# CVL100: Environmental Science


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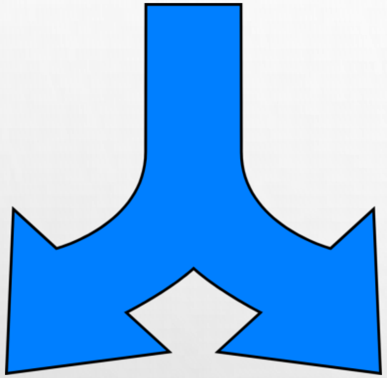
# Wastewater engineering

# Wastewater Treatment & Management

- **Wastewater engineering** is that branch of **environmental engineering** in which the basic principles of **science and engineering** are applied for solving the issues associated **wastewater treatment and management**.
- **Wastewater treatment** is the **removal of impurities** from wastewater, before it reaches **aquifers or natural waterbodies** such as rivers, lakes, estuaries, and oceans.
- **Wastewater management** is a holistic approach to protect water resources and it is defined as **the collection, treatment, and reuse of wastewater**.

# Wastewater Management (WWM)

**Wastewater**



Waste

Water

**Management**

# Wastewater Management

- Wastewater is any **water that requires cleaning** after it is used.
- Wastewater includes **discharges from laundry, bathing, dishwashing, toilets, garbage disposals, and industries**.
- Wastewater also **includes rainwater that has accumulated pollutants** as it runs into oceans, lakes, and rivers.

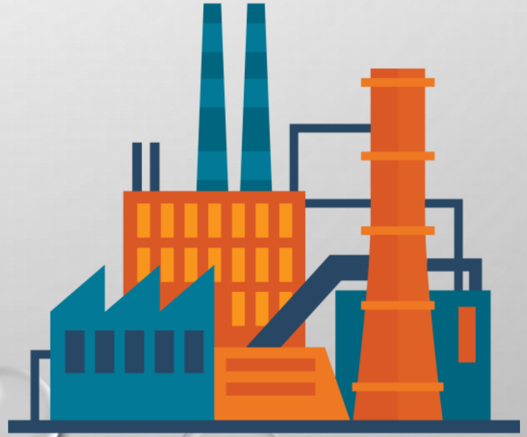
**Sources of wastewater**

Toilets

Bathing

Basins

Laundry

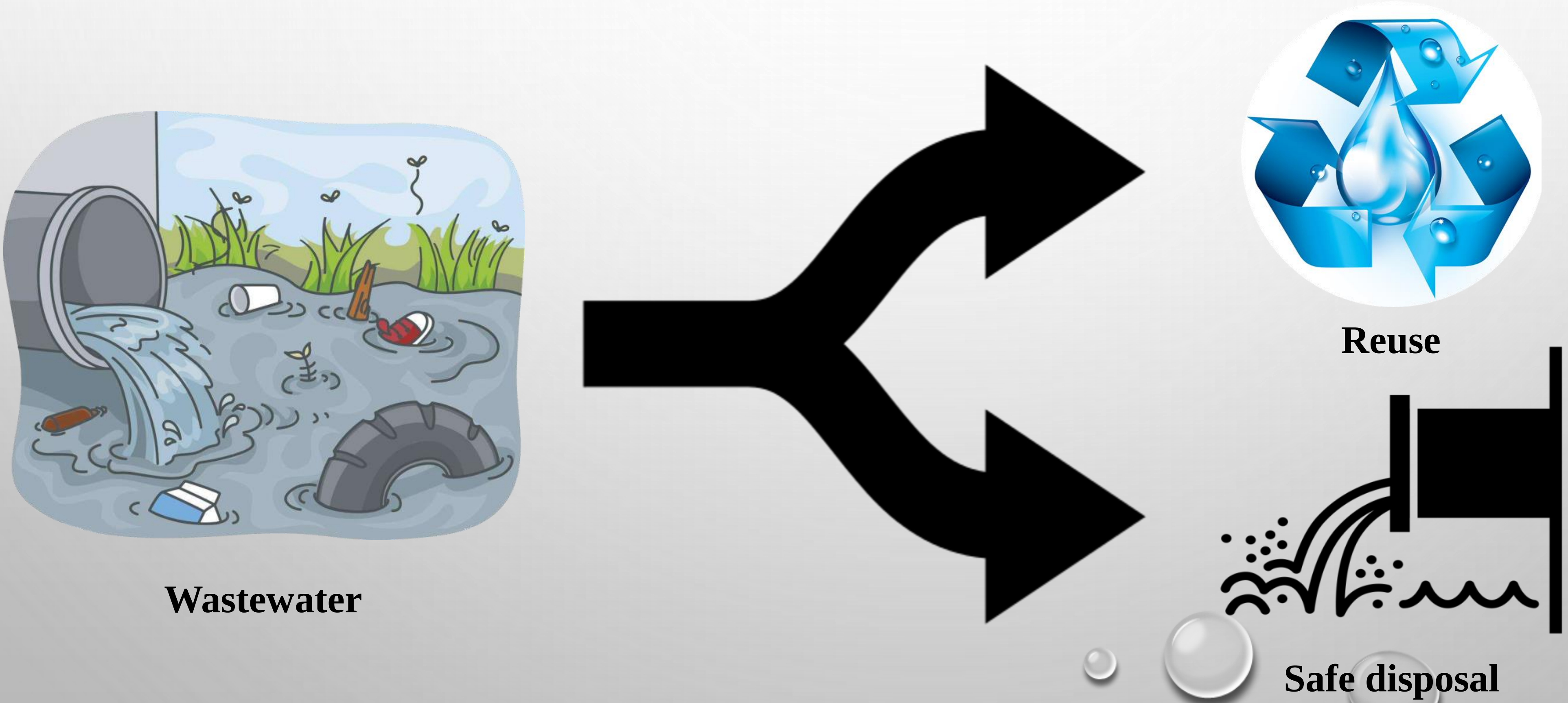


Industries

Rainwater

# Aims of WWM

- The goal of wastewater management is to **clean and protect water** so that water must be clean enough to be used by people **for drinking and washing, and by industry for commercial purposes**.
- It also must be **clean enough to discharged into water bodies** likes oceans, lakes, and rivers after it has been used.



# Discharge standards

Table 1: General standards for discharge of environmental pollutants as per CPCB

| Parameter | Surface water | Sewers | Land for irrigation | Marine body |
|---|---|---|---|---|
| Suspended solids (SS, mg/L) | 100 | 600 | 200 | 100 |
| pH | 5.5 to 9 | | | |
| Oil and grease (O & G, mg/L) | 10 | 20 | 10 | 20 |
| Biochemical oxygen demand (BOD, mg/L) | 30 | 350 | 100 | 100 |
| Chemical oxygen demand (COD, mg/L) | 250 | - | - | 250 |

# Pollutants

- Organic matter (dissolved or colloidal)
- Pathogens
- Nutrients
- Suspended solids and sediments (both organic and inorganic)
- Inorganic pollutants (salts and metals)
- Thermal pollution
- Radioactive pollutants
- Xenobiotics and biorefractory pollutants

# Organic Matter

- It is present in either **suspended, colloidal or dissolved form** and thus **consumes dissolved oxygen (DO)** when discharged into aquatic water bodies.
- This leads to **foul odour** and **DO depletion** of the water body.
- Depletion of the DO can lead to serious problems and can adversely **affect aquatic ecosystem**, if the **DO falls below 4.0 mg/L**.

DO depletion affecting aquatic ecosystem

Foul odour

# Sources of Organic Matter

Organic matter from toilets

Oil and Grease


Volatile organic compounds (VOCs)

# Pathogens

- Pathogens like **viruses and bacteria** are present in **fecal matter, urine and other body fluids.**

- Viruses and bacteria can **cause water borne diseases**, such as **cholera, typhoid, dysentery, polio** and **hepatitis** in human.

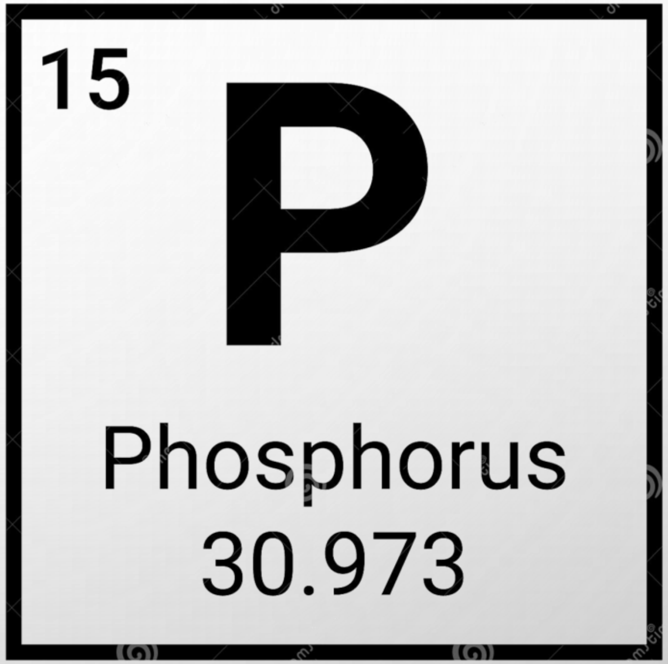
- If pathogens containing wastewater is discharged into water bodies then it **can spread diseases to the people using it as the source of drinking water**.

# Sources of Pathogens

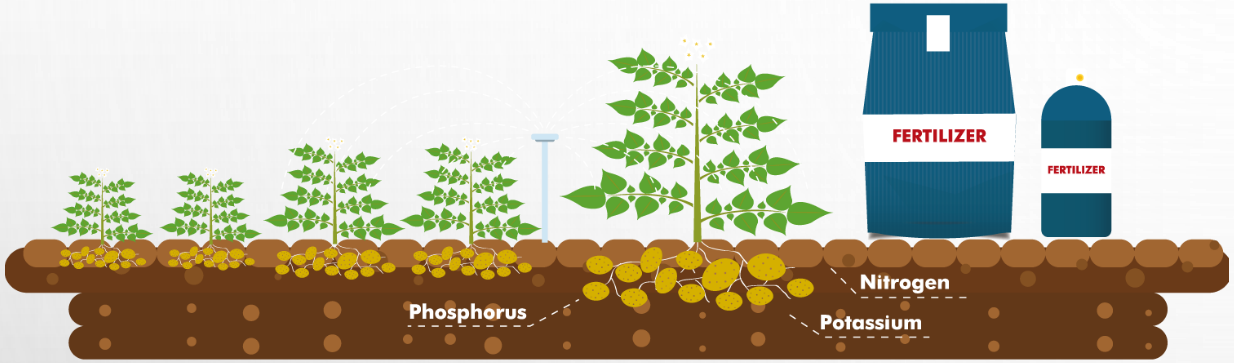
Faecal matter and urine

Body fluids from coughing, sneezing and sweating

# Nutrients

# Sources of Nutrients




Fertilizers

Pesticides

Faecal matter and urine

# Effects of Discharging Nutrients

Excessive growth of aquatic weeds and algae (algal bloom)

Blue baby disease in infants

Skin and eye irritation, gastroenteritis and vomiting

# Suspended Solids

- Suspended solids (SS) comprise of **silt, sand and minerals eroded from land**.
- These appear in the water through the **surface runoff during rainy season and room cleaning/washing**.


Produced from surface runoff and room cleaning

# Effect of Suspended Solids

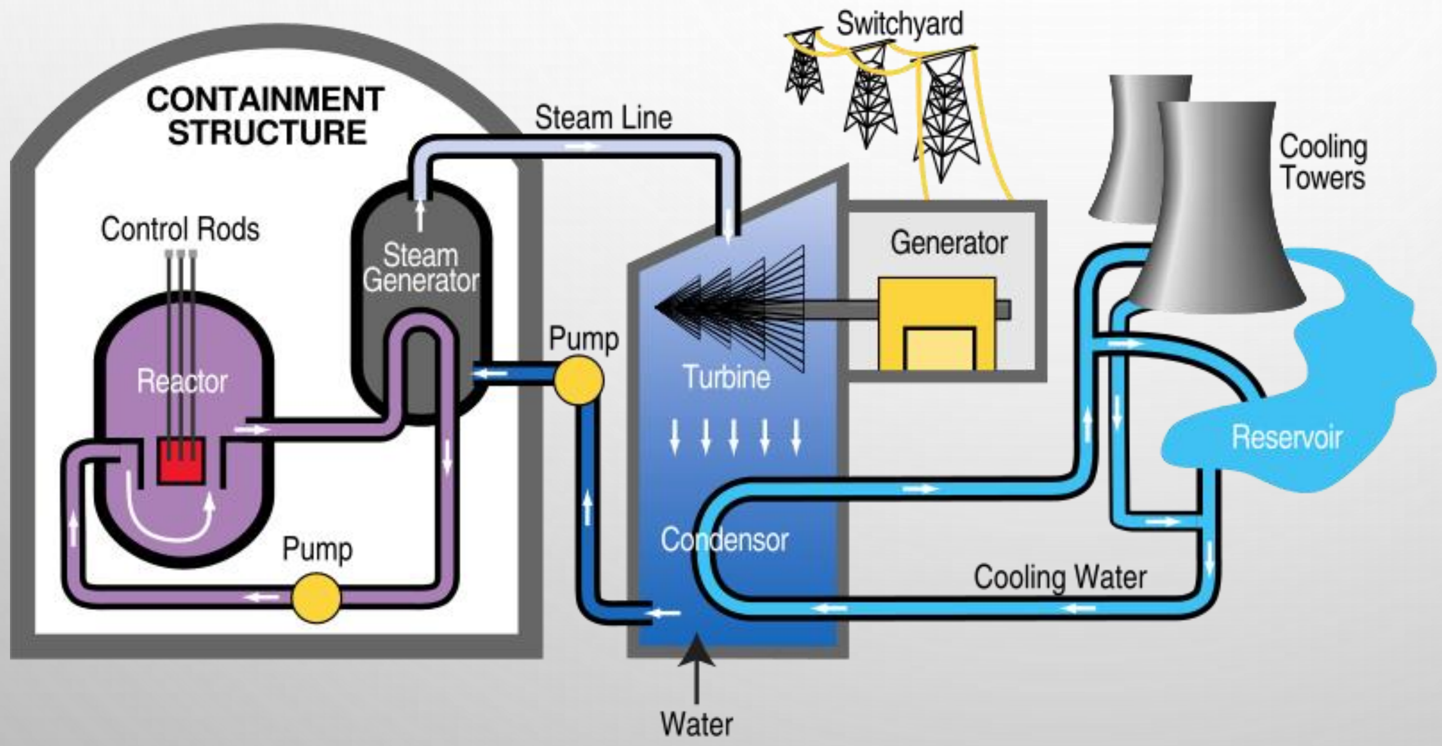
- Presence of SS in wastewater can **reduce storage capacities** of reservoirs due to **siltation**.
- Presence of suspended solids can **block the sunlight penetration in the water**, which is required for the **photosynthesis by bottom vegetation**.

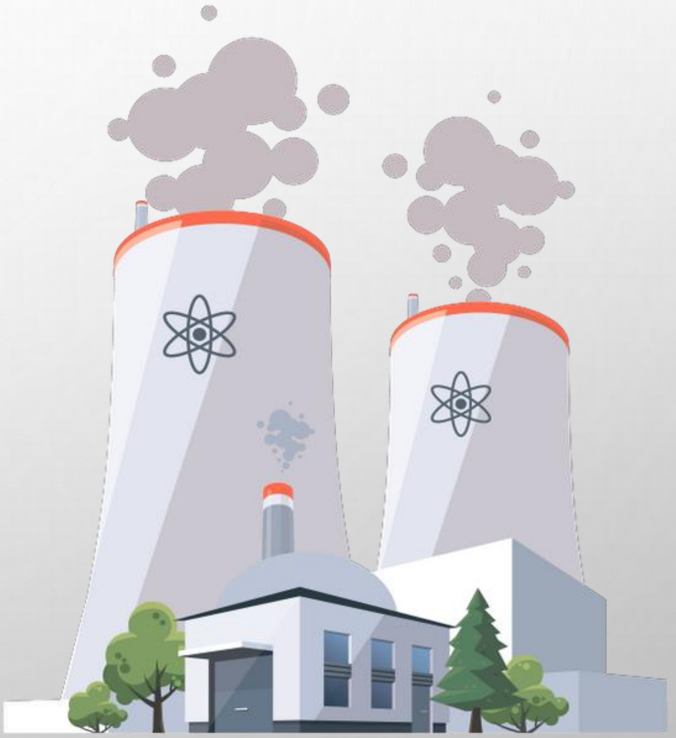
Leads to siltation reducing storage capacity

Severely affects aquatic animals

# Thermal Pollution

- Thermal pollution results due to the **discharge of hot water from thermal power plants, nuclear power plants, and industries** where water is used as coolant.

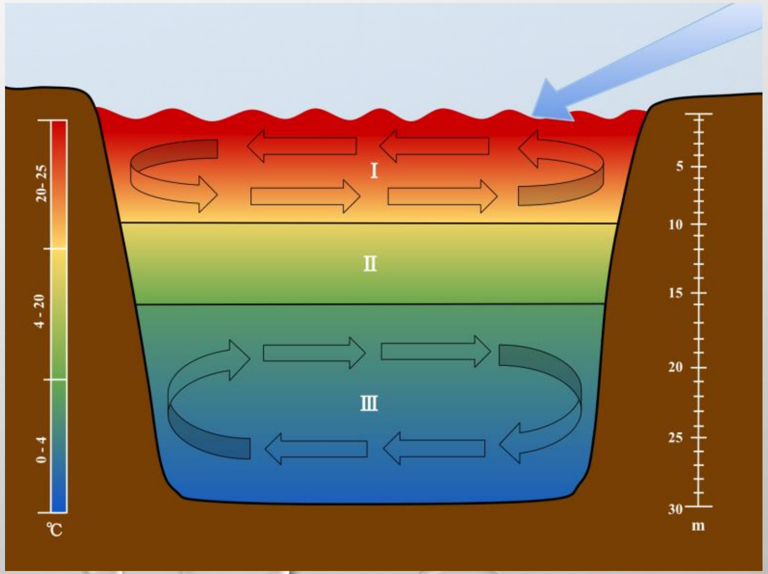


Produced from wastewater discharged from thermal power plants, nuclear power plants

# Effects of Thermal Pollution

- If hot water is discharged, the temperature of water body increases, which **reduces the DO thus adversely affecting the aquatic life**.
- The discharge of hot water **leads to the thermal stratification** in the water body, where hot water will remain on the top.




