4. Complete final treatment.

Types of Treatment units employed in sewage treatment, and their functions

S.No.	Type of Treatment	Purification effected	Process or unit employed	BOD remova l as% of original	Removal bacteria as% of original	Disposal of residuals
1.	Preliminary Treatment	(a) Removal of floating materials like dead animals, tree branches etc.	Coarse and fine screens of different designs.	5 – 10	10 – 20	Screeings can be disposed off, easily, either by burials or burnings
		(b) Removal of heavy settleable inorganic solids	Grit chamber or detritus tanks	10 –20	10–20	The grit can be easily disposed off either by burials or burning
		(c) Removal of fats and greases Removals of suspended settleable organic solids.	Skimming tank or Vacuators	20–30	10–20	Skimmings wasunstable volatile materials, and to disposed off by stabilising them in tanks by anaerobic decomposition
2.	Primary Treatment	Removal of fine suspended non settleable solids and colloidals, including dissolved organic matter.	(i) Sedimentation tank	30–35	25–75	Sludge containing organic materials has to be stabilised
			(ii) Septic tank	20–30	25–75	Stabilised first, in digestion tank and the digested material is then used as a manure or soil builder.
			(iii) Imhoff tanks	30–40	25–75	The effluents are disposd off for sewage farming on lands. These unitssludge digestional along with sedimentation tanks.
3.	Secondary or biological Treatment	Removal of pathogens and the remaining very fine dissolved organic matter.	(i) Chemical flocculations and sedimentation or	50–85	40–80	Sludge containing organic material has to be stabilised in digestion tanks and the residue is used as manure or soil builder.
			(ii) Intermittent sand filters, followed and preceeded by sedimenatation or	90–95	95–98	same as above.
			(iii) Conventional low rate tricking filters follwed and preceeded by sedimention	90–95	90–95	same as above.
			(iv) Modern high rate trickling fitter followed and preceded by sedimentation. or	65–95	80-95	same as above.
			(v) Activated sludge treatment in aeration tank and secondary settling tank or	75–95	90–98	Effluents are generally disposed off by using, them for irrigation.
			(vi) Oxidation ponds	85–90	90–98	
4.	Final or Tertiary Treatment		Chlorinotion	100%		

SCREENING

- It consists of passing the sewage through different types of screens, so as to trap and reverse the floating matter, such as piece of cloth, paper, wood, coin, hair present in the screen.
- While designing the screens, clear openings should have sufficient total area, so that the velocity through them is not more than 0.8 to 1m/s

  Head loss through the screen = $0.0729\,(V^2 - v^2)$

  where, V = velocity through screen = 0.8 to 1m/s.

  v = velocity above screen = 0.8 or 5/6 m/s
- The spacing of bars, in screens is generally more than 50 mm or so.
- Comminuters or shredders are the patented device, which break the large sewage solids to about 6 mm in size, when the sewage is screened through them.

Grit chamber:

- Grit chambers are in fact nothing but like sedimentation tanks to remove the inorganic particles such as sand, gravel, grit etc. of size 2mm or large to prevent their accumulation in sludge digestors.
- In grit chambers, the flow velocity should neither be too low so as to cause the setting of lighter organic matter, nor should be too high so as to cause the setting of entire silt in the sewage.
- The grit chamber may be placed either before or after the screens. Many engineers, howevers, prefer to place them before the screens, as to avoid silting of the screen chamber.
- Critical scour velocity, $V_H = 3$ to $4.5\sqrt{gd(G-1)}$ for grit chamber.
- In practice, a flow velocity of about 0.25 to 0.3 m/s is adopted for design of grit basins.
- A detention time of about 40 to 60 seconds is generally sufficient for a water depth of about 1 to 1.8 m.

$$\text{Detention time, (D.T)} = \frac{\text{Depth of the tank}}{\text{Settling velocity}}$$

$$V_s = d(3T + 70)$$

Also
$$\text{D.T.} = \frac{\text{Length of the tank}}{\text{Horizontal velocity}}$$

- At the bottom, a dead space depth of 0.45 m for collection of detritus is provided.
- Free board provided is 0.3 m to 0.5 m.
- The grit chambers of, sewage treatment plant is normally cleaned periodically at about 3 week interwale.

