INTRODUCTION

1. Why do we treat water and wastewater?
   - The main objectives of the conventional wastewater treatment processes are the reduction of biochemical oxygen demand, suspended solids and pathogenic organisms.

2. What are the materials in water and wastewater that we must remove?
   - There are a wide range of these pollutants (contaminants) ranging from municipal sewage to highly specific industrial wastes. The usual approach in discussing treatment schemes is to categorize pollutants into general classes so that a general class of treatment methods can be applied.

3. To what level do we need to remove contaminants?
   - The degree to which drinking water must be treated depends on the raw water quality and the desired quality of the finished water.
   - Similarly the degree of treatment of a wastewater depends on the quality of the raw waste and the required effluent quality.

   - BOD₅ = 30 mg/L monthly average
   - Suspended Solids = 30 mg/L monthly average
   - pH (if there is industrial input) = 6 – 9 continuous

For drinking water treatment the requirements are, of course, much more stringent with many more categories and lower contaminant limits.

   - Turbidity (a measure of suspended solids): less than 0.5 NTU in at least 95% of samples taken each month.
     - Lead: 0.010 mg/L
     - Copper: 1.3 mg/L
     - Total Coliform: no coliform detection in more than 5% of samples collected each month.

Also necessary to remove nutrients such as N and P, toxic components, non-biologically degradable compounds and dissolved solids.

Removal of these materials are necessary for the simple reason that discharge to the environment will result in “damage” of some sort.

For drinking water treatment the requirements are, of course, much more stringent with many more categories and lower contaminant limits.
4) How are these contaminants removed from water and wastewater?

- Contaminant removal is accomplished by a series of unit processes or unit operations.
- Unit operation is a physical, chemical, or biological treatment process.
- The system of integrated unit processes or unit processes used to treat a water or wastewater is called a treatment train.

General overview of plant components

Figure 26-11-2015

Figure Location of physical unit operations in a wastewater-treatment plant flow diagram

A. Bar Racks

Typical design information for mechanically cleaned bar rack:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Min</th>
<th>Max</th>
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B. Fine screens

Description of fine screen:

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<th>Parameter</th>
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**Flow Equalization**

**Description/Application**
- Used to equalize flows in wastewater treatment systems and reduce peak flows and loads.
- Helps in equalizing flows to calibration system, often filtration.
- Allows for proper operation and calibrating system flows.

**Benefits and Disadvantages**
- **Benefits:**
  - Shock loading, pH, inhibiting substances.
  - Improved consistency in solid loading.
  - Volume requirements for equalization basin.
- **Disadvantages:**
  - Large area usage.
  - More tools are required for site work.
  - Capital cost is increased.

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**Volume Requirements for Equalization Basin**

- Schematic view diagram for the volume of equalization basin.

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**Mixing**

- Important unit operation in wastewater treatment including:
  1. Mixing of one substance completely with another.
  2. Blending of miscible liquids.
  3. Flocculation of waste particles.
  5. Heat transfer.

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**Continuous Mixing**

- Used where the contents of a reactor or holding tank or basin must be kept in suspension such as in equalization basins, flocculation basins, aerated lagoons, suspended growth biological treatment process, and aerobic digestor.

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**Types of Mixers Used for Rapid Mixing**

- **Static Mixers**
- **High-speed Induction Mixers**
- **Pressurized Water Jets**
- **Turbine and Propeller Mixers**

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**Flocculation**

- Flocculation is a process of adding a coagulant to wastewater to promote the formation of large, cohesive particles that can be more easily removed from the water.

- Benefits of flocculation include:
  - Improved settling.
  - Reduced sludge production.
  - Enhanced biological nutrient removal.
Flocculation Purposes

- Precipitates smaller particles into larger ones.
- Designed to enhance the kinds of mixing intensity.
- Removes colloidal or fine-particle matter with other particles.
- Prevents making them too large and settle.

