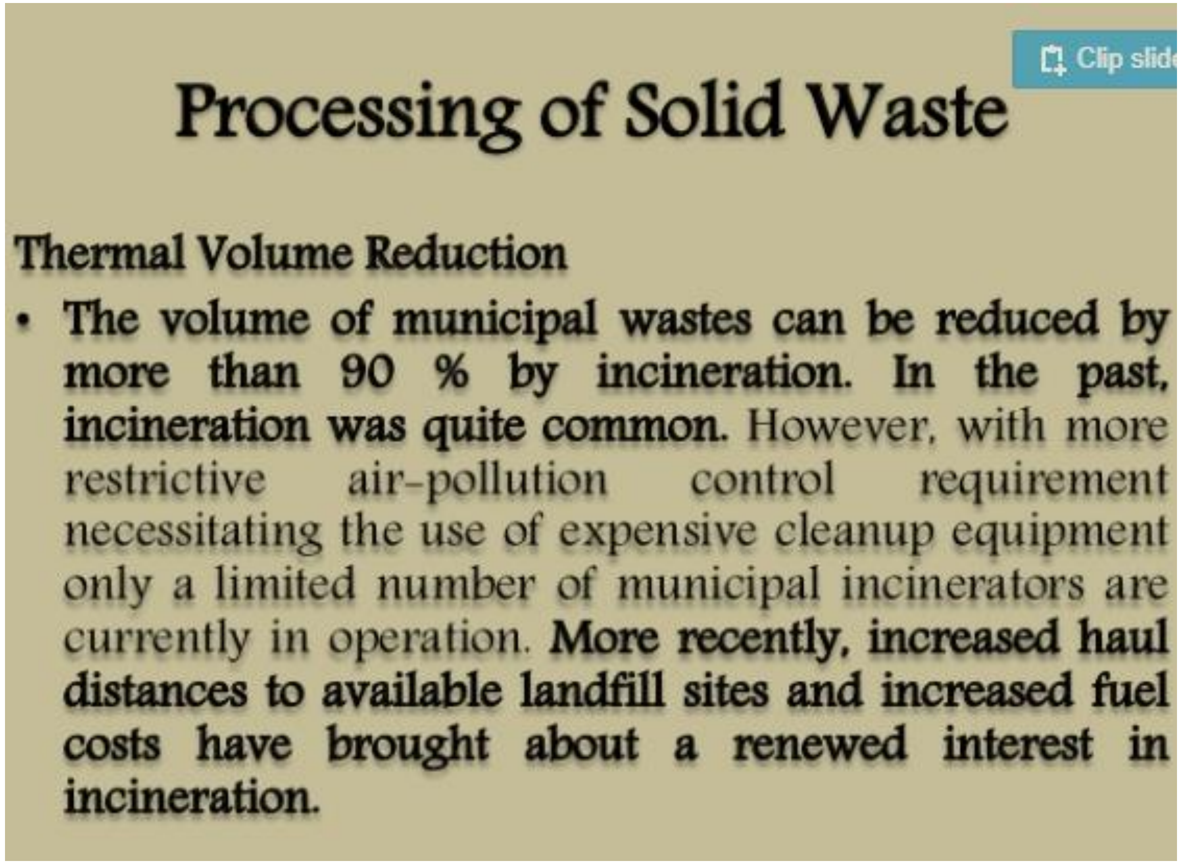
PROCESSING

Processing of Solid Waste

- Processing techniques are used in solid waste management systems to **(1) improve the efficiency of solid-Waste disposal systems (2) To recover Resources and (3) To prepare materials for the recovery of conversion products and energy**.
- **Mechanical Volume Reduction**
- **Mechanical Volume Reduction is perhaps the most important factor in development and operation of solid-waste management systems. Vehicles equipped with compaction mechanisms are used for the collection of most municipal solid wastes.** To increase the life of landfills, wastes are compacted. Paper for recycling is baled for shipping to processing centres.

Mechanical Volume Reduction

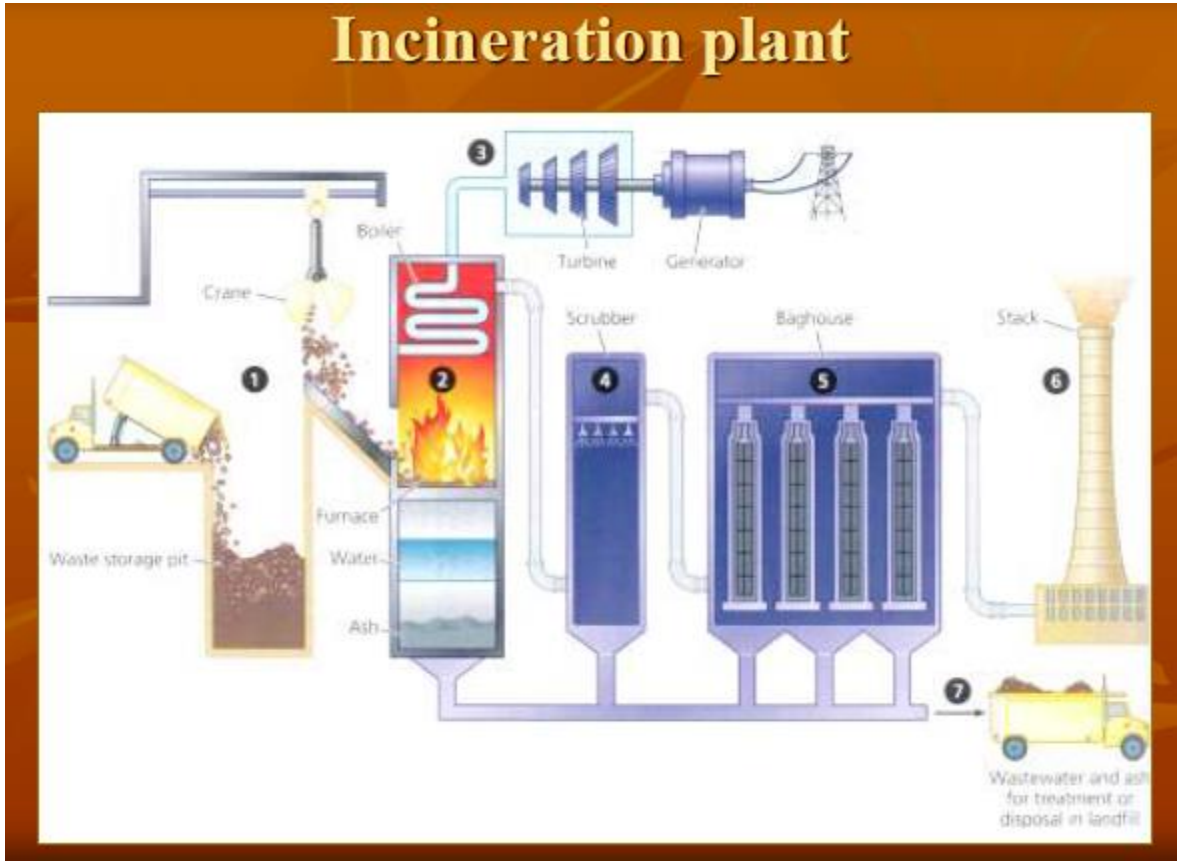
INCINERATION



Processing of Solid Waste

Thermal Volume Reduction

- **The volume of municipal wastes can be reduced by more than 90 % by incineration. In the past, incineration was quite common.** However, with more restrictive air-pollution control requirement necessitating the use of expensive cleanup equipment only a limited number of municipal incinerators are currently in operation. **More recently, increased haul distances to available landfill sites and increased fuel costs have brought about a renewed interest in incineration.**