Detritus Tanks:

Detritus tanks are nothing but grit chambers designed to flow with a smaller flow velocity (of about 0.09 m/sec) and longer detention periods (about 3 to 4 min).

Skimming Tanks:

- The tanks for removing oils and grease is called **skimming tanks**.
- A detention periods of about 3 to 5 minutes is usually sufficient, and the amount of compressed air required is about 300 to 6000 m^3 per millions litres of sewage.

Surface area required for the tank, $A = 0.00622\,\dfrac{q}{V_r}$

where, q = rate of flow of sewage in m^3/day.

V_r = minimum rising velocity of grease material to be removed in m/minutes.

= 0.25 m/minutes. (mostly)

Primary sedimentation Tank.

- The sedimentation tanks are designed to remove a part of the organic matter from the sewage effluent coming out from the grit chambers.
- In a complete sewage treatment, the sedimentation is, infact carried out twice, once before the biological treatment [*i.e.* primary sedimentation] and once after the biological treatment (i.e. secondary sedimentation).

Settling velocity,

$$V_s = \frac{1}{18}\frac{gd(G_S - 1)}{v} \text{ for } d < 0.1 \text{ mm.}$$

$$V_s = 418(G_s - 1)d^2\left(\frac{3T+70}{100}\right),$$

for $d > 0.1$ mm.

$$V_s = 1.8\sqrt{gd(G_S - 1)}, \text{ for } d > \text{Imm}$$

$$V_s = 418(G_s - 1)d\left(\frac{3T+70}{100}\right)$$

for d between 0.1 to 1mm.

where, d = diameter of particle (in mm)

T = temperature (in °C)

G_s = specific gravity of particle

V_s = settling velocity (in cm/sec)

Hazen equation for transition zone

$$V_s = 60.6\,d(G_s - 1)\left(\frac{3T+70}{100}\right) \text{ for between 0.1 to 1mm.}$$

For inorganic solids $V_s = d(3T + 70)$

For organic solid $V_s = 0.12d\,(3T + 70)$

Flow velocity, $V = \dfrac{Q}{BH}$

From geometric consideration $\dfrac{V}{V_s} = \dfrac{L}{H}$

But, $V = \dfrac{Q}{BL}$, hence $V_s = \dfrac{Q}{BL}$

It shows that all those particles with a settling velocity equal to or greater than Q/BL will settle down and be removed.

Settling velocity tanks is also known of **overflow** rate or **surface loading** or **overflow velocity**.

- $\dfrac{Q}{BL}$, the discharge per unit plan area is an important term for the design of flow type of settling tanks and is
- Normal value of overflow rates ranges between 40 to 50 cum/m^2/ day 1650 to 2100 l/h m^2 for plain primary sedimentation tanks; between 50 to 60 / m^2/day for sedimentation tanks using coagulants. a said; and between about 25 to 35 cm/m^2/day for secondary sedimentation tanks.

- Smaller particles will also settle down, if the overflow rate is reduced.
- Usual value of effective depth (*i.e.* depth excluding the bottom sludge zones) range between 2.4 to 3.6 m.
- Detention time for a rectangular tank = $\frac{\text{BLH}}{\text{Q}}$
- Detention time for circular tank

$$= \frac{(0.011/d + 0.785)d^2}{\text{Q}}$$

- Width of tank is usually kept about 6 m, and not allowed to exceed 7.5 m or so.
- Length of the tank is generally not allowed to exceed 4 to 5 times the width.
- The flow Velocity is generally taken as 0.3 m/minute.
- Displacement efficiency = $\frac{\text{flowing through period}}{\text{detention period}}$
- For tanks without mechanical sludge removal equipment, an additional minimum depth of about 0.8 to 1.2 m should be provided for storage of settled materials, and is called *sludge zone*.