Objectives of Sedimentation

- To separate solids from liquid using the force of gravity. In sedimentation, only suspended solids (SS) are removed.

Use

- Sedimentation is used in water and wastewater treatment plants.

Sedimentation Basics

- Types of settling
  - Type I settling (free settling)
  - Type II settling (settling of flocculated particles)
  - Type III settling (zone or hindered settling)
  - Type IV settling (compression settling)

Discrete Particle Settling

- The rate at which the fluid settles is governed by the equation:
  \[ Q = 3 \cdot \sqrt{g} \cdot \frac{D}{4} \cdot \frac{1}{1 + \frac{D}{4}} \]

where:
- \( Q \): flow rate (liters per second)
- \( g \): gravitational acceleration (m/s²)
- \( D \): diameter of sphere (m)

Rearranging:

\[ \sqrt{Q} = \frac{3g}{4} \left( 1 + \frac{D}{4} \right) \cdot \sqrt{\frac{1}{1 + \frac{D}{4}}} \]

Particle Setting Theory

- \( F_p = \frac{\rho_p - \rho}{\rho} \cdot g \cdot r^2 \)

where:
- \( F_p \): gravitational force, N
- \( \rho_p \): density of particle, kg/m³
- \( \rho \): density of water, kg/m³
- \( g \): acceleration due to gravity, m/s²
- \( r \): radius of particle, m

- \( r = \frac{C_d \rho V_s^2}{2} \)

where:
- \( C_d \): drag coefficient
- \( \rho \): density of water, kg/m³
- \( V_s \): settling velocity, m/s

Type II (Flocculent sedimentation)

- Particles flocculate as they settle
- Floc particle velocity increase with time
- Design parameters:
  1. Surface overflow rate
  2. Depth of tank
  3. Hydraulic retention time
2. Flocculent Particle Settling

The settling velocity in flocculent settling where

\[ v_s = \frac{H}{\sqrt{t}} \]

The fraction of particles removed is given by

\[ R_{100} = \sum_{i=1}^{n} \left( \frac{m_i}{M} \right) \left( \frac{R_i - R_{i-1}}{2} \right) \]

where
- \( R_i \) : total height of settling column
- \( R_{i-1} \) : distance between curves of equal percent removed
- \( m_i \) : mass of particles settle as a zone
- \( M \) : mass of particles settle as a zone

3. Hindered (zone) settling and compression

Type III settling (zone or hindered settling)
- Is the settling of an intermediate concentration of particles
- The particles are close to each other
- Interparticle forces hinder settling of neighbouring particles
- Particles remain in fixed position relative to each other
- Mass of particles settle as a zone

Type IV settling (compression settling)
- Settling of particles that are of high concentration
- Particles touch each other
- Settling occurs by compression of the compacting mass
- It occurs in the lower depths of final clarifiers of activated sludge

Chemical unit processes - precipitation
- Widely used technology for the removal of metals and other inorganics, suspended solids, fats, oils, greases, and some other organic substances from wastewater.
- Precipitation is a method of removing contaminants that are either dissolved or suspended in solution to settle out of solution as a solid precipitate, which can then be filtered, centrifuged out of solution as a solid, or otherwise separated from the liquid portion.
- It can be used on a small or large scale.
- A heater of waste, a 50,000 tank, 1,000,000 gallon lagoon or a lagoon can be batch treated with chemicals.
- Chemical precipitation can be used in a continuous treatment process on flows ranging from a trickle to 1 gallon/minute, 1,000 gallon/minute and more.
- Precipitation is assisted through the use of a coagulant, an agent which causes smaller particles suspended in solution to gather into larger aggregates.
- Frequently, polymers are used as coagulants.
- When colloidal matter such as emulsified oil or metal bearing particles are treated with metal salts and lime or NaOH, the metal salts act as primary coagulants.
- The positively charged metal ions combine with the negative colloidal particles and neutralize their charge.
- The particles then repel each other less strongly and tend to aggregate or collect into larger particles.
**Chemicals for precipitation**
- Lime - Calcium Oxide, CaO
- Ferrous Sulfate - Fe(SO₄)₃
- Alum or Filter Alum - Al₂(SO₄)₃.14H₂O
- Ferric Chloride - FeCl₃
- Polymer

**Advantages**
- Chemical precipitation is a well-established technology with readily availability of equipment and many chemicals.
- Some treatment chemicals, especially lime, are very inexpensive.
- Completely enclosed systems are often conveniently self-operating and low maintenance.

