Treatment of Sewage

9.1. Classification of Treatment Processes

Sewage must be treated before disposal into rivers or land to make it safe. The treatment process depends on disposal characteristics and is classified into:

1. **Preliminary Treatment**
2. **Primary Treatment**
3. **Secondary (or Biological) Treatment**
4. **Complete Final Treatment**

9.1.1. Preliminary Treatment

- Focuses on removing floating materials (dead animals, tree branches, papers, rags, wood) and heavy inorganic solids.
- Removes oils and greases, reducing **BOD** by 15-30%.
- **Processes used:**
  - **Screening**: Removes floating materials like rags, papers, clothes.
  - **Grit Chambers & Detritus Tanks**: Remove grit and sand.
  - **Skimming Tanks**: Remove oils and greases.

9.1.2. Primary Treatment

- Removes large suspended organic solids, mainly through **sedimentation in settling basins**.
- The **liquid effluent** from primary treatment still contains a high amount of organic material and has high **BOD (~60% of the original)**.
- **Primary and preliminary treatments are sometimes classified together.**
- Organic solids from this stage are often stabilized through **anaerobic decomposition in a digestion tank or incinerated**.

9.1.3. Secondary Treatment

- Further treats effluent from primary treatment using **biological decomposition** (either **aerobic** or **anaerobic conditions**).
- **Aerobic treatment:** Organic matter is decomposed by **aerobic bacteria**, known as **aerobic biological units**, which include:
  - **Filtration treatment** (sand filters, trickling filters)
  - **Aeration tanks** (used in **activated sludge processes**)
  - **Oxidation ponds & aerated lagoons**
- **Anaerobic treatment:** Organic matter is destroyed by **anaerobic bacteria**, known as **anaerobic biological units**, which include:

- **Anaerobic lagoons**
    - **Septic tanks**
    - **Imhoff tanks**
      (Note: Septic tanks and Imhoff tanks are classified as primary units, not secondary.)
- **Effluent from secondary treatment still contains some BOD (5-10% of the original) and suspended solids.**
- Organic solids/sludge from primary and secondary treatment are stabilized using **anaerobic sludge digestion tanks**.

9.1.4. Final or Advanced Treatment

- Also called **tertiary treatment**, it **removes remaining organic load** and kills **pathogenic bacteria**.
- Usually performed using **chlorination** (not for disposal but for water reuse purposes).
- May be adopted when sewage outfall is near a **drinking water intake**.
- **Modern treatment methods often combine physical, chemical, and biological processes, making the distinction between primary, secondary, and tertiary treatments arbitrary.**
- **Treatment plant design varies based on topography and local requirements.**

1. Classification of Treatment Processes

Sewage must be treated before disposal to ensure environmental safety. The degree of treatment depends on the disposal method and sewage characteristics. Treatment is classified into:

(i) Preliminary Treatment

- Removes floating materials (e.g., dead animals, tree branches, rags, paper, wood) and heavy inorganic solids.
- Reduces **Biochemical Oxygen Demand (BOD)** by 15-30%.
- **Processes used**:
    - **Screens** – Remove floating papers, rags, and clothes.
    - **Grit Chambers** – Remove sand and grit.
    - **Skimming Tanks** – Remove oil and grease.

(ii) Primary Treatment

- Removes large suspended organic solids via **sedimentation (settling basins)**.
- The effluent still contains high BOD (about 60% of the original).
- Settled solids are stabilized in **Sludge Digestion Tanks** via anaerobic decomposition.

(iii) Secondary (Biological) Treatment

- Further decomposes organic matter using **bacteria** (aerobic & anaerobic).
- **Aerobic biological units** (oxidation by aerobic bacteria):
    - **Filtration Treatment** (Trickling filters)
    - **Aeration Tanks** (Activated Sludge Process)
    - **Oxidation Ponds**
- **Anaerobic biological units** (decomposition by anaerobic bacteria):
    - **Anaerobic Lagoons, Septic Tanks, and Imhoff Tanks**
    - Imhoff tanks are considered **primary treatment** when handling raw sewage.

(iv) Tertiary or Advanced Treatment

- Removes remaining organic matter and pathogens.
- **Chlorination** is commonly used for disinfection.
- Used when sewage effluent is released near water supply intakes.