Lead to death of aquatic organisms and thermal stratifications

# Radioactive Pollutants

Mining activity

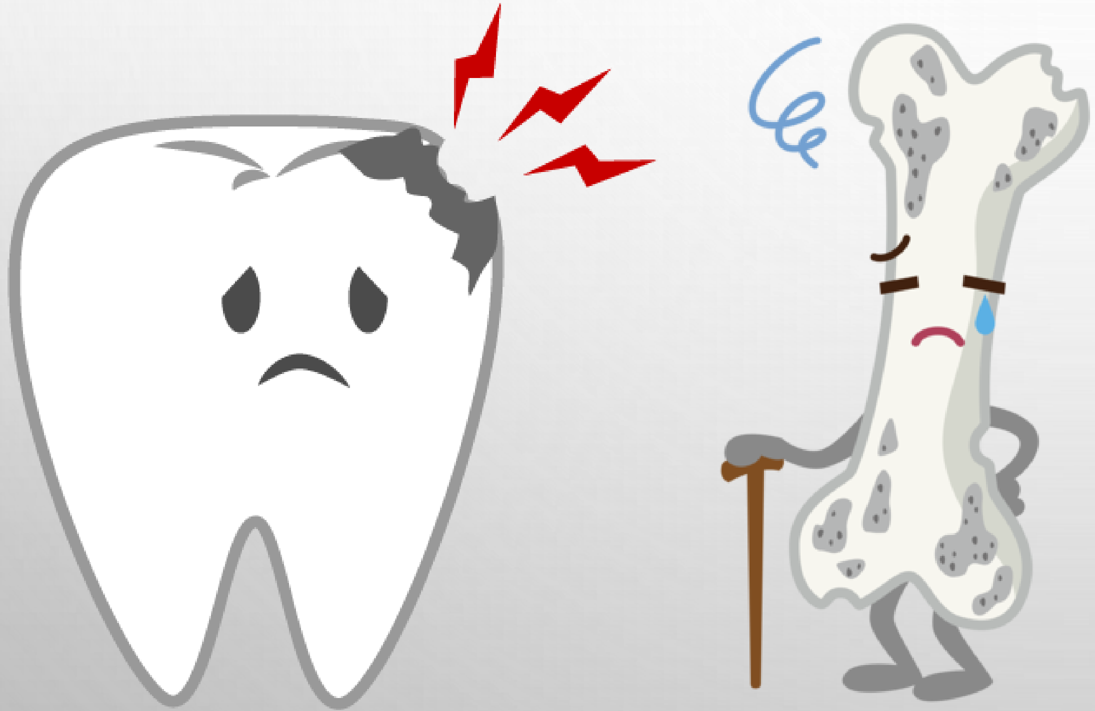
Research and medical applications

Industries

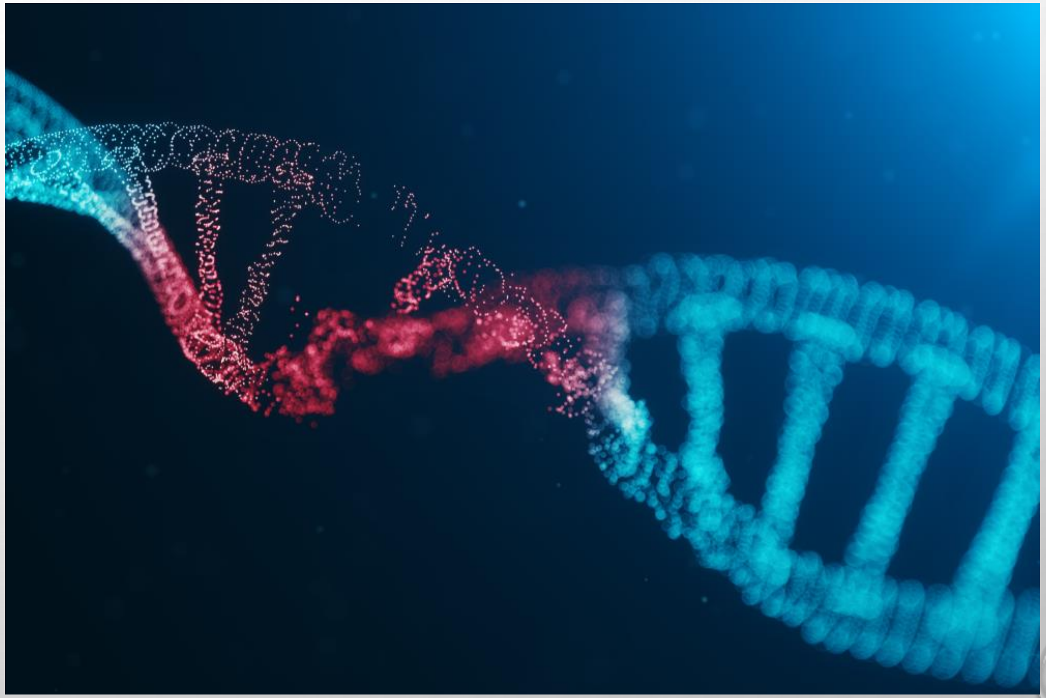
Nuclear plants and reactors

# Effects of Radioactive Pollutants

Radioactive pollutants **accumulate in the bones, teeth** and can cause **serious disorders in both offspring and parents.**



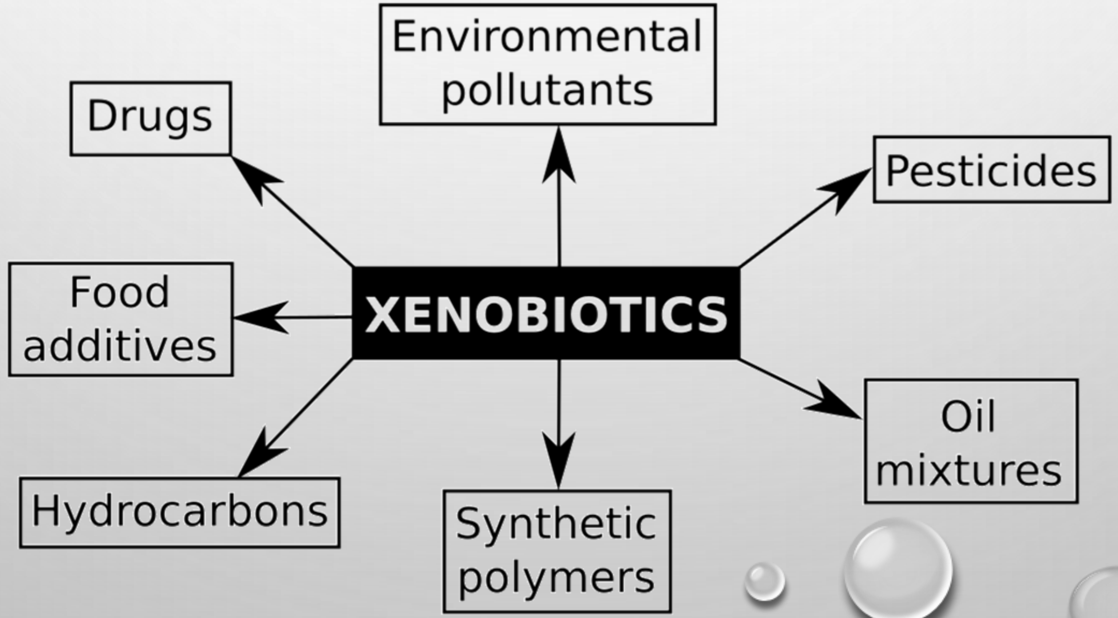
Weak tooth & bones



Genetic disorders in offspring

# Xenobiotic Compounds

- A xenobiotic is a **chemical substance** found within an organism that **is not naturally produced or expected to be present** within the organism.
- It can also cover substances that are **present in much higher concentrations** than are usual.



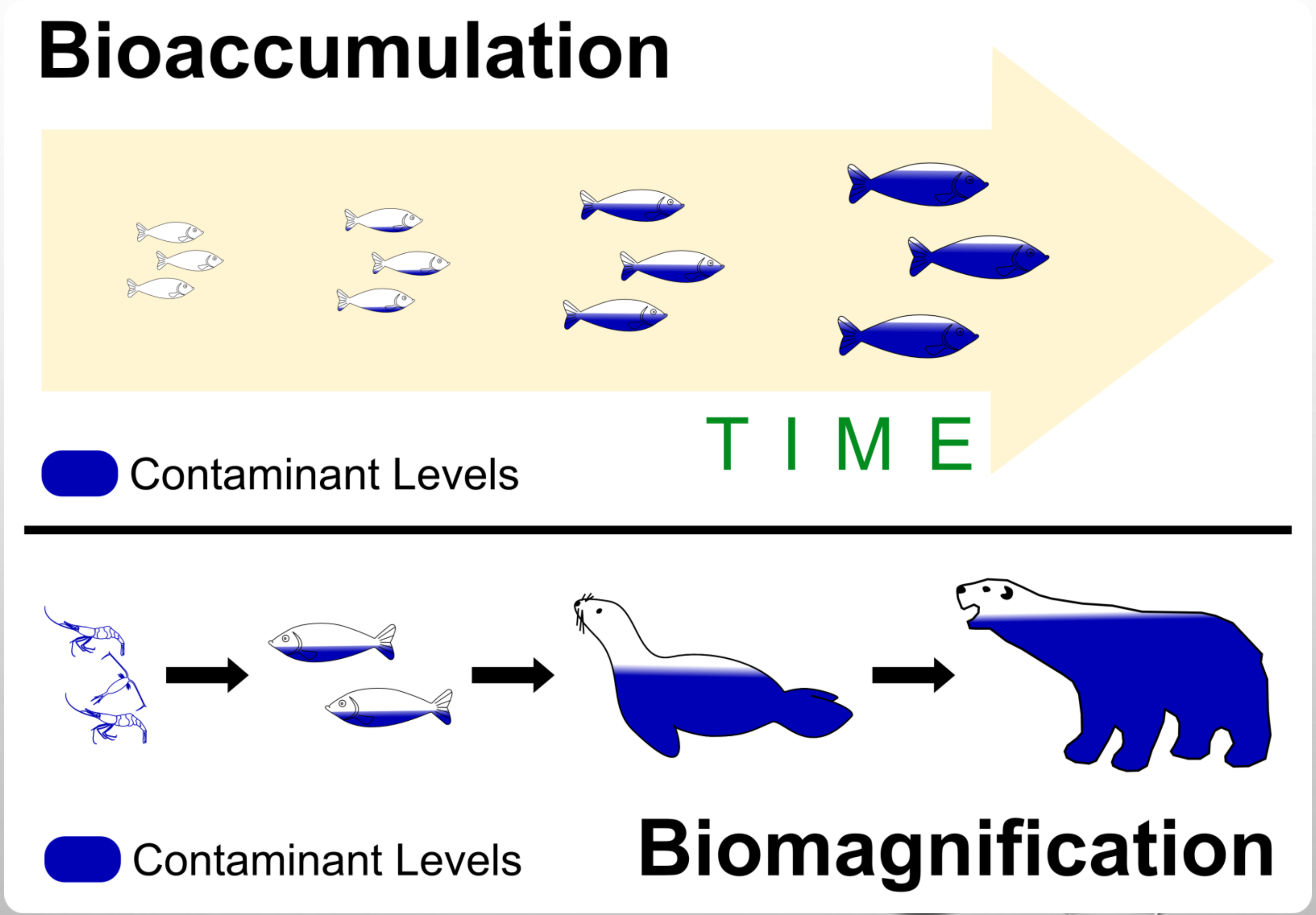
# Biorefractory Compounds

- Biorefractory compounds are substances, which **resist decomposition by ordinary biological mechanisms** and hence are persistent in the environment.

- Examples – Chemicals like phenolic compounds, polycyclic aromatic hydrocarbons (PAHs), fulvic acid and humic acid, herbicides and pesticides

- They can lead to **biomagnification** and **bioaccumulation**.

# Biomagnification & Bioaccumulation

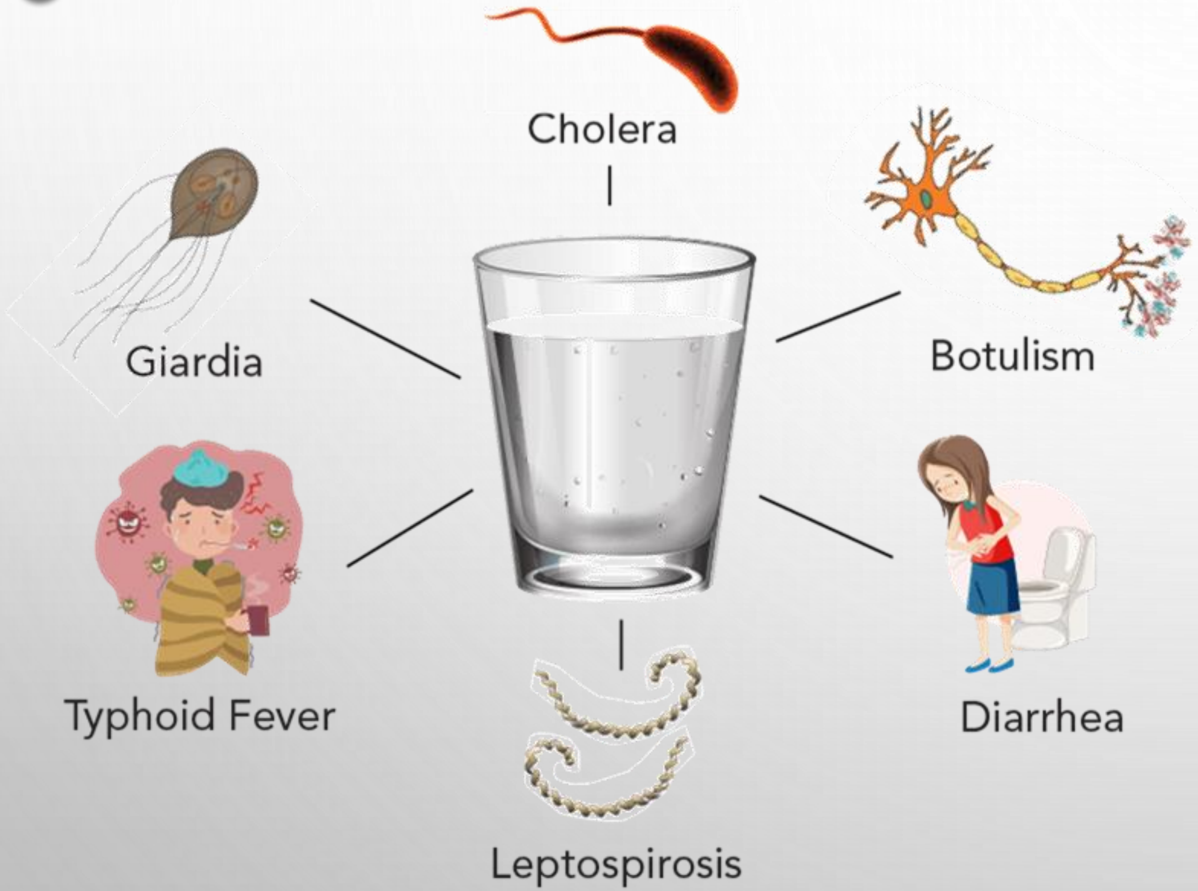


# Need for Treatment

Conserve natural ecosystems

Preserve Earth’s biodiversity

# Need for Treatment



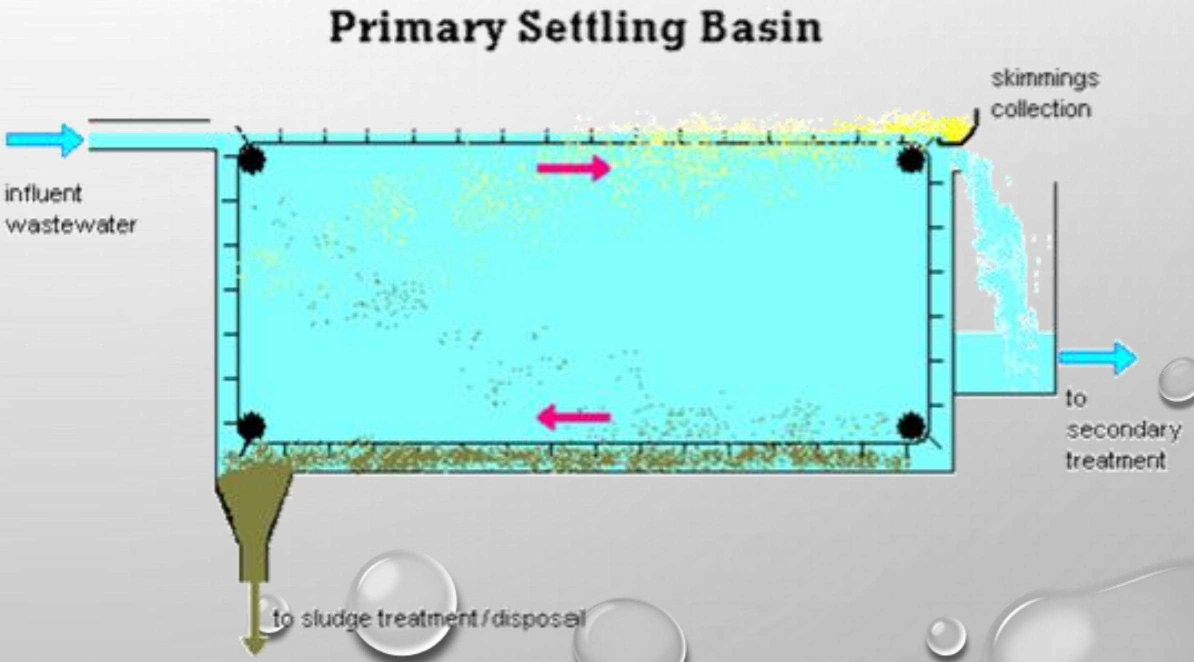

Prevent water borne diseases

To practise safe faming and irrigation

# Treatment Processes

**Physical Unit Operations:** Treatment methods in which the **application of physical forces predominates** are known as physical unit operations. Most of these methods are based on physical forces, e.g. **screening, mixing, flocculation, sedimentation, flotation, and filtration**.