SECONDARY TREATMENT THROUGH BIOLOGICAL FILTRATION OF SEWAGE

- The character of sewage may be changed by different methods such as

(*i*) Filtration; and

(*ii*) Activated sludge process.

These processes helps in changing the unstable organic matter into stable forms.

- All the secondary treatment process (*i.e.* filtration as well as activated sludge process) are designed to work on aerobic bacterial decompositions.
- Types of filters that may be used in sewage treatment:
  (*i*) Contact beds [obsolete these days]
  (*ii*) Intermittent sand filters [used at smaller plants]
  (*iii*) Trickling filters [most commonly used in modern days]
  (*iv*) Miscellaneous type of filters [used under special circumstances]

(*i*) Contact beds:

A contact bed is a water tight rectangular tank, filled with a filtering media, consisting of gravel, ballast, or broken bricks or stones. The size of the media particles may vary between 20 to 40 mm. The depth of the filtering media varies between 1 to 1.8 m.

(*ii*) Intermittent sand filters for Biological filteration of sewage:

Intermittent sand filters are more or less like contact beds, with the difference that the contact media here is finer than that in the contact beds; and also, these is no concrete lining around the filter media, as was there in the contact beds.

(*iii*) Trickling Filters for Biological Filteration of Sewage

The conventional trickling filters and their improved forms, known as *high rate trickling filters* are now almost universally adopted for giving secondary treatment to sewage. These filters, also called as *percolating filters* or *sprinkling filters*, consists of tanks of coarser filtering media, over which the sewage is allowed to sprinkle or trickle down, by means of spray nozzles or rotary distributors.

The sewage influent entering the filter must be given pre-treatment including screening and primary sedimentation.

Types of Trickling Filters:

1. Conventional trickling filter or Ordinary trickling filters or Standard rate or Low rate trickling filters.
2. High rate filters or High rate trickling filters.

- The high rate filters of modern advancements, also function on the same lines, and are having the same constructional details Standards rate trickling filters, but with the difference that provision is made in them for recirculation of sewage through the filter.

Design of Trickling Filters:

- The design of the trickling filter primarily involves the design of the diameter of the circular filter tank and its depth. The design of the rotary distributors and under-drainage system is also involved in the filter design. The design of the filter size is based upon the values of the filter loadings. This loading on a filter can be expressed in two ways:
  (*i*) *By the quantity of sewage applied per unit of surface area of the filter per day.*

  This is called hydraulic loading rate and expressed in ML/ha./day. The value of hydraulic loading for conventional filters may vary between 22 to 44 (normally 28) ML/ha./day (as against of 1.1 ML/ha./day for intermittent sand filters). The hydraulic loading can still be increased to about 110 to 330 (normally 220) ML/ha./day in the high rate trickling filters.

  (*ii*) *By the means of BOD per unit volume of the filtering media per day.*

This is called **organic loading rate**, and expressed in kg of BOD per hectare meter of the filter media per day. The value of organic loading for conventional filters may vary between 900 to 2200 kg. of BOD per ha-m. This organic loading value can be further increased to about 6000–1800 kg. of BOD per ha-m in high rate trickling filters.

Hence,

$$\text{Volume of the filter} = \frac{\text{Total BOD of the sewage entering the sewage}}{\text{Organic loading rate}}$$

$$\text{Area of the filter bed} = \frac{\text{Total volume of sewage entering the bed}}{\text{hydraulic loading rate}}$$

- It may also be mentioned here that the filter diameter and depth is designed for average value of sewage flow. The rotary distributors, under-drainage system and other connected pipe lines etc. are, designed for peak flow, and checked for the average flow.

Performance of Conventional Filters and their Efficiencies :

- The effluent obtained from a conventional trickling filter plant is highly nitrified and stabilised. The BOD is reduced to about 80 to 90% of the original value.