2. Types of Sewage Treatment Plants

Treatment plants provide full treatment and are chosen based on local needs:

1. **Imhoff Tanks & Low Rate Trickling Filters**
    - Used in **small towns** (now outdated).
2. **Sedimentation Tanks & High Rate Trickling Filters**
    - Used in **small to medium cities**.
3. **Sedimentation Tanks & Activated Sludge Treatment**
    - Used in **large cities**, requiring continuous supervision.

Factors influencing plant selection:

- **Topography & geology** – Trickling filters require slopes, while Imhoff tanks need depth.
- **Plant size** – Small plants avoid complex units needing constant monitoring.

3. Screening in Sewage Treatment

Definition: The first process in sewage treatment where floating matter (cloth, wood, paper, fecal solids) is removed to prevent clogging and equipment damage.

- Screens should be placed **before grit chambers**.
- In some cases (landfill waste), screens may be placed after grit chambers.

Types of Screens

Screens are classified based on the **size of openings**:

(i) Coarse Screens (Racks)

- **Opening size**: 50mm or more.
- **Removes**: Large floating objects (rags, wood, paper).
- **Disposal**: Incineration, burial, or dumping.

(ii) Medium Screens (Bar Screens)

- **Opening size**: 6-40mm.
- **Removes**: 30-90 liters of material per million liters of sewage.
- Contains organic matter, requiring disposal via **incineration or burial**.
- **Structure**:
  - Made of **steel bars** (fixed in frames).
  - **Inclined at 30°-60°** to increase efficiency.

(iii) Fine Screens

- **Opening size**: 1.5-3mm.
- **Removes**: Up to **20% of suspended solids**.
- **Issues**: Clogs frequently → Used mainly for **industrial wastewater**.

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4. Cleaning & Maintenance of Screens

Manual Cleaning

- Used in small plants with **hand-operated rakes**.

Mechanical Cleaning

- Used in larger plants with **automated rakes** operating continuously or intermittently.

Fixed vs. Movable Screens

- **Fixed Screens**: Stationary and permanently installed.
- **Movable Screens**: Can be lifted for cleaning.
- **Common movable screen**: 3-sided cage with perforated plates (used in deep pits before pumps).

Design Considerations

- Clear openings should allow a **flow velocity ≤ 0.8-1 m/sec** to prevent solid buildup.
- **Higher velocity → solids forced through screens → ineffective screening**.

Key Takeaways

- **Sewage treatment is essential** for environmental safety before disposal.

- **Treatment stages**: Preliminary → Primary → Secondary → Tertiary.
- **Screening is the first step** in removing large floating debris.
- **Types of screens**: Coarse, medium, and fine screens, based on opening size.
- **Cleaning methods**: Manual or mechanical rakes.
- **Proper screen design** improves efficiency and reduces clogging.

Screening in Sewage Treatment

1. **Purpose of Screens**
   - Screens remove large floating and suspended solids from sewage.
   - Prevent clogging of pumps and protect downstream treatment processes.
2. **Types of Screens**
   - **Coarse Screens:** Remove large debris like rags and plastics.
   - **Fine Screens:** Remove smaller particles; can be disk or drum type, operated electrically.
3. **Screen Design Considerations**
   - Velocity through the screen should not exceed 0.8 m/s.
   - Gross area of screens is calculated based on peak flow and bar spacing.
   - Head loss increases with clogging; cleaning is necessary to maintain efficiency.

Comminutors (Shredders)

1. **Function**
   - Break larger sewage solids into smaller pieces (6mm or less).
   - Used in place of screens to reduce disposal issues.
2. **Components**
   - Revolving slotted drum.
   - Cutters shear the screenings, allowing small pieces to pass through slots.

Disposal of Screenings

1. **Characteristics**
   - Contains 85-90% moisture and organic load, causing odor and decomposition.
2. **Methods of Disposal**
   - **Burning (Incineration):** Removes moisture through drying, then burns at 760-815°C.
   - **Burial (Composting):** Screenings buried in trenches with porous cover for decomposition.
   - **Dumping in Water:** Suitable in areas with strong currents to carry screenings away.
   - **Digestion:** Mixing with sewage sludge in digestion tanks (not very successful).

Grit Removal Basins

1. **Purpose**
   - Removes inorganic particles (sand, gravel, shells) that cause pump abrasion.
2. **Working Principle**
   - Grit chambers slow down sewage velocity, allowing heavier grit to settle.
   - Prevents excessive wear on downstream equipment.