Advantages and disadvantages of incineration

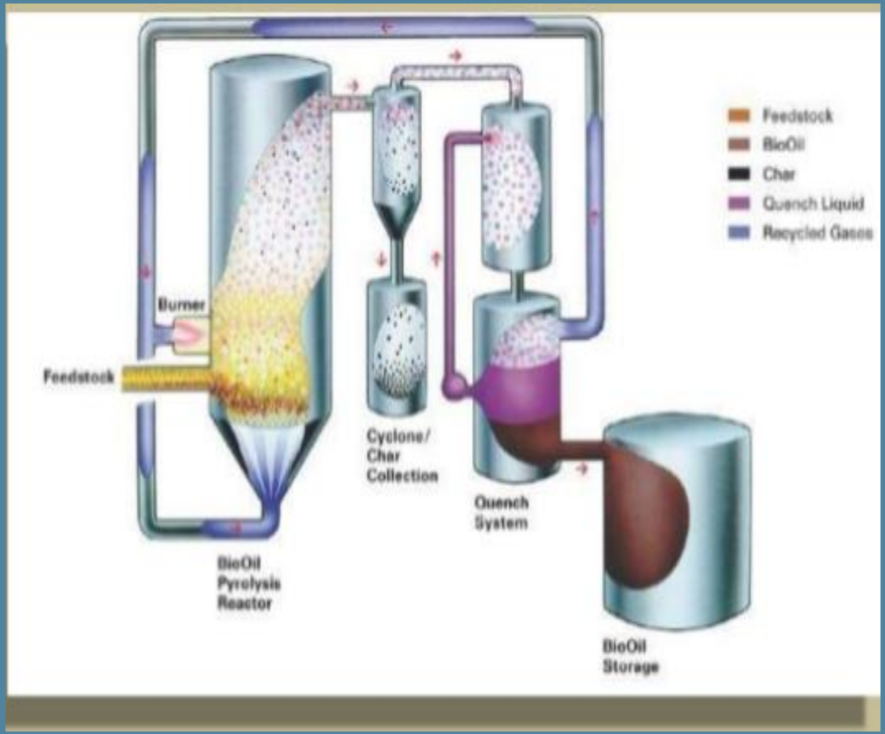
ADVANTAGES

- Minimum of land is needed compared to other disposal methods.
- The weight of the waste is reduced to 25% of the initial value.
- No risk of polluting local streams and ground waters as in landfills.
- Incineration plants can be located close to residential areas.
- Gases are used to generate power.

DISADVANTAGES

- Expensive
- Required skilled labour.
- The chemicals that would be released into the air could be strong pollutants and may destroy ozone layer (major disadvantage).
- high energy requirement.

PYROLYSIS



Pyrolysis

- It is defined as heating the solid waste at very high temperature in absence of air.
- Pyrolysis is carried out at a temperature between 500 ^{0} C to 1000 ^{0}C to produce three component streams.
- Gas: It is a mixture of combustible gases such as hydrogen, carbon dioxide, methane, carbon mono-oxide and some hydrocarbons.
- Liquid: It contains tar, pitch, light oil, and low boiling organic chemicals like acetic acid, acetone, methanol etc.
- Char: It consists of elemental carbon along with inert material in the waste feed.
- The char liquid and gases have high calorific values.
- It has been observed that even after supplying the heat necessary for pyrolysis, certain amount of excess heat still remains which can be commercially exploited.

COMPOSTING

Compost

Compost is organic matter that has been decomposed and recycled as a fertilizer and soil amendment. Compost is a key ingredient in organic farming. At its most essential, the process of composting requires simply piling up waste outdoors and waiting for the materials to break down from anywhere between 5-6 weeks or even more.

Modern, methodical composting is a multi-step, closely monitored process with measured inputs of water, air and carbon- and nitrogen-rich materials. The decomposition process is aided by shredding the plant matter, adding water and ensuring proper aeration by regularly turning the mixture. Worms and fungi further break up the material.

Aerobic bacteria manage the chemical process by converting the inputs into heat, carbon dioxide and ammonium. The ammonium is further converted by bacteria into plant-nourishing nitrites and nitrates through the process of nitrification.

Compost can be rich in nutrients. It is used in gardens, landscaping, and agriculture. The compost itself is beneficial for the land in many ways, including as a soil conditioner, a fertilizer, addition of vital humus or humic acids, and as a natural pesticide for soil.

In ecosystems, compost is useful for erosion control, land and stream reclamation, wetland construction, and as landfill cover. Organic ingredients intended for composting can alternatively be used to generate biogas through anaerobic digestion.

Anaerobic digestion is fast overtaking composting in some parts of the world including central Europe as a primary means of downcycling waste organic matter.

COMPOSTING


Composting
Composting organisms require four equally important things to work effectively:
Carbon — for energy; the microbial oxidation of carbon produces the heat, if included at suggested levels.
High carbon materials tend to be brown and dry.
Nitrogen — to grow and reproduce more organisms to oxidize the carbon.
High nitrogen materials tend to be green (or colorful, such as fruits and vegetables) and wet.[7]
Oxygen — for oxidizing the carbon, the decomposition process.
Water — in the right amounts to maintain activity without causing anaerobic conditions.
ost pile that is steaming with the
ted by thermophilic microorganisms.

INDORE METHOD FOR COMPOSTING

Indore Method of Composting

- **Indore Method of Composting:**
- In this method solid waste night soil and animal dung etc. are placed in brick lined pits 3 m x 3 m x 1 m deep in alternate layers of 7.5 to 10 cm height, till the total height becomes 1.5 m. Chemical insecticides are added to prevent fly breeding. The material is turned regularly for a period of **about 8 to 12 weeks and then stored on ground for 4 to 6 weeks. In about 6 to 8 turnings and period of 4 months time compost becomes ready for use as manure.** Insecticide used in Indore method was DDT but now because of very high half life of DDT in nature other suitable insecticide is recommended, e.g. Gamaxine.