  As per National Research Council of U.S.A.

$$\text{Efficiency } \eta\ (\%) = \frac{100}{1+0.0044\sqrt{u}}$$

where, η = efficiency of the filter in terms of% of applied BOD removed.

u = organic loading in kg/ha-m/day applied to the filter.

COMPARISON OF CONVENTIONAL AND HIGH RATE TRICKLING FILTERS

S.No.	Characteristics	Conventional or Standard rate filters	High rate filters
1.	Depth of filter media	Varies between 1.6 to 2.4 m.	Varies between 1.2 to 1.8 m
2.	Size of the filter media	25 to 75 mm	25 to 60 mm.
3.	Land required	More land area is required as the filter loading is less.	Less land area is required as the filter loading is more.
4.	Cost of operation	More for treating equal quantity of sewage.	It is less for treating equal quantity of sewage.
5.	Method of operation	Continuous application, less flexible requiring, less skilled supervision.	Continuous application, more flexible, and more skilled operation is required.
6.	Type of effluent produced.	The effluent is highly nitrified and stabilised with BOD in effluent $\leq$ 20 ppm or so.	The effluent is nitrified up to nitrite stage only and is thus less stable and hence it is of slightly inferior quality BOD in effluents
7.	Dosing interval	If generally varies between 3 to 10 minutes.	20 $\geq$ 20 ppm or so.
8.	Filter loading values (i) Hydraulic loading (ii) Organic loading	 Varies between 20 to 44 M.L. per ha./day Varies between 900 to 2200 kg of BOD per ha.m. of filter media per day.	 Varies between 110 to 330 ML per hectare per day. Varies between 6000 to 18,000 of BOD per ha.m. of filter media per day.
9.	Recirculation system.	Not provided generally.	Always provided for increasing hydraulic loading.
10.	Quality of secondary sludge produced.	Black, highly oxidized with slight fine particles.	Brown, not fully oxidized with fine particles.

RECIRCULATION OF TREATED SEWAGE AND ITS USE IN HIGH RATE TRICKLING FILTERS:

Recirculation of sewage is an essential and important feature of high rate filters. Filters consists in returning part of the treated or partly treated sewage to the treatment process.

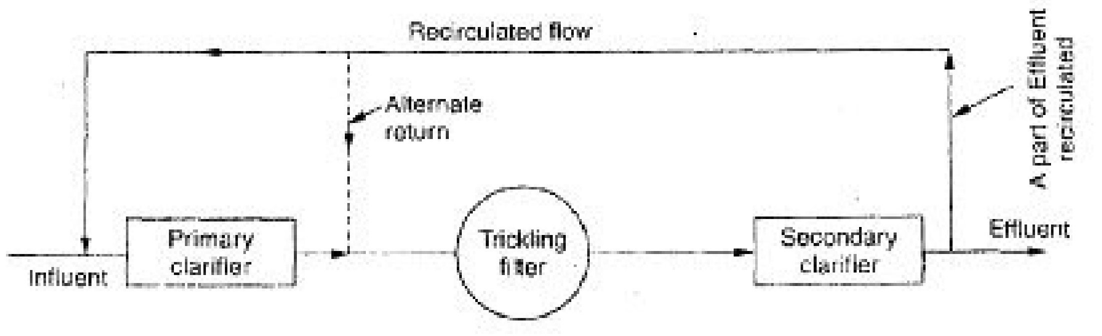


Fig. Single stage commonly adopted Recirculation Process.