Settling of Particles in Wastewater

1. **Principle**
   - Organic matter has a specific gravity > 1.0, causing it to settle due to gravity.
2. **Types of Settling**
   - **In Still Water:** Particles settle by gravity.
   - **In Flowing Water:** Turbulence can slow down settling.
3. **Factors Affecting Settling**
   - **Flow Velocity:** Lower velocity promotes better settling.
   - **Viscosity of Water:** Warmer water reduces viscosity, aiding settlement.
   - **Particle Size and Density:** Larger and denser particles settle faster.
4. **Types of Particles**
   - **Discrete (Granular) Particles:** Settle independently without shape change.
   - **Flocculent Particles:** Change shape and structure during settling.

Settling Velocity of Particles (Stoke's Law)

1. **Basic Concept:**
   - The weight and volume of a spherical particle vary with the cube of its diameter.
   - The area of a particle varies with the square of the diameter.
   - Smaller particles settle slowly due to lower weight and volume.
2. **Stoke's Law for Small Particles (d < 0.1 mm):**
   - Settling velocity formula:vs=G−118d2vvs=18G−1vd2 where:
     - vsvs = velocity of settlement,
     - dd = diameter of the particle,
     - GG = specific gravity of the particle,
     - vv = kinematic viscosity of water,
     - ReRe = Reynolds number (Re<0.5Re<0.5 for small particles).
3. **Derivation of Stoke's Law:**
   - A solid particle falling in water initially accelerates but eventually reaches a constant velocity (VtVt) when the drag force equals the effective weight.
   - Drag force formula:Fd=CDAρwv22Fd=CDAρw2v2 where:
     - CDCD = coefficient of drag,
     - AA = particle's cross-sectional area.
4. **Final Stoke's Equation:**

   - vsvs for small particles:vs=43g(G−1)dCDvs=34CDg(G−1)d
   - For viscous flow:CD=24ReCD=Re24
5. **Nature of Settling:**
   - **Laminar Settling (d < 0.1 mm):** Stoke’s equation holds, and settling follows a streamlined path.
   - **Transition Settling (0.1 mm < d < 1.0 mm):** Settling starts deviating from Stoke’s law.
   - **Turbulent Settling (d > 1.0 mm):** Settling follows Newton’s equation.
6. **Newton’s Equation for Turbulent Settling (d > 1.0 mm):**

   vs=1.8g(G−1)dvs=1.8g(G−1)d

7. **Empirical Observations:**
   - Theoretical settling velocities may differ from actual velocities due to:
     - Non-spherical shape of particles.
     - Upward fluid displacement.
     - Convection currents.
   - Hazen’s experiments provided practical settling velocity values.

Hydraulic Settling Values in Still Liquids (Table 9.5)

- Settling velocities of particles depend on their diameter and specific gravity.
- **Course sand** (1.00 mm) settles fastest (100 mm/sec).
- **Fine sand** (0.10 mm) has a lower settling velocity (~1.2 mm/sec).
- **Clay and colloidal particles** settle extremely slowly (less than 0.001 mm/sec).
- Settling velocities increase by **50% at higher temperatures (26°C).**
- A **mathematical model** is given for settling velocity in the **transition zone** using **Hazen's equation**:vs=60.6d(G−1)(37+70100)vs=60.6d(G−1)(10037+70) (Valid for particles between **0.1 mm and 1 mm**).

Grit Chambers or Grit Channels

- **Purpose:** Removes inorganic grit (sand, silt, gravel) **before primary sedimentation.**
- **Typical grit size: 0.15 to 0.92 mm.**
- **Grit quantity:** Varies widely (0.004 to 0.037 m^3/1000 m^3 of sewage).
- **Organic matter** is **not removed** in grit chambers, as it decomposes.
- **Settling velocity criteria:**
  - **Particles ≥ 0.2 mm** settle at **about 20 mm/sec** (10°C).
  - Some systems remove particles **above 0.15 mm**, needing ~15 mm/sec velocity.

Types of Grit Chambers

1. **Horizontal flow type** (open-aerated).
2. **Aerated type.**

Constant Velocity Horizontal Flow Grit Channels

- Designed to **reduce flow velocity** for efficient grit settlement.
- Flow velocity should not be:
    - Too low (**grit does not settle**).
    - Too high (**organic matter settles along with grit**).
- **Critical scouring velocity formula (Shields' equation):**Vh=3 to 4.5gd(G−1)Vh =3 to 4.5gd(G−1)
    - For **0.2 mm particles**, this gives a **critical velocity of 0.17 to 0.26 m/sec**.
    - **Optimum flow velocity: 0.25 to 0.3 m/sec**.

