OVERVIEW OF WATER TREATMENT

Water treatment involves a series of physical and chemical processes to remove contaminants and make water safe for **drinking**, **industrial**, or **domestic** use. The steps vary depending on the source of water.

Groundwater Treatment

- Typically, clear and low in pathogens.
- Contains minimal organic material.
- Often needs only disinfection (e.g., chlorination) for potable use.
- May require treatment if iron, manganese, or hardness is high.

Surface Water Treatment

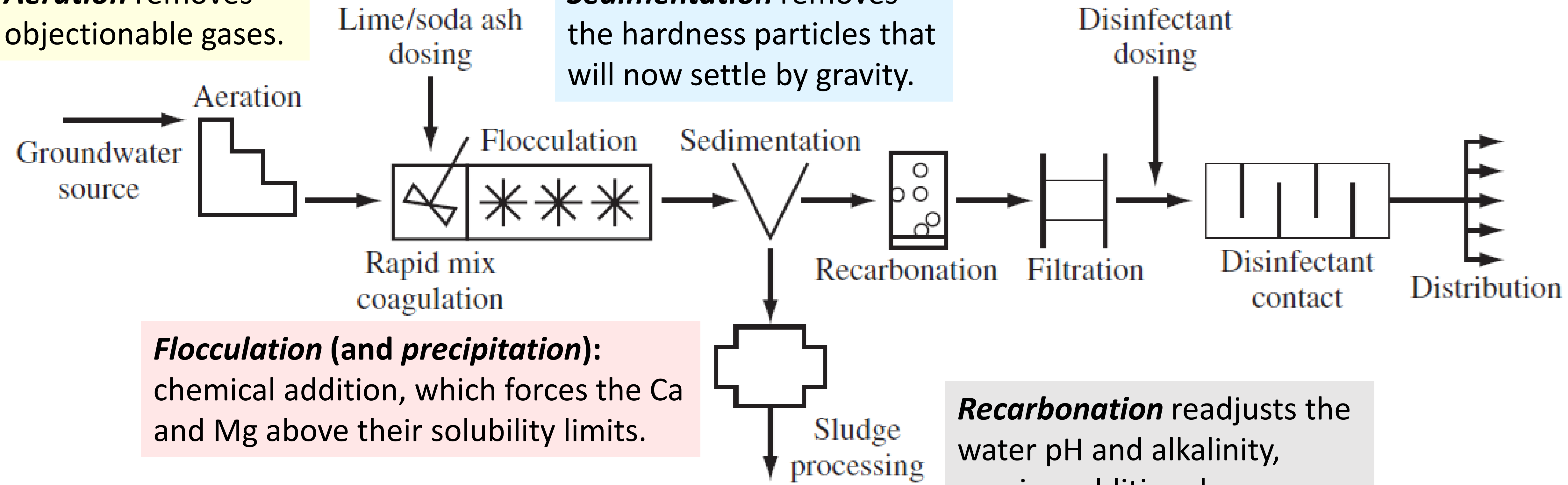
- Usually contains more diverse contaminants.
- High turbidity often exceeds safe limits.
- Colloidal particles are common – need chemical coagulation.
- Often contains pathogenic microorganisms.

Schematic of a typical water treatment plant for groundwater

Aeration removes objectionable gases.

Sedimentation removes the hardness particles that will now settle by gravity.

Filtration, disinfection, and *solids processing*



Flocculation **(and *precipitation*):** chemical addition, which forces the Ca and Mg above their solubility limits.

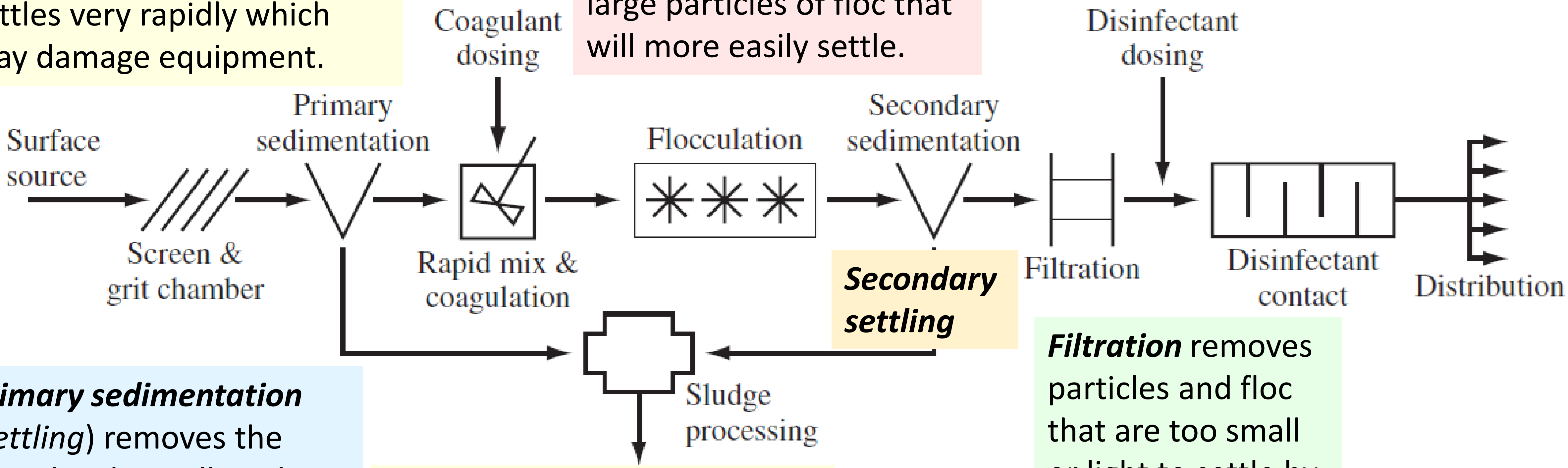
Recarbonation readjusts the water pH and alkalinity, causing additional precipitation of hardness-causing ions.

Schematic of a typical surface water treatment plant

Screening take out relatively large floating, suspended debris, sand and grit that settles very rapidly which may damage equipment.

Flocculation*:* process of gently mixing the water, encourages formation of large particles of floc that will more easily settle.

Disinfection *contact* provides sufficient time for the added disinfectant to inactivate any pathogens before the water is distributed.



Secondary settling

Primary sedimentation (*settling*) removes the particles that will settle out by gravity alone within a few hours.

Rapid mixing **and** ***coagulation*** use chemicals and agitation to encourage suspended particles to collide and adhere into larger particles.

Filtration removes particles and floc that are too small or light to settle by gravity.

Sludge processing refers to the dewatering and disposing of solids and liquids collected from the settling tanks.

AERATION

- Aeration brings water and air into close contact
- It helps to remove dissolved gases
- It also helps to remove dissolved metals through oxidation
- Iron and Manganese can be removed as precipitate after aeration as:

$$4\ Fe^{2+} + O_2 + 10\ H_2O \rightarrow 4\ Fe(OH)_3 \downarrow + 8\ H^+$$

$$2\ Mn^{2+} + O_2 + 2\ H_2O \rightarrow 2\ MnO_2 \downarrow + 4\ H^+$$

Principle of Aeration:

- The water body is exposed over a vast surface to the atmosphere.
- Atmospheric oxygen replaces other harmful gases.
- This process continues until an equilibrium is reached.

SOFTENING

- Process of reducing the concentration of calcium and magnesium ions, which cause water hardness.
- This is typically achieved through:

1. Physical Treatment: Boiling
2. Chemical Treatment: Lime-soda
    - This method involves adding lime (calcium hydroxide) and soda ash (sodium carbonate) to precipitate out calcium and magnesium ions as insoluble compounds.
3. Ion exchange:
    - In this process, hard water is passed through a resin that exchanges the calcium and magnesium ions for sodium or potassium ions, effectively reducing the hardness.

PLAIN SEDIMENTATION

- A process in which water is retained in a tank so that the suspended particles present may settle down under the action of gravity.
- Suspended solids having a specific gravity > water, settle down by gravity
- The settling velocity of a spherical particle is expressed by **Stoke's Law**

$$V_s = \frac{g}{18}(G-1)\frac{d^2}{\nu}$$

Valid for d< 0.1 mm

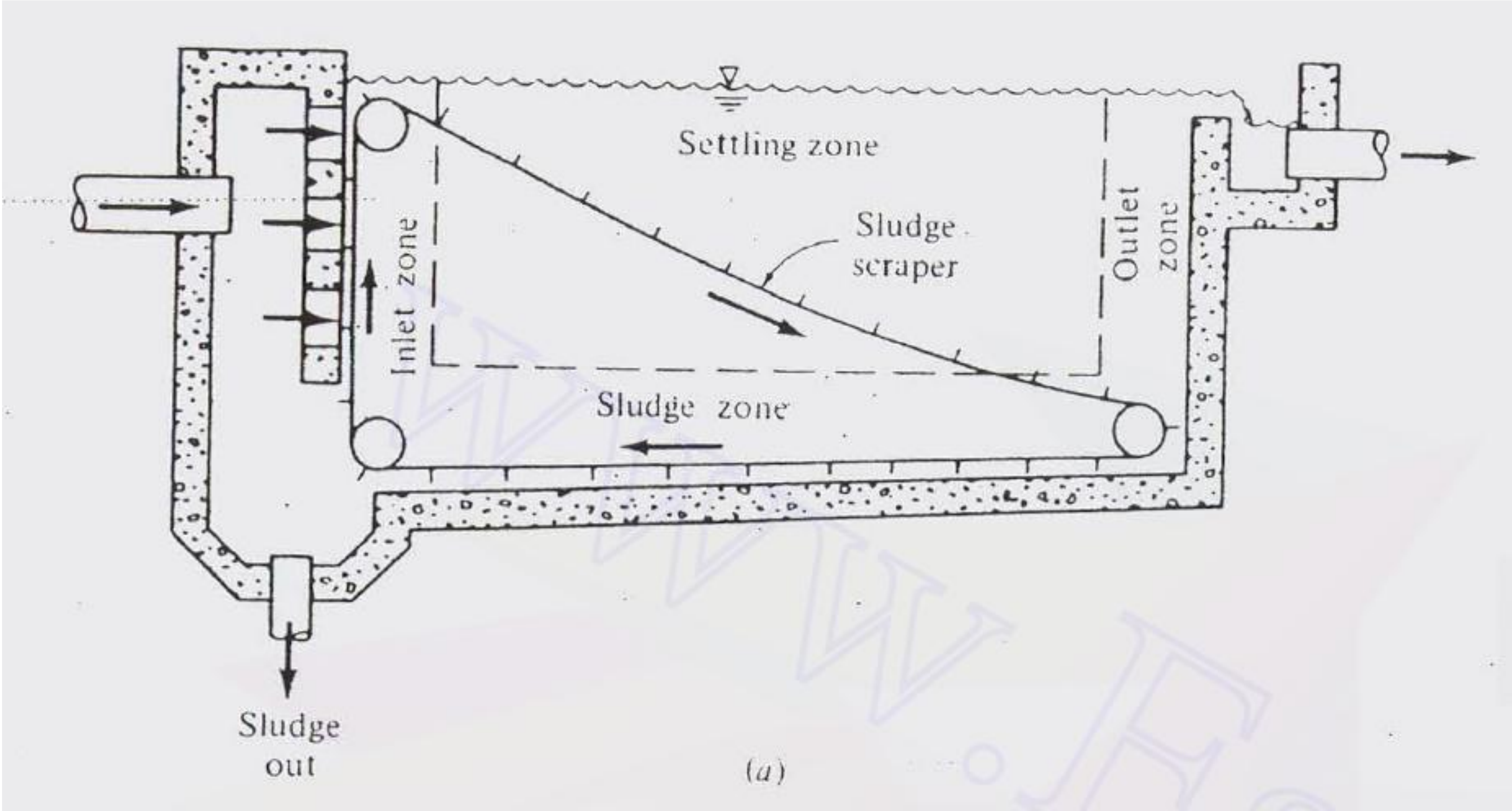
Vs = Velocity of settlement of particle (m/s)

