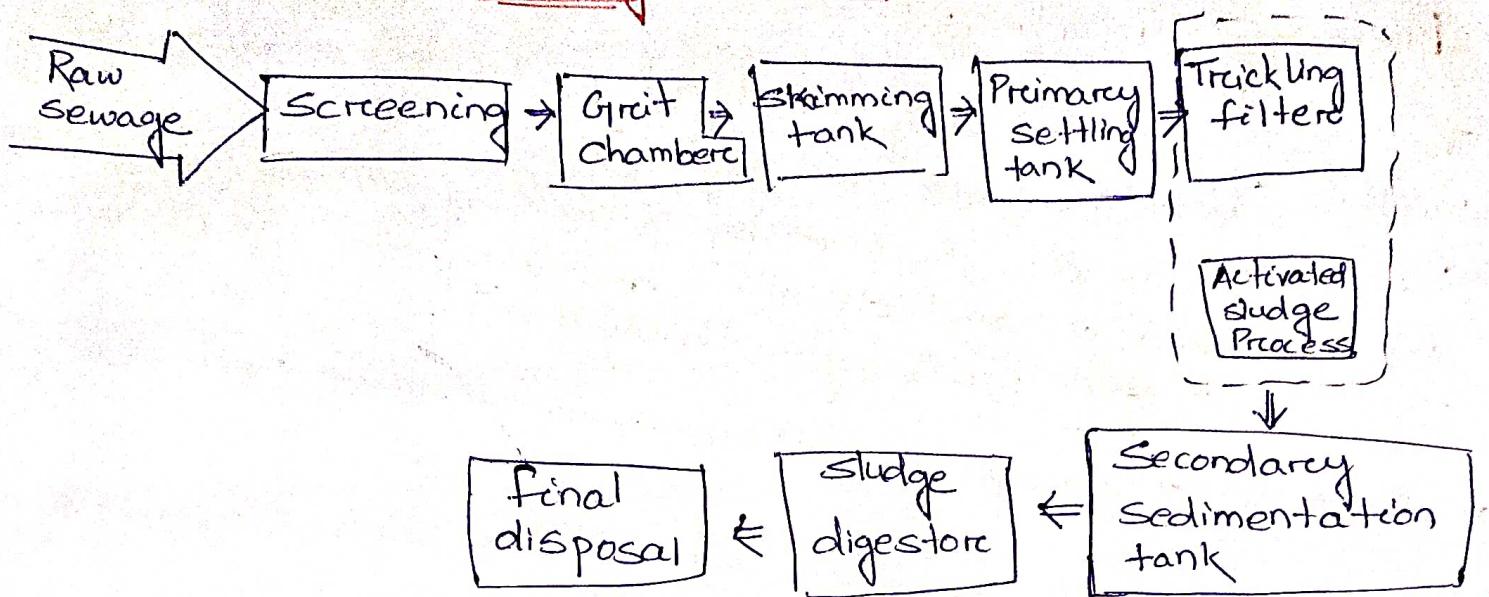


Sewage Treatment



Sewage treatment process can be classified as

- (i) Preliminary treatment
- (ii) Primary Treatment
- (iii) Secondary Treatment
- (iv) Final treatment

Preliminary Treatment :-

It consists solely in separating the floating materials (like ~~fish~~, dead animals, tree branches, papers, woods etc).

Primary Treatment :-

Primary treatment consists in removing large suspended organic solids.

Secondary Treatment :-

Secondary treatment involves further treatment of the effluent, coming from the primary sedimentation tank.

Final Treatment :-

Known as tertiary treatment and consists in removing the organic load left after the secondary treatment.

Primary Treatment :-

The purpose of primary treatment is to remove suspended matter (both inorganic and organic).

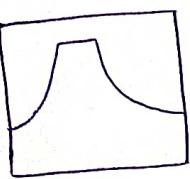
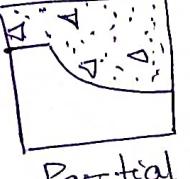
- Larger solids are removed by screening, inorganic solids are removed in grit chamber and organic solids are removed in ~~grit~~ primary settling tank.
- ~~Disposal of inorganic matter is convenient because~~
- Primary treatment removes approximately 60% suspended solids.
- BOD associated with it accounts for approximately 30-40% influent BOD.

Screening :-

Different types of screens are defined by their sizes.

- (i) Micro screen $< 0.5 \text{ } \mu\text{m}$
- (ii) Fine Screen $< 6 \text{ } \mu\text{m}$
- (iii) Coarse Screen $< 6 - 150 \text{ } \mu\text{m}$

Grit chamber

- ⇒ It is provided to remove inorganic matter like sand, gravel, silt, wood etc. and pass all type of organic matter.
 - ⇒ This is in the form of long channel which can be rectangular or parabolic.
 - ⇒ Velocity controlled devices like proportional weirs and partial flume are provided at the end of the channel.
- 
- Proportional weir.
- 
- Partial flume

- ⇒ Velocity in grit chamber should be such that it allows only settling of inorganic particles of size greater than equal to 0.2 mm and drag away the settled organic matter.
- ⇒ Horizontal flow velocity is $0.15 - 0.3 \text{ m/sec}$
- ⇒ Detention time = $40 - 60 \text{ sec}$
- ⇒ Depth = $1 - 1.8 \text{ m}$

Skimming Tank

- Removal of organic matter like oil, grease is done in skimming tank. It is provided before primary settling tank.
- ⇒ If these oil, grease are not removed properly, it affects the biological growth.
 - ⇒ In skimming tank compressed air is thrown from below to the surface of tank.
 - ⇒ Rise in air coagulate the grease, oil and it will rise to the surface from where it can be skimmed off.

Sedimentation :-

⇒ Basically four types of settling occurs depending on tendency of particles to interact and the concentration of solids.

- (i) discrete settling
- (ii) flocculant settling
- (iii) hindered zone settling
- (iv) compressed settling

⇒ Discrete :-

Discrete settling occurs when particles do not change their size, shape, mass, density during settling.

⇒ Grit in waste water behaves like discrete particles. Settling velocity of discrete particle can be determined by Stoke's Law.