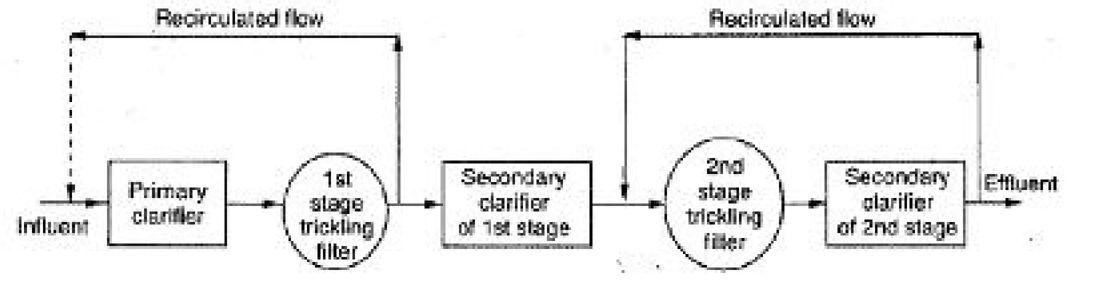


Fig. Two stage commonly adopted Recirculation Process

- In recirculated flow, a large volume of sewage through the filter tends to wash off the filter before nitrification has had time to take place, resulting in loss of nitrates in the effluent, therefore slightly lowering the quality of the effluent. For this reason, a high rate filter plant with single stage recirculation may not show as good results as those obtained from a conventional trickling filter plant.

Efficiency of High Rate Filters:

- The ratio of the volume of sewage recirculated (R) to the volume of raw sewage (I) is called **Recirculation Ratio**.

i.e. Recirculation Ratio $= \frac{R}{I}$

$$\text{Recirculation factor (F)} = \frac{1+\frac{R}{I}}{\left[1+0.1\frac{R}{I}\right]^2}$$

- The recirculation factor (F) also represents the number of effective passage through the filter.
- **Efficiency of the single stage high rate trickling filter,**

$$\eta\% = \frac{100}{1+0.0044\sqrt{\frac{Y}{VF}}}$$

where, Y = total organic loading in kg/day applied to the filter.

V = filter volume in hectare-metre.

F = recirculation factor.

In a two stage filter, the efficiency achieved in the first stage will be obtained as per equation (*i*); and in the second stage, it is obtained as:

Final efficiency in the two stage filter,

$$\eta' = \frac{100}{1+\frac{0.0044}{1-\eta}\sqrt{\frac{y'}{V'F'}}}$$

where, Y′ = total BOD in effluent from first stage in kg/day.

V′ = volume of second stage filter in ha-m.

F′ = recirculation factor for the seconds stage filter.

η′ = final efficiency obtained after two stage filtration.

Effect of Recirculation on Sizes of Treatment Units:

Recirculation through the primary sedimentation tanks requires extra capacity in these tanks, because the flow passing through them is increased, and under same conditions, size of the secondary sedimentation tanks many also have to be increased.

Types of High Rate filters:

(*i*) Biofilters

(*ii*) Accelo filters: These filter are normally 1.8 to 2.4 m deep, and utilises the direct recirculation of unsettled filter effluent to the distribution feed.

(*iii*) Aero filters.

Eekenfelder Trickling Filter Equation:

Eekenfelder has developed an equation for measuring the performance of trickling filters, on the basis of rate of waste removal. His final equation which help to compute the BOD removed by the filter, and is given as:

$$\frac{Y_t}{Y_0} = e^{\frac{KD}{(QL)^n}}$$

where, Y_0 = BOD_5 of the influent entering the filter, in mg/l

Y_t = BOD_5 of the effluent getting out of the filter, in mg/l

K = rate constant per day

D = depth of filter in *m*.

Q_L = Hydraulic loading rate per unit area of filter in $m^3/day/m^2$ = Q/A

DIGESTION AND DISPOSAL OF PRIMARY AND SECONDARY SLUDGE

- The sludge, which is deposited in a primary sedimentation tank is called **raw sludge**; and the sludge which deposited in a secondary clarifier is called **secondary sludge**. Raw sludge is more objectionable than secondary sludge.

- In case of raw sludge, the moisture content is about 95%; in case of secondary sludge from trickling filter plant, moisture content is about 96 to 98%; and in case of secondary sludge from an activated sludge treatment plant, moisture content is about 98% to over 99%. The sludge containing high moisture content becomes very bulky, and difficult to handle.