G = specific gravity of the particle

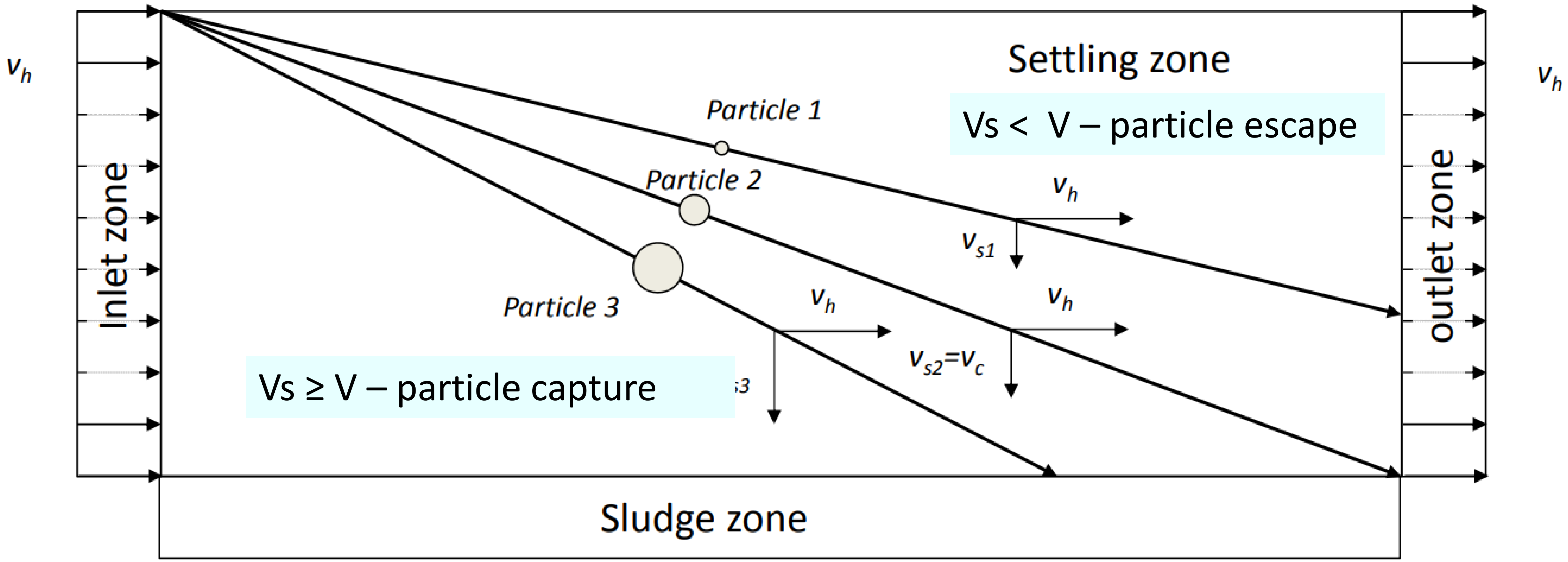
d = Diameter of the particle (m)

ν = Kinematic viscosity of water (m^2/s)

LONG RECTAGULAR BASIN



Settlement of DISCRETE particles



SURFACE LOADING RATE/ SURFACE OVERFLOW RATE (V_O)

- Volume of water applied in unit time per unit surface area (plan area) of settling tank is known as surface loading rate or surface overflow rate.
- It is a sedimentation tank property, and is not dependant on velocity

$$V_0 = \frac{\frac{Volume}{time}}{Surface\ area} = \frac{Q}{Surface\ area}$$

DETENTION TIME

Average time taken by water to travel from inlet to outlet of the settling tank is known as the detention time.

$$Detention\ time\ (DT) = \frac{Volume\ of\ the\ settling\ tank}{Q}$$

- Settling time of particles < DT: particles are captured
- Settling time of particles > DT: particles escape

FLOW THROUGH VELOCITY (V_H)

- The speed with which water travels in the settling tank is known as flow through velocity.

- For rectangular settling tanks:

$$V_H = \frac{Q}{BXH}$$

$$DT = \frac{L}{V_H}$$

NUMERICAL

Q. A rectangular sedimentation tank is treating 1.8 MLD of raw water with detention period 4 h. The allowable overflow rate is 500 L/h/m^2. Determine:

(i) the volume of tank required and

(ii) if L:B is 4:1, then find the length required for the tank.

SOLUTION

$$Q = 1.8 \text{ MLD} = 1.8 \times 10^3 \text{ m}^3/\text{day}$$

$$DT = 4 \text{ hrs}$$

$$\text{Volume of settling tank} = Q \times DT = \frac{1.8 \times 10^3}{24} \times 4 = 300 \text{ m}^3$$

Surface loading rate = $500 \text{ L}/\text{m}^2/\text{day}$

$$V_o = \frac{Q}{L \times B}$$

$$L \times B = \frac{\frac{1.8 \times 10^3}{24}}{500} = 150 \text{ m}^2$$

$$\frac{L^2}{4} = 150$$

$$L = 24.49 \text{ m} \ \ (\approx 24.5 \text{ m})$$

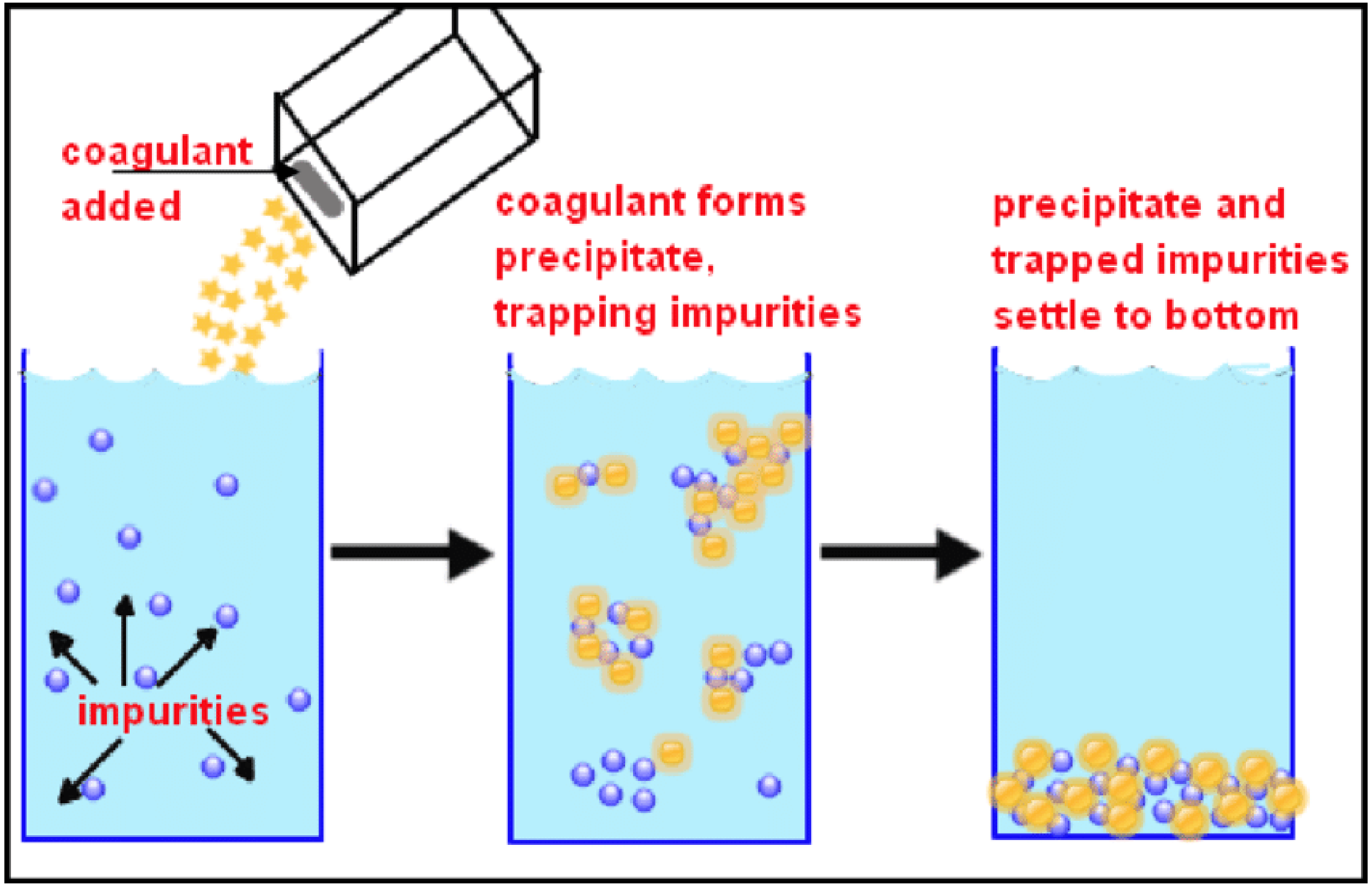
$$B = 6.123 \text{ m}$$

COAGULATION-AIDED SEDIMENTATION

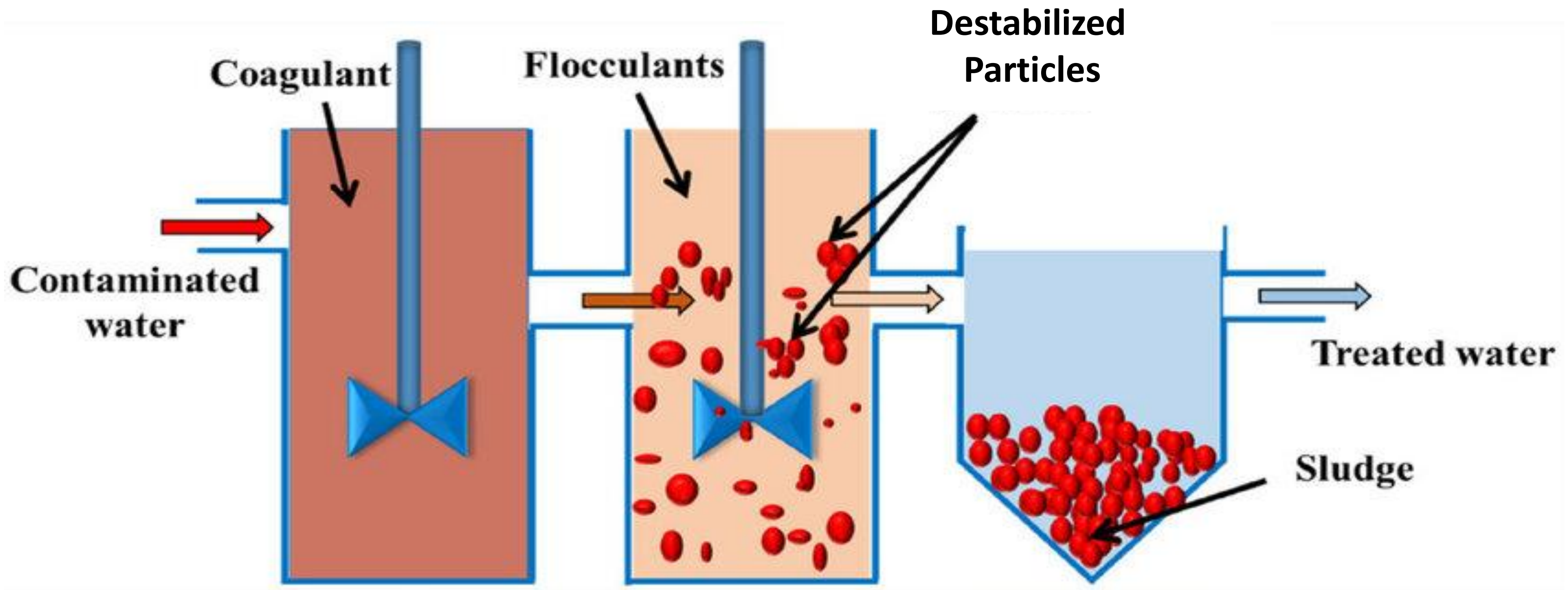
- Plain sedimentation is not efficient in removing very fine suspended particles of colloidal matter.
- The Stoke’s equation cannot be used for such particles, as these particles continually change size and shape.
- The settling down of such fine colloidal particles can be achieved by chemically assisted sedimentation.
- Coagulants are added to raw water and gently mixed with it, which causes insoluble, gelatinous, flocculent floc to be formed.
- This floc, being heavy, tends to settle down along with the colloidal particles.