Bangalore Method

- The solid waste is stabilized anaerobically. Earthen trenches of size 10 x 1.5 x 1.5 m deep are filled up in alternate layers of solid waste and night soil/cow dung. The material is converse with 15 cm earthen layer and left for biodegradation. **In about 4-5 months the compost becomes ready to use, normally a city produces 200 to 250 kg/capita/year of refuse** and 8 to 10 kg / capita/year of night soil.

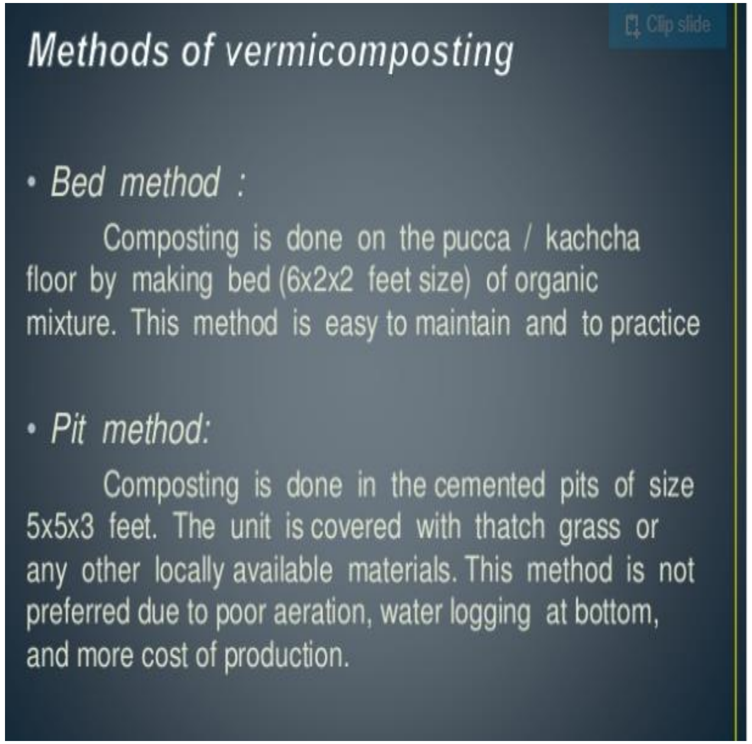
Vermicomposting

- Vermicompost (vermi-compost) is the product of the decomposition process using various species of worms, usually red wigglers, white worms, and other earthworms, to create a mixture of decomposing vegetable or food waste, bedding materials, and vermicast.

Biological advantages	In many soils, these play major role in converting large pieces of organic matter into rich humus and thus improving soil fertility
Burrowing activities	The earthworm is of great value in keeping soil structure open, creating multitude of channels that allow processes of both aeration and drainage to occur
Earthworm castings	In home garden, the presence of earthworm castings provide 5 to 11 times more nitrogen, phosphorous, and potassium as the surrounding soil
Secretions in intestinal tracts of earthworms	This help in making nutrients more concentrated as well as readily available for plant uptake including micro nutrients


Red earthworm is preferred because of its high multiplication rate and thereby converts the organic matter into vermicompost within 45-50 days.
Since it is a surface feeder it converts organic materials into vermicompost from top.


Species of earthworms
Eisenia foetida (Red earthworm), *Eudrilus eugeniae* (night crawler), *Perionyx excavatus* etc.


Clip slide
Methods of vermicomposting
• Bed method :
Composting is done on the pucca / kachcha floor by making bed (6x2x2 feet size) of organic mixture. This method is easy to maintain and to practice
• Pit method:
Composting is done in the cemented pits of size 5x5x3 feet. The unit is covered with thatch grass or any other locally available materials. This method is not preferred due to poor aeration, water logging at bottom, and more cost of production.

Phases of Vermicomposting

Phase 1	:	**Processing involving collection of wastes, shredding, mechanical separation of the metal, glass and ceramics and storage of organic wastes.**
Phase 2	:	Pre digestion of organic waste for twenty days by heaping the material along with cattle dung slurry. This process partially digests the material and fit for earthworm consumption. Cattle dung and biogas slurry may be used after drying. Wet dung should not be used for vermicompost production.
Phase 3	:	Preparation of earthworm bed. A concrete base is required to put the waste for vermicompost preparation. Loose soil will allow the worms to go into soil and also while watering, all the dissolvable nutrients go into the soil along with water.
Phase 4	:	Collection of earthworm after vermicompost collection. Sieving the composted material to separate fully composted material. The partially composted material will be again put into vermicompost bed.
Phase 5	:	Storing the vermicompost in proper place to maintain moisture and allow the beneficial microorganisms to grow.