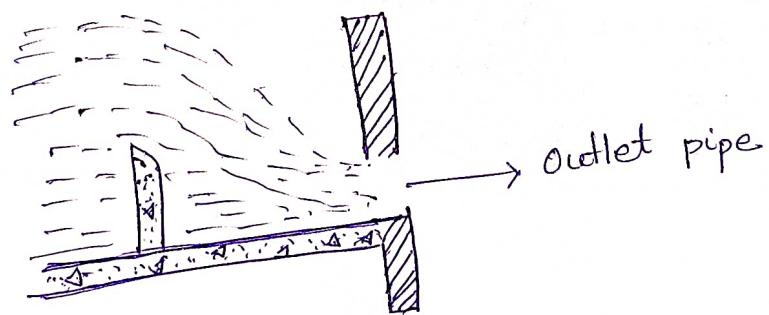
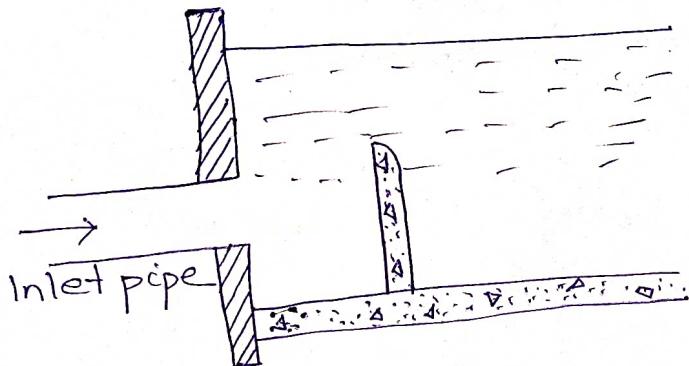
Constructional details of the sedimentation tank

The features of such tanks need special attention. So the most important constructional feature is, inlet and outlet arrangement.

To achieve a uniform flow, proper arrangement must be done for smooth entry of water.

A most suitable type of an inlet for a rectangular settling tank is in the form of a channel extending to full width of the tank, with a submerged weir type baffle wall.

About 0.8 to 1.2m should be provided for storage of settled material and is called sludge zone.



Mercits and demerits of coagulation Process in sewage Treatments

- ⇒ After primary treatment the sewage are given the secondary treatment having biological action. So, sewage treatment do not require coagulation process.
- ⇒ The chemicals used in coagulation react with sewage and during these reaction, they destroy certain micro-organism, which are helpful in digestion of sludge.
- ⇒ But the sewage coming from industries, using some specific chemicals the sewage are treated.
- ⇒ Sedimentation aided with coagulation produces better effluent with lesser BOD and suspended solids as compared to plain sedimentation.

Secondary Treatment :-

- Secondary treatment is generally aerobic. End product is stable, rate of reaction is fast and no foul gases are evolved.
- Units based on aerobic reaction like trickling filter, RBC, oxidation pond, ASP.
- Aerobic treatment is done by two different methods,
 - attached growth system :- Trickling filter, RBC
 - suspended growth system :- ASP
- In attached growth system, biomass is attached to a medium surface and sewage containing organic matter is passed through this medium.
- The suspended growth system biomass is in suspension in the liquid containing organic matter.

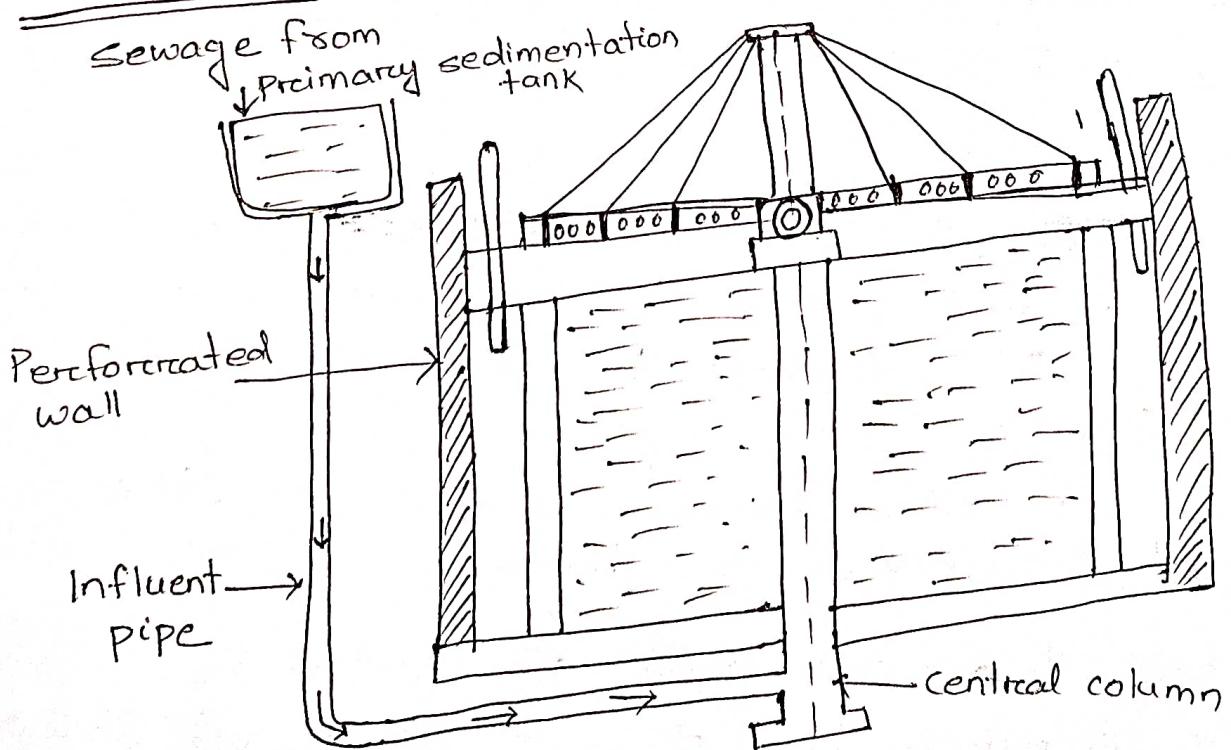
Trickling Filter :-

- As the waste pass through the filter media, biomass grows attached to the media surface. This process takes time of 2 weeks and trickling filter is steady for operation!
- During operation, the organic matter present in the waste water is metabolised by the biomass attached to the system. The attached biomass is called biological film or slime layer.
- The thickness of slime layer is 0.1 to 2 mm. It consists of both aerobic and anaerobic layers.
- The thickness of aerobic layer is limited by
 - i) depth of penetration of O_2 in the microbial layer
 - ii) availability of oxygen

a) overall oxygen utilisation rate which depends on type of microorganisms.