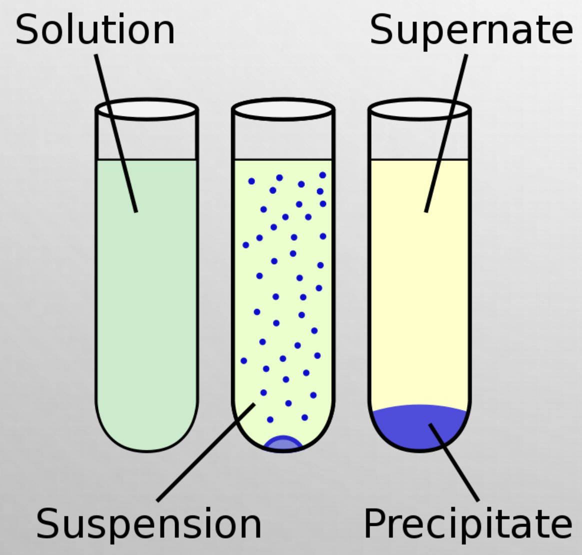
Screens




Sedimentation tank

# Treatment Processes

**Chemical Unit Processes:** Treatment methods in which removal or conversion of contaminant is brought by **addition of chemicals or by other chemical reactions** are known as chemical unit processes, for example, **precipitation, gas transfer, adsorption, and disinfection**.

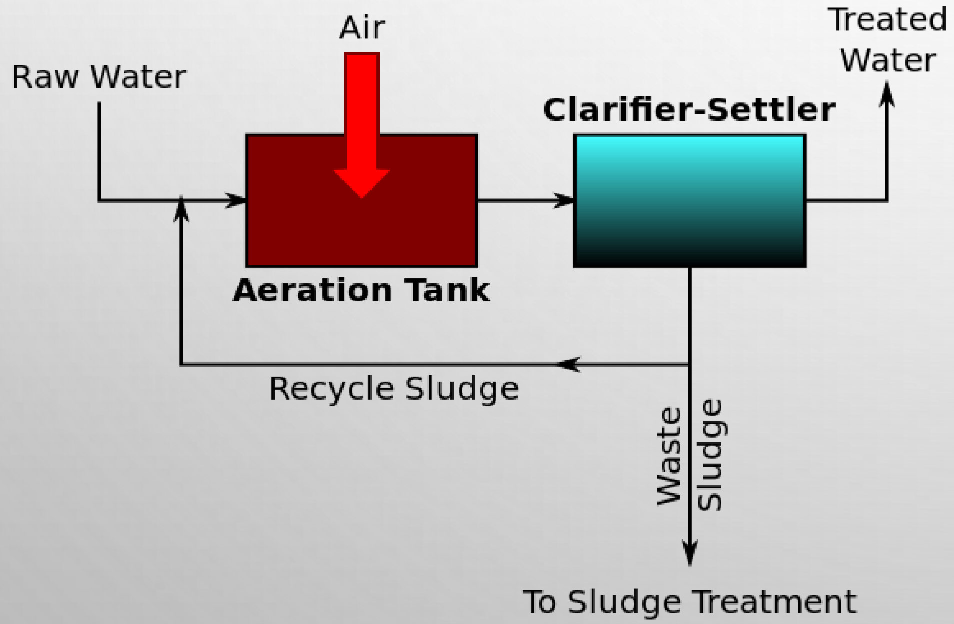



Precipitation

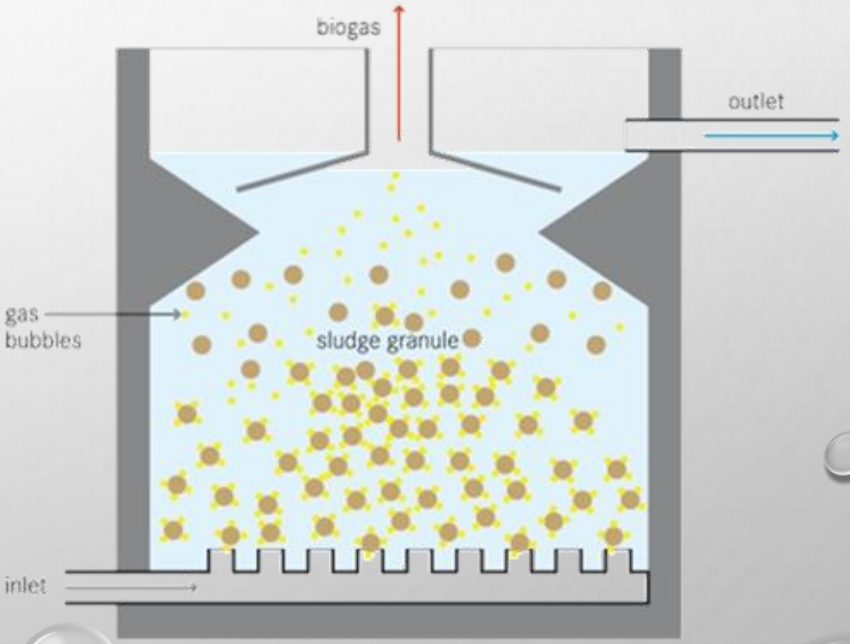
Gas transfer using aerators

# Treatment Processes

- **Biological Unit Processes:** Treatment methods in which the removal of contaminants is brought about **by biological activity** are known as biological unit processes.
- This is primarily used to **remove biodegradable organic substances** from the wastewater, either in **colloidal or dissolved form**.




Activated sludge process (ASP)

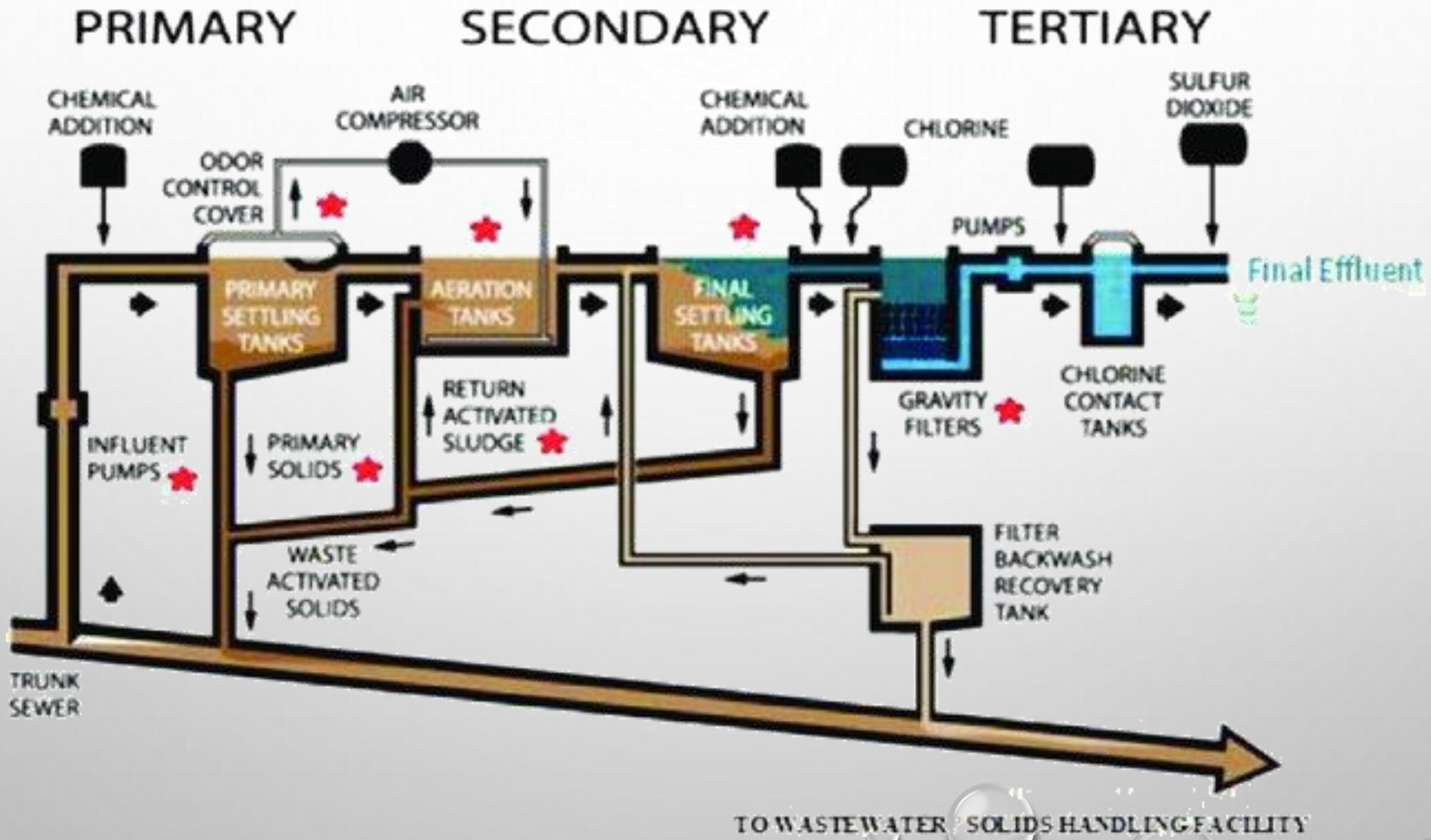



Upflow anaerobic sludge blanket (UASB)

# Treatment Methods

- Based on the **stage of the treatment**, these can be classified as:
  - **Primary Treatment:** Refers to **physical unit operations**.
  - **Secondary Treatment:** Refers to **chemical and biological unit processes**.
  - **Tertiary Treatment:** Refers to any **one or combination of two or all three** i.e., **physical unit operations and chemical or biological unit processes**, used after secondary treatment.

# Treatment Methods



# Population forecasting

# Population forecasting

- Design of water supply and sanitation scheme is based on the **projected population** of a particular city, estimated for the **design period**.
- Any **underestimated** value will make system **inadequate for the purpose intended**; similarly **overestimated** value will make it **costly**.
- Changes in the population of the city over the years occur, and the system should be designed taking into account of the **population at the end of the design period**.
- Factors affecting **changes in population** are:
  - increase due to **births**
  - decrease due to **deaths**
  - increase/decrease due to **migration, pandemic**
  - increase due to **colonization, war, invasion** etc.

# Methods used for population forecasting

- Arithmetical Increase Method
- Geometrical Increase Method/Geometrical Progression Method
- Incremental Increase Method
- Graphical Method
- Comparative Graphical Method
- Master Plan Method
- Logistic Curve Method

# Arithmetical Increase Method

- This method is suitable for **large and old city** with **considerable development**.
- If it is used for **small, average or comparatively new cities**, it will give **lower population estimate** than actual value.
- In this method the **average increase in population per decade** is calculated from the **past census reports**.
- This **increase is added to the present population** to find out the population of the next decade.
- Thus, it is assumed that the **population is increasing at constant rate**.

# Arithmetical Increase Method

- The population of a city for the last few years are given below. Estimate the population in **2020, 2030 and 2040 by arithmetic increase method**.

| **Year** | **1970** | **1980** | **1990** | **2000** | **2010** |
|---|---|---|---|---|---|
| **Population (in millions)** | 908 | 1008 | 1109 | 1223 | 1320 |

# Arithmetical Increase Method

- Solution

| Year | Population (in millions) | Increment (in millions) |
|---|---|---|
| 1970 | 908 | - |
| 1980 | 1008 | - |
| 1990 | 1109 | - |
| 2000 | 1223 | - |
| 2010 | 1320 | - |

| | | | |
|---|---|---|---|
| Avg. increment = | - | - | millions |
| | - | - | |
| Population in the year of 2020 = | - | - | millions |
| Population in the year of 2030 = | - | - | millions |
| Population in the year of 2040 = | - | - | millions |

# Arithmetical Increase Method

- Solution

| Year | Population (in millions) | Increment (in millions) |
|---|---|---|
| 1970 | 908 | - |
| 1980 | 1008 | 100 |
| 1990 | 1109 | 101 |
| 2000 | 1223 | 114 |
| 2010 | 1320 | 97 |

| | | | |
|---|---|---|---|
| Avg. increment = | (100+101+114+97)/4 | 103 | millions |
| | | | |
| Population in the year of 2020 = | 1320+103*1 | 1423 | millions |
| Population in the year of 2030 = | 1320+103*2 | 1526 | millions |
| Population in the year of 2040 = | 1320+103*3 | 1629 | millions |

# Geometrical Increase Method

- In this method the **percentage increase in population** from **decade to decade** is assumed to **remain constant**.
- **Geometric mean** increase is used to find out the **future increment in population**.
- Since this method **gives higher values** and hence should be applied for a **new industrial town** at the **beginning of development** for **only few decades**.
- The population at the end of n<sup>th</sup> decade '$P_n$' can be estimated as:

$$P_n = P\,(1 + I_G/100)^{n}$$

Where, $I_G$ = geometric mean (%)

P = Present population

N = no. of decades.

# Geometrical Increase Method

- The population of a city for the last few years are given below. Estimate the population in **2020, 2030 and 2040 by geometrical increase method**.

| Year | 1970 | 1980 | 1990 | 2000 | 2010 |
|---|---|---|---|---|---|
| **Population (in millions)** | 908 | 1008 | 1109 | 1223 | 1320 |

# Geometrical Increase Method

- Solution

| Year | Population (in millions) | Increment (in millions) | Rate of growth |
|---|---|---|---|
| 1970 | 908 | - | - |
| 1980 | 1008 | - | - |
| 1990 | 1109 | - | - |
| 2000 | 1223 | - | - |
| 2010 | 1320 | - | - |

| | | | |
|---|---|---|---|
| Geometric mean = | - | - | - |
| | - | - | - |
| Population in the year of 2020 = | - | - | - |
| Population in the year of 2030 = | - | - | - |
| Population in the year of 2040 = | - | - | - |

# Geometrical Increase Method

- Solution

| Year | Population (in millions) | Increment (in millions) | Rate of growth |
|---|---|---|---|
| 1970 | 908 | - | - |
| 1980 | 1008 | 1008-908=100 | 100/908=0.110 |
| 1990 | 1109 | 1109-1008=101 | 101/1008=0.100 |
| 2000 | 1223 | 1223-1109=114 | 114/1109=0.103 |
| 2010 | 1320 | 1320-1223=97 | 97/1223=0.079 |

| | | | |
|---|---|---|---|
| Geometric mean = | (0.110*0.100*0.103*0.079)^(1/4) | 0.097 | or 9.7% |
| | | | |
| Population in the year of 2020 = | 1320*(1+0.097)^1 | 1448 | millions |
| Population in the year of 2030 = | 1320*(1+0.097)^2 | 1588 | millions |
| Population in the year of 2040 = | 1320*(1+0.097)^3 | 1743 | millions |

# Incremental Increase Method

- This method is **modification of arithmetical increase method** and it is suitable for an **average size town** under **normal condition** where the **growth rate** is found to be in **increasing order**.
- While adopting this method, the **increase in increment** is considered for calculating future population.
- The **incremental increase** is determined for each decade from the past population and the **average value is added** to the present population along with the **average rate of increase**.