Velocity Control Methods

- **Proportional flow weir** at the **effluent end**.
- **Varying cross-section geometry** (e.g., parshall flume).

Design of a Rectangular Grit Chamber

- **Proportional weir ensures controlled velocity.**
- **Detention time: 40 to 60 sec** (for **water depth of 1 to 1.8 m**).
- **Multiple chambers** recommended (one for high flow, one for low flow).

Example Calculation for Settling Velocity

- For **T = 25°C, d = 0.2 mm**:Vs=d37+70=0.029 m/secVs=d37+70=0.029 m/sec
- Detention time in seconds:=depth×34settling velocity=settling velocitydepth×34
    - **For depth = 1.8 m:** Detention time = **60 sec**.

Notes on Sewage Treatment (Grit Chambers & Sedimentation Tanks)

1. Grit Chambers

- Used to remove heavy inorganic solids (e.g., sand, silt, gravel) from sewage.
- **Types of Cleaning:**
    - *Manual Cleaning*: Shovels, done for small plants (<4.5M liters/day).
    - *Mechanical Cleaning*: Machines help remove grit.
    - *Hydraulic Cleaning*: Water jets remove grit through bottom/side pipes.
- Grit may contain organic matter, which can be washed before disposal.
- Grit is usually disposed of by burying or burning.

2. Design of Proportional Flow Weir

- Ensures constant velocity of flow in grit chambers.
- Uses the formula:x=2BVaCd2gT·yx=Cd2gT·y2BVa where:
    - BB = width of channel
    - VaVa = horizontal flow velocity
    - CdCd = discharge coefficient
    - gg = gravity
    - yy = depth on weir profile

3. Example Calculation (Rectangular Grit Chamber)

- Flow velocity: 0.3 m/s
- Settling velocity: 0.016 to 0.022 m/s
- Width BB calculated as **0.4 m**
- Overall depth **1.75 m** (water depth 1m + 0.3m above weir crest + 0.45m freeboard)
- Detention time **50 sec**
- Length of tank **15 m**

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4. Sedimentation Tanks

- Used to remove suspended organic solids.
- Sedimentation occurs twice in sewage treatment:
  - **Primary Sedimentation** (before biological treatment).
  - **Secondary Sedimentation** (after biological treatment).
- **Efficiency:**
  - Removes **60-65%** of suspended solids.
  - Removes **30-35%** of Biochemical Oxygen Demand (BOD).

5. Types of Sedimentation Tanks

1. **Intermittent (Quiescent) Type:**
   - Stores sewage for ~24 hours.
   - Becomes **obsolete** due to long operation time.
2. **Continuous Flow Type:**
   - Modern design, sewage flows through continuously.
   - Velocity is reduced to allow sedimentation.

6. Design of Continuous Flow Sedimentation Tank

- Horizontal velocity VV given by:V=QBHV=BHQ where:
  - QQ = discharge
  - BB = width
  - HH = depth
- Settling velocity:Vs=QBLVs=BLQ
  - Particles settle if their velocity VsVs is **greater than or equal to** Q/BLQ/BL.

Coagulation in Sewage Treatment

- **Definition:** The process of adding chemicals (e.g., ferric chloride, alum) to wastewater to form flocs, which absorb fine particles and facilitate sedimentation.
- **Process Similarity:** Similar to water coagulation.
- **Reasons for Limited Adoption in Modern Treatment:**
  - More advanced biological treatments are preferred.
  - Various disadvantages of coagulation.

Disadvantages of Coagulation:

1. **Not Required in Modern Biological Treatments:** Secondary treatments are often self-sufficient.
2. **Destroys Helpful Microorganisms:** Chemicals may harm bacteria essential for sludge digestion.
3. **Costly:** Additional chemical costs and sedimentation expenses.
4. **Produces Large Sludge Volumes:** Leads to sludge disposal problems.
5. **Requires Skilled Supervision:** Handling chemicals demands expertise.

Advantages of Coagulation (Selective Use Cases):

- Enhances sedimentation, reducing suspended solids and BOD.
- Reduces space requirements for settling tanks.
- Helps in phosphate removal, controlling eutrophication.