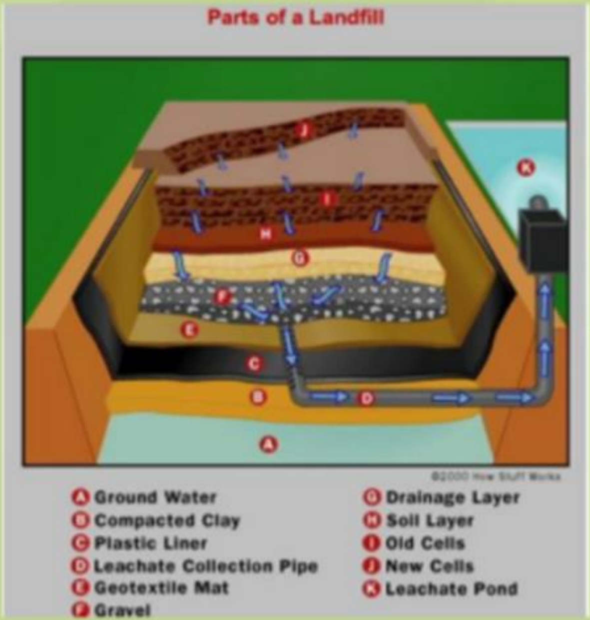
DISPOSAL-LANDFILLING

What is a Sanitary Landfill

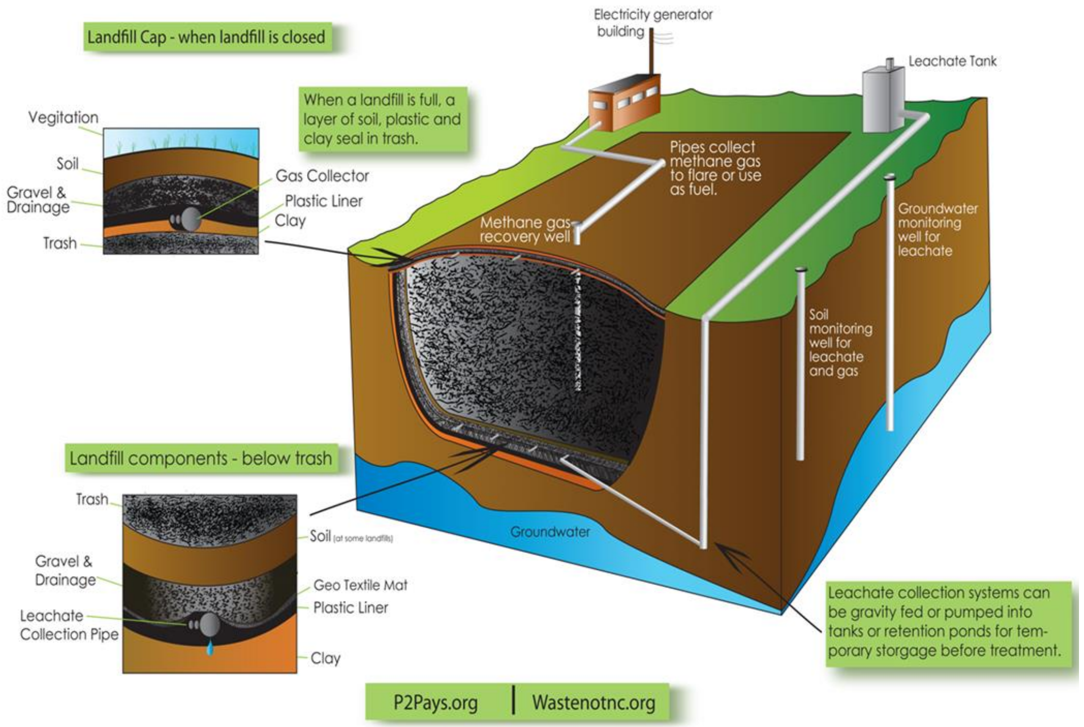
- A sanitary land fill is a waste disposal location where layers of compressed garbage is covered with layers of earth. When the facility reaches the end of its life and is full, a cap is used to close the top of site. Sanitary land fills are among the most popular methods for disposing of waste, although they have some serious disadvantages.

Parts of a Sanitary Landfill

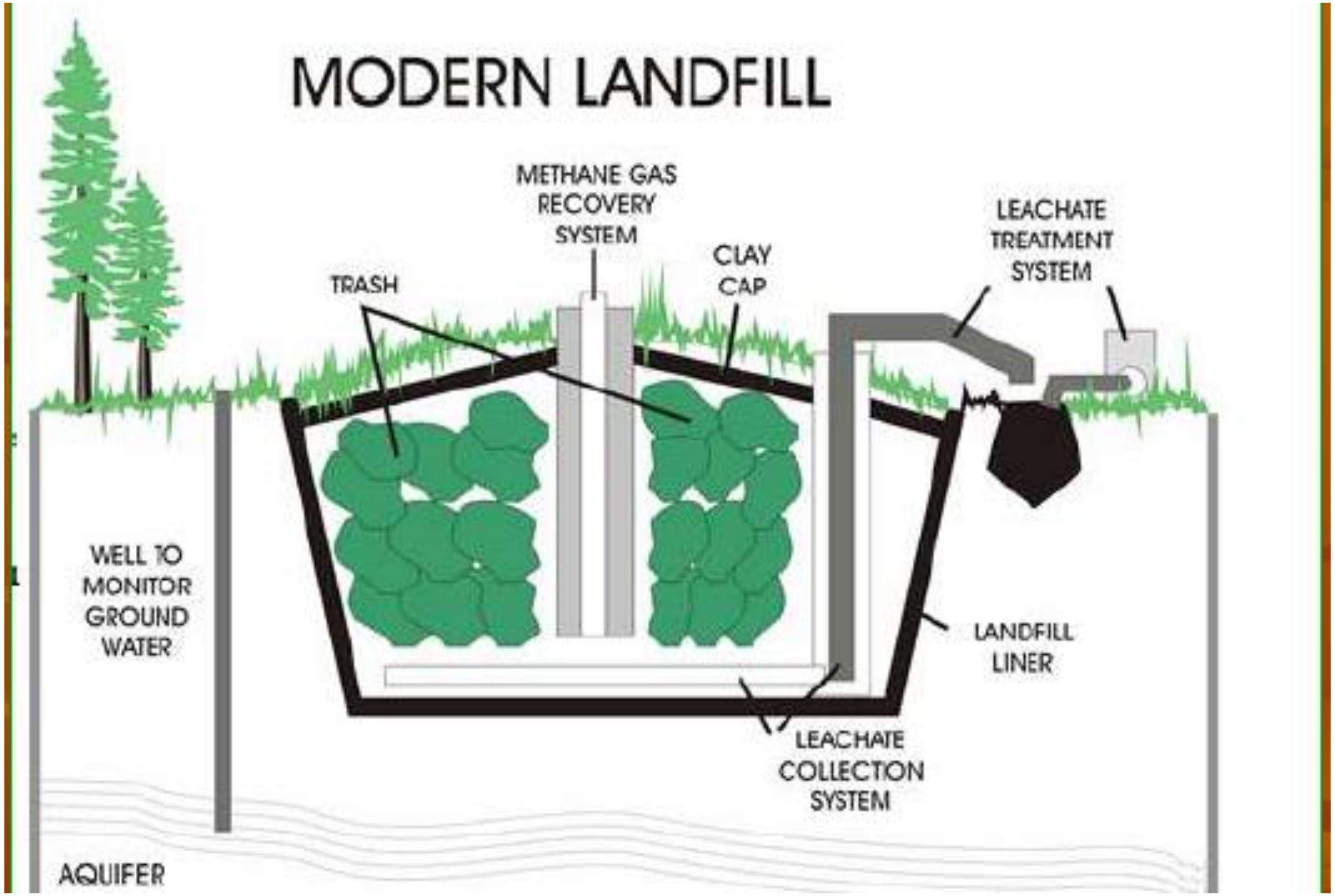
- **Bottom liner system** - separates trash and subsequent leachate from groundwater
- **Cells (old and new)** - where the trash is stored within the landfill
- **Storm water drainage system** - collects rain water that falls on the landfill
- **Leachate collection system** - collects water that has percolated through the landfill itself and contains contaminating substances (**leachate**)
- **Methane collection system** - collects methane gas that is formed during the breakdown of trash
- **Covering or cap** - seals off the top of the landfill



Parts of a Municipal Solid Waste Landfill



LANDFILL



MODERN LANDFILL
METHANE GAS RECOVERY SYSTEM
LEACHATE TREATMENT SYSTEM
CLAY CAP
TRASH
WELL TO MONITOR GROUND WATER
LANDFILL LINER
LEACHATE COLLECTON SYSTEM
AQUIFER