Hence, population after $n^{th}$ decade is $P_n = P + n.X + \{n(n+1)/2\}.Y$

Where, $P_n$ = Population after $n^{th}$ decade

$X$ = Average increase

$Y$ = Incremental increase

# Incremental Increase Method

- The population of a city for the last few years are given below. Estimate the population in **2020, 2030 and 2040 by incremental increase method**.

| Year | 1970 | 1980 | 1990 | 2000 | 2010 |
|---|---|---|---|---|---|
| **Population (in millions)** | 908 | 1008 | 1109 | 1223 | 1320 |

# Incremental Increase Method

- Solution

| Year | Population (in millions) | Increment (in millions) [X] | Incremental increase [Y] |
|---|---|---|---|
| 1970 | 908 | - | - |
| 1980 | 1008 | - | - |
| 1990 | 1109 | - | - |
| 2000 | 1223 | - | - |
| 2010 | 1320 | - | - |
| | **Total** | - | - |
| | **Average** | - | - |

| | | | |
|---|---|---|---|
| Population in the year of 2020 = | - | - | - |
| Population in the year of 2030 = | - | - | - |
| Population in the year of 2040 = | - | - | - |

# Incremental Increase Method

- Solution

| Year | Population (in millions) | Increment (in millions) [X] | Incremental increase [Y] |
|---|---|---|---|
| 1970 | 908 | - | - |
| 1980 | 1008 | 1008-908=100 | - |
| 1990 | 1109 | 1109-1008=101 | 101-100=1 |
| 2000 | 1223 | 1223-1109=114 | 114-101=13 |
| 2010 | 1320 | 1320-1223=97 | 97-114=-17 |
| | **Total** | **100+101+114+97=412** | **-3** |
| | **Average** | **412/4=103** | **-3/3=-1** |

| | | | |
|---|---|---|---|
| Population in the year of 2020 = | 1320+1*103+1*(-1) | 1422 | millions |
| Population in the year of 2030 = | 1320+2*103+3*(-1) | 1523 | millions |
| Population in the year of 2040 = | 1320+3*103+6*(-1) | 1623 | millions |

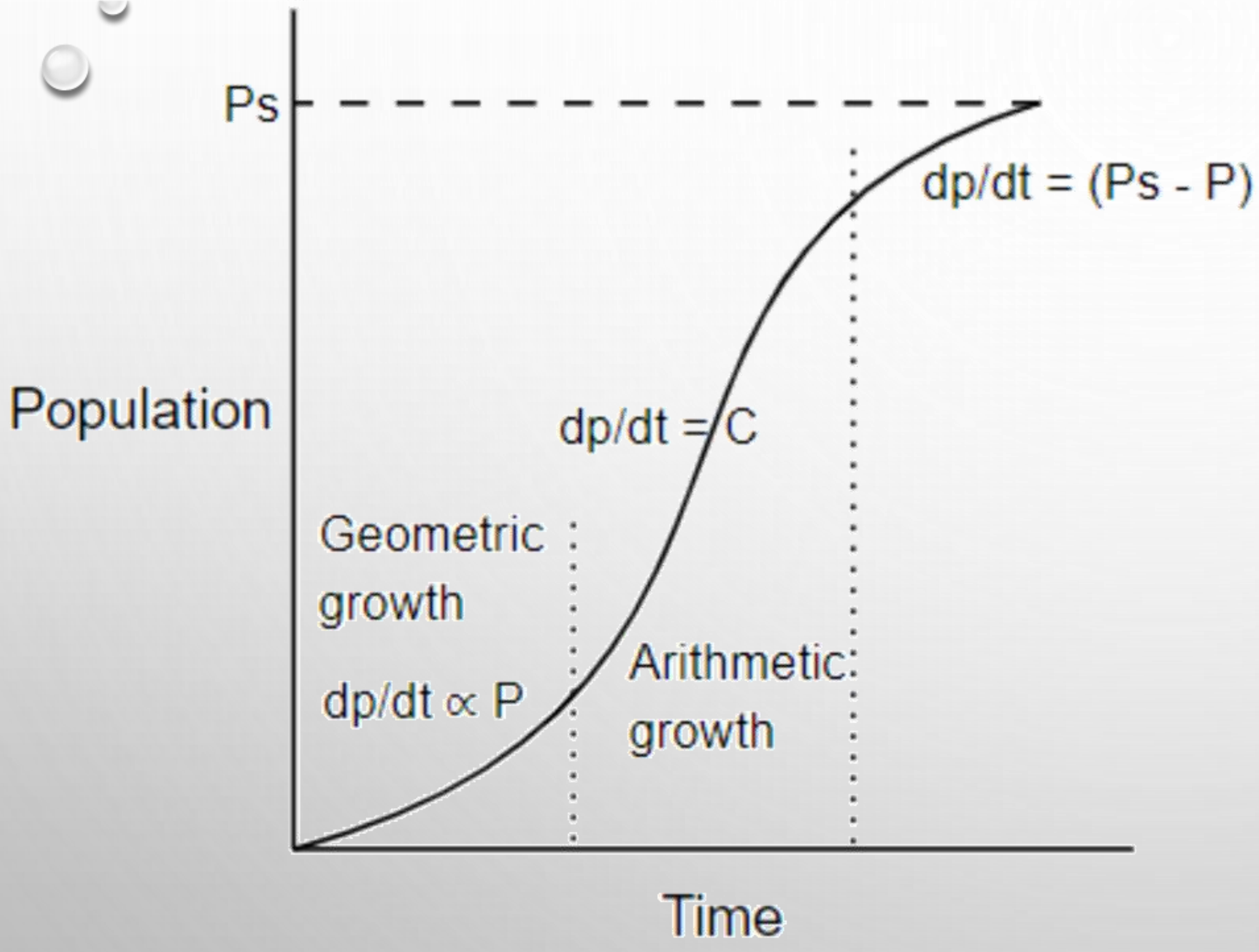
# Comparison between methods

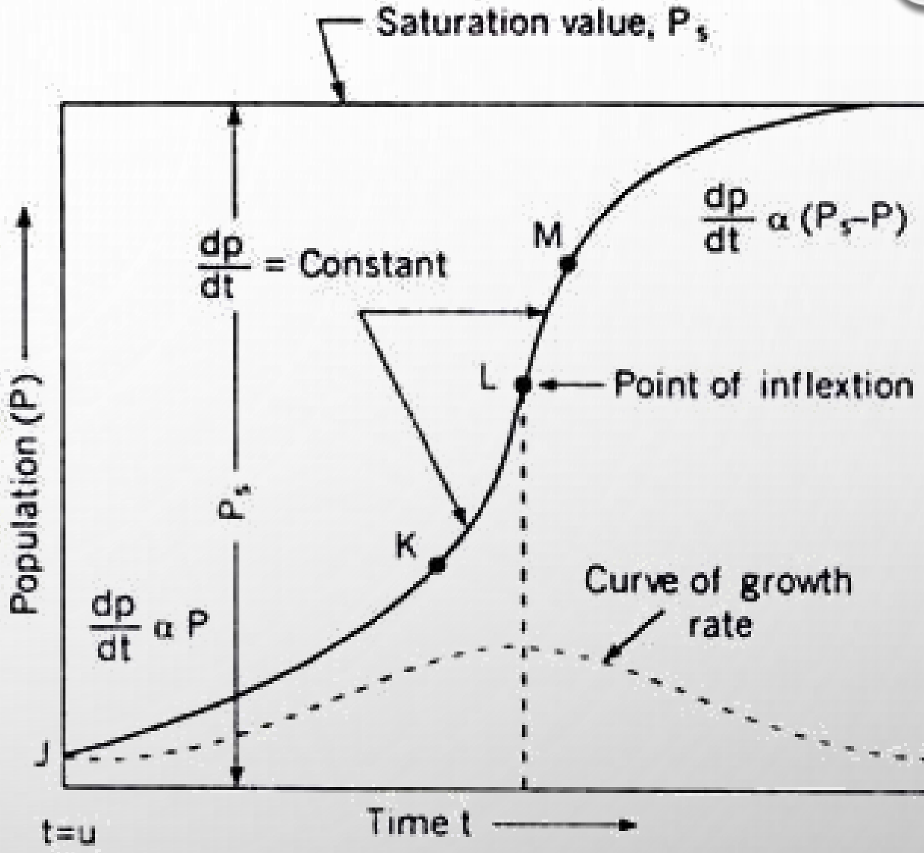
| Year | Population (in millions) | Arithmetic increase method | Geometric increase method | Incremental increase method |
|---|---|---|---|---|
| 1970 | 908 | - | - | - |
| 1980 | 1008 | - | - | - |
| 1990 | 1109 | - | - | - |
| 2000 | 1223 | - | - | - |
| 2010 | 1320 | - | - | - |
| 2020 | - | 1423 | 1448 | 1422 |
| 2030 | - | 1526 | 1588 | 1523 |
| 2040 | - | 1629 | 1743 | 1623 |

# Logistic Curve Method

- This method is used when the **growth rate of population due to births, deaths and migrations takes place under normal situation** and it is not subjected to any **extraordinary changes** like **epidemic, war, earthquake or any natural disaster**.
- This method follows the principle that the population follows the **growth curve characteristics of living things** within **limited space** and **economic opportunity**.
- If the population of a city is **plotted with respect to time**, the curve so obtained under **normal condition** looks like **S-shaped curve** and is known as **logistic curve.**

# Logistic Curve Method




- The point of inflextion of the logistic growth equation **represents the point of maximum population growth rate**.
- Saturation population is populations when the **growth is nearly to zero** and **shows the maximum population** a city can hold.

# Logistic Curve Method

$$\log_e\left(\frac{Ps-P}{P}\right) - \log_e\left(\frac{Ps-P_0}{P_0}\right) = -K.P_s.t$$

where, P = Population at any time t from the origin

$P_s$ = Saturation population

$P_0$ = Population of the city at the start point

K = Constant

t = Time in years

$$\log_e\left(\frac{Ps-P}{P}\right)\left(\frac{P_o}{Ps-P_o}\right) = -K.P_s.t$$

# Logistic Curve Method

If only three pairs of characteristic values $P_0$, $P_1$, $P_2$ at times $t = t_0 = 0$, $t_1$ and $t_2 = 2t_1$ extending over the past record are chosen, the saturation population Ps and constant m and n can be estimated by the following equations:

After solving we get,

$$P = \frac{P_S}{1 + \frac{P_S - P_0}{P_0} \log_e^{-1}(-K.P_S.t)}$$

Substituting $\frac{Ps - P_0}{P_0} = m$ (a constant)

and $-K.P_s = n$ (another constant)

we get, $$\boxed{P = \frac{P_S}{1 + m\log_e^{-1}(n.t)}}$$

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

$$m = \frac{Ps - P_0}{P_0}$$

$$n = \frac{2.3}{t_1} \log_{10}\left(\frac{P_0(P_S - P_1)}{P_1(P_S - P_0)}\right)$$

# Logistic Curve Method

- Forecast population of a city for **year 2031** using logistic curve method. The past population of a city in three consecutive decades, i.e., **in year 2001, 2011 and 2021** was **36,300; 76,400 and 118,700**, respectively. Determine (a) **the saturation population**, (b) **the expected population in 2031**.

# Logistic Curve Method

- Forecast population of a city for **year 2031** using logistic curve method. The past population of a city in three consecutive decades, i.e., **in year 2001, 2011 and 2021** was **36,300; 76,400 and 118,700**, respectively. Determine (a) **the saturation population**, (b) **the expected population in 2031**.
- **Solution:**
- Saturation population=161203, m=3.44, n=-0.113
- Population in 2031=144456

# Logistic Curve Method

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

$$= \frac{2 \times 36,300 \times 76,400 \times 118,700 - 76,400 \times 76400 \times (36,300 + 118,700)}{36,300 \times 118,700 - 76,400 \times 76,400}$$

$$= 161,203$$

$$m = \frac{Ps - P_0}{P_0} = \frac{161,203 - 36,300}{36,300} = 3.44$$

$$n = \frac{2.3}{t_1} \log_{10} \frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}$$

$$= \frac{2.3}{10} \log_{10}\left(\frac{36,300(161,203 - 76,400)}{76,400(161,203 - 36,300)}\right) = -0.113$$

Population for year 2031

$$P = \frac{P_s}{1 + m\log_e^{-1}(n.t)} = \frac{161,203}{1 + 3.44 \times \log_e^{-1}(-0.113 \times 30)}$$

$$= \frac{161,203}{1 + 3.44 \times 0.0337} = 144,456$$

# Important definitions

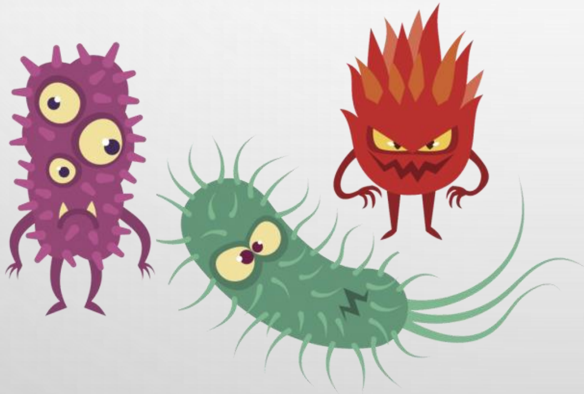
# Definitions

- **Sewage -** It indicates the liquid waste originating from the **domestic uses** of water like **sullage, discharge from toilets, urinals, wastewater generated from commercial establishments, institutions, industrial establishments** and also the **stormwater** that may enter into the sewers.
- **Sanitary sewage:** Sewage originated from the **residential buildings comes** under this category. This is very **foul** in nature. It is the wastewater generated from the **lavatory basins**, **urinals** and **water closets** of residential buildings, office building, theatre and other institutions. It is also referred as **domestic wastewater**.

# Pollutants present in sewage

Decomposition of sewage produces **large quantities of malodorous gases**, and it contains **numerous pathogenic or disease producing bacteria**, along with **high concentration of organic matter** and **suspended solids**.

Organic matter



Disease causing microbes (Pathogens)

Suspended solids

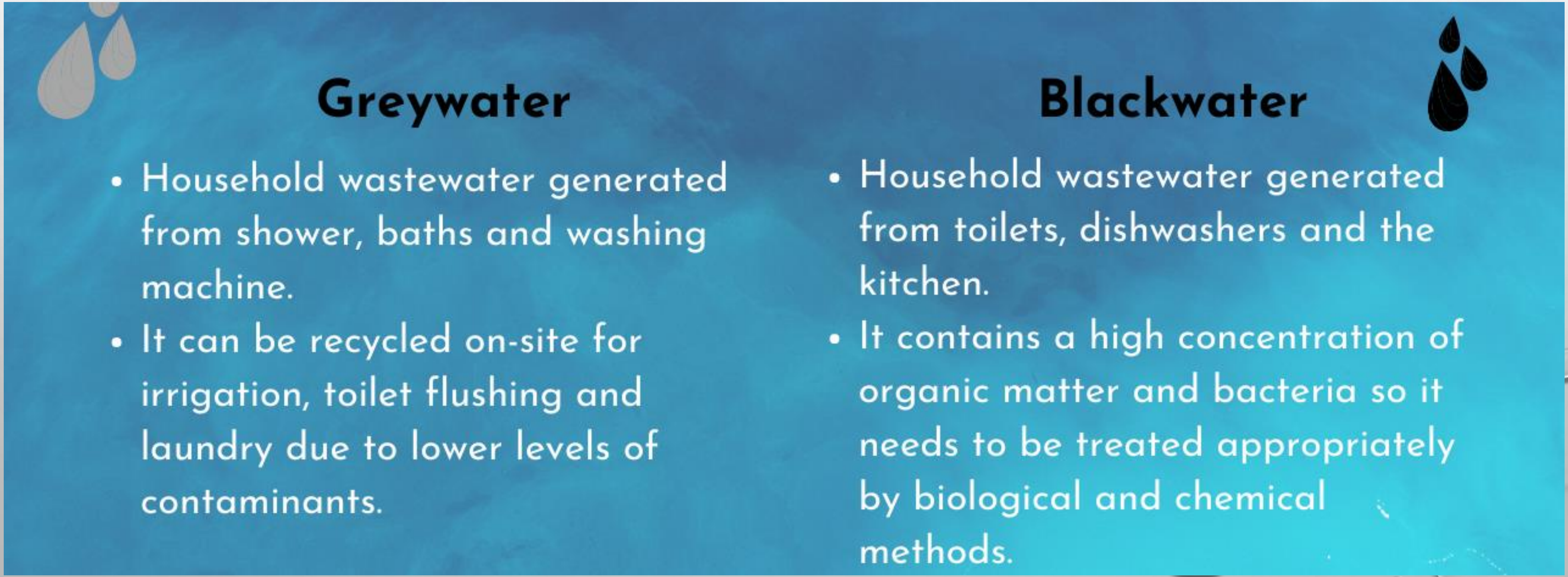
Produces foul gases

# Grey water

- Greywater or sullage refers to **domestic wastewater generated in households or office buildings** from streams **without fecal contamination**, i.e., all streams except for the wastewater from toilets.
- Sources of greywater **include sinks, showers, baths, washing machines or dishwashers**.
- As greywater contains **fewer pathogens** than blackwater, it is generally **safer to handle** and **easier to treat** and **reuse** onsite for **toilet flushing**, **landscape or crop irrigation**, and other non-potable uses.
- Greywater may contain **traces of dirt, food, grease, hair, and certain household cleaning products**.
- While greywater **may look "dirty,"** it is a **safe and even beneficial source of irrigation water**.
- If greywater is released into rivers, lakes, or estuaries, **its nutrients become pollutants**, but to plants, they are **valuable fertilizer**.

# Black water

- **Blackwater** denotes **wastewater from toilets** which likely **contains pathogens** that may spread by the **fecal–oral route**.
- Blackwater can contain **feces**, **urine**, **water** and **toilet paper** from flush toilets.



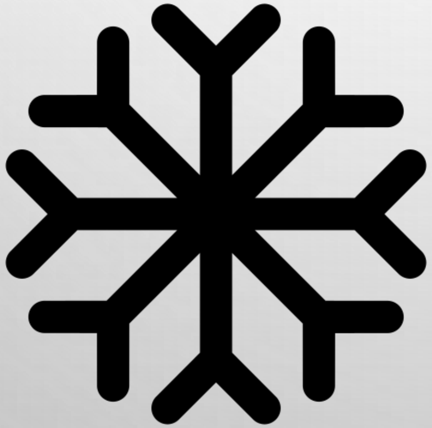
# Definitions

- **Stormwater -** It indicates the water that has originated from **rain, snow and ice melt**.
- It mainly **contains silty matter**; however, **less organic matter and pathogens**.

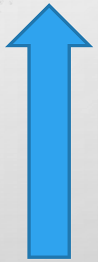
**Originates from**

**Contains**

Rain



Snow & Ice



Sand or silt

Pathogens

# Definitions

- **Industrial wastewater -** It is the wastewater generated from the various **industrial sectors**.
- It contains **objectionable organic and inorganic compounds** that may not be amenable to **conventional treatment processes**.