**Disadvantages**
- Competing reactions, varying levels of alkalinity and other factors typically make calculation of proper chemical dosages impossible.
- Chemical precipitation may require working with corrosive chemicals, increasing operator safety concerns.
- The addition of treatment chemicals, especially lime, may increase the volume of waste sludge up to 50 percent.
- Large amounts of chemicals may need to be transported to the treatment location.
- Polymers can be expensive.

**APPLICATION OF DIFF. CHEMICALS**
- **Lime - Calcium Oxide, CaO**
  - Produces calcium carbonate in wastewater which acts as a coagulant for hardness and particulate matter. Often used in conjunction with other coagulants, since:
    1. by itself, large quantities of lime are required for effectiveness, and
    2. lime typically generates more sludge than other coagulants.

- **Ferrous Sulphate - Fe(SO₄)₃**
  - Typically used with lime to soften water. The chemical combination forms calcium sulfate and ferric hydroxide. Wastewater must contain dissolved oxygen for reaction to proceed successfully.

- **Ferric Chloride - FeCl₃**
  - Reacts with alkalinity or phosphates to form insoluble iron salts.

- **Alum or Filter Alum - Al₂(SO₄)₃.14H₂O**
  - Used for water softening and phosphate removal.
  - Reacts with available alkalinity (carbonate, bicarbonate and hydroxide) or phosphate to form insoluble aluminium salts.

- **Polymer**
  - High molecular weight compounds (usually synthetic) which can be anionic, cationic, or non-ionic. When added to wastewater, can be used for charge neutralization for emulsion-breaking, or as bridge-making coagulants, or both. Can also be used as filter aids and sludge conditioners.

**Biological unit processes**
- In the case of domestic wastewater treatment, the objective of biological treatment is:
  1. To stabilize the organic content
  2. To remove nutrients such as nitrogen and phosphorus

**Attached Growth Process**
- **What can this process do?**
  1. Remove Nutrient
  2. Remove dissolved organic solids
  3. Remove suspended organic solids
  4. Remove suspended solids

**Cross-section of an attached growth biomass film**
- Oxygen (the natural or forced draft)
- Wastewater
- Organics/nutrients
- Sludge
- Filter media
- Biomass: a viscous, jelly-like substance containing bacteria
### Major Aerobic Biological Processes

<table>
<thead>
<tr>
<th>Type of Growth</th>
<th>Common Name</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended Growth</td>
<td>Activated Sludge (AS)</td>
<td>Carbonaceous BOD removal (nitrification)</td>
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<tr>
<td></td>
<td>Aerated Lagoons</td>
<td>Carbonaceous BOD removal (nitrification)</td>
</tr>
<tr>
<td>Attached Growth</td>
<td>Trickling Filters</td>
<td>Carbonaceous BOD removal, nitrification</td>
</tr>
<tr>
<td></td>
<td>Rotating Biological Contactors</td>
<td>Carbonaceous BOD removal (nitrification)</td>
</tr>
<tr>
<td></td>
<td>Packed-bed reactors</td>
<td>Carbonaceous BOD removal (nitrification)</td>
</tr>
<tr>
<td>Combined Suspended &amp; Attached Growth</td>
<td>Activated Biofilter Process</td>
<td>Carbonaceous BOD removal (nitrification)</td>
</tr>
</tbody>
</table>

#### Activated Sludge Process
- The aeration tank contains a suspension of the wastewater and microorganisms, the mixed liquor. The liquor is mixed by aeration devices (supplying also oxygen).
- A portion of the biological sludge separated from the secondary effluent by sedimentation is recycled to the aeration tank.