- ⇒ As the film thickness increases, food and oxygen can not penetrate deep inside and hence endogenous respiration starts at medium film interface.
- ⇒ Thus the bend breaks up from this biofilm is known as sloughing.
- ⇒ These slough mass are removed in secondary settling tank, where it settles.
- ⇒ The rate of removal in attached growth system depends on
 - a) flow rate
 - b) organic loading rate
 - c) Temperature
 - d) rate of diffusibility of food and oxygen in biofilm.

Construction and Operation of trickling filter :-



Types of trickling filters

Trickling filters can be broadly classified into

- Conventional trickling filters or standard rate trickling filters
- 2) High rate trickling filters.

Standard rate filters :-

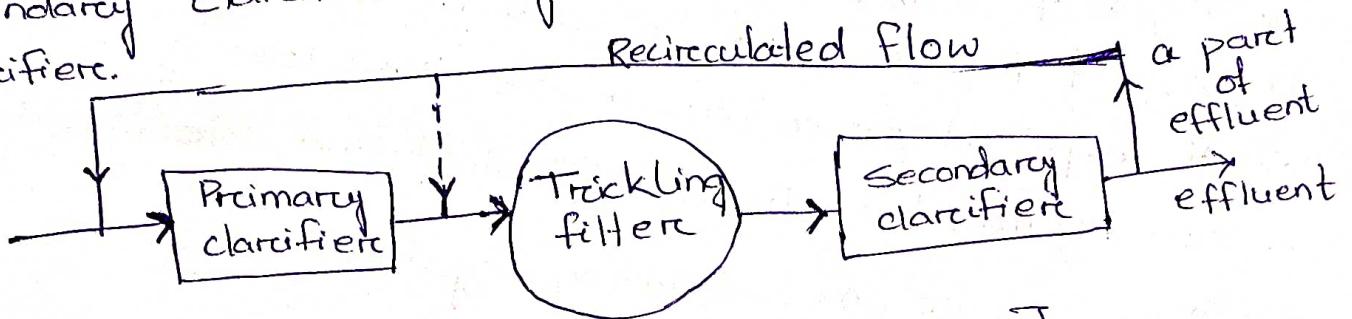
- Depth of filter media varies between 1.6 m to 2.4 m.
- Size of filter media is 25 to 75 mm
- It requires more area as the loading rate is less.
- The effluent is highly nitrified and stabilised.
- There is no recirculation system.

High Rate trickling filter :-

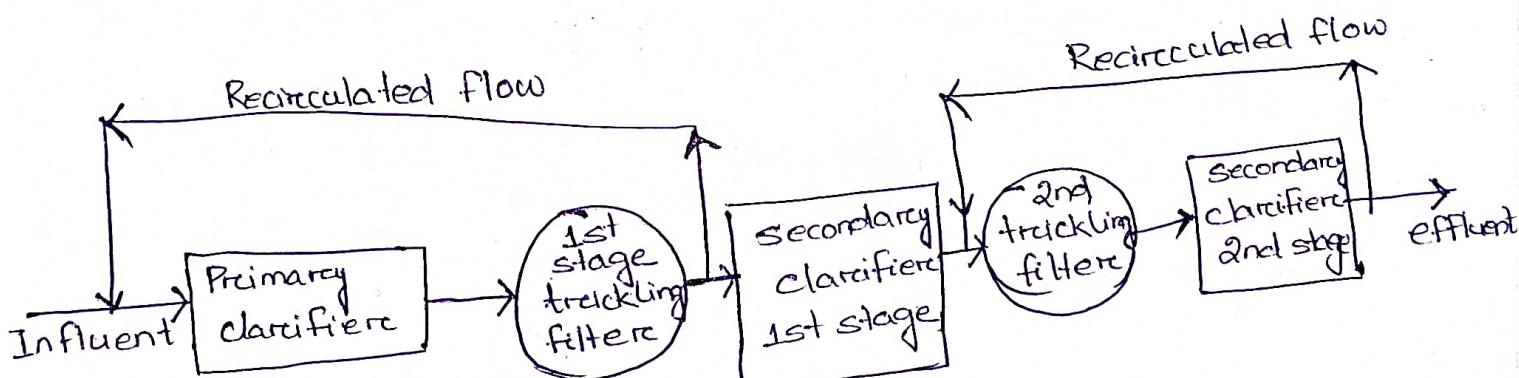
- Depth of filter media varies between 1.2 to 1.8 m
- Less land area is required as the loading rate is more.
- The effluents are nitrified but less stable.
- Recirculation is done for increasing hydraulic loading rate.

Recirculation in high rate trickling filter

- The recirculation consists in returning a portion of the treated or partly treated sewage to the treatment process.
- Usually the return is from the secondary settling tank to the primary settling tank. Sometimes, the effluent from the filter itself, before it enters the secondary clarifier may be sent back to the primary clarifier.



Single stage commonly adopted
Recirculation Process



Two stage commonly adopted
Recirculation Process

Operational Troubles of trickling filter

Trickling filters pose a number of operational troubles such as,

a) Fly Nuisance :-

Insects are generated on the trickling filter surface because of which flies comes to the trickling filter. To avoid it, insecticides like DDT, Chlorodane etc can be applied on trickling filter.

b) Odour Nuisance :-

Odours generally do not prevail in trickling filters using rotary distributors. But however, when fixed nozzles are used H_2S and other gases are frequently released.

→ The remedy is to chlorinate the sewage and also to keep sewage fresh by recirculation.

c) Ponding Trouble :-

Sometimes, the voids in the filter media gets clogged due to heavy growth of fungi and algae.

→ Ponding is the main cause happen in winter season.