Industries

Toxic chemicals

# Definitions

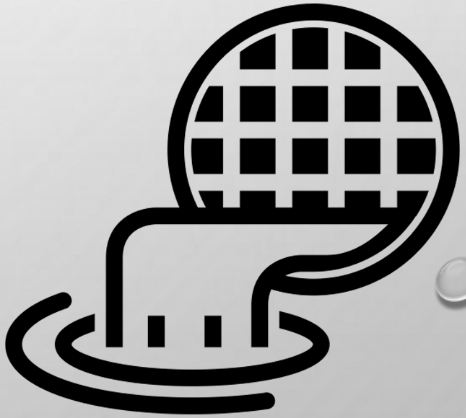
- **Night Soil**: It is a term used to indicate the **human and animal excreta** entering in sewers through water carriage system.
- **Subsoil water: Groundwater** that enters into the sewers through **leakages** is called subsoil water.
- **Wastewater:** Wastewater is water generated after the **use of freshwater, raw water**, drinking water or saline water in a variety of deliberate applications or processes. **Businesses** and **industries** also contribute their share of used water that must be **treated prior to disposal**.

# Definitions

- **Sewer -** It is an **underground conduit or drain** through which sewage is carried from the **point of generation to the point of discharge or treatment**.
- There are **three types of sewer systems** that are commonly used for sewage collection, namely, **separate sewers, combined sewers and partially separate sewers**.

Underground pipelines


Pipes & conduits



Drains

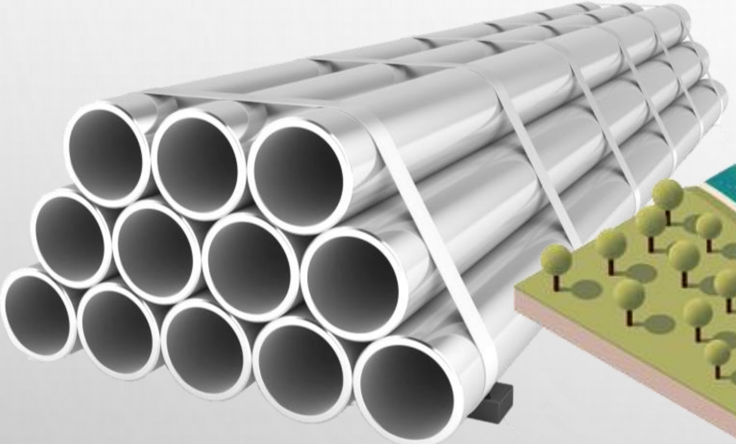
# Definitions

- **Sewerage -** The term sewerage refers the **infrastructure** which includes **device, equipment and appurtenances** for the **collection, transportation and pumping** of sewage.

- However, it excludes the **treatment system of sewage**.

- Basically, it is a **water carriage system** designed and constructed for **collecting and carrying of sewage** through sewers from the **source to point of discharge or treatment**.

# Sewerage Network



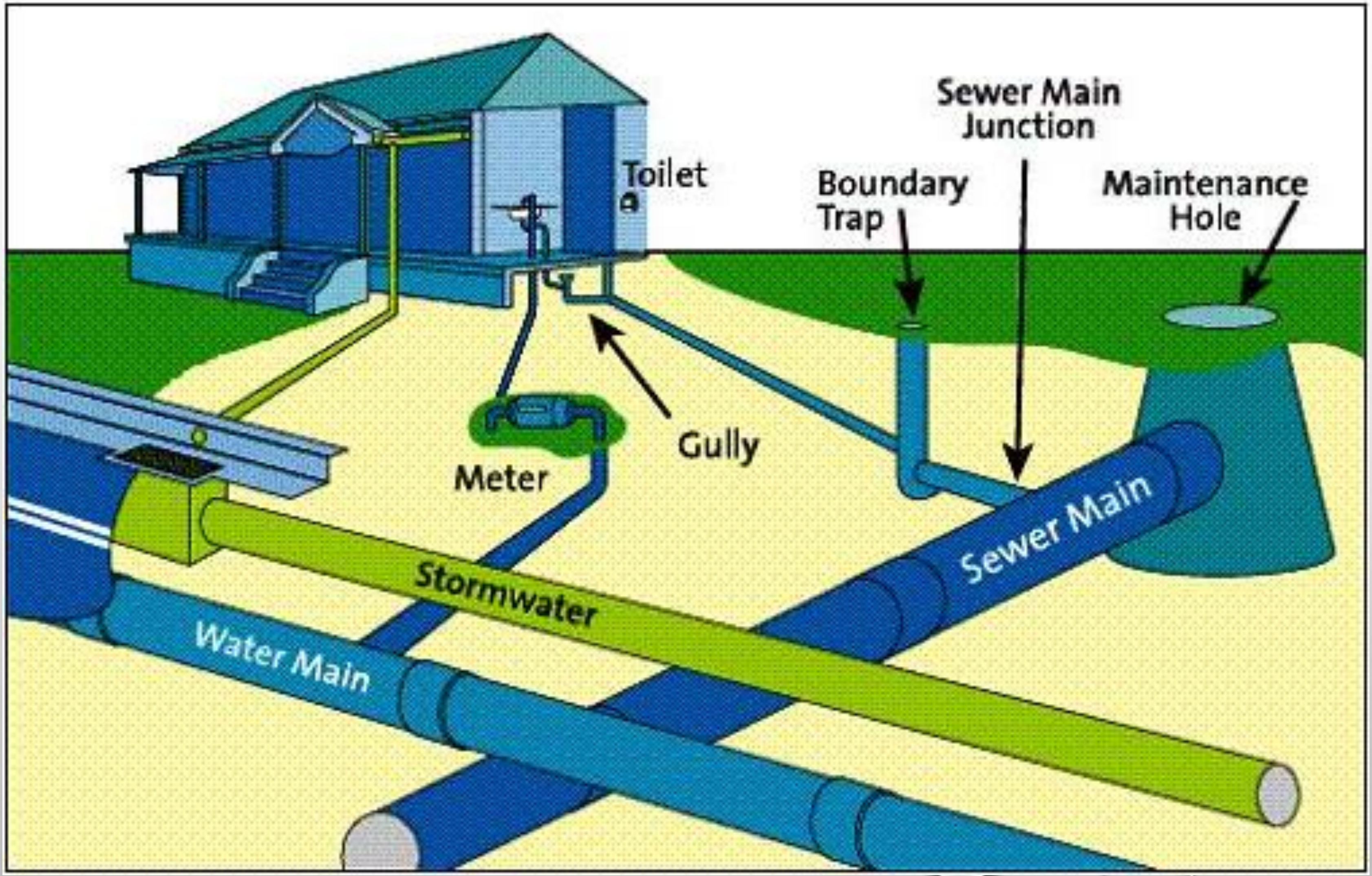
Sewers

Pumps

Treatment plant


Manholes

# Sewerage Network



# Sewage Treatment Plant (STP)

- It is a facility designed to **receive the wastewater** from **domestic, commercial and industrial sources** and to **remove materials that damage water quality** and **compromise public health and safety** when discharged into water receiving systems or land.

- It is the combination of **unit operations** and **unit processes** developed to treat the sewage to **desirable standards** to suit **effluent discharge norms** defined by the **regulating authority**.

# Sewage Treatment Plant (STP)

# Sewage Treatment Plant (STP)

# Sewage characteristics

# Sewage characteristics

- Characterization of wastes is essential for **an effective and economical** design of treatment plant.
- It helps in the **choice of treatment methods** deciding **the extent of treatment**, assessing the **beneficial uses of wastes** and **utilizing the waste purification capacity of natural bodies** of water in a **planned** and **controlled manner**.
- While **analysis of wastewater** in each particular case is advisable, data from the **other cities** may be utilized during **initial stage of planning**.
- The factors which contribute to variations in **characteristics of the domestic sewage** are **daily per capita use of water**, **quality of water supply** and **the type**, **condition and extent of sewerage system**, and **habits of the people**.

# Temperature

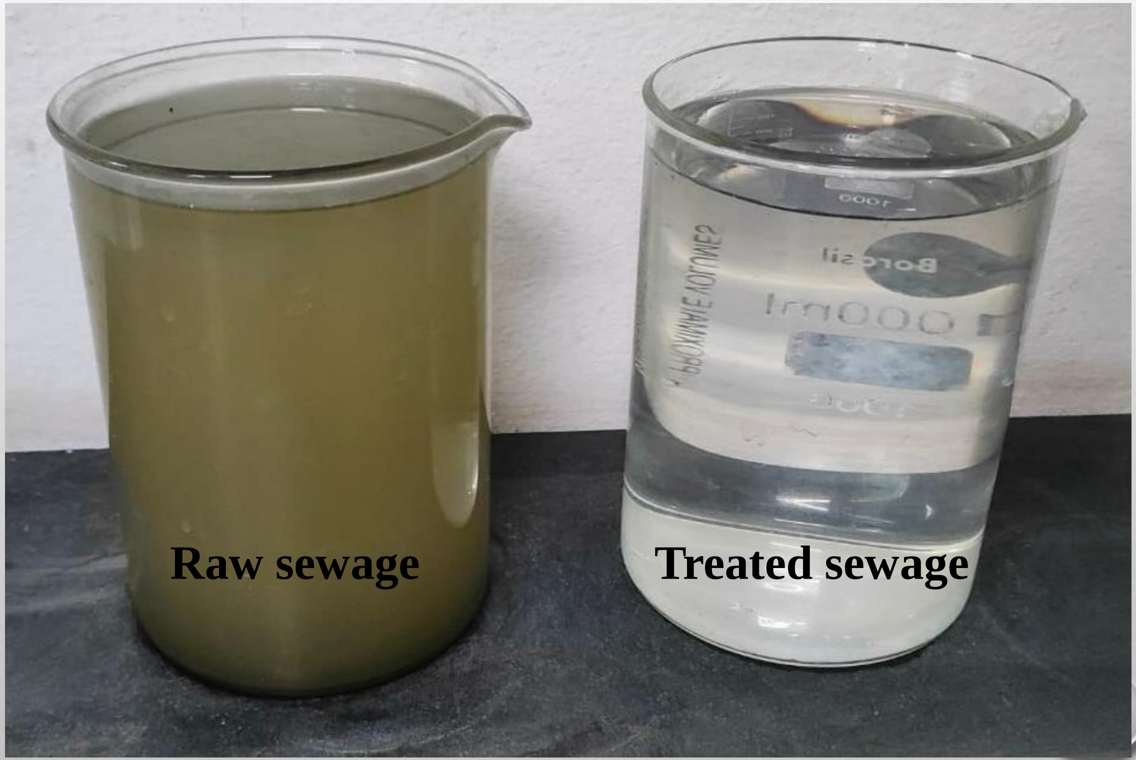
- The observations of temperature of sewage are useful in **indicating solubility of oxygen**, which affects **transfer capacity of aeration equipment** in **aerobic systems**, and **rate of biological activity**.
- **Extremely low temperature** affects adversely on the **efficiency of biological treatment systems** and on **efficiency of sludge settling**.
- In general, under **Indian conditions,** the temperature of the raw sewage is observed to be between **15 and 35°C** at various places in **different seasons**.

# pH

- The **hydrogen ion concentration** expressed as pH, is a valuable parameter in the operation of **secondary treatment units** like **biological and chemical** units.
- The pH of the **fresh sewage** is **slightly more** than the **water supplied** to the community due to the **presence of residual chlorine in water supplied**.
- However, **decomposition of organic matter** may **lower the pH**, while the presence of **industrial wastewater** may produce **extreme fluctuations**.
- Generally the pH of **raw sewage** is in the range **5.5 to 8.0.**

# Colour and Odour

- Fresh domestic sewage has a **slightly soapy and cloudy** appearance depending upon its concentration.
- As time passes the **sewage becomes stale**, **darkening in colour** with a pronounced smell due to **microbial activity**.



# Solids

- Though sewage generally contains **less than 0.5 percent solids**, the rest being water, still the **nuisance** (**choking and blocking**) caused by the solids cannot be overlooked, as these solids are **highly degradable** and **therefore need proper disposal**.
- The sewage solids may be classified into **dissolved solids, suspended solids and volatile suspended solids**.
- The estimation of **suspended solids, both organic and inorganic**, gives a general picture of the load on **sedimentation and grit removal** system during sewage treatment.
- **Dissolved inorganic fraction (salts, minerals, metals etc.)** is to be considered when sewage is used for **land irrigation** or any **other reuse** is planned.

# Nitrogen

- The principal nitrogen compounds in domestic sewage are **proteins, amines, amino acids, and urea**.
- **Ammonia nitrogen** in sewage results from the **bacterial decomposition** of these organic constituents.
- Nitrogen being an essential component of **biological protoplasm**, its concentration is important for **proper functioning** of **biological treatment systems** and disposal on land.
- Generally, the domestic sewage contains **sufficient nitrogen**, to take care of the needs of the **biological treatment**.
- Generally nitrogen content in the **untreated sewage** is observed to be in the range of **20 to 50 mg/L** measured as **Total Kjeldahl Nitrogen (TKN=Organic+$NH_3$).**

# Phosphorus

- Phosphorus is contributing to domestic sewage from **food residues** containing phosphorus and their **breakdown products**.
- The use of increased quantities of **synthetic detergents** adds substantially to the **phosphorus content** of sewage.
- Phosphorus is also an **essential nutrient** for the **biological processes**.
- The concentration of phosphorus in **domestic sewage** is generally **adequate** to support **aerobic biological wastewater** treatment.
- However, it will be **matter of concern** when the treated effluent is to be **reused**.
- The concentration of $PO_4$ in **raw sewage** is generally observed in the range of **5 to 10 mg/L.**

# Chlorides

- Concentration of chlorides in **sewage is greater** than the normal chloride content of **water supply**.
- The **daily contribution** of chloride averages to about **8 g per person**.
- Based on an **average sewage flow** of **150 LPCD**, this would result in the chloride content of sewage around **50 mg/L higher** than that of the **water supplied**.
- Any **abnormal increase** should indicate discharge of **chloride bearing wastes** or **saline groundwater infiltration**, the latter **adding to the sulphates** as well, which may lead to **excessive generation of hydrogen sulphide leading to corrosion** .

# Organic Material

- Organic compounds present in sewage are of **particular interest for environmental engineering**.
- A large variety of microorganisms (that may be present in the sewage or in the receiving water body) interact with the **organic material** by using it as an **energy or material source**.
- The **utilization of the organic material by microorganisms** is called **metabolism**.
- The **conversion of organic material** by microorganism **to obtain energy** is called **catabolism** and the **incorporation of organic material** in the **cellular material** is called **anabolism**.

# Biochemical Oxygen Demand (BOD)

- The BOD of the sewage is **the amount of oxygen required** for the **biochemical decomposition of biodegradable organic matter** under **aerobic conditions**.
- The **oxygen consumed** in the process is related to the **amount of decomposable organic matter**.
- The general range of BOD observed for **raw sewage** is **100 to 400 mg/L**.
- Values in the **lower range** are being common under **average Indian cities**.

# Chemical Oxygen Demand (COD)

- The COD gives the measure of the **oxygen required** for **chemical oxidation**.
- It **does not differentiate** between **biological oxidisable** and **nonoxidisable** substances.
- However, the ratio of the **COD to BOD** does not change significantly for particular waste and hence this test could be used conveniently for **interpreting performance efficiencies** of the treatment units.
- In general, the **COD of raw sewage** at various places is reported to be in the range **200 to 700 mg/L**.

# Toxic Metals and Compounds

- Some heavy metals and compounds such as **chromium, copper, cyanide**, which are **toxic** may find their way into **municipal sewage** through **industrial discharges**.
- The concentration of these compounds is important if the sewage is to treat by **biological treatment** methods or **disposed off in stream or on land**.
- In general these compounds are **within toxic limits in sanitary sewage**; however, with receipt of **industrial discharges** they **may cross the limits** in municipal wastewaters.

