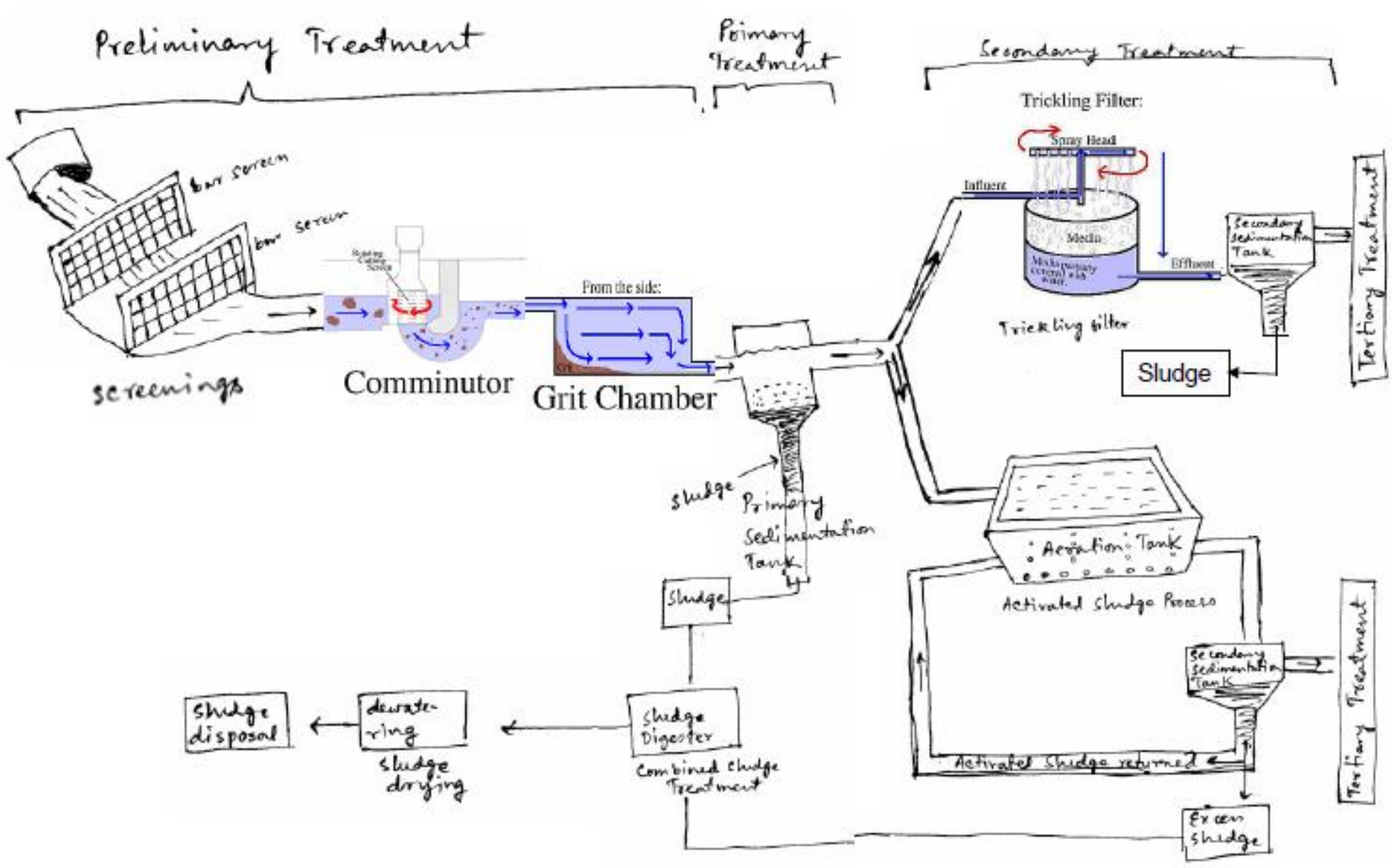
Wastewater Treatment

Sewage treatment is a multi-stage process:

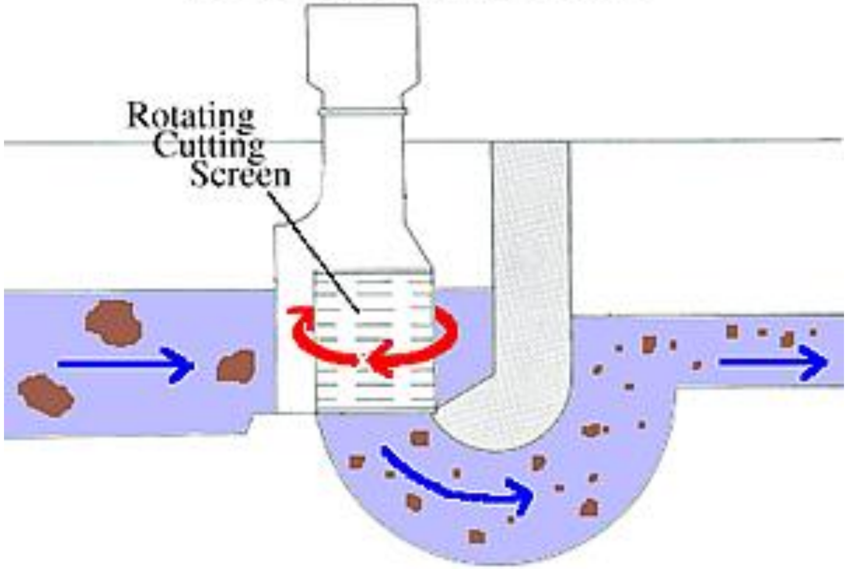
- Preliminary, Primary, Secondary, Tertiary.



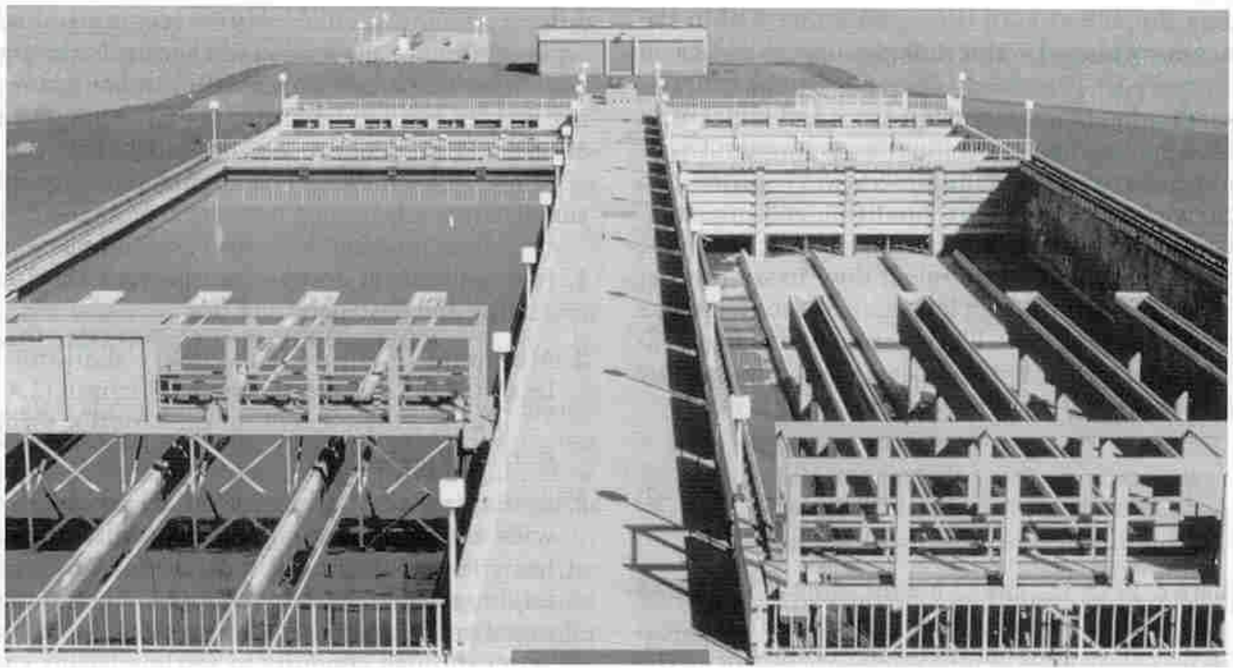
Preliminary Treatment

Bar Screen

Comminutor



Grit removal :



Grit Chamber

- Inert dense material such as sand, broken glass, silt, and pebbles is called grit.

Primary Treatment : Primary sedimentation tank

Primary Sedimentation Tank

Alum ($Al_2(SO_4)_3 \cdot 18H_2O$) forms gelatinous metal hydroxide precipitate at high pH, it eventually settle downs by gravity and it settle downs along with the colloidal particles.

REACTION : $Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4$

Secondary Treatment : Trickling Filter Method

- Some tanks are more than 200 feet in diameter
- sufficient amount of oxygen, blower may be used.
- Ample supply of oxygen
- microbes decompose the biodegradable organic matter

- Microorganisms are used to destroy waste materials.
- Microorganisms include:
  - Bacteria
  - Fungi
  - Algae
  - Actinomycetes (filamentous bacteria).

Air is circulated upward through the spaces among the stones providing sufficient oxygen for the metabolic processes.