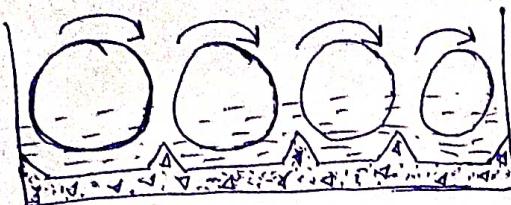
Efficiency of trickling filter

$$\eta (\%) = \frac{100}{1 + 0.00441u}$$

u = Organic loading in kg/ha-m applied to the filter

Secondary treatment through Rotating Biological Contractors

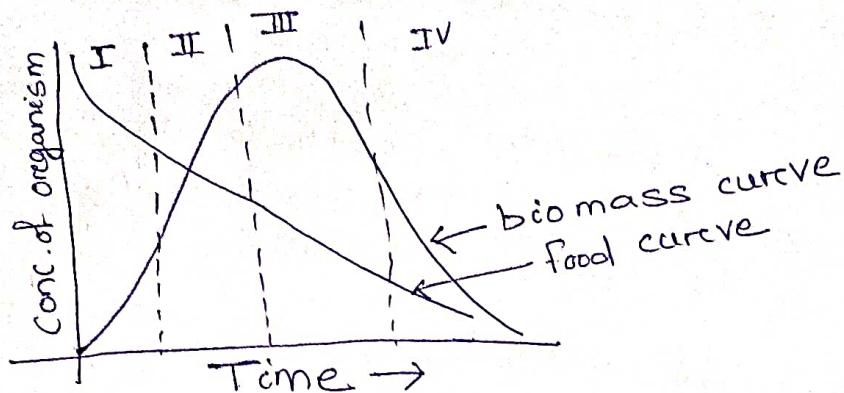
RBC



- It is an attached growth system.
- RBC is a cylindrical media made of closely mounted thin flat circular plastic sheets or discs of 3 to 5 m in diameter, 10 mm thick, and placed 40 mm spacing mounted on a common shaft.
- These are immersed in wastewater by about 40% of their diameter.
- The surface area of disc is alternatively immersed and exposed to atmosphere above the liquid.
- The bio-film attached to the surface gets the chance to interact with dissolved oxygen from the atmosphere when exposed to atmosphere.
- When growth of micro organism becomes excessive the bio-film slough.
- The slough mass is kept in suspension due to turbulence created by disc. The slough mass remains in suspension for some time and then taken to the SST.
- This method provides a high degree of treatment.

Activated sludge process (ASP)

→ The ASP provides an excellent method of treating either raw sewage or more generally the settled sewage.



I :- Lag phase

II :- Log-growth phase

III :- Stationary phase

IV :- Endogenous phase

→ In lag phase, micro-organism first become settled to the environment and to the food given.

→ During this phase, bacterial growth is not much.

→ In log-growth phase, cell reproduced by cell division and the rate of growth is very high.

→ In stationary phase, rate of growth of bio mass is roughly offset by the killing of micro organisms due to endogenous respiration as the food starts becoming limited.

→ The endogenous phase is the last phase in which biomass decreases due to endogenous respiration because food become scarce.

$$\frac{dx}{dt} = -k_d x$$

$x \Rightarrow$ bio mass conc.

$k_d \Rightarrow$ Max. rate of growth

$$= \left[\frac{k_o S}{k_o + S} - k_d \right] x \quad S \Rightarrow \text{conc. of limited food}$$

$k_d \Rightarrow$ endogenous decay.

Activated Sludge

- ⇒ The settled sludge in SST is composed of mostly living bacteria which is also called active bacteria. This active bacteria or living bacteria is recycled into the system. Hence this process is called activated sludge process.
- ⇒ The new activated sludge is continuously being produced by this process and a portion of it being utilised and sent back to the aeration tank.
- ⇒ ASP is a suspended culture process in which sludge returning is two type.
 - (i) Completely mix
 - (ii) Plug flow
- ⇒ Completely mix process is adopted for less than 25 MLD.
- ⇒ In this process, incoming sludge is completely mixed with whole tank volume. F/m ratio is const.
- ⇒ Plug flow is a conventional process and this process has been adopted for a large plant upto 300 mLD.
- ⇒ In this case the sewage and biomass let in at the head and withdrawn at other side.
- ⇒ At inlet F/m ratio is high and then progressively decreases.

Design parameters in ASP

The important terms which define the loading rates of an activated sludge plant include,

(a) Aeration Period

(b) BOD loading per unit volume of aeration tank

(c) food to Micro-organism Ratio (F/M)

(d) Sludge age.

(a) Aeration Period :- The aeration period empirically decides the loading rate at which the sewage is applied to the aeration tank.

$$\text{Detention time} = \frac{\text{Vol of the tank}}{\text{Rate of sewage flow in the tank}}$$

$$t = \frac{V \text{ in m}^3}{Q \text{ in m}^3/\text{day}}$$

(b) Volumetric loading rate :-

→ Mass of BOD applied per day to the aeration

$$= \frac{\text{tank through influent sewage in gm}}{\text{Vol. of aeration tanks in m}^3}$$

$$= \frac{Q \cdot Y_0}{V} \quad Y_0 = \text{BOD}_5 \text{ in mg/l}$$

(c) Food to Micro organism (F/M) ratio :-

$$F/M = \frac{\text{Daily BOD load applied to the aeration system in gm}}{\text{Total microbial mass in the system in gm}}$$

$$= \frac{Q \cdot Y_0}{V \cdot X_T}$$

$$X_T = \text{MLSS in mg/l}$$
$$V = \text{Vol. of tank}$$

MLSS = mixed liquor suspended Solids (MLSS)

d) Sludge age :-
 Defined as the average time for which particles of suspended solids remain under aeration.