Biological Filtration of Sewage

- **Purpose:** Removes 60-80% of organic matter from sewage effluent.
- **Process:** Organic matter is converted into stable forms (e.g., nitrates, sulphates) via oxidation or nitrification.
- **Methods:**
    - **Filtration:** Physical removal.
    - **Activated Sludge Process:** Biological decomposition.

Types of Filters:

1. **Contact Beds:** Used in small plants, now obsolete.
2. **Intermittent Sand Filters:** Used for smaller plants.
3. **Trickling Filters:** Most common in modern sewage treatment.
4. **Miscellaneous Filters:** Used for special projects.

Contact Beds for Biological Filtration

- **Process:** Sewage contacts filtering media, where bacteria attach and form biofilm.
- **Aerobic Decomposition:** Oxygen is required to break down organic matter.
- **Cycle:** Biofilm absorbs organic matter, then regenerates by absorbing atmospheric oxygen.

Trickling Filters

- **Function:** Sprays sewage over coarse filtering media, allowing bacterial biofilm formation.
- **Decomposition:** Bacteria degrade organic matter in biofilm.

- **Issues:**
  - **Sloughing:** Biomass detaches, requiring secondary settling.
  - **Oxygen Supply:** Essential for bacterial growth.
- **Types of Distributors:**
  - **Rotary Distributors:** Continuous sewage application.
  - **Spray Nozzles:** Periodic application, requiring dosing tanks.

Types of Trickling Filters:

1. **Conventional Trickling Filters (Ordinary/Standard Rate)**
2. **High Rate Trickling Filters**
   - Have similar construction to conventional filters but allow **recirculation** of sewage for higher efficiency.
   - Require **lesser land area** due to greater loading capacities.

Merits and Demerits of Trickling Filters:

Advantages:

- **High Rate of Filter Loading** → Requires **less land area**.
- **Effluent Quality**:
  - **75% of BOD** and **80% of suspended solids** removed.
  - Effluent is **stabilized** and can be disposed of with less dilution water.
- **Simple Operation**:
  - No **skilled supervision** required.
  - **Flexible** in handling varying wastewater concentrations.
  - **Self-cleaning** ability.
- **Low Mechanical Wear & Tear** → Fewer moving parts.
- **Moisture Content of Sludge** is high (up to **99%**).
- **Efficient in Warm Climates** → Higher BOD removal.

Disadvantages:

- **High Head Loss** → Needs **automatic dosing**.
- **Construction Cost** is high.
- **Cannot Treat Raw Sewage** → Requires **primary sedimentation**.

Operational Problems in Trickling Filters:

1. **Fly Nuisance** (Psychoda flies):
   - Flies develop in filter particles, causing **nuisance**.
   - Controlled by **flooding the filter** for **24 hours**.
   - Use of **insecticides** (e.g., DDT, benzene hexachloride).
2. **Odor Problems**:
   - **H_2S and other gases** may be released.

- Controlled by **chlorination** and neutralizing H_2S.
- Anaerobic conditions worsen the smell.

3. **Ponding Troubles**:
   - **Fungi and algae** cause clogging.
   - Controlled by **chlorination** and **resting the bed**.
   - Copper sulfate can be used to control algae.
4. **Spring-Off Loading**:
   - Occurs when worms and larvae burrow, bringing **organic humus** to the surface.
   - More common in **winter months**.

Design of Trickling Filters:

- **Filter Loading**:
  1. **Hydraulic Loading Rate** (ML/day per hectare)
     - Conventional filters: **22-44 ML/ha/day**.
     - High rate filters: **110-330 ML/ha/day**.
  2. **Organic Loading Rate** (kg BOD_5 per ha-m)
     - Conventional: **900-2200 kg/ha-m**.
     - High rate: **6000-18000 kg/ha-m**.
- **Filter Size**:
  - Determined by the **organic loading** and **hydraulic loading**.
  - **Rotary distributors and drainage systems** should be designed for **peak flows**.

Performance of Conventional Trickling Filters:

- Effluent is **highly nitrified** and stabilized.
- **BOD reduction**: **80-90%**.
- **Effluent sludge**:
  - **Less than 20 ppm** solids.
  - Moisture content: **92%** (thick, digestible).
- **Flexible and durable** → Can handle **intermittent loading**.