  There is a sewage sludge with volume (V_1) containing a certain moisture content P_1%. Then value of sewage at moisture content P is given by

$$V = \left[\frac{(100 - P_1)}{(100 - P)}\right] V_1$$

SLUDGE DIGESTION PROCESS

In order to avoid pollutions, the sludge is first of all, stabilised by decomposing the organic matter under controlled anaerobic condition and then disposed off suitably after drying on drying beds, etc. The process of stabilisation is called the **sludge digestion**; and the tank where the process is carried out is called the **sludge digestion tank**. In a sludge digestion process, the sludge gets broken into the following three forms:

(*i*) **Digested sludge:** stable humus like solid matter, tarry black in colour.

(*ii*) **Supernatant liquor:** Having high BOD (about 3000 ppm); and

(*iii*) **Gases and decomposition:** CH_4 (65 to 70%), CO_2 (30%) and traces other inert gases like N_2, H_2S etc.

- The digested sludge is dewatered, dried up, and used as fertiliser; while the gases produced are also used for fuel or for driving gas engines. The supernatant liquor contains about 1500 to 3000 ppm. of suspended solids; and is, therefore, retreated at the treatment plant along with the raw sewage.

Stages in the Sludge Digestion Process:

(*i*) **Acid fermentation Stage:** Highly putrefactive odours are evolved during this stage which continues for about 15 days or so (at about 21°C). BOD of the sludge increases to some extant, during this stage.

(*ii*) **Acid regression Stage:** This stage continues for of period of about 3 months or so (at 21°C). BOD of the sludge remains high even during this stage.

(*iii*) **Alkaline fermentation Stage :** During this stage, the liquid separates out from the solids, and the digested sludge is formed. This digested sludge is collected at the bottom of the digested tank and is also called **ripened sludge**. Digested sludge is alkaline in nature. Large volumes of methane gas along with small amount of CO_2 and nitrogen, are evolved during this stage. This stage extend, for a period of about one month or so (at about 21°C). The BOD of the sludge also rapidly falls down during this stage.

- About $4\frac{1}{2}$ months are required for the complete process of digestion to take place under natural uncontrolled condition at about 21°C.

Factors Affective Sludge Digestion and Their Control:

(*i*) Temperature

(*ii*) pH value

(*iii*) Seeding with digested sludge; and

(*iv*) Mixing and stirring of the raw sludge with digested sludge.

Temperature:

The rate of digestion being more at higher temperature and vice versa.

(*i*) **Zone of Thermophilic Digestion:** The temperature in this zone ranges between 40 to 60°C. The optimum temperature in this zone is about 54°C, and at this temperature, the digestion period can be brought down to about 10 – 15 days only. However, thermophilic range temperature are generally not employed for digesting sewage sludge, owning to odour and other operational difficulties.

(*ii*) **Zone of Mesophilic Digestion:** The temperature in this zone ranges between 25 to 40°C. The optimum mesophilic temperature is about 29°C; and at this temperature, the digestion period can be brought down to about 30 days.

(*iii*) **pH value:** During digestion, care must be taken to keep the acidity well under control, so that the pH during the digester start-up does not fall below 6.5 or so, and thus to see that alkaline conditions may prevail ultimately, in the final stage of digestion.

Sludge Digestion Tank or Digestor :