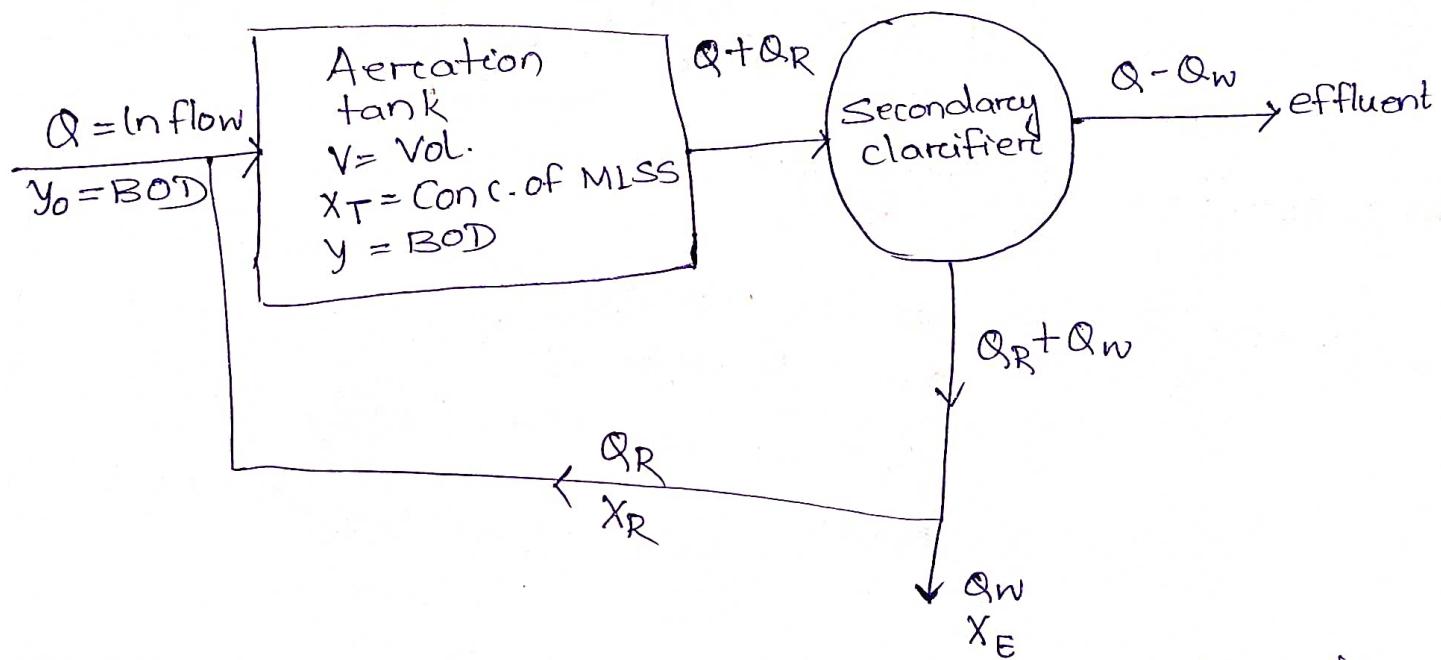
→ Measured in days.

$$\Rightarrow \text{sludge age} = \theta_c = \frac{\text{MLSS in the system (M)}}{\text{mass of solid leaving the system per day}} \\ = \frac{V \cdot X_T}{Q_w X_R + (Q - Q_w) X_E}$$

X_R = Conc. of return sludge

X_E = Conc. of solids in the effluent in mg/day

Q_w = Vol of wasted sludge.



When the value X_E is very small then $(Q - Q_w) X_E$ is neglected.

$$\boxed{\text{sludge age} = \theta_c = \frac{V X_T}{Q_w X_R}}$$

Design of Aeration Tank :-

- ⇒ In completely mix process is designed as square or circular tank whereas in plug flow long narrow channel is used.
- ⇒ Depth of tank controls aeration efficiency. Depth in plug flow system is 3-4.5 m.
- ⇒ Width control the mixing efficiency. Width adopted generally is 5-10 m.

Q) An average operating data for conventional activated sludge treatment plant is as follows,

- i) Waste water flow = $35000 \text{ m}^3/\text{d}$
- ii) Vol. of aeration tank = 10900 m^3
- iii) Influent BOD = 250 mg/l
- iv) Effluent BOD = 20 mg/l
- v) MLSS = 2500 mg/l
- vi) Effluent suspended solid = 30 mg/l
- vii) Waste sludge suspended solid = 9700 mg/l
- viii) Quantity of waste sludge = $220 \text{ m}^3/\text{d}$

Based on above information, Determine

- a) Aeration period (hrs)
- b) f/M ratio
- c) % efficiency of BOD removal
- d) sludge age (days)

Given, $Q = 35000 \text{ m}^3/\text{d}$
 $y_0 = 250 \text{ mg/l}$
 $X_T = 2500 \text{ mg/l}$
 $X_R = 9700 \text{ mg/l}$
 $V = 10900 \text{ m}^3$
 $y_E = 20 \text{ mg/l}$
 $X_E = 30 \text{ mg/l}$
 $Q_w = 220 \text{ m}^3/\text{d}$

a) Aeration period = $t = \frac{V}{Q}$

$$= \frac{10,900}{35,000} \times 24$$

$$= 7.47 \text{ h}$$

b) F/M ratio = $\frac{Q \cdot Y_0}{V \cdot X_T} = \frac{35,000 \times 250 \times 1000}{1000 \times 10900 \times 2500}$

$$= 0.32 \text{ kg BOD per day / kg of MLSS}$$

c) Percentage efficiency of BOD removal,

$$= \frac{\text{Incoming BOD} - \text{Outgoing BOD}}{\text{Incoming BOD}} \times 100$$

$$= \frac{250 - 20}{250} \times 100$$

$$= \frac{230}{250} \times 100$$

$$= 92\%$$

d) Sludge age = $\frac{V \cdot X_T}{Q_w \cdot X_R + (Q - Q_w) \cdot X_E}$

$$= \frac{27250}{(220 \times 9700) + (35000 - 220) \times 30}$$

$$= 8.58 \text{ days.}$$

Sludge digestion process :-

- The sludge withdrawn from the sedimentation basin contains a lot of organic matter, and if disposed without any treatment, the organic matter may decompose, producing foul gases.
- In order to avoid such pollutions, the sludge is first stabilized by decomposing the organic matter under controlled condition.
- The process of stabilisation is called sludge digestion and the tank where, the process is carried out is called the sludge digestion tank.
- In three distinct phase the sludge digestion is done. These stages are,
- a) Acid fermentation
 - b) Acid regression
 - c) Alkaline fermentation.