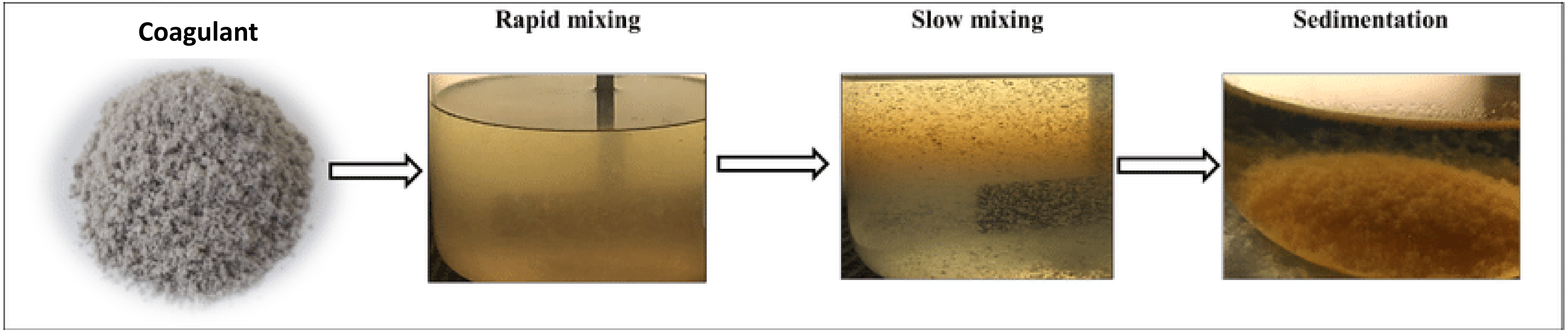
COAGULANTS

- Aluminium sulphate (Alum)
- Iron salts
- Chlorinated copperas
- Sodium aluminate



COAGULATION, FLOCCULATION, AND SEDIMENTATION PROCESS





COAGULATION AND ALKALINITY

- When metallic salt coagulants like alum are added to water, they release hydrogen ions that reduce alkalinity.
- For example, 1 mg/L of alum removes about 0.5 mg/L of alkalinity. If the water already has low alkalinity, this reduction can remove its buffering ability, causing the pH to drop quickly.
- Since good coagulation needs the right pH and alkalinity for floc formation, low-alkalinity water is often treated with lime to increase alkalinity.

ALUMINUM SULPHATE (ALUM)

- Alum is known as a universal coagulant
- Cheapest chemical, therefore, coagulation with alum is economical.
- Besides producing floc, it removes color and odor, and improves taste.
- It is very effective when pH is 6.5-8.5.

$$\boxed{\text{Alum} + \text{alkalinity} \rightarrow \text{Non-carbonate hardness (NCH)} + \text{floc} + CO_2 + H_2O}$$

$$\underset{666}{Al_2(SO_4)_3 \cdot 18H_2O} + \underset{162}{3\,Ca(HCO_3)_2} \longrightarrow \underset{136}{3\,CaSO_4} + \underset{78}{2\,Al(OH)_3} \downarrow + \underset{44}{6\,CO_2} \uparrow + \underset{18}{18\,H_2O}$$

FILTRATION

- The process of passing the water through the beds of granular materials (filters) is known as filtration.
- To remove very fine suspended and colloidal particles that do not settle in the sedimentation process.
- To remove dissolved impurities in water.

Mechanism:

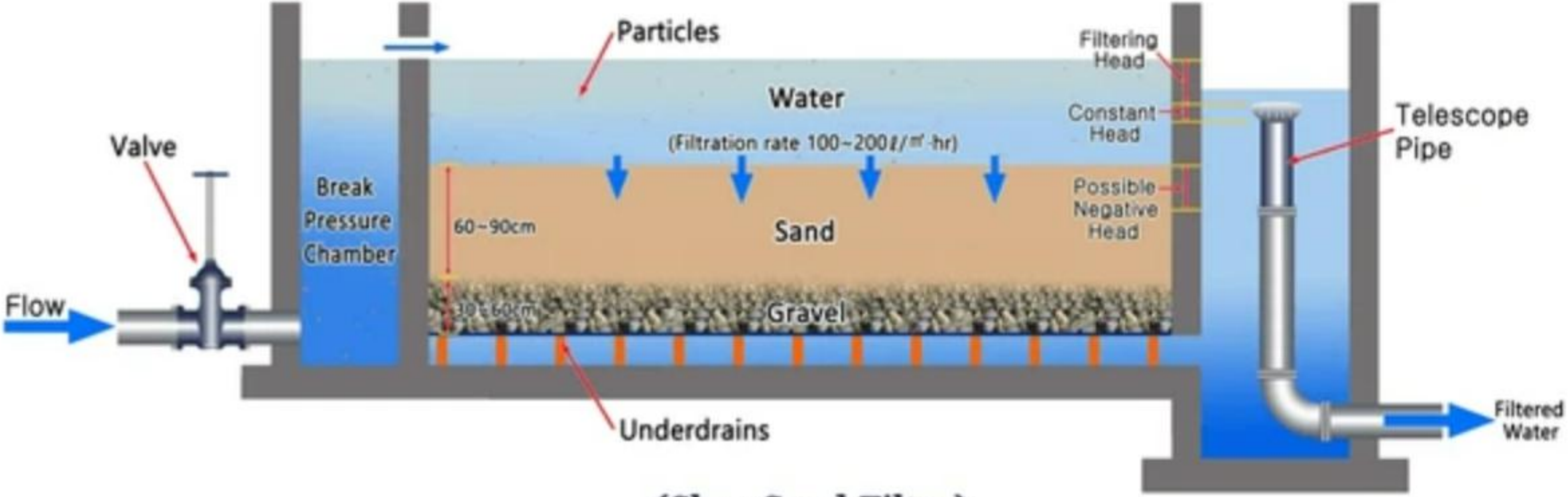
i. Mechanical straining
ii. Sedimentation
iii. Biological action

Filter media:

- Sand (fine or coarse) is generally used as filter media and supported on gravel.

Component	Slow sand filters	Rapid sand filters
Rate of filtration	100-200 L per m^2 per h	3000-6000 L per m^2 per h
Size of bed	Requires large area	Requires small area
Pretreatment	Pretreatment is not required except sedimentation	Coagulation, Flocculation, and Sedimentation is required
Filter media or sand	Effective size: 0.25mm to 0.35 mm Depth: 80-100 cm	Effective size: 0.35mm to 0.6 mm Depth: 60-90 cm
Base material or gravel	Size: 3-65 mm Depth: 30-75 cm	Size: 3-40 mm Depth: 60-90 cm
Method of cleaning	Scrapping of the top layer to 15-25 mm	Backwashing
Frequency of cleaning	1 to 2 month	2 to 3 days
Efficiency	Efficient in bacteria removal (98-99%), but less efficient in removal of color and turbidity.	Efficient in color and turbidity removal but less efficient in bacteria removal (80-90%)
Economy	High initial cost but low cost of operation.	Low initial cost , but higher operational cost. Overall, economical.
Flexibility	Not flexible in meeting variations	Quite flexible for reasonable variation
Skilled supervision	Not essential	Essential

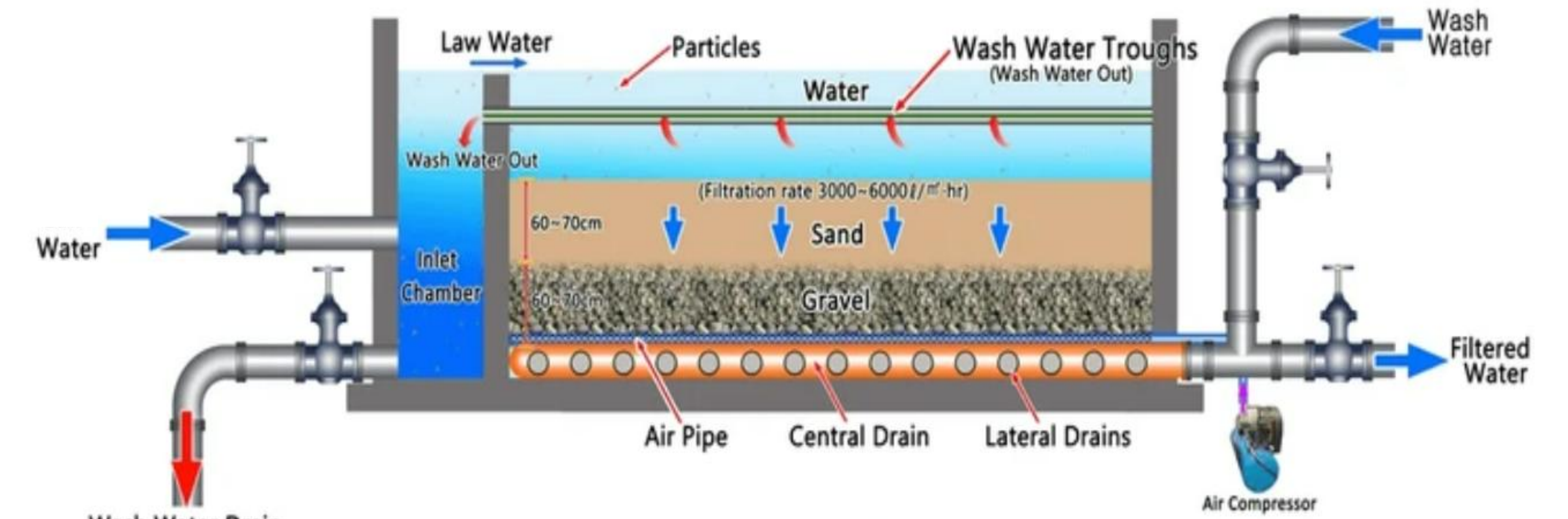
SLOW SAND FILTRATION (SSF)



(Slow Sand Filter)

Efficiency: 98 to 99%

RAPID SAND FILTRATION (RSF)



(Rapid Sand Filter)

Efficiency: 80 to 90 %

DISINFECTION

- Process of destroying disease-causing organisms (pathogens) and rendering water safe for use.
- Destroys existing germs present in water and also protects water against future possible contamination.
- Substances used to carry out disinfection are called disinfectants.

Mechanism of Disinfection

- Destroying the cell wall
- Destroying the protoplasm
- Alteration of cell wall permeability
- By precipitating enzymes, nutrients, etc.

METHODS OF DISINFECTION

PHYSICAL METHODS

a. Using Heat Energy (Boiling)

b. Using Light Energy (UV rays)

CHEMICAL METHODS

a. Excess Lime (pH> 9.2)

b. Metal Ions (Silver)

c. Potassium permanganate

d. Ozone

e. Halogen group chemicals (Iodine, Bromine, Chlorine)

CHLORINATION

- Chlorine can be added to water as:
    - Chlorine gas ($Cl_2(g)$) – dissolves in water following Henry's Law ($K_h = 6.2 \times 10^{-2}$).
    - Sodium hypochlorite (NaOCl) or bleaching powder.
- Dissolved chlorine reacts with water to form hypochlorous acid (HOCl).

$$\boxed{Cl_{2(aq)} + H_2O \longrightarrow HOCl + H^+ + Cl^-}$$

- HOCl dissociates to form hypochlorite ion (OCl^-) ($K_a = 3.2 \times 10^{-8}$).

$$\boxed{HOCl \longrightarrow OCl^- + H^+}$$

- **Free chlorine residual** = HOCl + OCl^- (measured as mg/L of Cl_2).
- But HOCl is 80 times more powerful than OCl^-.
- Free chlorine produced gets into the cell along with food and forms chlorotoxic chemical substances which precipitate enzymes, nutrients, etc., and inhibit microbial life.

WASTEWATER TREATMENT

References: *(i) Introduction to Environmental Engineering, M.L. Davis & D.A. Cornwell*

(ii) Environmental Engineering (Vol. II) by S.K. Garg

❖**Wastewater**: Liquid wastes from residences, institutions, commercial establishments, industries together with groundwater, surface water and stormwater.