Stages of decomposition in landfills

- **Phase I**: Initial adjustment phase - This phase is associated with initial placement of solid waste and accumulation of moisture within landfills. An acclimation period (or initial lag time) is observed until sufficient moisture develops and supports an active microbial community. Preliminary changes in environmental components occur in order to create favourable conditions for biochemical decomposition.
- **Phase II**: Transition phase - In the transition phase, the field capacity is sometimes exceeded, and a transformation from an aerobic to anaerobic environment occurs, as evidenced by the depletion of oxygen trapped within a landfill media.
- **Phase III**: Acid formation phase - The continuous hydrolysis (solubilization) of solid waste, followed by the microbial conversion of biodegradable organic content results in the production of intermediate short chain carboxylic acids at high concentrations throughout this phase. A decrease in pH values is often observed. Viable biomass growth associated with the acid formers (acidogenic bacteria), and rapid consumption of substrate and nutrients are the predominant features of this phase. The leachate contains a high chemical oxygen demand (COD) that is attributable to carboxylic acids. Because these acids are biodegradable, **the highest BOD and COD concentrations in the leachate will be measured during this phase .**
- **Phase IV**: Methane fermentation phase - During Phase IV, intermediate acids are consumed by methanogenic bacteria and converted into methane and carbon dioxide. Sulphate and nitrate are reduced to sulphides and ammonia, respectively. The pH value is elevated, being controlled by the bicarbonate buffering system, and consequently supports the growth of methanogenic bacteria. Heavy metals are removed by complexation and precipitation. Carboxylic acid concentrations decrease **with corresponding decreases in the leachate COD and BOD.**
- **Phase V**: Maturation phase - During the final state of landfill stabilization, nutrients and available substrate become limiting, and the biological activity shifts to relative dormancy. Gas production drops dramatically and leachate strength stays steady at much lower concentrations. Reappearance of oxygen and oxidized species may be observed slowly. However, the slow degradation of resistant organic fractions. In this phase the BOD/COD is relatively low because dissolved organic matter that is degradable is consumed as rapidly as it is produced.

Major chemical reactions of different phases

Hydrolysis

- Equation 1 : $C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_2$

Fermentation/Acidogenesis

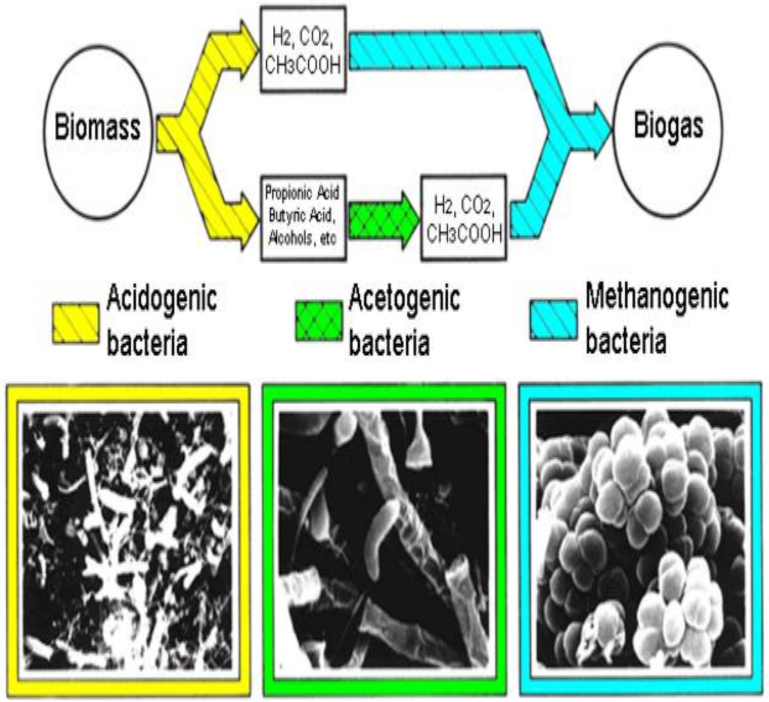
Equation 2 : $C_6H_{12}O_6 \leftrightarrow 2CH_3CH_2OH + 2CO_2$
Equation 3 : $C_6H_{12}O_6 + 2H_2 \leftrightarrow 2CH_3CH_2COOH + 2H_2O$
Equation 4 : $C_6H_{12}O_6 \rightarrow 3CH_3COOH$

Acetogenesis

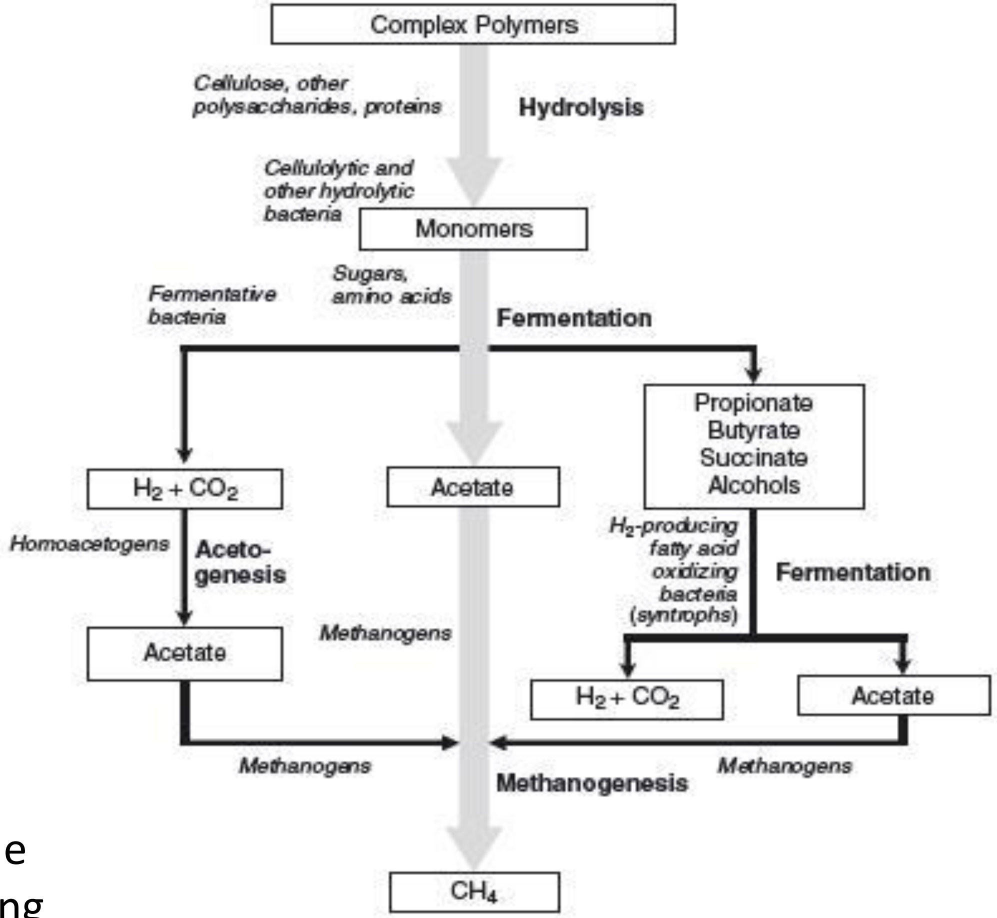
Equation 5 : $CH_3CH_2COO^- + 3H_2O \leftrightarrow CH_3COO^- + H^+ + HCO_3^- + 3H_2$
Equation 6 : $C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2CO_2 + 4H_2$
Equation 7 : $CH_3CH_2OH + 2H_2O \leftrightarrow CH_3COO^- + 2H_2 + H^+$