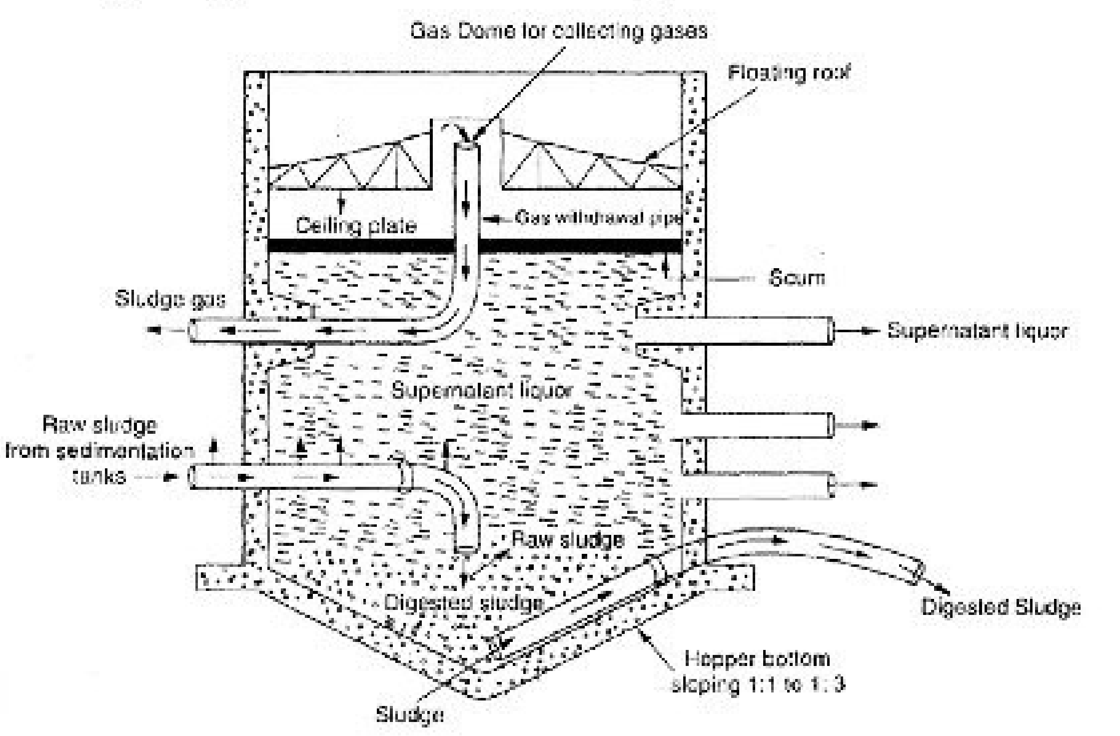


Fig: Cross Section and a typical sludge digestion tank

Design considerations

Cylindrical in shape, diameter 3 to 12 m. depth is usually taken at about 6 m. The capacity of digestion tank is a function of sludge production, digestion period, degree of digestion required, loss of moisture and conversion of organic matter.

If the progress of sludge digestion is assumed to be linear, then

$$V = \left(\frac{V_1 + V_2}{2}\right)t$$

where, V = volume of the digestor, m^3

V_1 = raw sludge added per day, m^3/d.

V_2 = equivalent digested sludge produced per day on completion of digestion, $m^3/\text{day} = \frac{V_1}{3}$

t = Digestion period, days.

- In monsoon season, total digestor volume,

$$V = \left(\frac{V_1 + V_2}{2}\right)t + V_2T$$

where, T = number of days for which the digested sludge is stored.

- **When the change during digestion is assumed to be parabolic, then**

$V = [V_1 - \frac{2}{3}(V_1 - V_2)]t$ without monsoon storage.

or $V = [V_1 - \frac{2}{3}(V_1 - V_2)]t + V_2T$ with monsoon storage.

Estimated gas production: (approx method)

- About 60% of the suspended solids of sewage are removed by sedimentation, 5% by chemical coagulation and settling; and 90% by complete treatment.
- About 70% of the suspended solids in the sewage are volatile, and the reduction of the volatile matter in sludge, is about 65%. In digestion, the amount of gas produced is about 0.6 m^3 per kg. of volatile matter present in the sewage, or is about *0.9 m^3 per kg. of volatile matter reduced*.

DISPOSAL OF DIGESTED SLUDGE

The digested sludge is first of all dewatered or dried up before disposal (burning or dumping).