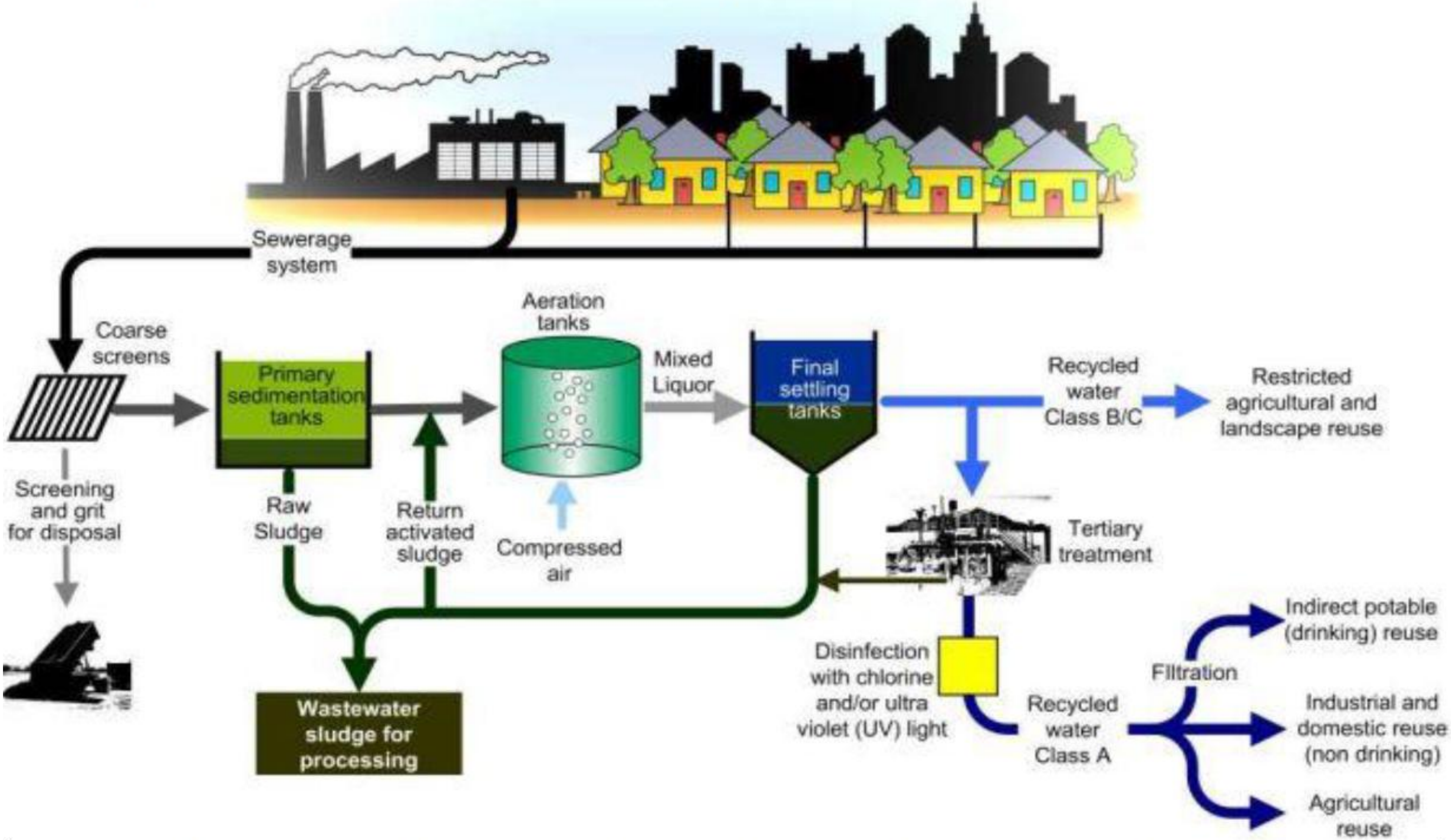
❖**Sewage**: Mixture of water and waste products is popularly called sewage.

TYPES OF SEWAGE

(i) **Domestic sewage**: From residential, commercial or institutional buildings.

(ii) **Industrial sewage**: From industrial processes.

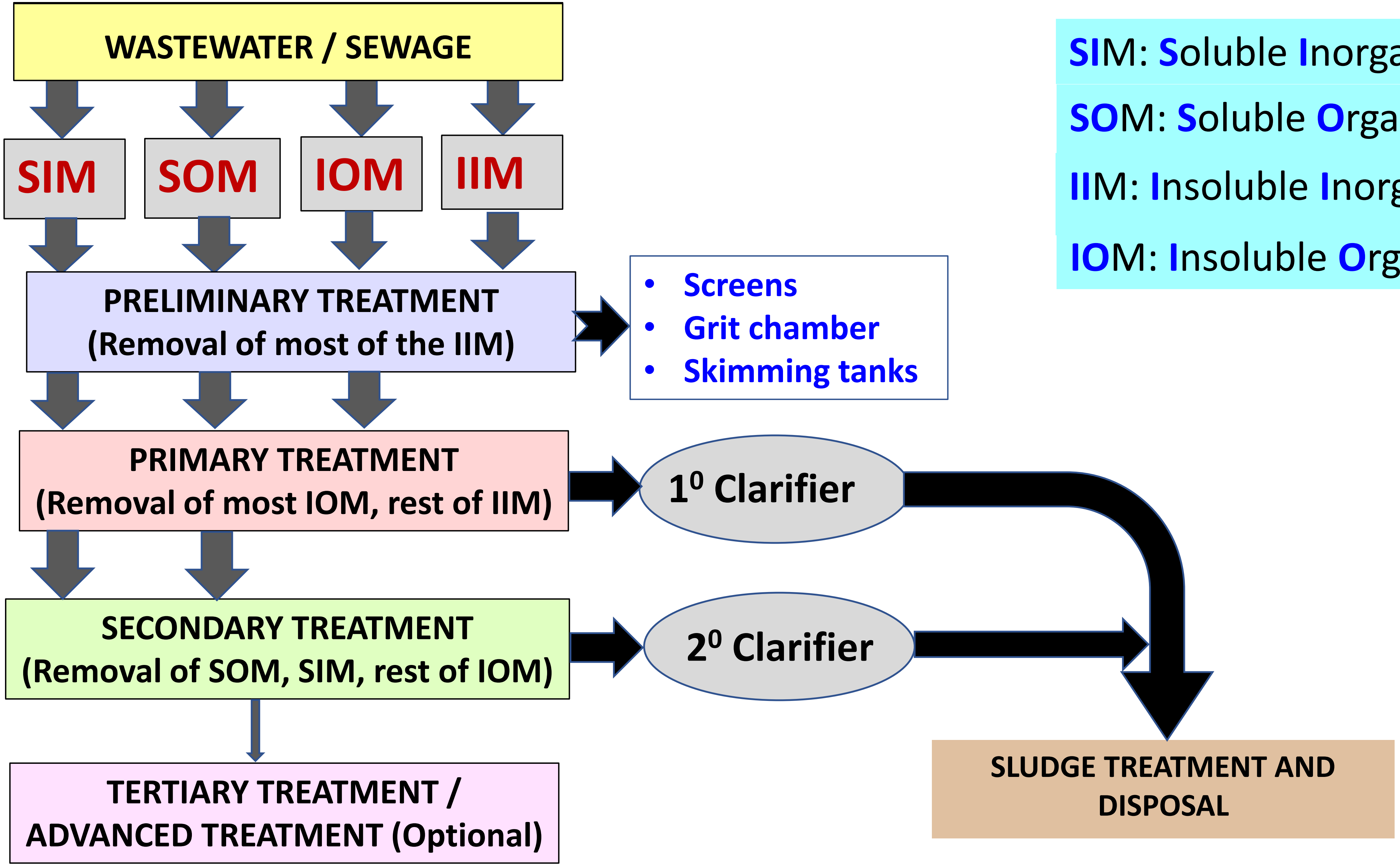
(iii) **Storm sewage**/ storm drainage/ drainage


Sewerage system
Coarse screens
Screening and grit for disposal
Primary sedimentation tanks
Raw Sludge
Return activated sludge
Aeration tanks
Compressed air
Mixed Liquor
Final settling tanks
Recycled water Class B/C
Restricted agricultural and landscape reuse
Tertiary treatment
Disinfection with chlorine and/or ultra violet (UV) light
Recycled water Class A
Filtration
Indirect potable (drinking) reuse
Industrial and domestic reuse (non drinking)
Agricultural reuse
Wastewater sludge for processing

NEED FOR TREATMENT OF WASTEWATER

- Foul Smell
- Deplete Dissolved Oxygen
- Pathogenic bacteria

WASTEWATER CONSTITUENTS



SIM: Soluble Inorganic Matter

SOM: Soluble Organic Matter

IIM: Insoluble Inorganic Matter

IOM: Insoluble Organic Matter

BUREAU OF INDIAN STANDARDS (BIS) FOR SEWAGE EFFLUENTS

Table General standards for Discharge of Environmental Pollutants, Part A: Effluents as per Schedule VI of the Environmental (Protection) Rules 1986 and National River Conservation Directorate Guidelines for Faecal Coliforms, (Values in mg/l unless stated)

No	Characteristics	Standards			
		Inland Surface Water	Public Sewers, (A)	Land for Irrigation	Marine Coastal Areas
1	Colour and odour	(B)		(B)	(B)
2	SS	100	600	200	(C), (D)
3	Particle size of SS	(E)	-	-	(F), (G)
4	pH value	5.5 to 9.0			
5	Temperature	(H)	-	-	(H)
6	Oil and grease	10	20	10	10
7	Total residual chlorine	1.0	-	-	1.0
8	Ammoniacal nitrogen (as N)	50	50	-	50
9	Total Kjeldahl Nitrogen, (TKN) (as N)	100	-	-	100
10	Free ammonia (as NH_3)	5.0	-	-	5.0
11	Biochemical Oxygen Demand	30	350	100	100
12	Chemical Oxygen Demand	250	-	-	250
13	Arsenic (as As)	0.2			
14	Mercury (as Hg)	0.01	0.01	-	0.01
15	Lead (as Pb)	0.1	1.0	-	2.0
16	Cadmium (as Cd)	2.0	1.0	-	2.0
17	Hexavalent Chromium (as Cr 6+)	0.1	2.0	-	1.0
18	Total Chromium (as Cr)	2.0	2.0	-	2.0
19	Copper (as Cu)	3.0	3.0	-	3.0
20	Zinc (as Zn)	5.0	15.0	-	15.0
21	Selenium (as Se)	0.05	0.05	-	0.05
22	Nickel (as Ni)	3.0	3.0	-	5.0
23	Cyanide (as CN)	0.2	2.0	0.2	0.2
24	Fluoride (as F)	2.0	15.0	-	15.0
25	Dissolved phosphates (as P)	5.0	-	-	-
26	Sulphide (as S)	2.0	-	-	5.0

TYPES OF WASTEWATER TREATMENT METHODS

Physical Unit Operations:

- Involve the use of physical forces to remove contaminants.

Chemical Unit Processes:

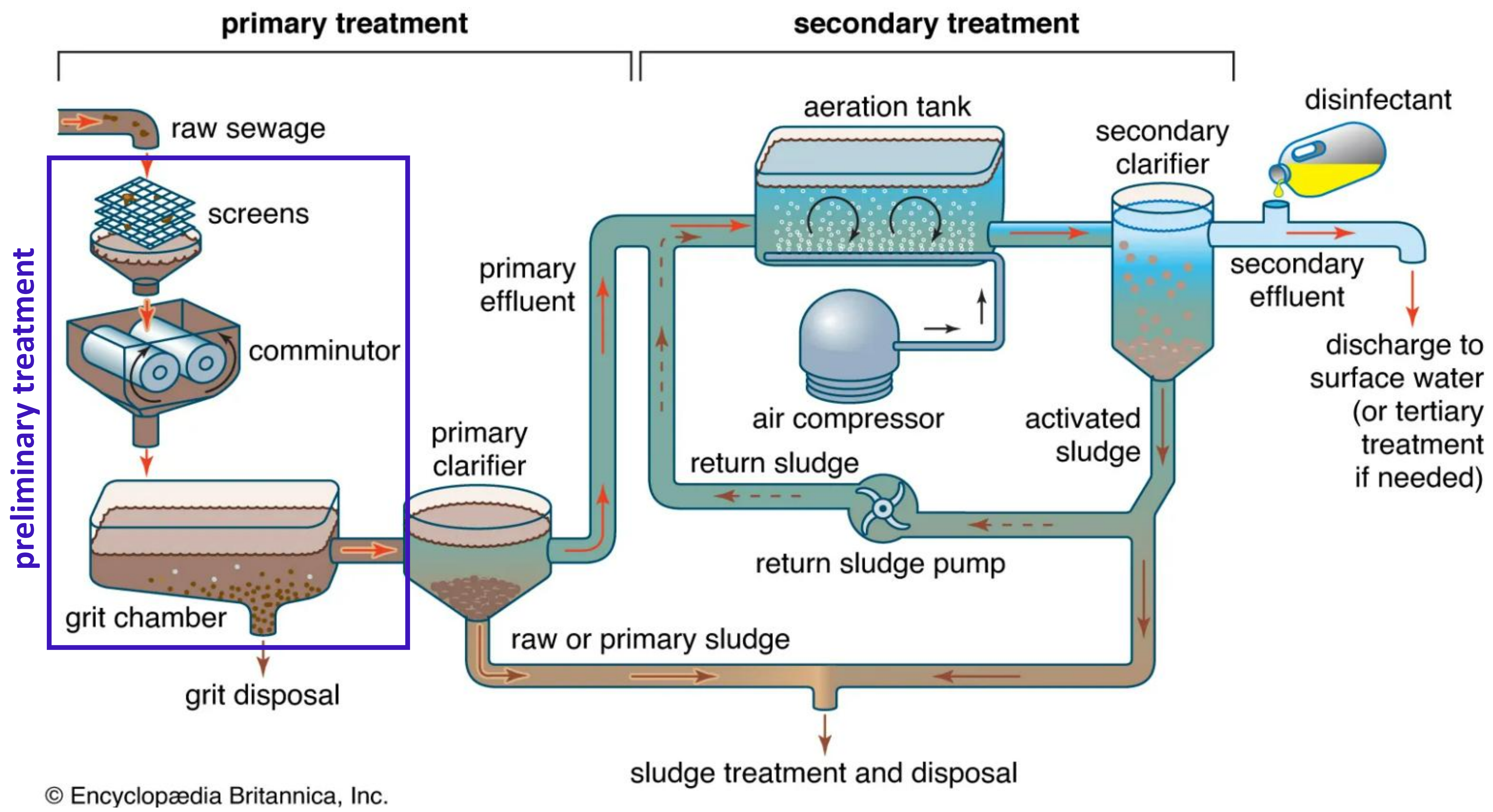
- Rely on chemical reactions or the addition of chemicals to remove or transform pollutants.