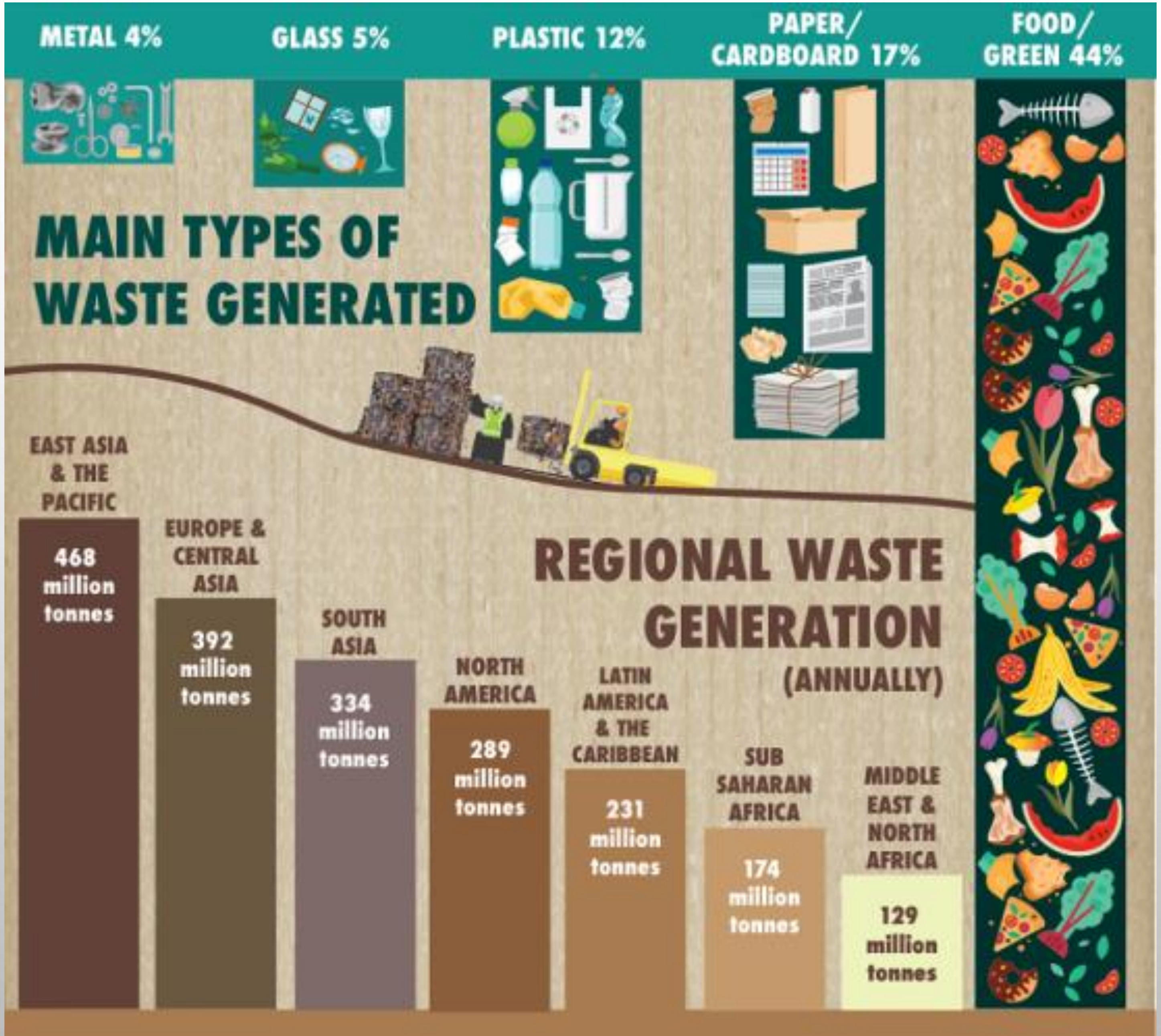
# Solid Waste Management

# Waste Generation

- **Waste** is material that has no further value to its owner and is thrown away
- Some has further value to others (reuse)
  - Chemical **ingredients**
  - **Electronic** parts
  - **Compost** for your garden
- Some is just waste (**disposal**)
  - Food **wrappings**
  - Product **containers**
  - Household **hazardous substances**
- As technology develops, something that was previously considered as waste may have renewed value:
  - **Food to $CH_4$** for energy production

https://www.123rf.com/clipart-vector/food_waste.html

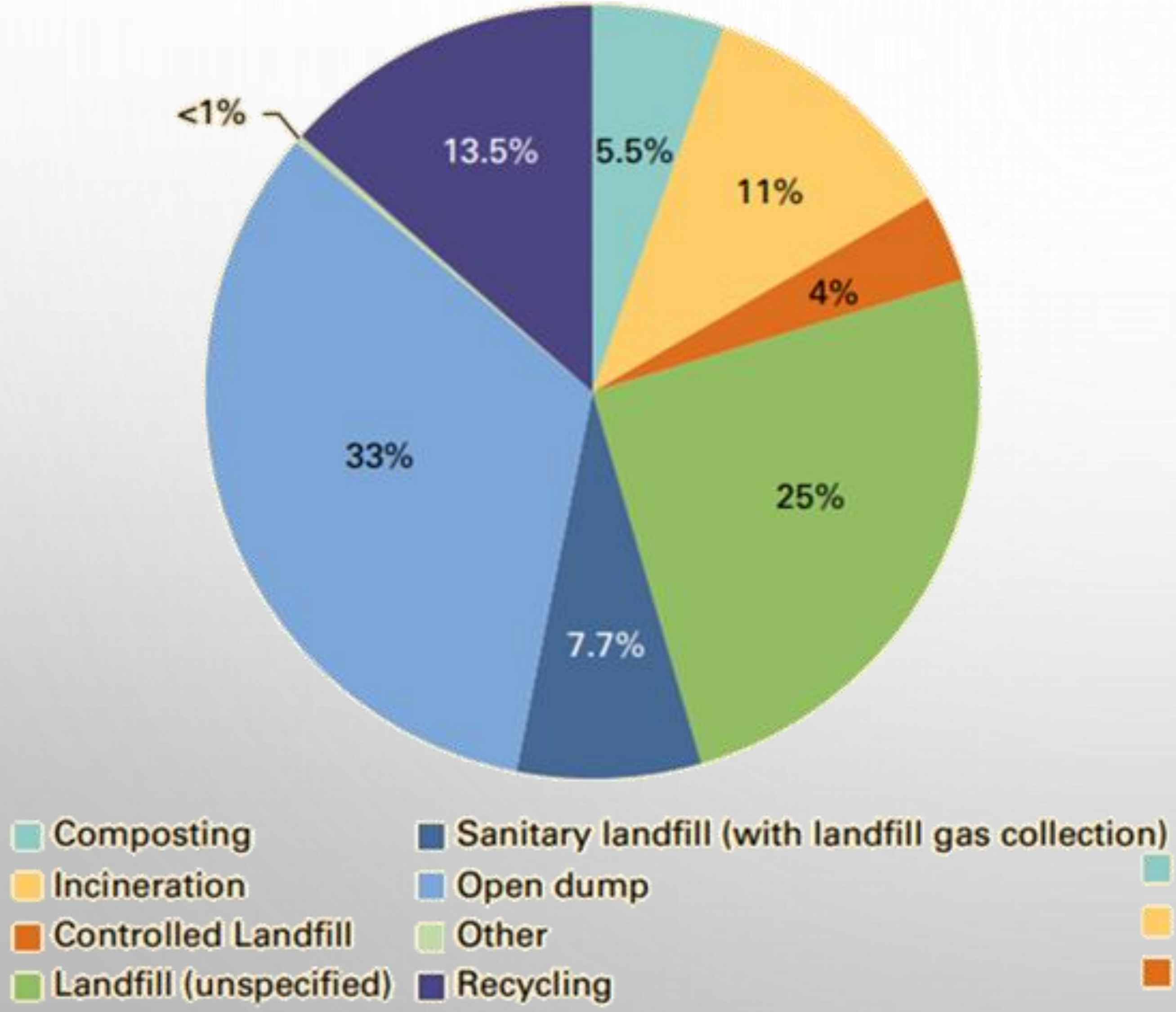
# Waste generation and characteristics

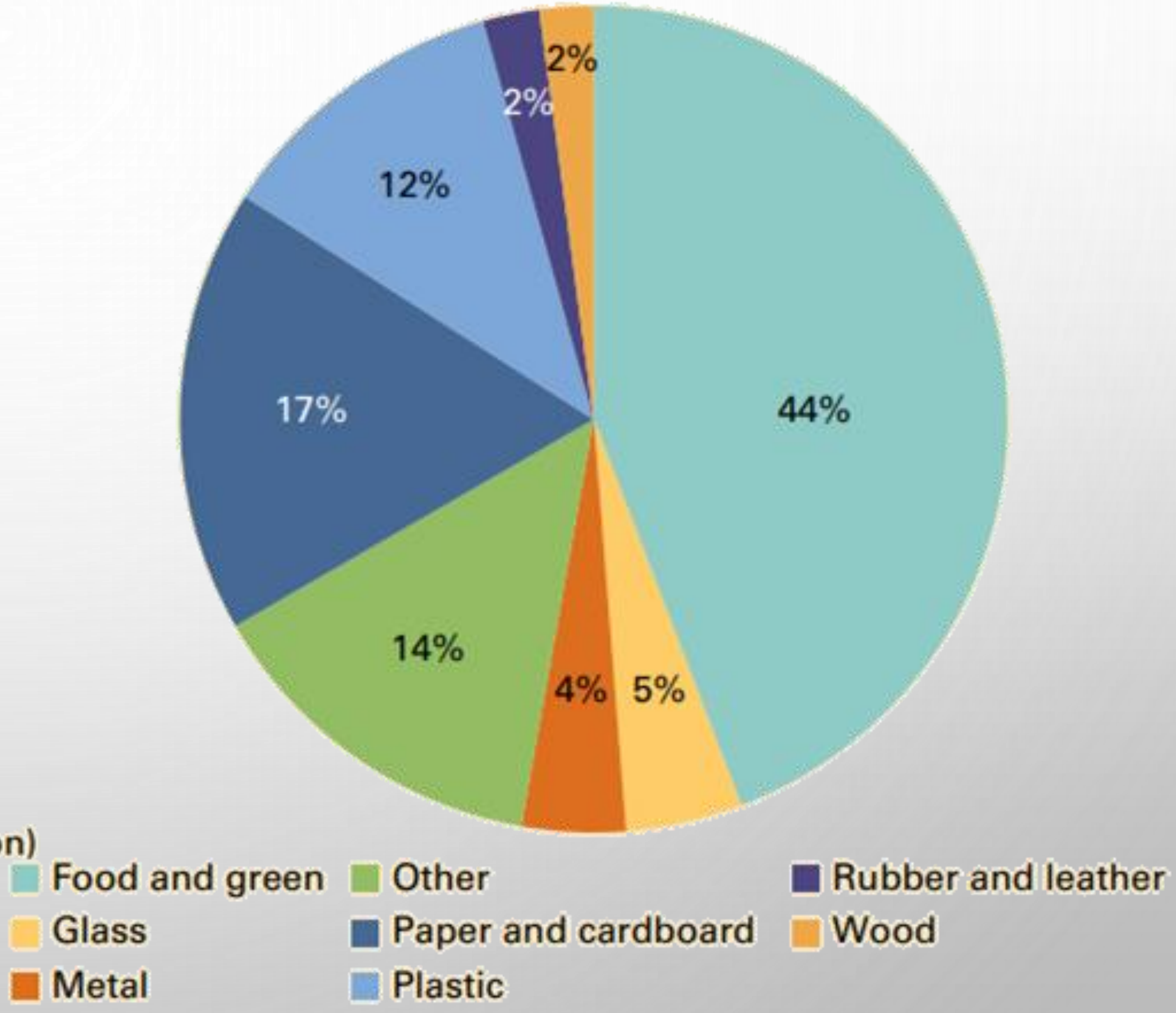


# Dumping of solid waste

https://science.howstuffworks.com/environmental/conservation/issues/deadly-1948-donora-smog-launched-clean-air-movement.htm