Methanogenesis

Equation 8 : $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
Equation 9 : $2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$
Equation 10 : $CH_3COOH \rightarrow CH_4 + CO_2$

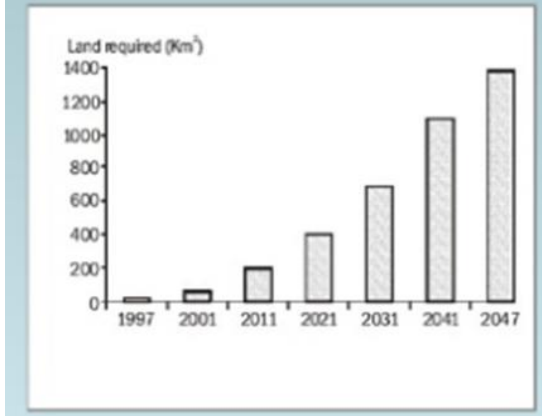


Schematic representation of the course of anaerobic methane generation from complex organic substances showing scanning electron micrographs of individual microorganisms involved

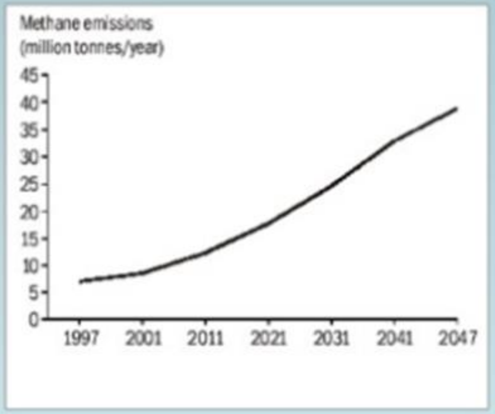


Overall process of anaerobic decomposition

Advantages and disadvantages



LAND REQUIRED FOR DISPOSAL OF MSW



EMMISION OF METHANE FROM LANDFILL

ADVANTAGES

- Landfill site is a cheap waste disposal option for the local council.
- Jobs will be created for local people.
- Lots of different types of waste can be disposed of by landfill in comparison to other waste disposal methods.
- The gases given off by the landfill site could be collected and used for generating power.

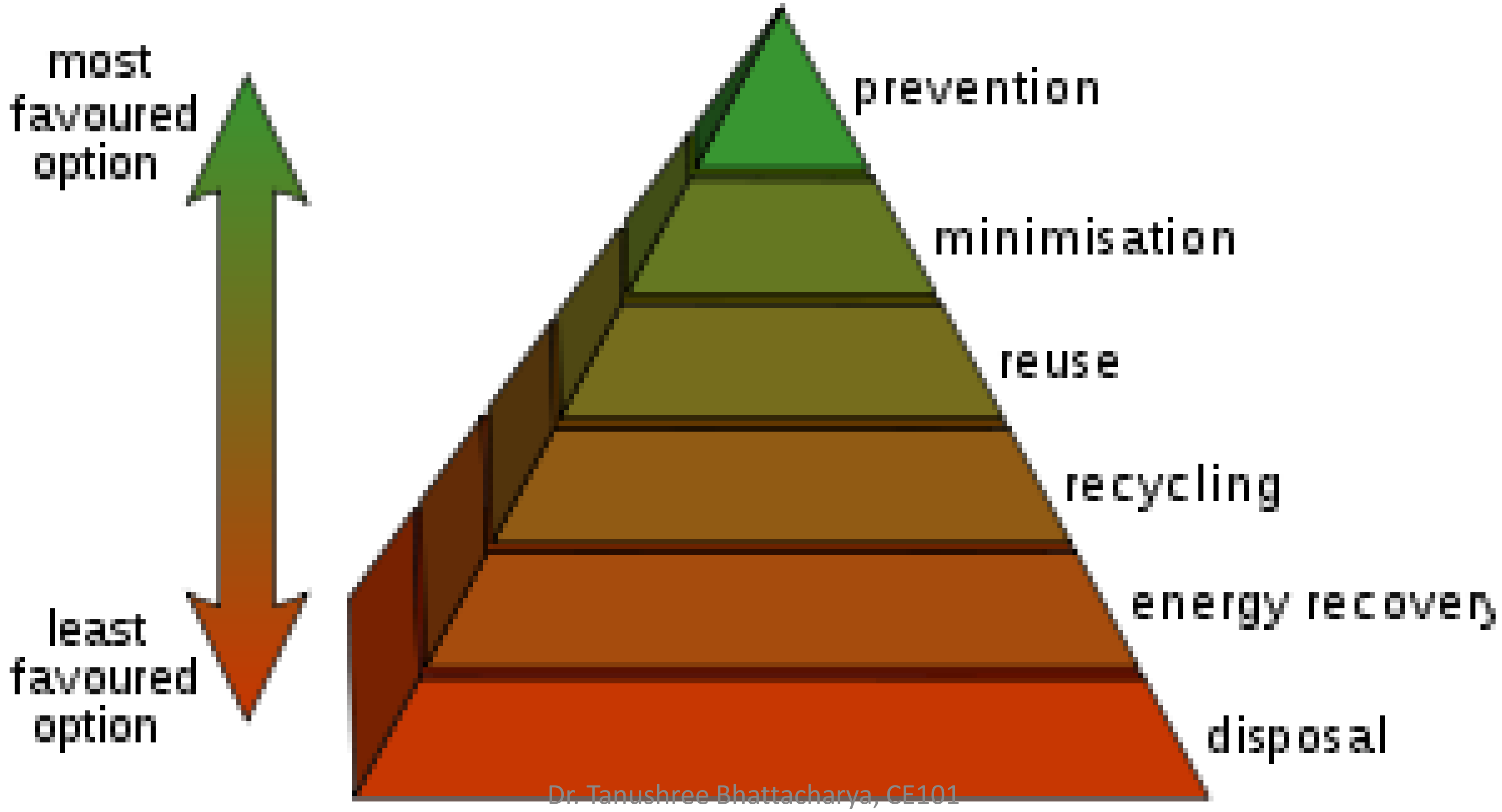
DISADVANTAGES

- The site will look ugly while it is being used for landfill.
- Dangerous gases are given off from landfill sites that cause local air pollution and contribute to global warming.
- Local streams could become polluted with toxins seeping through the ground from the landfill site.
- Once the site has been filled it might not be able to be used for redevelopment as it might be too polluted.