#### Advantages/Disadvantages
- **Advantages**
  - Flexible, can adapt to minor pH, organic and temperature changes
  - Small area required
  - Degree of nitrification is controllable
  - Relatively minor odor problems
- **Disadvantages**
  - High operating costs (skilled labor, electricity, etc.)
  - Generates solids requiring sludge disposal
  - Some process alternatives are sensitive to shock loads and metallic or other poisons
  - Requires continuous air supply

### Trickling Filters
- The trickling filter or biofilter consists of a bed of permeable medium of either rock or plastic.
- Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Periodically, portions of the film slough off the media.

#### Flow Diagram for Trickling Filters

![Flow Diagram for Trickling Filters](image)

#### Advantages/Disadvantages
- **Advantages**
  - Good quality (80-90% BOD removal) for 2-stage efficiency could reach 95%
  - Moderate operating costs (lower than activated sludge)
  - Withstands shock loads better than other biological processes
- **Disadvantages**
  - High capital costs
  - Clogging of distributors or beds
  - Snail, mosquito and insect problems

### Rotating Biological Contactors
- It consists of a series of circular disks of polystyrene or polyvinyl chloride that are submerged in wastewater and rotated slowly through it.
- The disk rotation alternately contacts the biomass with the organic material and then with atmosphere for adsorption of oxygen.
- Excess solids are removed by shearing forces created by the rotation mechanism.

#### Advantages/Disadvantages
- **Advantages**
  - Short contact periods
  - Handles a wide range of flows
  - Easily separates biomass from soluble stream
  - Low operating costs
  - Short retention time
  - Low sludge production
  - Excellent process control
- **Disadvantages**
  - Need for covering units installed in cold climate to protect against freezing
  - Shaft bearings and mechanical drive units require frequent maintenance

### Major Anaerobic Biological Processes

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<tr>
<td>Suspended Growth</td>
<td>Anaerobic Contact Process</td>
<td>Carbonaceous BOD removal</td>
</tr>
<tr>
<td></td>
<td>Upflow Anaerobic Sludge Blanket (UASB)</td>
<td>Carbonaceous BOD removal</td>
</tr>
<tr>
<td>Attached Growth</td>
<td>Anaerobic Filter Process</td>
<td>Carbonaceous BOD removal, waste stabilization (denitrification)</td>
</tr>
<tr>
<td></td>
<td>Expanded Bed</td>
<td>Carbonaceous BOD removal, waste stabilization (denitrification)</td>
</tr>
</tbody>
</table>
Anaerobic Contact Process
- Untreated wastewater is mixed with recycled sludge solids and then digested in a sealed reactor.
- The mixture is separated in a clarifier.
- The supernatant is discharged as effluent, and settled sludge is recycled.

Advantages/Disadvantages

**Advantages**
- Methane recovery.
- Small area required.
- Volatile solids destruction.

**Disadvantages**
- Heat required.
- Effluent in reduced chemical form requires further treatment.
- Requires skilled operation.
- Sludge to be disposed off is minimal.

Upflow Anaerobic Sludge Blanket
- Wastewater flows upward through a sludge blanket composed of biological granules that decompose organic matter.
- Some of the generated gas attaches to granules that rise and strike degasifying baffles, releasing the gas.
- Free gas is collected by special domes.
- The effluent passes into a settling chamber.

Low Cost Sanitation System
Septic Systems

What is a septic system?
- A septic system is a gravity flow and disposal system for wastewater.
- All the treatment and disposal takes place within the septic tank. Biological and physical processes.

Why use a septic system?
- Safeguard and disposal of sewage.
- Prevents the spread of disease.
- Prevents damage to land.
- Protects underground water.
- Keeps homes odor free.
- Keeps waste affordable.