Acid Fermentation

- In this first stage of sludge digestion, sludge is converted to volatile acid and organic alcohol by anaerobic and facultative bacteria. Also gases like methane, carbon dioxide are evolved.
- The product of sludge after fermentation is very acidic thus its pH is less than 6.

Acid Regression

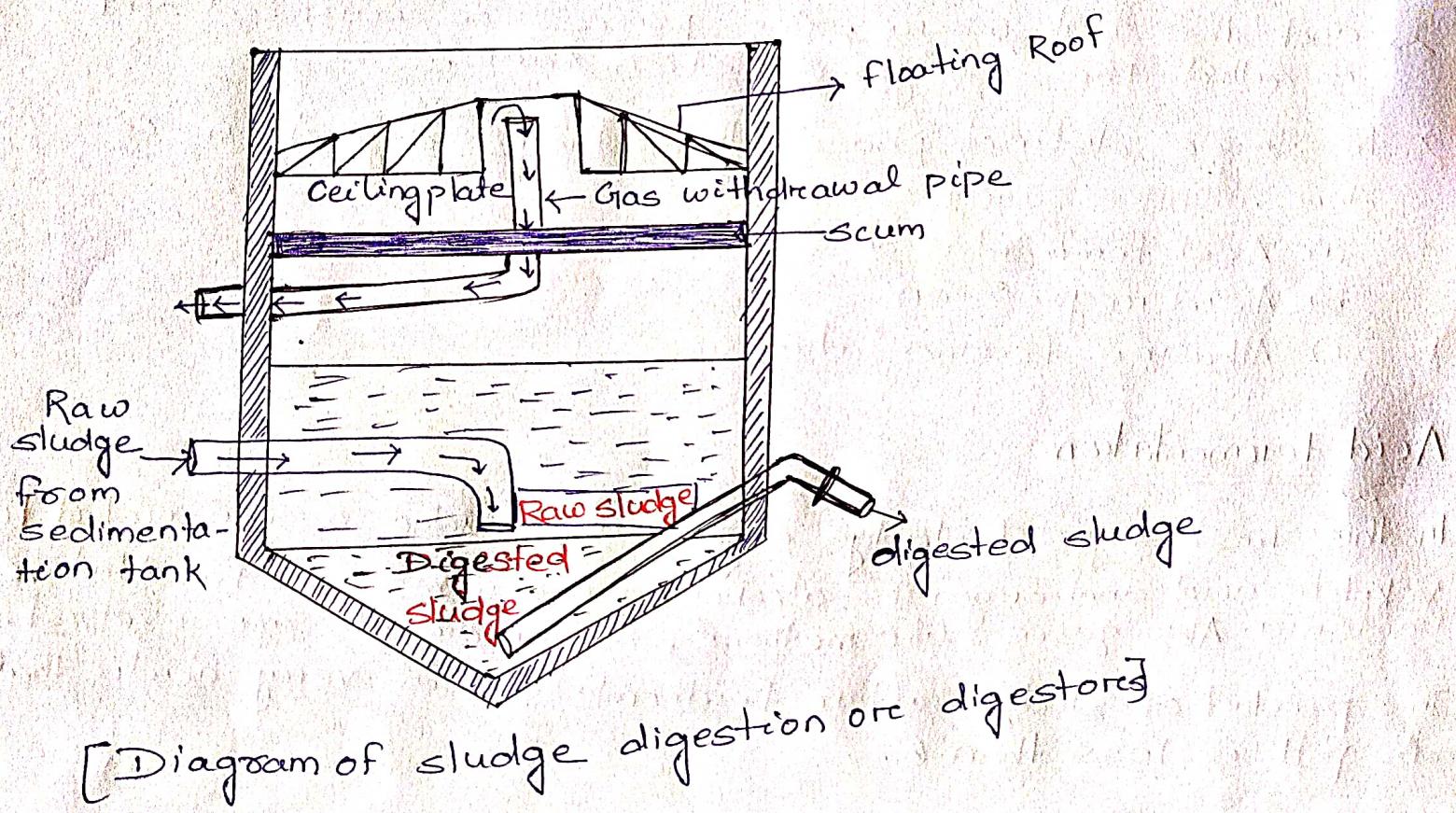
- In this intermediate stage, the volatile organic acids are attacked by the bacteria and form acid carbonate and ammonia compound.
- In this stage pH of sludge rises a little i.e. 6.8.

Alkaline Fermentation Stage

- In the final stage, proteins and organic acids are attacked and broken up by anaerobic bacteria called methane former.
- In this stage high amount of methane gas is evolved and the sludge become alkaline.

Factors affecting sludge digestion

- 1) Temperature
- 2) pH Value
- 3) Seeding with digested sludge
- 4) Mixing and stirring of the raw sludge with digested sludge.



Anaerobic Process / Anaerobic Stabilisation Units

Anaerobic stabilisation units are :-

- a) Anaerobic and facultative stabilisation ponds
- b) Septic Tank
- c) Imhoff Tank
- d) High Rate Anaerobic system