Waste hierarchy

Waste hierarchy refers to 3 Rs

Reduce, Reuse, Recycle



- Resource recovery
- Composting
- Vermicomposting

- Energy recovery
- Incineration
- Pyrolysis
- Gasification
- Bio-methanation or anaerobic digestion

WASTE MANAGEMENT 3R CONCEPT

- The **waste hierarchy** refers to the 3 (or 4) R's of **reduce, reuse, recycle, (recovery)** which classify waste management strategies according to their desirability.
- The R's are meant to be a hierarchy, in order of importance. However in Europe the waste hierarchy has 5 steps: reduce, reuse, recycle, recovery, and disposal.
- **The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.**

Some waste management experts have recently incorporated a additional R: "Re-think", that effective system of waste management may need an entirely new way of looking at waste.

- *Source reduction* involves efforts to reduce hazardous waste and other materials by modifying industrial production.
- Source reduction methods involve changes in manufacturing technology, raw material inputs, and product formulation.
- At times, the term "pollution prevention" may refer to source reduction.

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REDUCE

Waste minimisation is the process and the policy of reducing the amount of waste produced by a person or a society.

Waste minimisation involves efforts to minimise resource and energy use during manufacture. For the same commercial output, usually the fewer materials are used, the less waste is produced.

Waste minimisation usually requires knowledge of the production process, cradle-to-grave (now *cradle-to-cradle*) analysis - the tracking of materials from their extraction to their return to earth (start a new cycle) and detailed knowledge of the composition of the waste.

The main sources of waste vary from country to country. In the UK, most waste comes from the construction and demolition of buildings, followed by mining, industry and commerce. Household waste constitutes a relatively small proportion of all waste.

In the waste hierarchy, the most effective approaches to managing waste are at the top. In contrast to waste minimisation, waste management focuses on processing waste after it is created, concentrating on re-use, recycling, and waste-to-energy conversion.

REDUCE

In industries, using more efficient manufacturing processes and better materials will generally reduce the production of waste. The application of waste minimisation techniques has led to the development of innovative and commercially successful replacement products. Waste minimisation has proven benefits to industry and the wider environment.

Waste minimisation often requires investment, which is usually compensated by the savings. However, waste reduction in one part of the production process may create waste production in another part.

There are government incentives for waste minimisation, which focus on the environmental benefits of adopting waste minimisation strategies.

REDUCE

RESOURCE OPTIMISATION - Minimising the amount of waste produced by organisations or individuals goes hand-in-hand with optimising their use of raw materials. For example, a dressmaker may arrange pattern pieces on a length of fabric in a particular way to enable the garment to be cut out from the smallest area of fabric.

REUSE OF SCRAPS MATERIAL - Scraps can be immediately re-incorporated at the beginning of the manufacturing line so that they do not become a waste product. Many industries routinely do this; for example, paper mills return any damaged rolls to the beginning of the production line, and in the manufacture of plastic items, off-cuts and scrap are re-incorporated into new products.

IMPROVED QUALITY CONTROL AND PROCESS MONITORING - Steps can be taken to ensure that the number of reject batches is kept to a minimum. This is achieved by increasing the frequency of inspection and the number of points of inspection. For example, installing automated continuous monitoring equipment can help to identify production problems at an early stage.

WASTE EXCHANGES - This is where the waste product of one process becomes the raw material for a second process. Waste exchanges represent another way of reducing waste disposal volumes for waste that cannot be eliminated.

SHIP TO POINT OF USE - This involves making deliveries of incoming raw materials or components direct to the point where they are assembled or used in the manufacturing process to minimise handling and the use of protective wrappings or enclosures.

REUSE

To reuse is to use an item more than once. This includes conventional reuse where the item is used again for the same function, and new-life reuse where it is used for a different function. In contrast, recycling is the breaking down of the used item into raw materials which are used to make new items.

By taking useful products and exchanging them, without reprocessing, reuse help save time, money, energy, and resources. In broader economic terms, reuse offers quality products to people and organizations with limited means, while generating jobs and business activity that contribute to the economy.

Historically, financial motivation was one of the main drivers of reuse. In the developing world this driver can lead to very high levels of reuse,

However rising wages and consequent consumer demand for the convenience of disposable products has made the reuse of low value items such as packaging uneconomic in richer countries, leading to the demise of many reuse programs.

Current environmental awareness is gradually changing attitudes and regulations, such as the new packaging regulations, are gradually beginning to reverse the situation.

One example of conventional reuse is the doorstep delivery of milk in refillable bottles; other examples include the retreading of tires and the use of returnable/reusable plastic boxes, shipping containers, instead of single-use corrugated (*rievots*) fiberboard boxes.

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An electric wire reel reused as a center table in a Rio de Janeiro fair

Tires, bottles and cans as building materials


RECYCLING
Publicity photo for US aluminium salvage campaign in 1942
Papier
Recycling and rubbish bin in
a railway station, Germany
SZKŁO
SZKŁO
Early sorting of recyclable materials: glass and plastic bottles in Poland
WASTE NOT THE WASTE
Sign at Tamil Nandi, India

ENVIRONMENTAL EFFECTS OF RECYCLING

Material	Energy savings	Air pollution savings
Aluminium	95 %	95 %
Cardboard	24 %	—
Glass	5 - 30 %	20 %
Paper	40 %	73 %
Plastics	70 %	—
Steel	60 %	—

E-waste in India

- According to United Nations' "Global E-waste Monitor", 2017:

- Globally, 44.7 million metric tonnes of e-waste was generated in 2016 and only 20% was recycled through appropriate channels. China was the top e-waste producer in the world, generating 7.2 Mt.
- India generated about 2Mt of electronic waste in 2016. According to the report, India's electronics industry is one of the world's fastest growing industries and plays an "important role" in the domestic generation of e-waste. The report also highlighted the issue of imports of electronic waste to India from developed countries.