- Sludge is produced by this process and these sludges comprise remaining undecomposed solids found in wastewater plus organisms used in the treatment process.
- These sludges reach the secondary basin and collected from the bottom of the secondary basin

Sludge Treatment :

Anaerobic Digestion : Fundamental Microbiology

- Sludges generated at primary and secondary sedimentation tank are pumped to anaerobic digesters.
- "Digestion" :
- Digester : An air-tight container where the substrates are heated and the fermentation process takes place
- Mesophilic: organisms whose growth is optimum within 30 to 45°C.
- Thermophilic: organisms whose growth is optimum within 45 to 60°C
- $C_6H_{12}O_6 \longrightarrow 3CH_4 + 3CO_2 + \ldots\ldots\ldots\ldots\ldots$

Two end products of Anaerobic Digestion

(a) Energy from sludge Treatment (biogas formation)
(b) Sludge cake formation : used as fertilizer

- ## (a) Energy from sludge Treatment

Composition of biogas is
50 to 75 per cent CH_4 and
25 to 45 per cent CO_2 together with minor quantities of nitrogen (< 1%), hydrogen (< 1%), ammonia (< 1%) and hydrogen sulphide (< 1%).
Biogas may be used as the source of alternative energy.

(b) Fertilizer pellets from Sludge Treatment

❖ After the sludge digestion, the sludge is dewatered and hence the *volume is reduced*.

❖ This dried sludge is called a *sludge cake*.

❖ *sludge cakes are turn into fertilizer pellets* and can be used as fertilizer. The product is then sold to the local market.

Advantages of anaerobic digestion:

(a) Less energy is required : 0.5 -0.75kWh energy is needed for every 1 kg of COD removal by anaerobic process.

(b) Energy generation in the form of methane gas : 1.16kWh energy is produced for every 1 kg of COD removal by anaerobic process. *The caloric value of the biogas is about 5.5–6.0 kWh m^{-3}. This corresponds to about 0.5 L of diesel oil.*

(c) Less sludge generation : Anaerobic process produces only 20% of sludge that of aerobic process.

(d) Production of sludge cake :

Tertiary treatment :

Final cleanup of the water effluent from the secondary treatment

1. REMOVAL OF ARSENIC

- Arsenic, a toxic metalloid → not allowed more than 10 μg per liter of water
- Arsenic usually is present in water as As(V).
- Groundwater supplies → if contains the more toxic As(III) then,

Removal Technique

a. Chlorine, ozone, or permanganate oxidants is applied to convert the As(III) to the As(V) followed by

b. coagulation with aluminum sulfate/ iron(III) salts and with lime effectively removes arsenic (V).

2. REMOVAL OF NITROGEN (AMMONIA)

Nitrogen in municipal wastewater → generally present as organic nitrogen or ammonia.

(a) Nitrification followed by denitrification is arguably the most effective technique for the removal of nitrogen from wastewater.

This is the only biological process in the tertiary wastewater treatment.

I) ammonia and organic nitrogen compounds are completely converted into nitrate under strongly aerobic conditions. For reactions see class notes.

II) The second step → reduction of nitrate to nitrogen gas. This reaction is also bacterially catalyzed and requires a carbon source and a reducing agent such as methanol, CH3OH

b) CHLORINATION FOR REMOVING AMMONIA

$$Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$$

$$NH_4^+ + HOCl \rightarrow NH_2Cl \text{ (monochloramine)} + H_2O + H^+$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 \text{ (dichloramine)} + H_2O$$ *(causes 'smell' and 'chlorine odour')*

$$NHCl_2 + HOCl \rightarrow NCl_3 \text{ (trichloramine)} + H_2O$$

$$2\,NH_3 + 3\,HOCl \rightarrow N_2 + 3\,HCl + 3\,H_2O \qquad 2\,NH_3 + 3\,Cl_2 \rightarrow N_2(g) + 6\,H^+ + 6\,Cl^-$$

- ***Trichloramine is unstable, breaks down to N_2***
- ***Chloramines cause the "chlorine" smell***
- The trichloramines are especially irritating to the eyes, nose and lungs.

3. Water disinfection

Secondary sewage effluent often contains a number of disease-causing microorganisms, requiring disinfection.

Common Disinfection Agents

(a) chlorine and chloramines; (b) bleaching powder (c) Chlorine dioxide etc

DISINFECTION WITH Chlorine and chloramines

$$Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$$

HOCl is a weak acid that dissociates

$$HOCl \rightleftarrows H^+ + OCl^-$$

- The two chemical species formed by chlorine in water, (HOCl and OCl-), are known as free available chlorine
- Free available chlorine is very effective in killing bacteriabut not virus.

$$NH_4^+ + HOCl \rightarrow NH_2Cl \text{ (monochloramine)} + H_2O + H^+$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 \text{ (dichloramine)} + H_2O$$

$$NHCl_2 + HOCl \rightarrow NCl_3 \text{ (trichloramine)} + H_2O$$

- The chloramines are called combined available chlorine.
- These are weaker disinfectant than free available chlorine, (40-60% less effective than free available chlorine.