Anaerobic and facultative stabilisation ponds :-

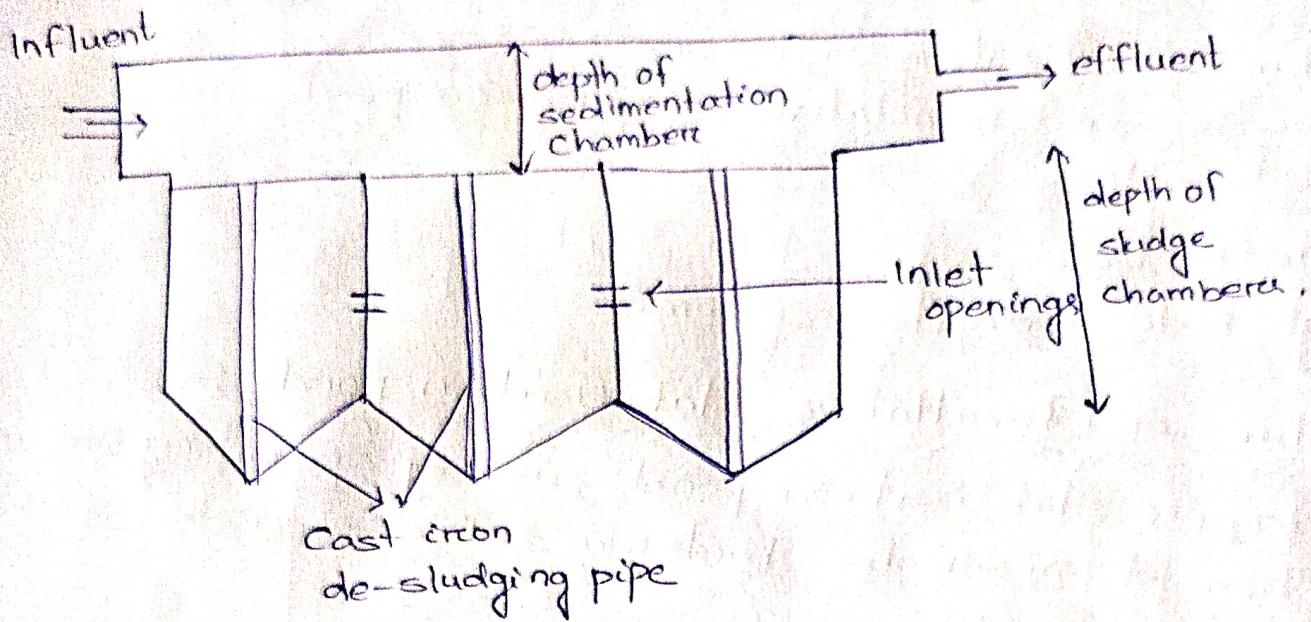
- ⇒ The deeper stabilisation ponds, usually operating under the action of anaerobic bacteria called anaerobic stabilisation pond.
- ⇒ This treatment involve two distinct stages.
 - i) acid fermentation
 - ii) Methane fermentation.

Septic Tank

- ⇒ A septic tank is defined as a primary sedimentation tank, with a longer period.
- ⇒ Since the digestion of the settled sludge is carried out by anaerobic process.
- ⇒ It is a completely closed tank having heavy foul gases, disposed the effluent in either fore sub surface irrigation or in any soak pits.

Imhoff Tank

- ⇒ An imhoff tank is improvement over septic tank, in which the incoming sewage is not allowed to mixed up with the sludge produced.



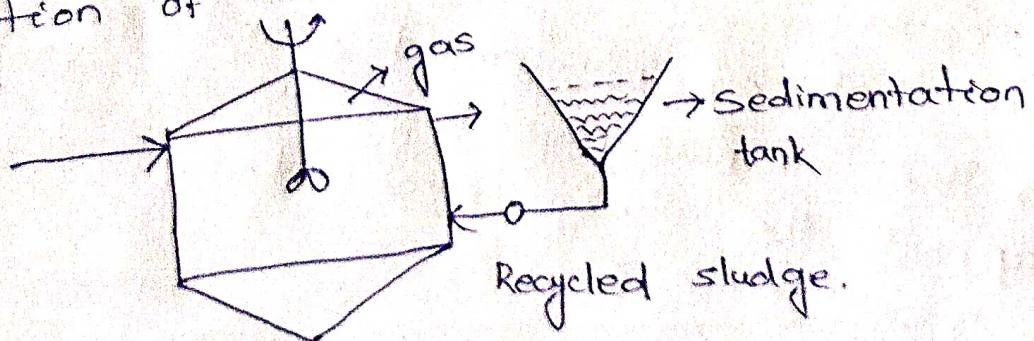
High Rate Anaerobic System :-

High rate anaerobic system has been devised and constructed to treat concentrated industrial waste waters and for direct treatment of municipal waste waters.

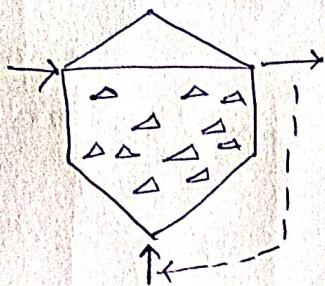
- ⇒ The various high rate anaerobic systems :-
- a) Anaerobic contact (AC) process
- b) Anaerobic filters (AF)
- c) Anaerobic fixed films (AFF) reactors
- d) fluidized bed (FB) reactor
- e) Upflow Anaerobic Sludge Blanket (UASB) reactors.

⇒ Anaerobic contact process involves the close mixing process, in which the biomass leaving with the reactor effluent, is settled in the sedimentation tank and is recycled to the stirred tank.

⇒ On the other hand inadequate mixing may lead to the formation of dead zones inside the reactor.



Anaerobic filter :-



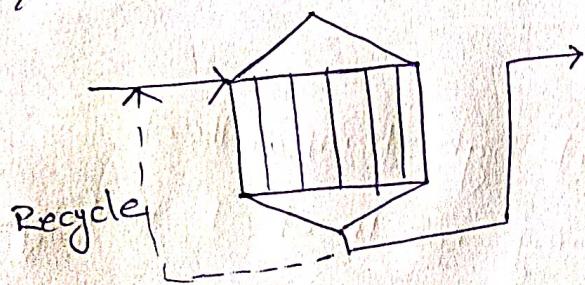
A stationary filter media through which the sludge is recycled.

→ By this method upto 65 to 75 % BOD is removed.

Anaerobic fixed film

Hence the sludge flow in downward manner and no entrapment.

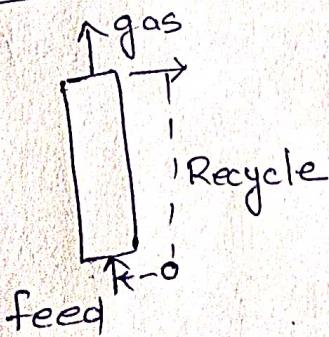
→ Such film is created to treat high strength waste.



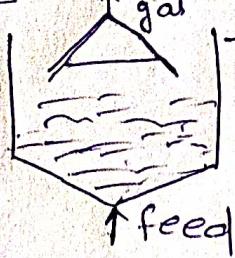
Fluidized and expanded bed reactors

→ In this process the tank is partially filled by mobile packing material, such as clay, sand, coal etc.