Biological Unit Processes:

- Use microbial activity to degrade biodegradable organic matter (dissolved or colloidal).
- Organic pollutants are converted into gases and biomass, which is later removed by settling.
- Also applied for the removal of nitrogen, phosphorus, and sulphates.

WASTEWATER TREATMENT OPTIONS

- Physical Processes: Screening, Sedimentation, Flotation, Filtration, Absorption, Adsorption, Centrifugation etc
- Chemical Processes: Coagulation, Absorption, Oxidation-Reduction, Ion-exchange, Disinfection
- Biological Processes: Aerobic Treatment, Anaerobic Treatment



primary treatment
secondary treatment
preliminary treatment
raw sewage
screens
comminutor
grit chamber
grit disposal
primary clarifier
primary effluent
aeration tank
air compressor
return sludge
return sludge pump
secondary clarifier
activated sludge
disinfectant
secondary effluent
discharge to surface water (or tertiary treatment if needed)
raw or primary sludge
sludge treatment and disposal
© Encyclopædia Britannica, Inc.

PRELIMINARY TREATMENT

- Focuses on removal of **floating and settleable solids** (organic & inorganic).
- Removes **oils and grease** from sewage.
- Reduces BOD by 15–30%.
- Involves **physical processes** only; no biological or chemical treatment.

Main Treatment Units:

- **Screens**: Remove large objects (rags, plastics, sticks, etc.).
- **Grit Chambers**: Remove sand, gravel, and inorganic grit.
- **Skimming Tanks**: Separate oils, grease, and floating scum.

PRIMARY TREATMENT

- Removes **30 to 40% of the total BOD and 50 to 70% of suspended solids**
- Involves **physical processes** only; no biological or chemical treatment.
- Prepares wastewater for secondary (biological) treatment.

Main Treatment Unit:

- **Primary Sedimentation Tanks**: Settle out heavier suspended solids.

TYPES OF SETTLING TANKS

Rectangular sedimentation tank
Long, narrow with horizontal flow

Circular sedimentation tank
Radial or spiral flow

SECONDARY TREATMENT

- Aims to remove **dissolved and colloidal organic matter** from wastewater.
- Involves **biochemical decomposition** using microorganisms.
- Can be carried out under:
  - Aerobic conditions (with oxygen)
  - Anaerobic conditions (without oxygen)
- Microorganisms (mainly bacteria) break down organic pollutants.
- Results in a clearer and more stable effluent.

OBJECTIVES OF SECONDARY TREATMENT

1. To transform (oxidize) dissolved and particulate **carbonaceous BOD** present in the wastewater (Stabilization of organic matter)
2. To transform (remove) **nutrients** (N/P) from wastewater

$$\text{Organic matter} + \underbrace{O_2 + NH_3 + PO_4^{3-}}_{\text{Nutrients}} \xrightarrow{\text{microbes}} \underbrace{CO_2 + H_2O}_{\text{End products}} + \text{New cells}$$

REQUIREMENTS FOR MICROBIAL GROWTH

Substrates

1. **Source of C** for synthesis of new cellular material
2. **Source of energy** for cell synthesis
3. Inorganic elements (nutrients)

$$\text{Organic matter} + O_2 + NH_3 + PO_4^{3-} \xrightarrow{\text{microbes}} CO_2 + H_2O + \text{New cells}$$

UTILIZATION OF BIOCHEMICAL OXYGEN DEMAND (BOD)

$$\text{Organic matter} + O_2 + NH_3 + PO_4^{3-} \xrightarrow{\text{microbes}} CO_2 + H_2O + \text{New cells}$$

- **Oxidation:** COHNS + O_2 + Bacteria → CO_2 + H_2O + NH_3 + **Energy** + other end products

- **Synthesis:** COHNS + O_2 + Bacteria + Energy → $C_5H_7NO_2$ (**new cells)**

Secondary treatment/Biological treatment

Degradation of Organic matter

Aerobic

- Active cells
- No production of bad smell/odour
- Enhanced degradation efficiency

$$\textbf{OM + Bacteria} \xrightarrow{O_2} \textbf{CO}_2 + \textbf{H}_2\textbf{O} + \textbf{New cells}$$

(Sludge)

Anaerobic

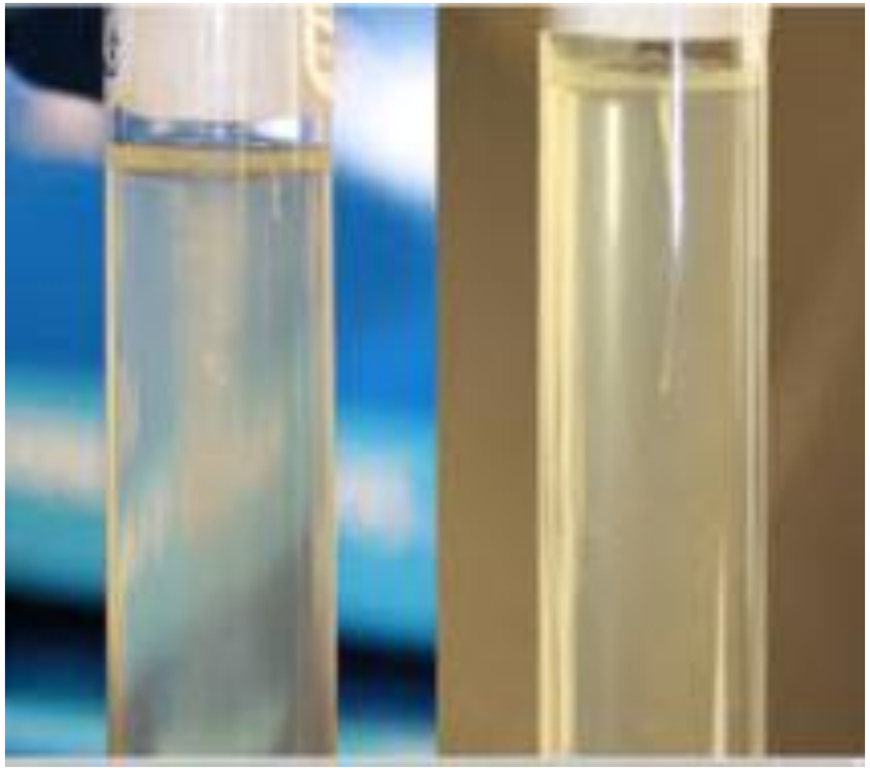
- Production of biogas
- Less generation of sludge
- No aeration/oxygenation requirement

$$\textbf{OM + Bacteria} \longrightarrow \textbf{CH}_4 + \textbf{CO}_2 + \textbf{New cells}$$

(Less Sludge)

Types of Biological processes for wastewater treatment

Suspended Growth processes



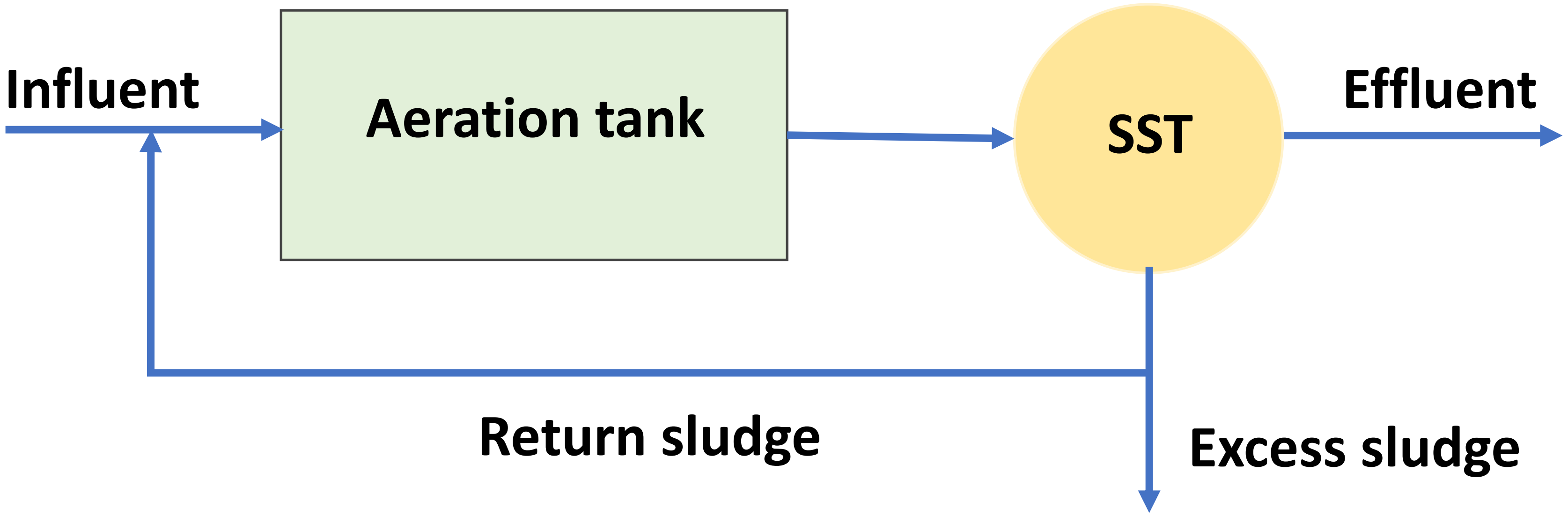
Activated Sludge Process (ASP)

Attached growth processes

Trickling filter

ACTIVATED SLUDGE PROCESS

Mixed with 20-30% volume of sludge (active microorganisms)



ACTIVATED SLUDGE PROCESS

- Biological wastewater treatment technique in which a **mixture of wastewater and biological sludge** (microorganisms) is agitated and aerated.
- Microorganisms are mixed thoroughly with the **organic compounds** under conditions that **stimulate their growth** through use of the organic compounds as food.
- As the microorganisms grow and are mixed by the agitation of the air, the individual organisms clump together (flocculate) to form an **active mass of microbes (biologic floc)** called **activated sludge**.
- The **biological solids** are subsequently separated from the treated wastewater and **returned/ recycled** to the aeration process **(Return sludge).**
- Because more activated sludge is produced than is desirable in the process, some of the return sludge is diverted or **wasted** to the sludge handling system for treatment and disposal.
- A balance is then achieved between growth of new organisms and their removal by wasting.
- **Air** is injected to **mix** the activated sludge with the wastewater and to **supply the oxygen** needed for the organisms to break down the organic compounds.
- The mixture of activated sludge and wastewater in the aeration tank is called **mixed liquor**.

ECOLOGY

tiredearth

ECOLOGY

Scientific study of **interactions** between **organisms** and their **environment.**

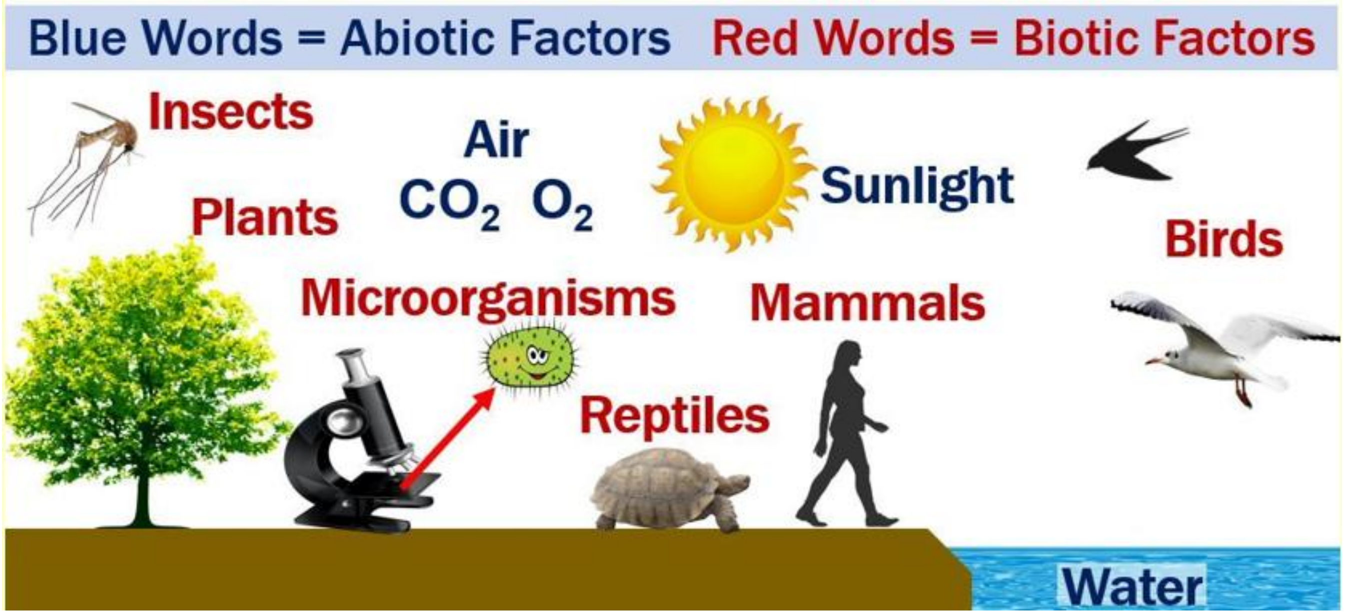
- *Ecology* (*Greek Oikos = home/habitat, logy = study*) was coined over a century ago.
- The word Ecosystem was first coined by British ecologist, Sir Arthur G. Tansley in 1935.