Break Point Chlorination

- If the water to be chlorinated contains significant amounts of ammonia, then addition of sufficient amount of chlorine will form monochloramine to di- or tri-chloramines (ie., all present ammonia is oxidized).
- The ratio of Cl:N (7.6:1 (mg/L:mg/L)) at which all ammonia present in the water has been oxidized to nitrogen gas (which leaves the system) is known as breakpoint
- At breakpoint, oxidation of ammonium ion is essentially complete.
- The overall breakpoint reaction is as follows:

$$2NH_3 + 3HOCl \rightarrow N_2 + 3H_2O + 3H^+ + 3Cl^-$$

$$2\,NH_3 + 3\,Cl_2 \rightarrow N_2(g) + 6\,H^+ + 6\,Cl^-.$$

- Chlorination beyond this point ensures formation of “free available chlorine”. It is known as “breakpoint chlorination”

The excess chlorine may be removed

(i) by filtering the overchlorinated water through activated carbon.

(ii) by addition of a small % of SO_2, Na_2SO_3 or $Na_2S_2O_3$.

$$SO_2 + Cl_2 + 2H_2O \longrightarrow H_2SO_4 + 2HCl$$

$$Na_2SO_3 + Cl_2 + 2H_2O \longrightarrow Na_2SO_4 + 2HCl$$

b) Removal of microorganisms by adding beaching powder:

In small water-works, about 1 Kg of bleaching powder per 1000kiloliters of water is mixed and water is allowed to stand undisturbed for several hours. This produces hypochlorous acid.

$$Ca(OCl)Cl + 2H_2O \longrightarrow Ca(OH)_2 + Cl_2$$

$$Cl_2 + 2H_2O \longrightarrow HOCl + OCl^- \text{ (Hypochlorite ion)}$$

c) <u>Chlorine Dioxide</u>

Chlorine dioxide, ClO_2, is an effective water disinfectant that is of particular interest because, *it does not chlorinate or oxidize ammonia or other nitrogen-containing compounds.*

In neutral water, the two half-reactions for ClO_2 acting as an oxidant are the following:

$$ClO_2 + 4H^+ + 5e^- \longleftrightarrow Cl^- + 2H_2O$$

$$ClO_2 + e^- \longleftrightarrow ClO_2^-$$

Reactions are ONLY for your information, no need to memorize

ClO_2^- is the actual species that kills the pathogens

d) Ozone is sometimes used as a disinfectant in place of chlorine.
ozone is more destructive to viruses than is chlorine.

<u>Disadvantage:</u>
(i) Quite expensive method, hence not employed for disinfection of municipal water supply.

4. Removal of Taste and Odor :

- ✓ Both organic and inorganic substances may produce *taste, odor, and color in water*. So, before we supply the treated water for domestic purpose, we should remove these taste, odor or colour producing substances.

- ✓ Taste, odor, and color agents can come from

  i) microorganisms in the water - end products generated from biological reactions in soil

  ii) mineral substances in water,

  iii) salts from soil, and

  iv) from chemical pollutant sources.

Odor producing substances:

- ❑ The most commonly reported taste and odor compounds, geosmin and methylisoborneol are produced in surface water sources by naturally occurring cyanobacteria (blue-green algae).
- ❑ Geosmin and methylisoborneol typically produce earthy or musty tastes and odors in water

Color producing inorganic substances:

- Yellow tinge indicates the presence of chromium.
- Yellowish red color tinge indicates the presence of iron.
- Red brown color indicates the presence of peaty matter (partially decomposed vegetable matter saturated with water).

Odor producing inorganic substances:

- ✓ *Iron and hydrogen sulfide are two common inorganic compounds known to produce odors in drinking water*.

Taste producing inorganic substances:

Most of the mineral substances affect water taste but do not cause odor.

- Bitter taste is due to the presence of iron, aluminium, manganese, sulphate or excess of lime.
- Soapy taste is due to the presence of large amount of $NaHCO_3$.
- Brakish taste is due to the presence of unusual amount of salts.

Various processes are used to remove agents that cause taste & odor.

i) Simple aeration can remove *volatile materials,* such as odorous hydrogen sulfide.

ii) *For non-volatile metabolic products* by bacteria*, oxidation that destroys organics usually removes taste, odor, and color.* Chlorine, Potassium permanganate, chlorine dioxide can be used.

iii) Ozone Water Treatment : Ozone used by itself or UV has been found to be effective in removing geosmin and MIB.