→ The organics attached to these materials.



USAB Reactor :-

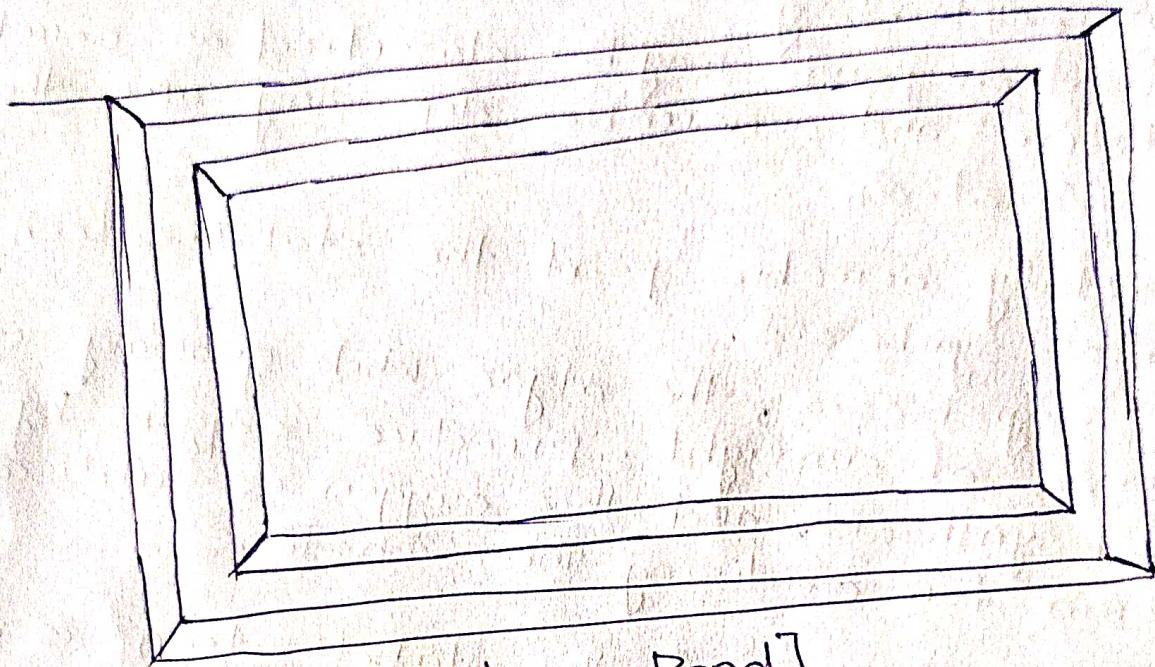
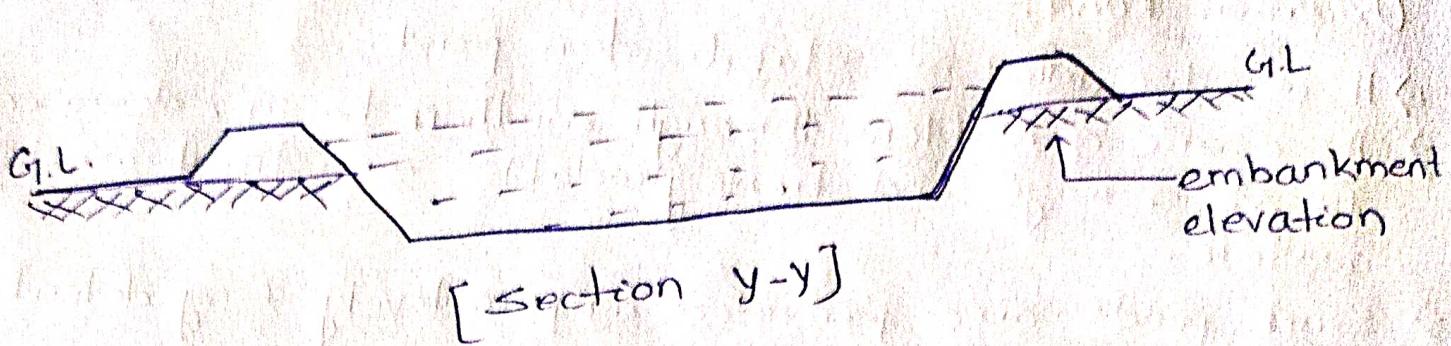


→ The waste water flows upwards through a layer of very high activate sludge.

→ At the top solid, liquid and gases are separated.

Oxidation Pond:-

- It is also called as stabilisation pond.
- These are open flow through earthen basin, designed to treat sewage and biodegradable industrial waste water.
- Such ponds are provided comparatively long detention periods.
- Stabilisation ponds may be classified as aerobic, facultative and anaerobic depending upon the mechanism of purification.
- In a totally aerobic pond the stabilisation is done by algal-symbiosis.
- In this symbiosis, the algae while growing in the presence of sunlight, produce oxygen by the action of photosynthesis, and this oxygen is utilised by the bacteria for oxidising the waste.
- In an anaerobic pond, the stabilisation is done by the usual anaerobic conversion of organic waste to carbon dioxide, methane and gaseous end products.
- In a facultative pond, the upper layers work under aerobic conditions, while the anaerobic conditions, which the ~~anaerobic~~ prevail in the bottom layers.
- The term oxidation pond was originally reffered that stabilisation pond which received partially treated sewage.
- Whereas the pond received raw sewage was used to called a sewage lagoon.



- ⇒ The detention ~~pond~~ time in the oxidation pond is usually 2 to 6 weeks, depending upon the sunlight and temperature.
- ⇒ For better efficiency several ponds are placed in series.

Disposal of solid waste and effluent :-

In general, the following scientifically managed methods can be used for disposal of solid waste are,

a) Land-filling :-

The refuse are dumped and compacted in layers upto 0.5m thickness.

b) Pulverisation :-

The size and volume of the waste can be reduced by pulverisation method. Pulverisation refers to the grinding and crushing of sludge.

c) Composting :-

It is a biological method in which sludge are decomposed by bacteria under aerobic condition.

d) Incineration :-

Burning of refuse at high temp called incinerators, is quite a sanitary method of refuse disposal, and is widely adopted.