COMPONENTS OF ECOSYSTEMS

Biotic ⟷ Abiotic

Biotic factors: any **living part** of an environment with which an organism might interact. Ex: Animals, plants, mushrooms, bacteria etc.

Abiotic factors: **non living part of the environment** that influence the organism. Ex: Sunlight, heat, precipitation, humidity, wind, soil type etc.



LEVELS OF ECOLOGICAL ORGANIZATIONS

- **Species**: Group of **similar organisms** that breed and produce fertile offspring.
- **Population**: Group of individuals that **belong to the same species** and **live in the same area.**
- **Community**: **Different populations** living together **in a defined area.**
- **Ecosystem**: All the **organisms** that live in a place together with their **physical environment.**
- **Biome**: **Group of ecosystems** that share similar climates and typical organisms (Ex: Grassland, Desert)
- **Biosphere**: All life on earth and **all parts of Earth in which life exists**.

Species→ Population→ Community→ Ecosystem→ Biome → Biosphere

BIOTIC COMPONENTS OF AN ECOSYSTEM

I. **Producers/ Autotrophs:** Producers are **autotrophic organisms** that utilize energy from the environment, along with inorganic and mineral substances, to synthesize organic components through processes such as **photosynthesis or chemosynthesis**. They are the foundation of the food chain, converting energy from sunlight or chemical reactions into organic matter.

II. **Consumers/ Heterotrophs:** Consumers are **heterotrophic organisms** that rely on the organic matter produced by producers.
   - **Primary consumers**, or herbivores, feed directly on producers.
   - **Secondary consumers** consume other consumers, and there can be further trophic levels of consumers.

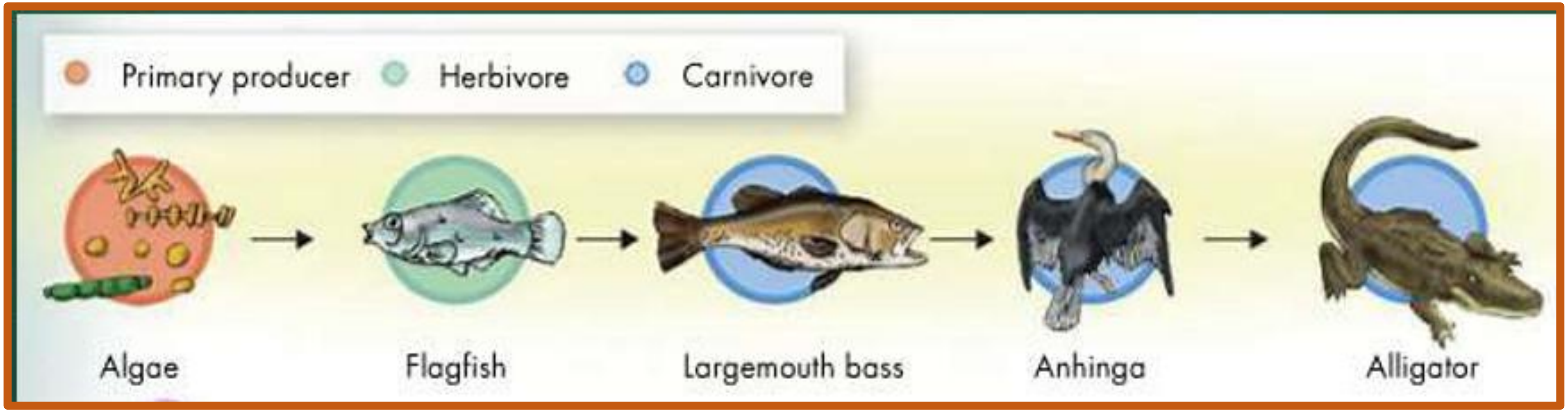
III. **Decomposers:** Decomposers, mostly **microscopic organisms**, occupy the final trophic level. They play a crucial role in recycling organic matter by breaking it down into inorganic substances, returning vital compounds to the environment. Decomposers help to complete nutrient cycles and maintain ecosystem balance.

ABIOTIC COMPONENTS OF AN ECOSYSTEM

- **Inorganic:** carbon dioxide, water, nitrogen, calcium, phosphate all of which are involved in matter cycle (biogeochemical cycles)
- **Organic components**: proteins, carbohydrates, lipids and amino acids, all of which are synthesized by the biota. These reach the ecosystem as their wastes, dead remains etc.
- **Climate**: temperature, light, soil etc. are abiotic components of the ecosystems.

ENERGY FLOW IN AN ECOSYSTEM

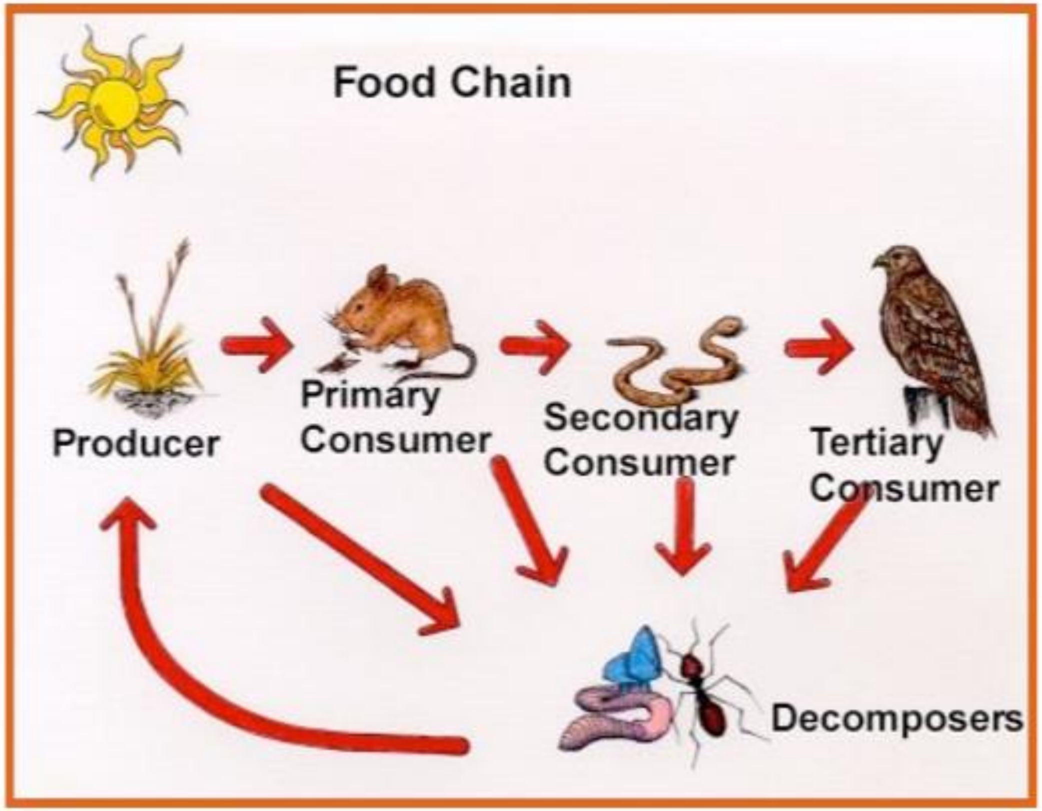
- All energy that comes to earth comes from the **SUN**.
- Energy flows through an ecosystem in **one direction**, from primary producers to consumers.