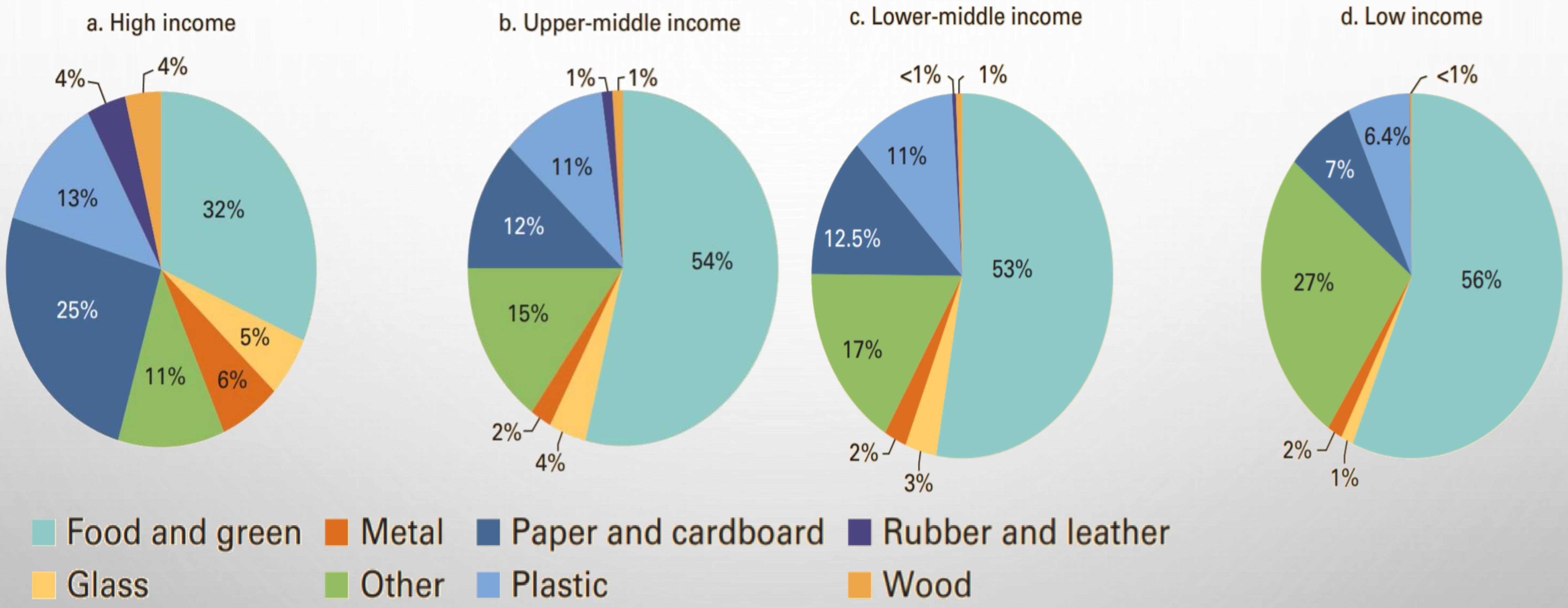
# Global waste treatment & disposal



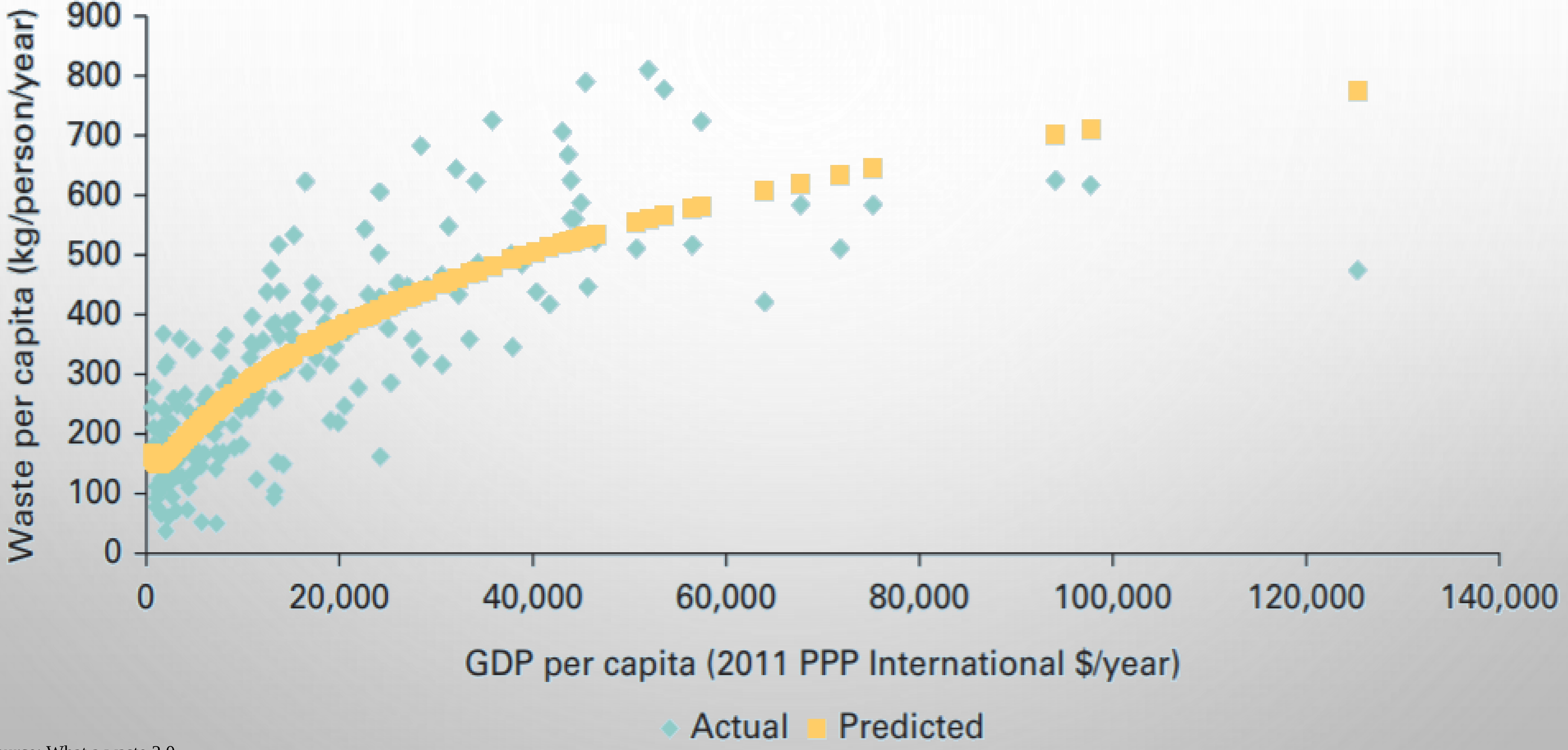

Source: What a waste 2.0

# Global waste composition by income level




Source: What a waste 2.0

# Relationship between GDP & waste generation




Source: What a waste 2.0

# Waste segregation


Source: https://depositphotos.com/vector-images/bin.html

# Source segregation

**Biodegradable**

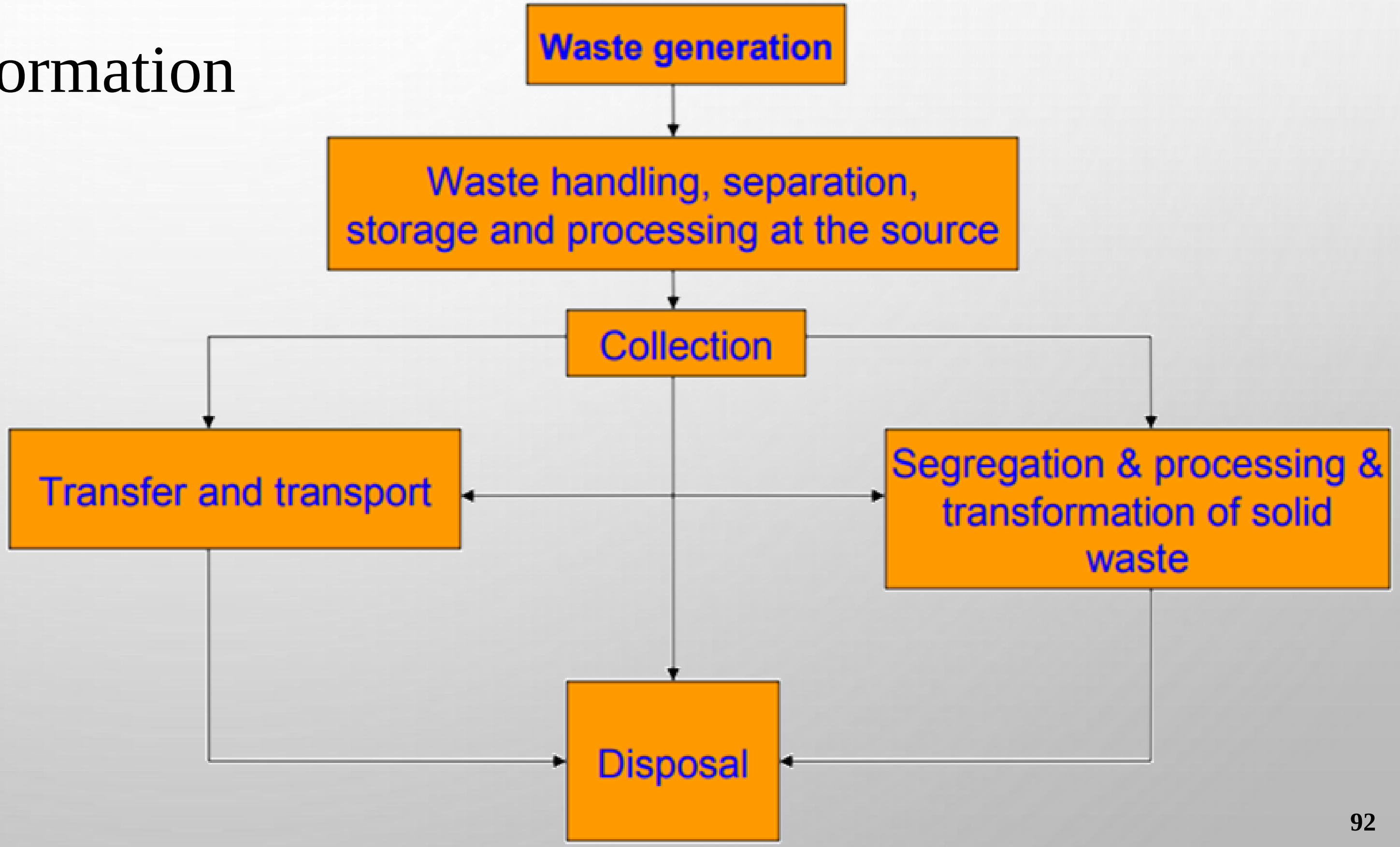
Vegetables peels
Fruit peels
Food Remains
Coffee powder
Coconut shells
Egg shells


**Recyclables**

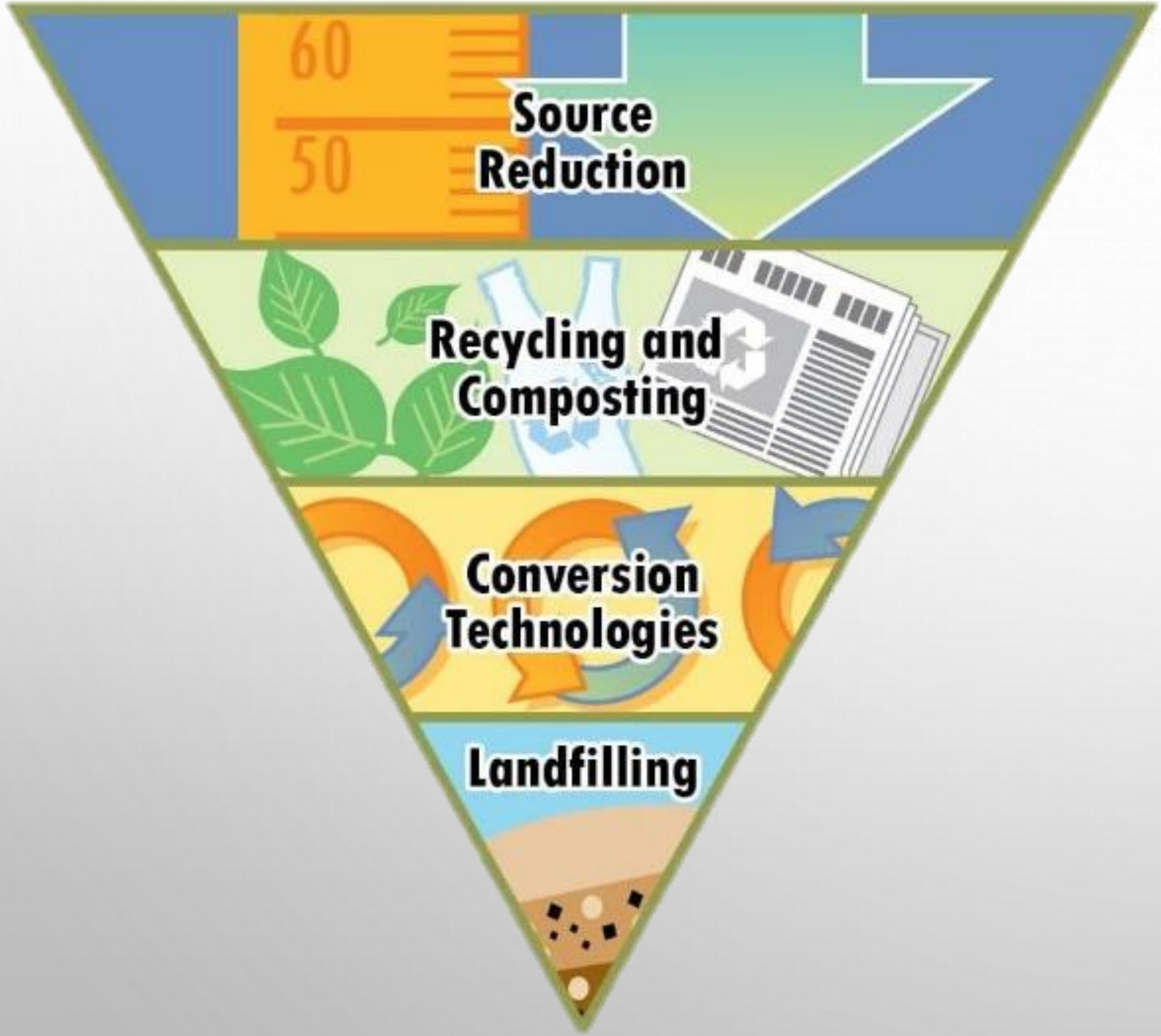
Plastic
Paper
Wood
Glass
Rubber
Metal

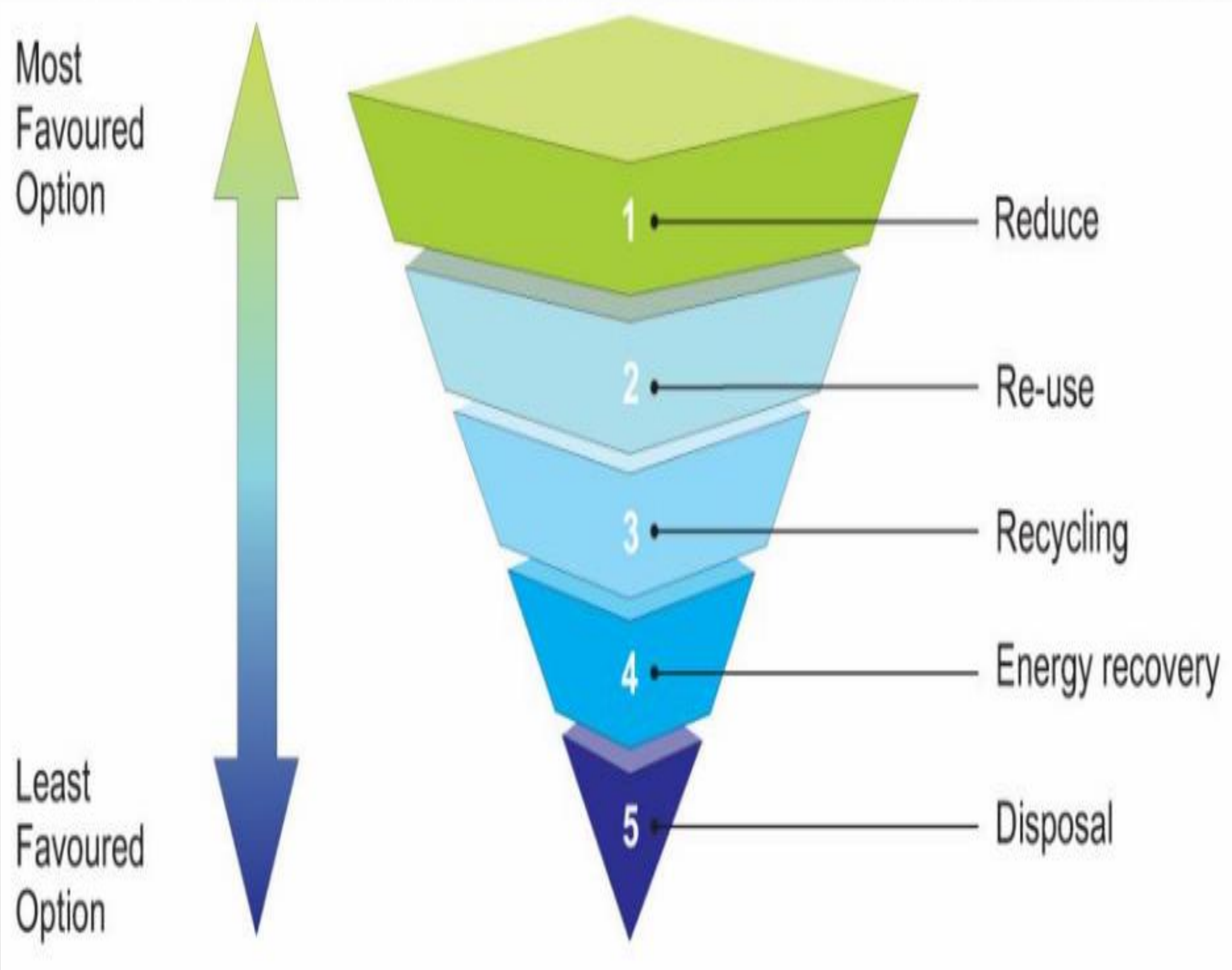
# 6 elements of a waste management system

1. Waste Generation
2. Handling separation storage and processing at source
3. Collection
4. Separation processing and transformation
5. Transfer and transport
6. Disposal



# Integrated solid waste management






https://wasteadvantagemag.com/evolution-of-integrated-solid-waste-management-systems-enhanced-with-municipal-utilities-and-green-energy-production/

# Recycling

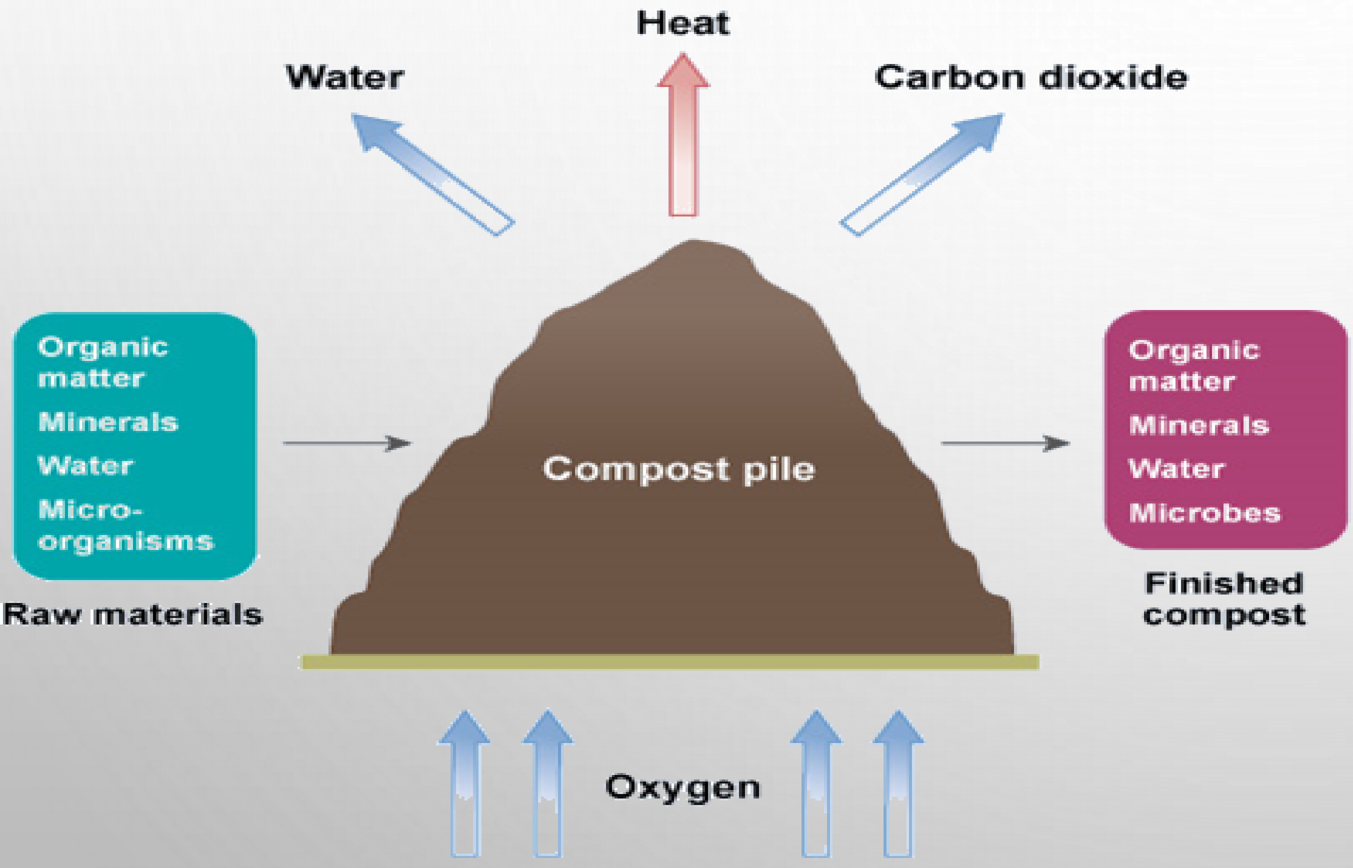
Pros:

- Save **precious resources**
- Lessens **need for mining** of virgin materials
- **Lowers environmental impact** of mining/processing
- Stretch **landfill capacity**
- **Improves efficiency** of incinerators and composting facilities

Cons:

- Waste oil recycling, newspaper **de-inking,** solvent and metal recycling can be **problematic**
- Can result in **contamination** of soil, **groundwater**, air
- Require **stable market**
- Only works if it is **convenient**
  - Curbside pick-up
  - Drop off centers
  - Mail back programs

# Composting


- Natural decomposition of organic material
  - Need **organic**, **water**, **oxygen**
  - Does not use preserved wood, human wastes, bones, meat, fat, certain weeds
- Individual
- Municipal
- **Major factors of consideration**: Temperature and pH
- **Major Types**: windrow composting & aerated static pile composting



https://www.open.edu/openlearncreate/pluginfile.php/170069/mod_oucontent/oucontent/13842/90723551/2f744a9c/m4_ss8_fig8.4.jpg

# Waste to Energy


**Through**

- Heat
- Electricity
- Co-generation (harnessing of useful heat and electricity from one power plant)