Septic tank
- All household wastewater systems will have a septic tank.
- Microbial action digests solid wastes.
- Liquids flow through tank to disposal area.
- Tank size:
  - 1000 gallon liquid capacity (4-BR house or less).
  - Add 250 gallons per additional bedroom.

Role of the septic tank
- Anaerobic fermentation of solids.
- Reduce the load of pathogens in the effluent.
- Hold the effluent for 2-3 days for improved safety.
- Retain solid material to prevent blockage of further disposal system.

- The field requires periodic maintenance.
- Diversion of the flow at distribution box and repacking of the rock fill, removal of plant roots etc.
Connection to a sewage system: what are the alternatives?

- Conventional sewage connection...expensive
- Small bore sewage system: less expensive
- Use roadside drains, and hope for the best....
- Unfortunately this is the common outcome

Where do we go from here:

- The effluent must be disposed of in a sanitary manner
- The system should be inexpensive and easy to manage
- Tropical areas do have long hours of sunlight, why not exploit this.
- We can by using evaporation ponds...

Soak pit

- Soak Pit, also known as a soak away or leach pit, is a covered, porous-walled chamber that allows water to slowly soak into the ground.
- Pre-settled effluent from a Collection and Storage/Treatment technology is discharged to the underground chamber from where it infiltrates into the surrounding soil.

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Advantages/Disadvantages

Advantages
- Can be built and repaired with locally available materials.
- Small land area required.
- Low capital cost but operating costs.
- Can be built and maintained with locally available materials.
- Simple technique for all users.

Disadvantages
- Pre-treatment is required to prevent clogging, although eventual clogging is inevitable.
- May negatively affect soil and groundwater properties.

Health Aspects

- The Soak Pit is not used for raw sewage, and as long as the previous Collection and Storage/Treatment technology is functioning well, health concerns are minimal.
- The technology is located underground and thus, humans and animals should have no contact with the effluent.
- It is important however, that the Soak Pit is located a safe distance from a drinking water source (ideally 30m).
- Since the Soak Pit is odourless and not visible, it should be accepted by even the most sensitive communities.
Maintenance

- A well-sized Soak Pit should last between 3 and 5 years without maintenance.
- To extend the life of a Soak Pit, care should be taken to ensure that the effluent has been clarified and/or filtered well to prevent excessive build up of solids.
- The Soak Pit should be kept away from high-traffic areas so that the soil above and around it is not compacted.

When the performance of the Soak Pit deteriorates, the material inside the soak pit can be excavated and refilled.

To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained.

Particles and biomass will eventually clog the pit and it will need to be cleaned or moved.

Stabilization ponds

- One of the most ancient wastewater treatment methods known to humans are waste stabilization ponds, also known as oxidation ponds or lagoons.
- They’re often found in small rural areas where land is available and cheap.
- Such ponds tend to be only a meter to a meter and a half deep, but vary in size and depth, and may be three or more meters deep.

Consist of shallow man-made basins comprising a single or several series of anaerobic, facultative or maturation ponds.

The primary treatment takes place in the anaerobic pond, which is mainly designed for removing suspended solids, and some of the soluble element of organic matter (BOD).

Secondary stage in the facultative pond: most of the remaining BOD is removed through the coordinated activity of algae and heterotrophic bacteria.

The main function of the tertiary treatment in the maturation pond is the removal of pathogens and nutrients (especially nitrogen).

Three processes of stabilization: anaerobic

The second process is facultative

In the maturation pond, pathogens are reduced: the water an be released to a river

Application and suitability

- Stabilization ponds are particularly well suited for tropical and subtropical countries because the intensity of the sunlight and temperature are key factors for the efficiency of the removal processes.
- It is also recommended by the WHO for the treatment of wastewater for reuse in agriculture and aquaculture, especially because of its effectiveness in removing nematodes (worms) and helminth eggs.