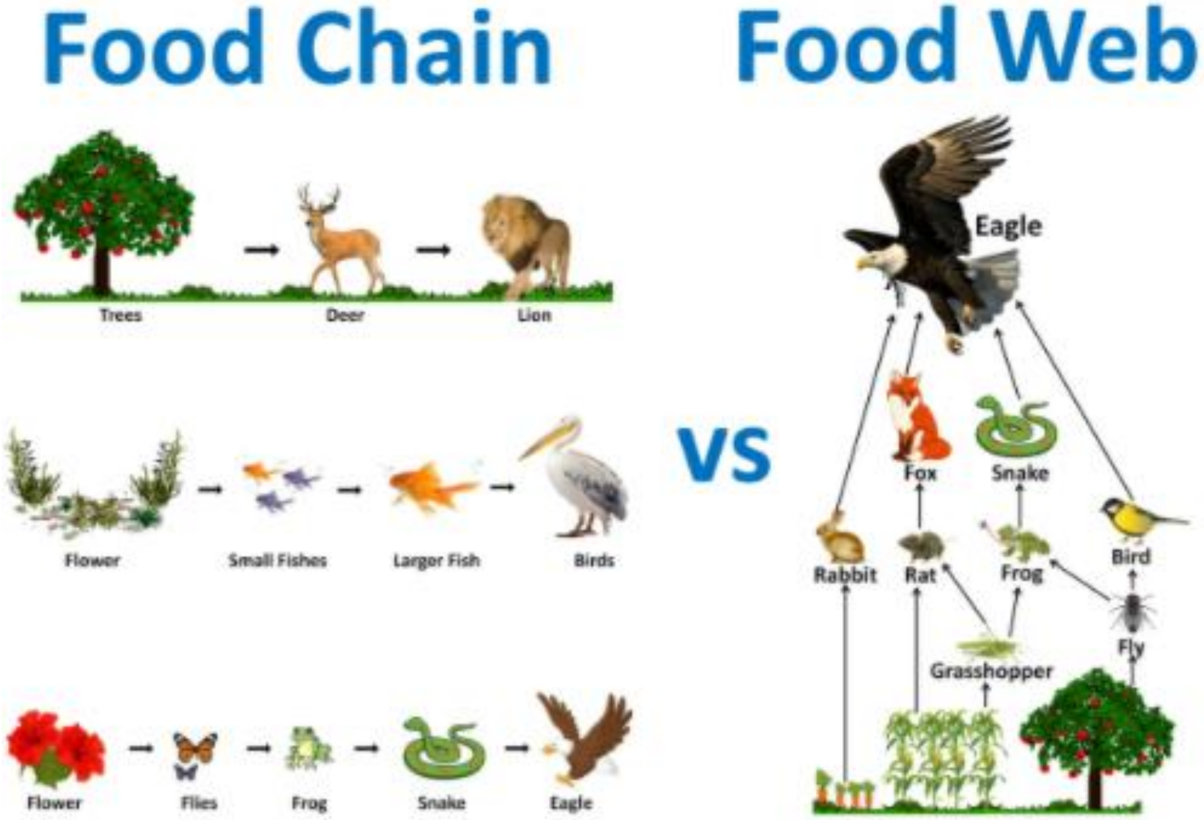


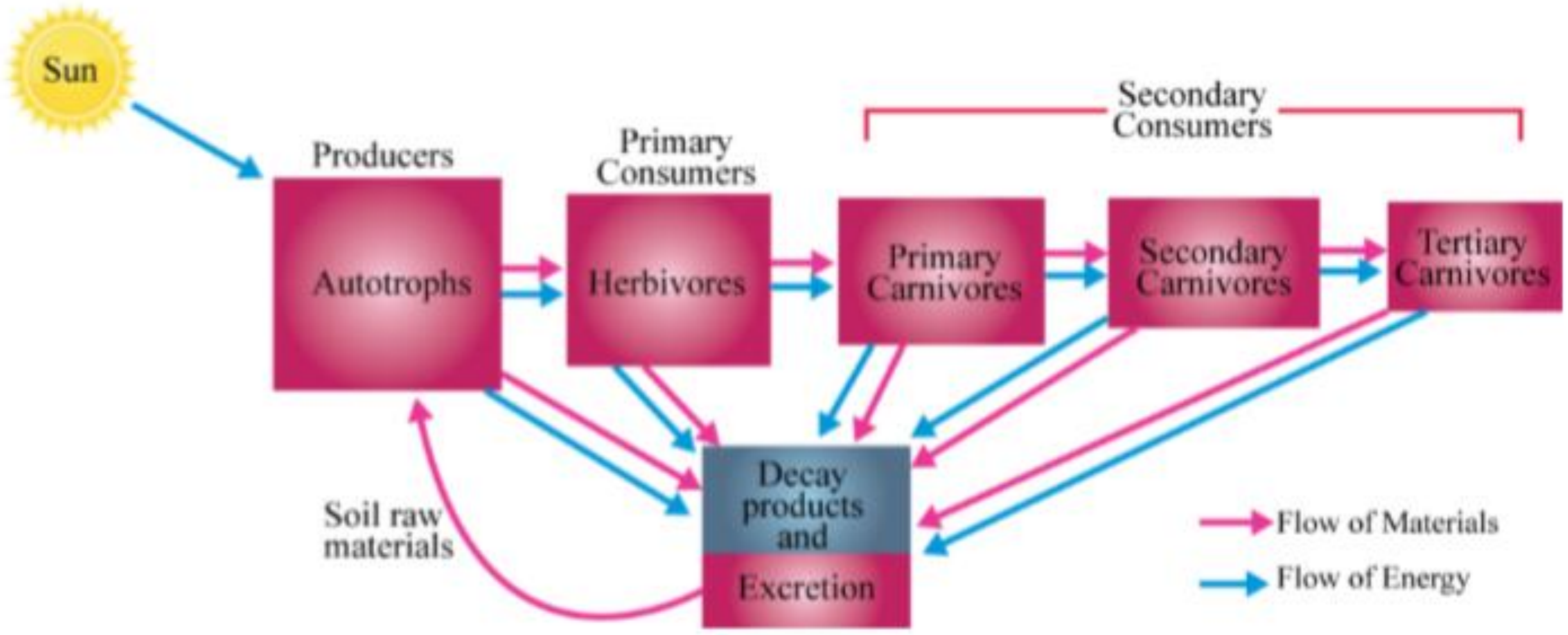
Food chain: series of steps in which organisms transfer energy by eating and being eaten.

- **Grazing food chain** focuses on **energy transfer** from living organisms
- **Detritus food chain** emphasizes **decomposition and nutrient recycling**

Food web: Networks of feeding interactions involving multiple producers, herbivores, producers, and consumers.







An Over-view of relationship between different organism in ecosystem.

The distinct sequential steps in the straight food chains are referred as different **trophic levels**. For ex. Green plants stand at the first trophic level; the herbivorous are the second trophic level; and flesh eaters represent the third trophic levels.

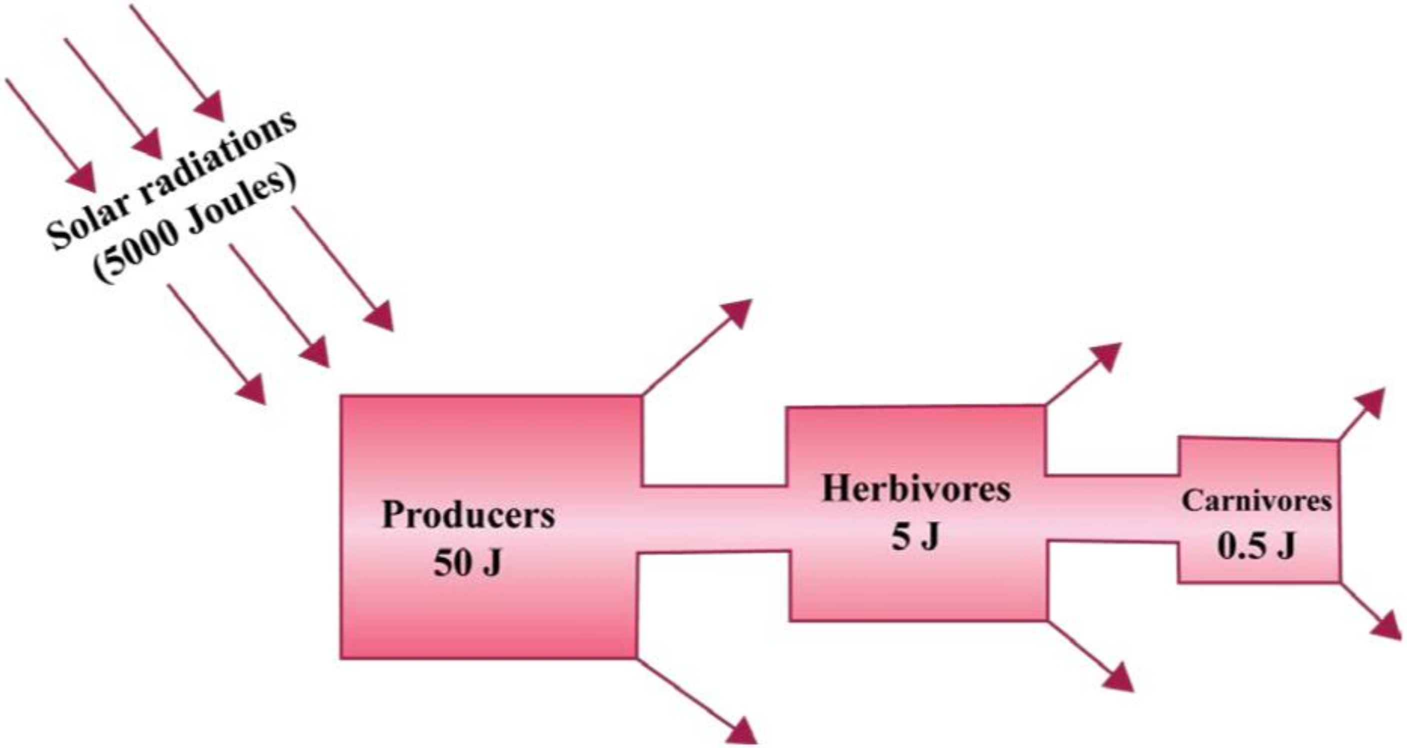
ECOLOGICAL PYRAMIDS

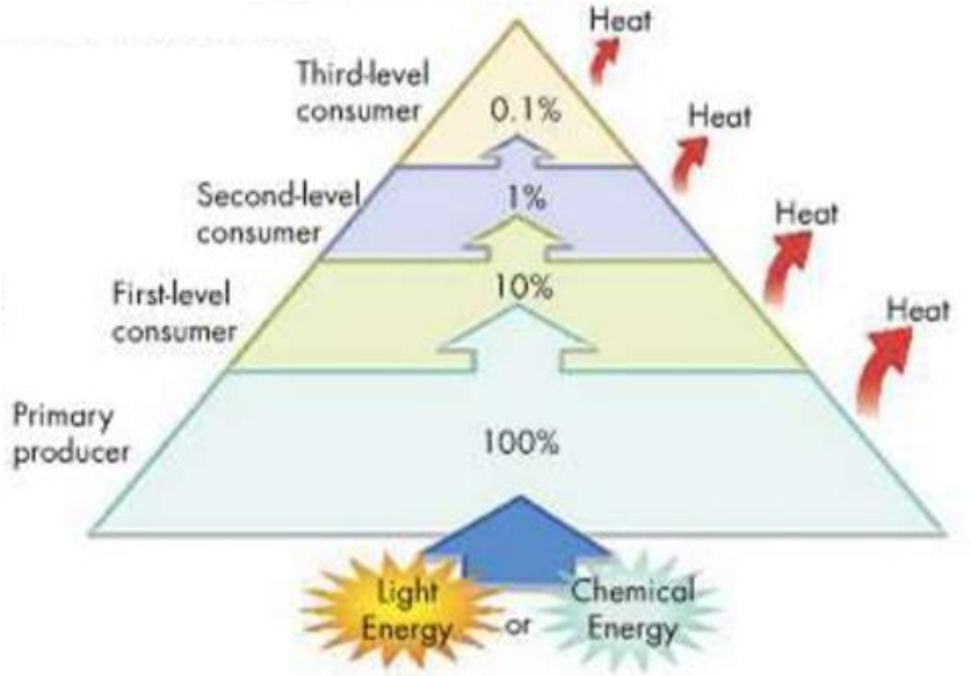
- Trophic levels are illustrated by drawing **ecological pyramids**.
- Ecological pyramid shows the **relative amount of energy** or **matter** contained within each trophic level.

- **Pyramid of energy**
- **Pyramid of biomass**
- **Pyramid of numbers**

PYRAMID OF ENERGY

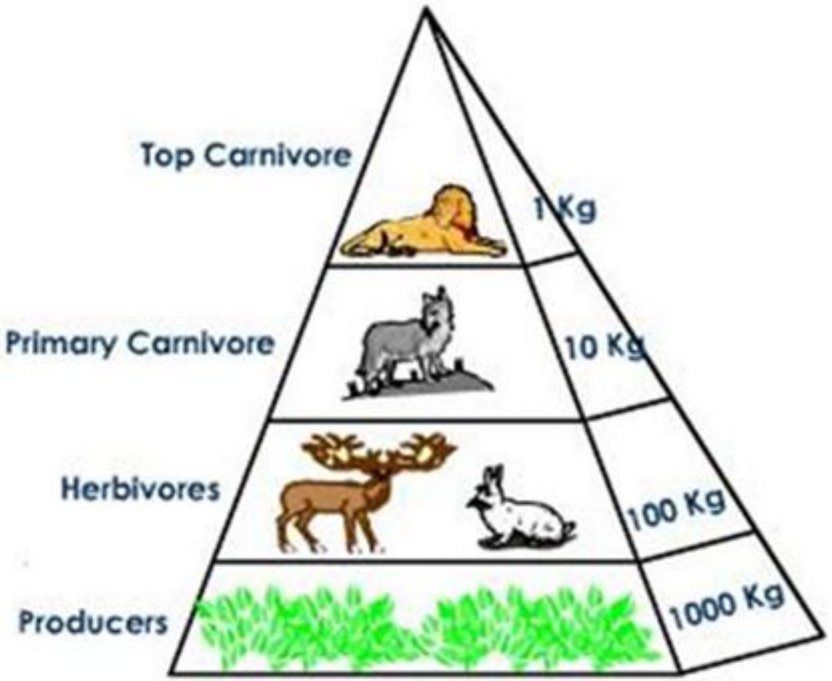
- Pyramids of energy show relative amount of energy available at each trophic level.
- On an average, **only 10% of energy** available in one trophic level is transferred to the next level! The rest is given off as heat.
- Lindermann proposed the ten per cent law.



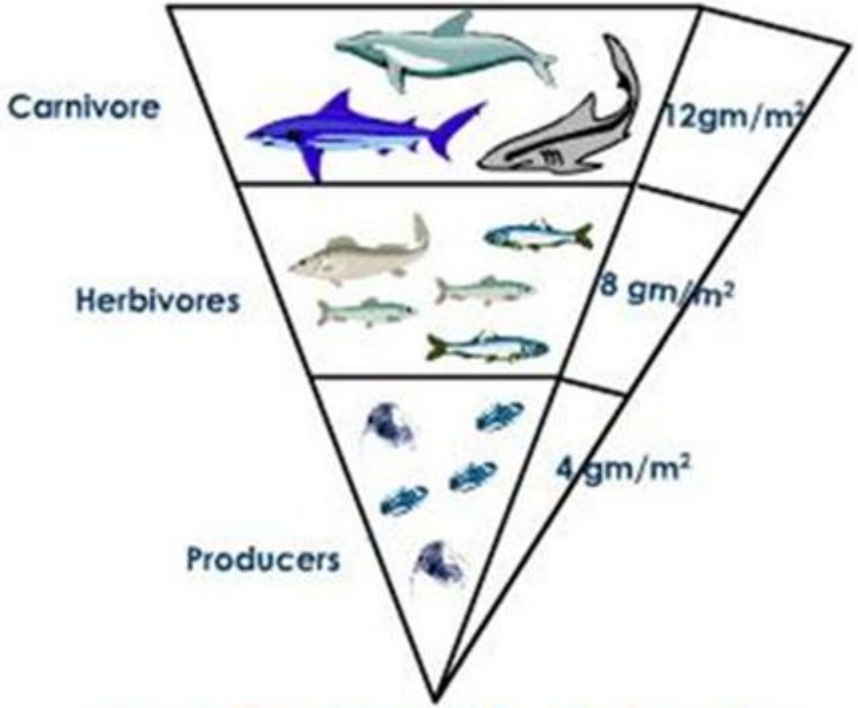


PYRAMID OF BIOMASS

- Biomass: The **total amount of living tissue** within a given trophic level.
- Pyramids of biomass illustrates the relative amount of **living organic matter** in each trophic level of an ecosystem.