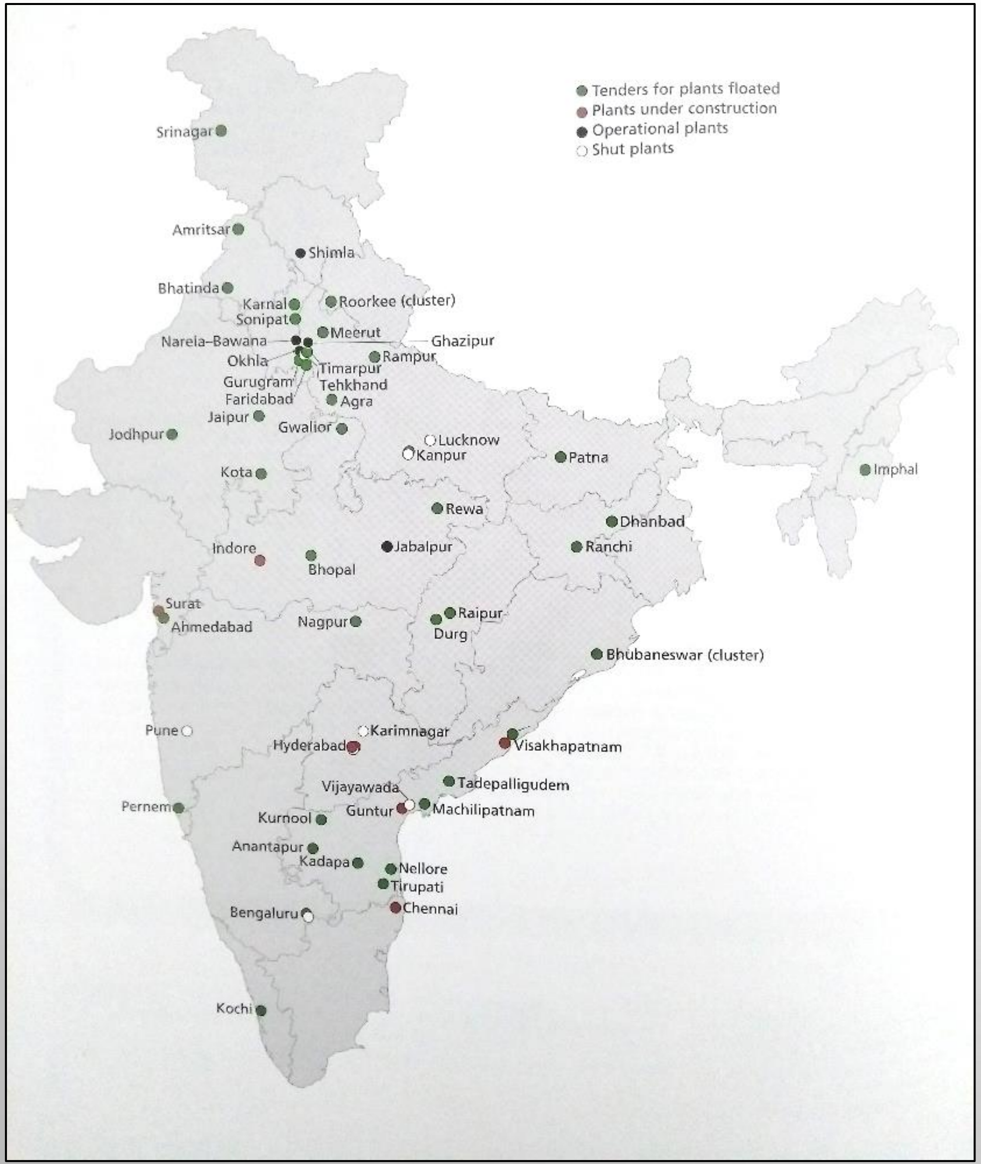
PROS:

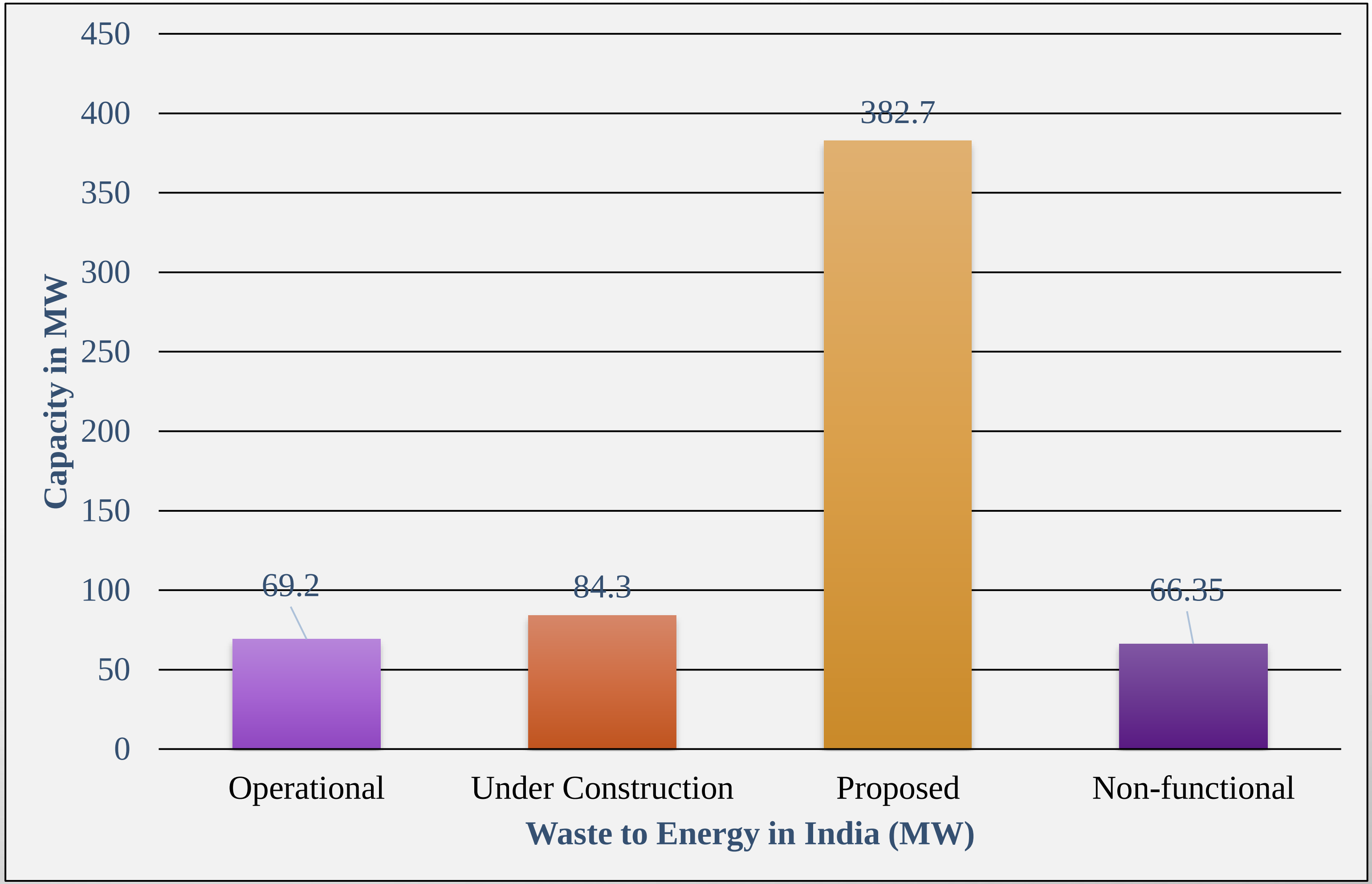
- Reduce **volume of waste**
- **Recover useful energy**
  - Steam
  - Waste
- Incinerator ash can be used in **building material**

CONS:

- Cost
- **High degree of sophistication** needed to operate safely
- Public perception of **safety**
  - Stack emissions
  - Toxicity of ash

# Waste to Energy in India

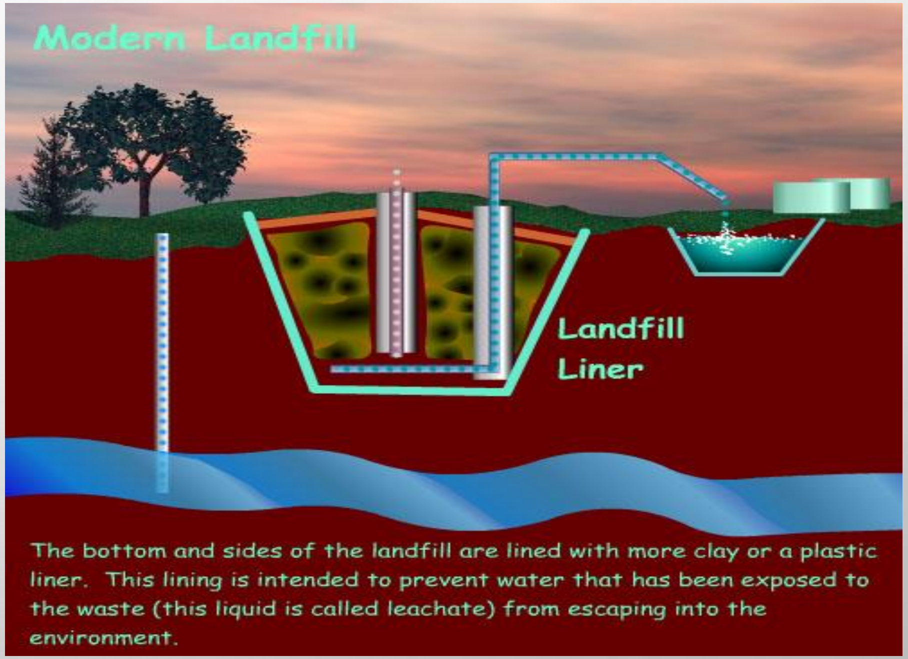



***Source:*** *Sambyal, S. S., and Richa, A. 2018. To burn or not to burn: Feasibility of Waste to Energy Plants in India. CSE Publishers, India*

# Landfilling

- Concept fostered in **early 20$^{th}$ century**
- An area of land that has solid waste deposited on it in such a quantity to noticeably **change the surface elevation**.
- **50-70% of municipal solid** waste is landfilled.




**<u>Advantages</u>**

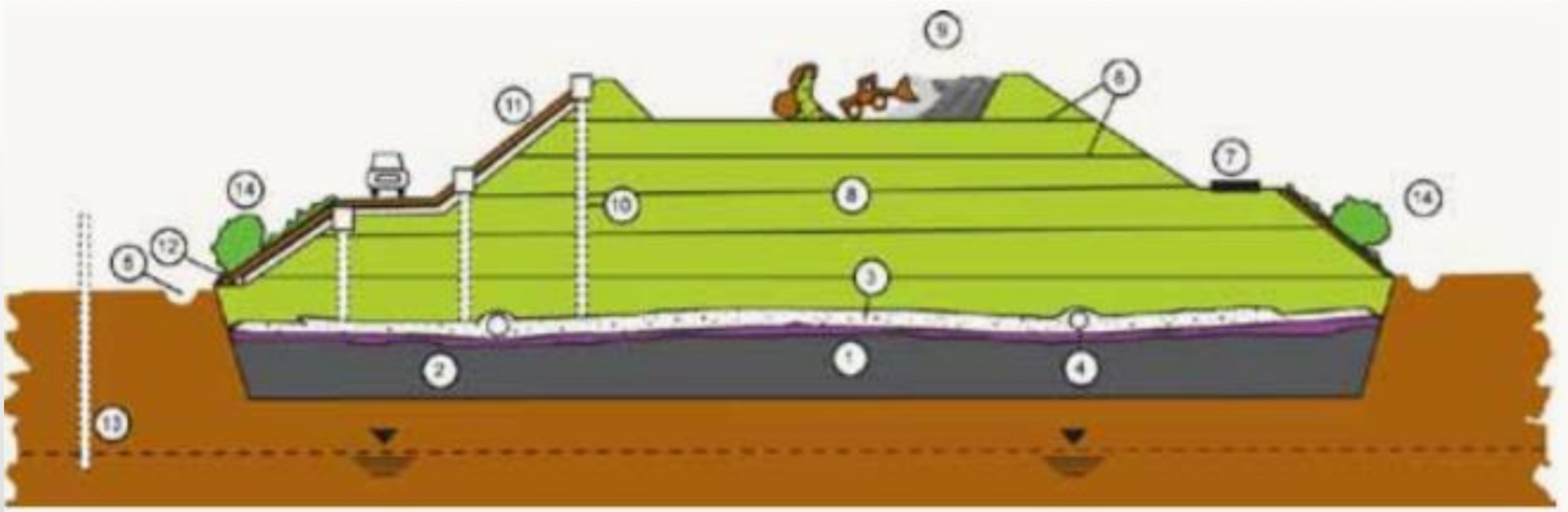
- Carbon **sequestration** ?
- Easy and **cheap** solution !!
- **Nutrients** from leachate ?
- **Energy** from landfill gas ?
- A **quick fix solution** for hazardous and infectious waste ?

# Dumping vs Landfill

- Dumps are **open places** where trash is buried and where animals swarm.
- They offer n**o environmental protection** and are **not regulated**.

- Landfills are carefully **designed** and **monitored structures** that isolate trash from the surrounding environment.
- They typically use a **bottom liner** and **daily covering** of soil.

# Components of a sanitary Landfill



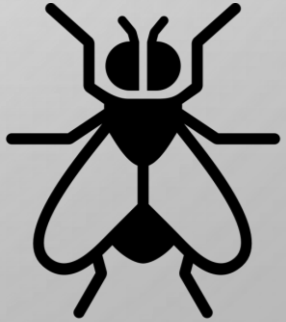
1. Geological barrier
2. Impermeable base liner
3. Drainage layer
4. Leachate collection system
5. Storm - water drain ditch
6. Bordering dams
7. Circulation roads
8. Landfill body
9. Filling and compacting in layers
10. Gas venting system
11. Protective cover system
12. Gas collectors
13. Grondwater control
14. Re-planting



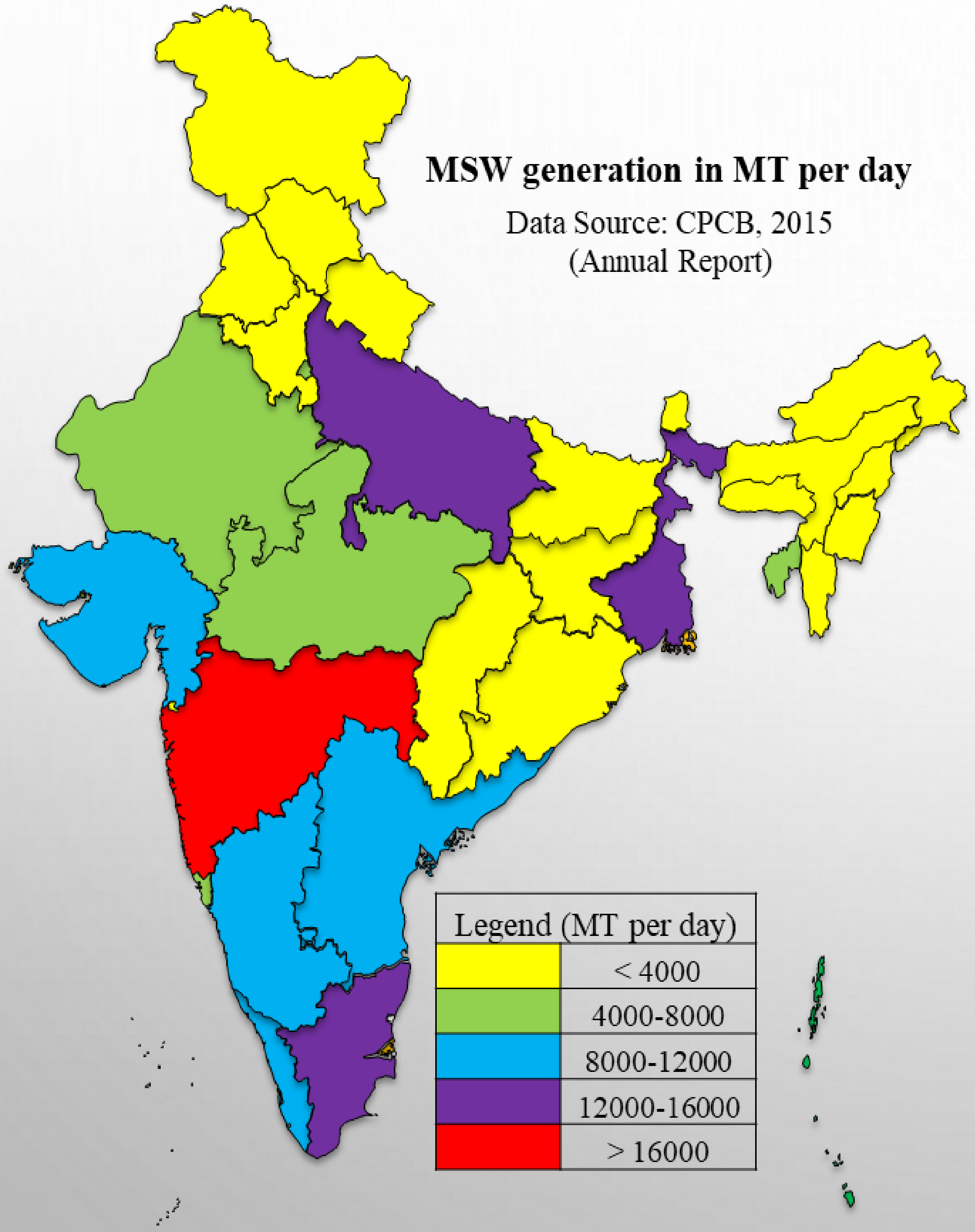
https://smartnet.niua.org/sites/default/files/resources/Book%201.pdf

# Problems associated with Landfilling


- Physical amount and disposal sites
- Costs to collect, handle, and dispose
- Litter
- Odor
- Insects (flies, cockroaches) & rodents
  - food
  - harborage
- Resource lost

# Solid Waste Management in India




| S. No | Item | Description | Source |
|---|---|---|---|
| 1 | Solid waste generation in India | 62 million tonnes annually | PIB, 2016 |
| 2 | Percentage of waste being collected | 70% | |
| 3 | Percentage of waste being treated | 22 – 28% of the collected waste | |
| 4 | Status of remaining collected waste | Dumped in unlined landfill | |
| 5 | Compost and vermi-compost units | 553 | CPCB, 2015 |
| 6 | Bio-methanation plants | 56 | |
| 7 | Refuse Derived fuel plants | 22 | |
| 8 | Waste to Energy plants | 13 | |

***PIB**: Press Information Bureau; **CPCB**: Central Pollution Control Board*

# Solid Waste Management rules in India

- To enhance the existing waste management practices, Government of India conglomerated policies and structure for solid waste management. They are entitled as **Solid Waste Management (SWM) rules 2016**.
- Selection Criteria for waste processing technologies was drafted by CPCB in compliance with **National Green Tribunal (NGT).**
- A manual is developed by **Ministry of Urban Development**, which provides stepwise guidance to local authorities in development of solid waste management systems (CPHEEO, 2016).