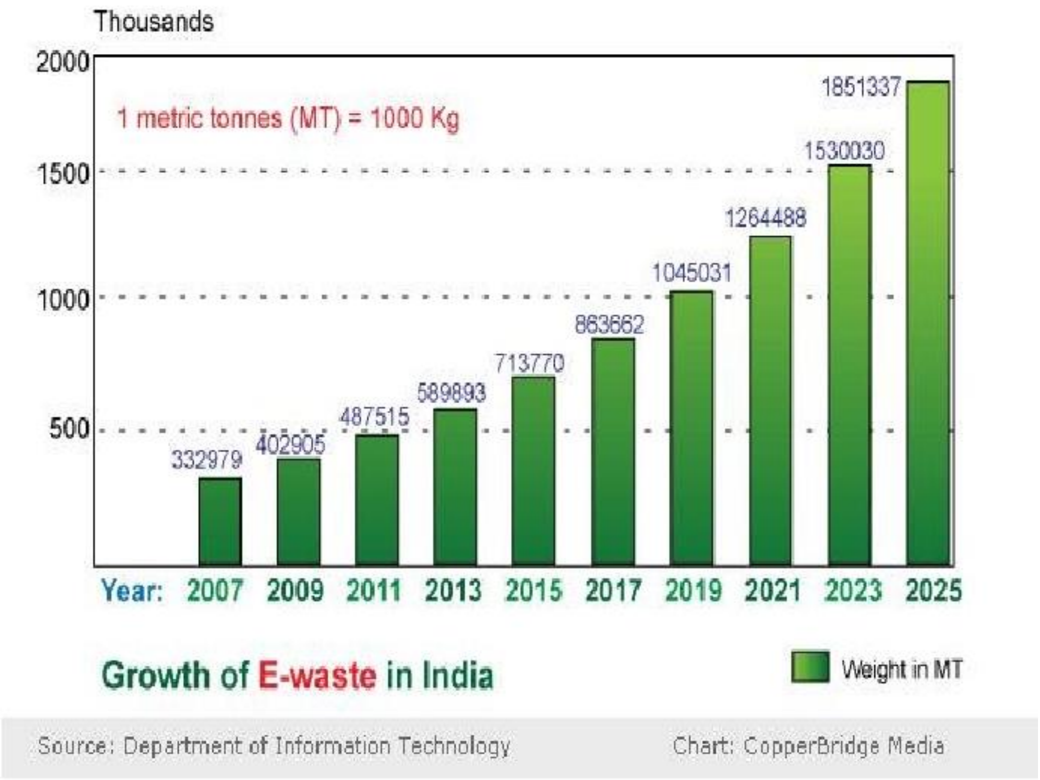

Fig. 1 Forecast of e-waste estimate in India[14]

E-waste in India

- India is ranked fifth in the world amongst top e-waste producing countries after the USA, China, Japan, and Germany and recycles less than 2 per cent of the total e-waste it produces annually formally.
- Since 2018, India generates more than two million tonnes of e-waste annually, and also imports huge amounts of e-waste from other countries around the world.
- Dumping in open dumpsites is a common sight which gives rise to issues such as groundwater contamination, poor health, and more.
- The Associated Chambers of Commerce and Industry of India (ASSOCHAM) and KPMG study, Electronic Waste Management in India identified that computer equipment account for almost 70 per cent of e-waste, followed by telecommunication equipment phones (12 per cent), electrical equipment (8 per cent), and medical equipment (7 per cent) with remaining from household e-waste.

The problem….

- E-waste collection, transportation, processing, and recycling is dominated by the informal sector. The sector is well networked and unregulated. Often, all the materials and value that could be potentially recovered is not recovered. In addition, there are serious issues regarding leakages of toxins into the environment and workers' safety and health.

- Seelampur in Delhi is the largest e-waste dismantling centre of India. Adults as well as children spend 8–10 hours daily extracting reusable components and precious metals like copper, gold and various functional parts from the devices. E-waste recyclers use processes such as open incineration and acid-leeching. This situation could be improved by creating awareness and improving the infrastructure of recycling units along with the prevalent policies. The majority of the e-waste collected in India is managed by an unorganized sector.

Impact on Human Health:
Pollutants, their sources and effects on human health (Table: 1)

Pollutant	Sources	Effect
Arsenic	Semiconductors, diodes, microwaves, LEDs, solar cells	Black-foot disease
Barium	Electron tubes, filler for plastic and rubber, lubricant additives	neurodegenerative diseases, lung diseases
Cadmium	Batteries, pigments, solder, alloys, circuit boards, computer batteries	Contain Carcinogens; causes Itai-Itai disease which affects kidneys and softens bones
Cobalt	Insulators	
Lead	Lead rechargeable batteries, solar, transistors, lithium batteries, PVC	chronic kidney disease, neurological problems
Lithium	Mobile telephones, batteries	
Mercury	Components in copper machines and steam irons; batteries in clocks and pocket calculators, switches, LCDs	Affects the central nervous system, kidneys and immune system; causes Minamata disease
PCBs (polychlorinated biphenyls)	Transformers, capacitors, softening agents for paint, glue, plastic	Cardiovascular diseases, neurobehavioral and immunological changes in children
Silver	Capacitors, switches (contacts), batteries, resistors	Inhalation of silver dust can cause respiratory problems
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances	Metal fume fever, respiratory diseases
Beryllium	Switch boards and printed circuit boards.	Carcinogenic and causes lung diseases.
Plastic	circuit boards, cabinets and cables	Contain carcinogens, harms reproductive, gastro-intestine and immune system
Chromium	Used to protect metal housings and plates in a computer from corrosion	

Opportunities of E-Waste Management in India

- The Ministry of Environment, Forest and Climate Change rolled out the E-Waste (Management) Rules in 2016 to reduce e-waste production and increase recycling. Under these rules, the government introduced EPR which makes producers liable to collect 30 per cent to 70 per cent (over seven years) of the e-waste they produce, said the study.
- E-waste is a rich source of metals such as gold, silver, and copper, which can be recovered and brought back into the production cycle. There is significant economic potential in the efficient recovery of valuable materials in e-waste and can provide income-generating opportunities for both individuals and enterprises. The E-Waste Management Rules, 2016 were amended by the government in March 2018 to facilitate and effectively implement the environmentally sound management of e-waste in India. The amended Rules revise the collection targets under the provision of EPR with effect from October 1, 2017. By way of revised targets and monitoring under the Central Pollution Control Board (CPCB), effective and improved management of e-waste would be ensured.

Some recent data…

- India collected just 10 per cent of the electronic waste (e-waste) estimated to have been generated in the country 2018-19 and 3.5 per cent of that in the generated in 2017-18, said a recent report by the Central Pollution Control Board.

- India generated 708,445 tonne e-waste in 2017-18 and 771,215 tonne the following fiscal, the report estimated. In 2019-20, the figure rose 32 per cent to 1,014,961 tonne.

- The figures have taken into account the 21 types of electrical and electronic equipments listed in the E-Waste Management Rules, 2016. These include discarded computer monitors, mobile phones, chargers, motherboards, headphones, television sets, among other appliances.

- The report published on December 18, 2020 mentioned that the collection targets for 2017-18 and 2018-19 based on the rules were 35,422 tonnes and 1,54,242 tonnes, respectively.

- The actual collection, however, was lower in both the years — 25,325 tonnes in 2017-18 and 78,281 tonnes in 2018-19.

E-waste management

- Thanks