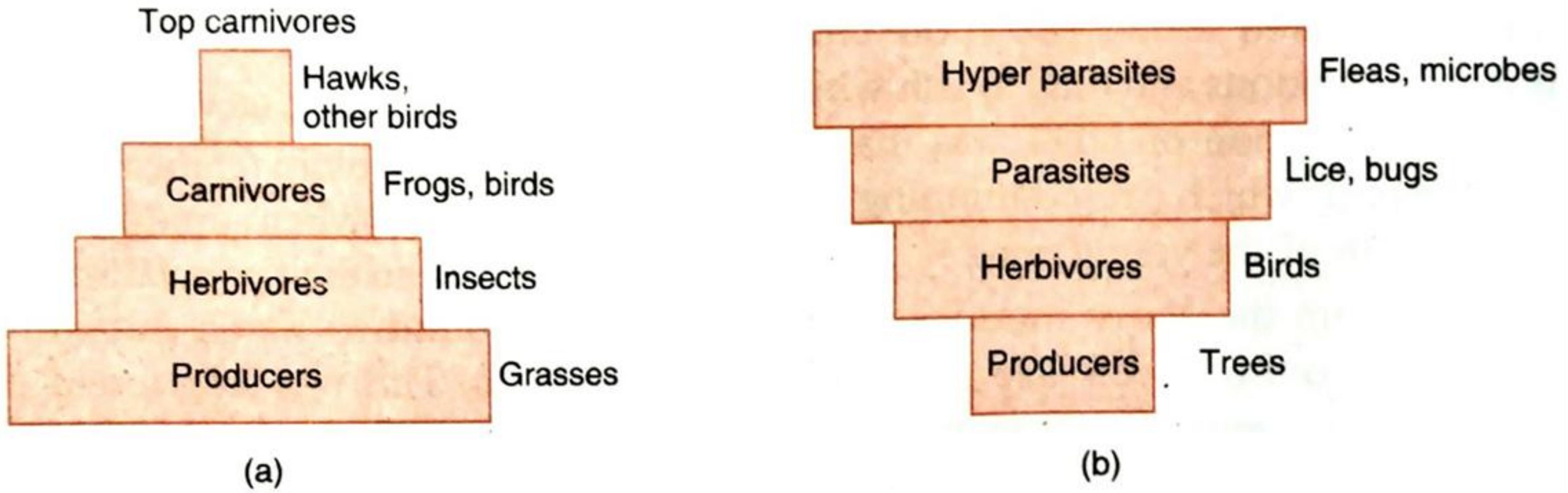
Upright Pyramid of biomass in a Terrestrial Ecosystem



Inverted Pyramid in an Aquatic Ecosystem

PYRAMID OF NUMBERS

Pyramid of the numbers: shows **relative number** of individual organisms at each trophic level of an ecosystem.



Pyramid of numbers (*a*) grassland (*b*) Parasitic food chain.

VARIOUS ECOSYSTEMS

1. **TERRESTRIAL ECOSYSTEM**
   - FOREST
   - GRASSLAND
   - DESERT
2. **AQUATIC ECOSYSTEM**
   - FRESHWATER (Rivers, Lakes, Ponds)
   - MARINE (Salt lakes, seas, oceans)

TYPES OF SPECIES TO SPECIES INTERACTIONS

A. Interactions that involve mostly **brief encounters:**
   1. Competition
   2. Predation
   3. Herbivory
   4. Keystone species

B. Symbiotic interactions that involve **long term associations:**
   1. Mutualism
   2. Parasitism
   3. Commensalism

COMPETITION

- **Intraspecific competition:** Competition for limited ecological resources between **members of the same species**. [Resources: light, space, food, oxygen etc.].
- **Interspecific competition:** Competition for limited ecological resources between **members of different species**.
- **Competitive exclusion principle** states that no two species can occupy the same niche in exactly the same habitat at exactly the same time. If two species attempt to, one will be better at competing for limiting resources and will eventually exclude the other species.

PREDATION

- One organism captures, kills and feeds upon the prey.
- Predator gains and prey loses (+/-)
- Usually limited to external interactions (as opposed to parasites)
- Most predators are bigger than their prey
- **Can affect the size of prey populations** in a community and determine the places the prey can live and feed.

HERBIVORY

- Occurs when herbivores feed on plants (producers).
- Interactions can be brief or long term.
- Herbivores can **affect the size and distribution of plant populations** in a community and determine the places that plants can survive and grow.

KEYSTONE SPECIES

- **Single species** that is not usually abundant in a community yet **exerts strong control** on the structure of the community. Ex: Sharks

LONG-TERM ASSOCIATIONS

SYMBIOSIS: Any relationship in which two species live closely together.

1. **Mutualism**: type of symbiotic relationship in which **both species benefit.**
   - *Often involve one organism providing food, shelter, or protection to the other, in exchange for a different vital resource or service, such as nutrition, reproduction, or defense.*
   - **Bees and Flowers:** Bees get nectar for food, while flowers benefit from cross-pollination as pollen sticks to the bees and gets transferred to other flowers.
   - **Lichens:** Lichens are a mutualistic partnership between algae and fungi. The algae provide food through photosynthesis, and the fungal partner provides structure, absorbs water and minerals, and protects the algae from environmental stresses.

2. Parasitism: type of symbiotic relationship in which **one organism (the parasite) benefits** at the expense of the other organism, the host, which is harmed.

- The parasite typically lives on or inside the host, deriving nutrients, shelter, or other resources.
- Lice are external parasites that feed on blood or skin, harming their hosts.
- Tapeworms live in the intestines of humans, consuming nutrients at the human's expense.

3. Commensalism: a long-term biological interaction between two different species where one organism (the commensal) benefits by obtaining food, shelter, or transportation from the other organism (the host), while the host is neither significantly helped nor harmed by the interaction.

- Remora fish attaches to sharks to ride along and feed on leftover food from the shark's meals, while the shark is not affected.
- Clownfish live within the stinging tentacles of sea anemones, protected from predators, while the anemones are not harmed.


ECOLOGICAL SUCCESSION

Series of predictable changes that occur in a community over time is called ecological succession.

1. **Primary succession**: succession **beginning in an area** with no remnant of a community.
   - Ex. After a volcanic eruption.
   - Pioneer species – first species to colonize a barren area.
2. **Secondary succession**: succession in an area that has been **disturbed**, but not completely destroyed.
   - Ex. After a wildfire or hurricane.
   - Faster than primary because soil has survived and vegetation can regrow rapidly.

CLIMAX COMMUNITY

- A biological community of plants, animals, and fungi which, through the process of ecological succession, have reached a ***steady state***.
- Following ***natural disturbances***, secondary succession in healthy ecosystems often reproduces the original climax community.
- Following ***human-caused disturbances***, ecosystems may or may not recover the original climax community.

LIMITS TO GROWTH OF A POPULATION

- Limiting factor: factors that controls the growth of a population.
- Limiting factors determine the carrying capacity of an environment for a species.
  - **Density dependent limiting factors**: operate only when population density reaches a certain level. Ex. Competition, predation, parasitism, disease.
  - **Density independent limiting factors**: affect all populations in similar ways, regardless of population size or density. Ex. Natural disasters.

POPULATION GROWTH

Population growth is the increase in the number of individuals in a population

Factors can affect population size

1. **Birth rate** – populations grow when more individuals are born than die in any period of time.
2. **Death rate** – populations shrink when the death rate is greater than the growth rate.
3. **Immigration** – populations grow if individuals move into a region from elsewhere.
4. **Emigration** – populations may decrease in size if individuals move out of the population's range.

Change in population size = (Births + Immigration) – (Deaths + Emigration)

If immigration and emigration are ignored, Population growth rate = Birth - Death

$$\frac{\Delta N}{\Delta t} = B - D$$

ΔN = Change in population size
Δt = time interval
B= Number of births
D= Number of deaths

$$Birth\ rate\ b = \frac{B}{N}$$

N= number of individuals in that population

$$Death\ rate\ m = \frac{D}{N}$$

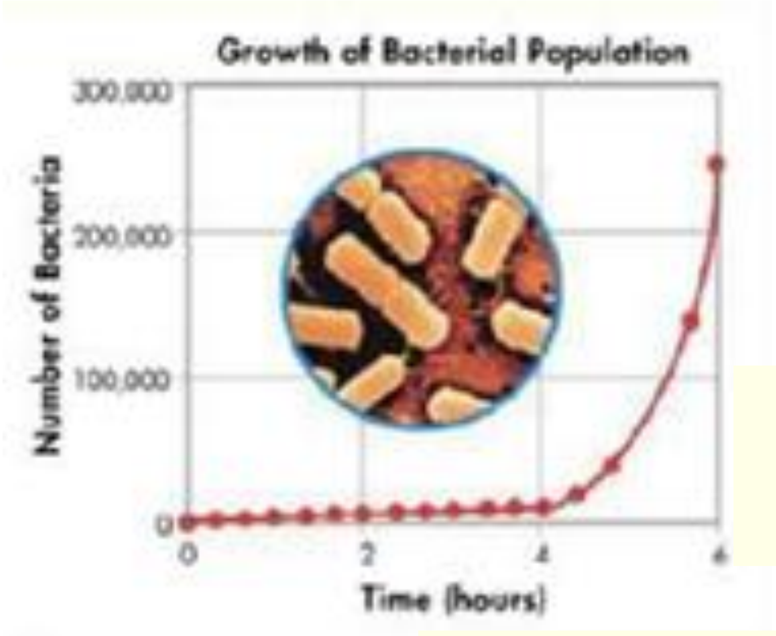
$$\frac{\Delta N}{\Delta t} = bN - mN$$

$$\boxed{\frac{\Delta N}{\Delta t} = rN}$$

$$\boxed{N_t = N_0 e^{rt}}$$

Per capita rate of increase (r) = b-m

r>0; Population growing
r<0; Population declining
r=0; Zero population growth



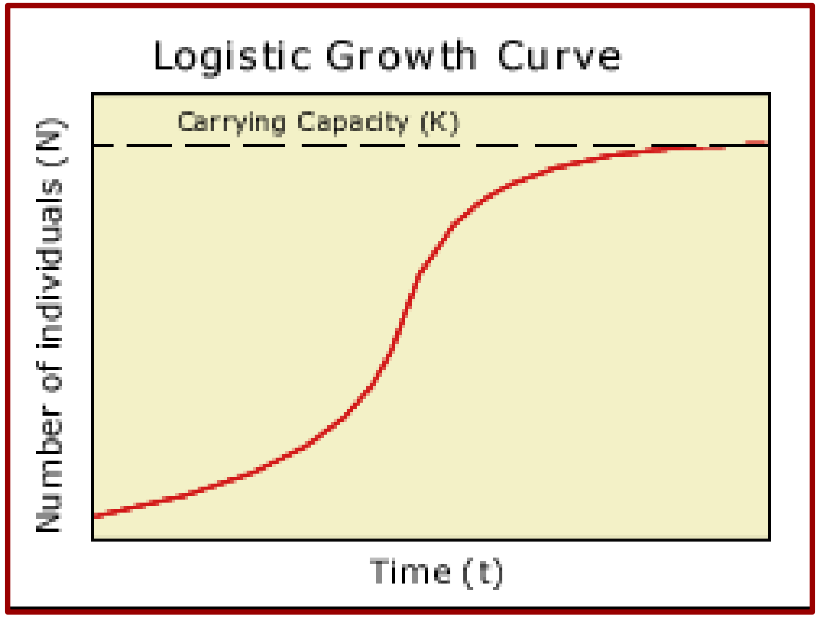
$$\frac{\Delta N}{\Delta t} = rN$$

Exponential growth

- Occurs under ideal conditions with **unlimited resources**
- Per capita growth rate (r) does not change even if population gets very large

$$\frac{dN}{dt} = r_{max}N$$

Logistic growth



- Occurs when a population's growth slows and then stops, following a period of exponential growth.
- Per capita growth rate (r) gets smaller as population approaches its maximum size.

Carrying capacity: maximum number of individuals of a particular species that a particular environment can support.

$$\frac{dN}{dt} = r_{max}\left(\frac{K-N}{K}\right)N$$

A certain population A is experiencing exponential growth. Population size 50, Births 10, Deaths 4.

- Calculate the individual growth rate (r).
- Calculate the population growth rate (dN/dt)

r= 0.12

dN/dt= rn= 6

Find out dN/dt when carrying capacity is 400 , population size is 300 and r is =0.01.

dN/dt= 0.75