Summary:

- Trickling filters are effective in **sewage treatment** with **high BOD removal**.
- Require **less land** but involve **high costs and head loss**.
- Operational issues include **fly nuisance, odor problems, and clogging**, which can be controlled.
- **Hydraulic & organic loading rates** determine filter **size and efficiency**.

Notes on Tricking Filters and Recirculation in Sewage Treatment

Comparison of Conventional and High-Rate Tricking Filters

Characteristic	Conventional Filter	High-Rate Filter
Depth of filter media	1.6 - 2.4 m	1.2 - 1.8 m
Size of filter media	25 - 75 mm	25 - 60 mm
Land required	More land needed	Less land required
Cost of operation	Higher	Lower
Method of operation	Continuous, less flexible	Continuous, more flexible
Type of effluent produced	Highly nitrified, BOD < 20 ppm	Nitrified but less stable, BOD < 20 ppm
Dosing interval	3 - 10 minutes	Not more than 15 seconds
Filter loading values	22 - 44 ML/L per hectare/day	110 - 330 ML/L per hectare/day
Recirculation system	Not provided	Always provided
Quality of secondary sludge	Black, highly oxidized	More fully oxidized

Recirculation of Treated Sewage

- **Purpose**: Enhances efficiency of high-rate filters by returning treated or partly treated sewage to the treatment process.
- **Types**:
  - **Single-stage recirculation**: Effluent is sent from the secondary tank to the primary tank or directly back to the filter.
  - **Two-stage recirculation**: Uses two filters in series for better efficiency.
- **Advantages**:
  1. Ensures continuous dosing despite fluctuations in flow.
  2. Equalizes and reduces loading, improving efficiency.
  3. Provides longer contact with filter media, aiding bacterial action.
  4. Keeps influent fresh, reducing odors and fly nuisance.
- **Drawback**: High flow can wash off filter media before nitrification occurs, lowering nitrate levels and effluent quality.

Types of High-Rate Filters

1. **Bio-filters**:
   - Shallow filters (1.2 - 1.5 m depth).
   - Main treatment occurs in upper layers.
   - Uses recirculation to improve efficiency.
   - Second-stage filters may be added for stronger sewage.
2. **Accelo filters**:
   - Patent-based proprietary filter.
   - Designed for optimized application of sewage.
3. **Aero filters**:

- Patent-based system.
- Focus on aeration for improved performance.

Notes on Oxidation Tanks

Definition

An **oxidation tank** (also known as an aeration tank or biological oxidation tank) is a key component in sewage treatment plants where wastewater undergoes **biological treatment** using aerobic microorganisms. These microorganisms break down organic matter, reducing Biological Oxygen Demand (BOD) and improving water quality.

Working Principle

1. **Aeration**: Air or oxygen is introduced into the tank to promote the growth of aerobic bacteria.
2. **Biological Decomposition**: Microorganisms feed on organic matter, converting it into simpler compounds like carbon dioxide, water, and biomass.
3. **Settling & Removal**: After biological treatment, the treated water is sent to a **settling tank** where the sludge is removed, and the clarified effluent is further treated or discharged.

Types of Oxidation Tanks

1. **Extended Aeration Tank**:
   - Used in small treatment plants.
   - Long retention time (24-36 hours) allows for complete stabilization of organic matter.
2. **Contact Stabilization Tank**:
   - Uses a two-stage process: adsorption of organic matter followed by stabilization.
   - Reduces tank volume and energy costs.
3. **Oxidation Ditch**:
   - Circular or oval-shaped tank used for long-duration aeration.
   - Suitable for small communities with **low maintenance requirements**.
4. **Activated Sludge Process (ASP) Tank**:
   - The most commonly used system in sewage treatment plants.
   - Recirculates sludge to maintain a high microbial concentration.

Advantages

✅ **Efficient Organic Matter Removal** – Reduces BOD and improves effluent quality.
✅ **Odor Control** – Aeration prevents the formation of foul-smelling gases.
✅ **Scalable Design** – Can be adapted for both **small** and **large** treatment plants.

Disadvantages

❌ **High Energy Consumption** – Requires continuous aeration.
❌ **Sludge Disposal** – Regular sludge removal and treatment are necessary.
❌ **Requires Skilled Operation** – Proper monitoring of dissolved oxygen (DO) and microbial activity is needed.