Methods of dewatering

1. Dewatering of sludge by Sludge Drying Beds.
2. Mechanical Methods of Dewatering sludge.

- The dried sludge from the drying beds is either use as a manure or is used for filling low lying areas.

Disposal of wet Digested Sludge:

(*i*) Disposal by dumping into the sea;

(*ii*) Disposal by burial into the trenebes; and

(*iii*) Incineration.

Use of Lagoons for Disposal of Raw Sludge

This method is, sometimes, used at smaller places for disposing off raw sludge without digestion. In this method, the raw sludge is kept at rest in a large shallow open pond, called a lagoon. During the detention (1 to 2 month) in the lagoon, the sludge undergoes anaerobic digestion thereby getting stabilised.

Secondary Treatment Through Activated sludge Process

Activated sludge process: The sewage effluent from primary sedimentation tank, is mixed with 20 to 30% of volume of activated, sludge, which contains a large concentration of highly active aerobic micro-organism, and the sewage are intimately' mixed together, with a large quantity of air for about 4 to 8 hours. Under these conditions, the moving organisms will oxidise the organic matter and the suspended and colloidal matter tend to coagulate and forms precipitate, which settled in secondary settling tank.

- The effluent obtained from a properly operated activated sludge plant is of high quality. BOD removed is upto 80-95%, and bacteria removal is upto 90-95%.
- A new plant may also sometimes be seeded with the activated sludge from another plant, so as to quickly start the process in the new plant.

Various Operations and units of an activated Sludge Plant

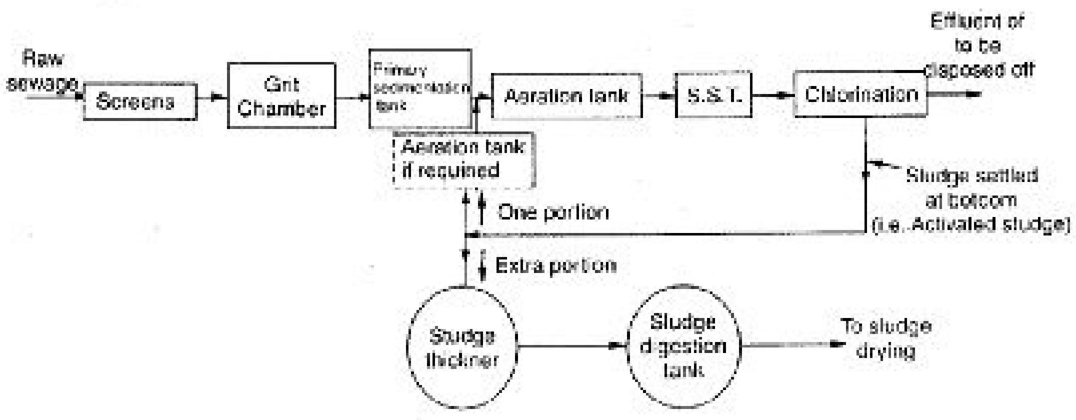


Fig. Flow diagram for a conventional Activated sludge plant.

- Screeing, grit removal and primary sedimentation tanks are necessary for the activated sludge plant.

AERATION TANKS OF AN ACTIVATED SLUDGE PLANT

It is normally rectangular in shape, 3 to 4.5 m. deep, and about 4 to 6 m. wide. The length may ranges between 20 to 200 m.; and the detenation pesion between 4 to 8 hours for municipal sewages. Air is continuously introduced into these tanks.

Methods of Aeration:

(*i*) Diffused air aeration or Air diffusion;

(*ii*) Mechanical aeration; and

(*iii*) Combined aeration.

Quantity of air required: 4000 to 8000 m^3 of free air will be required per million litres of sewage being treated. With respect to BOD removal, the usual rate adopted is 100 m^3 of air per kg. of BOD removed. Only about 5% of the oxygen in the air is actually involved in the biochemical action.

Volume of returned activated sludge:

The volume of returned activated sludge normally depends upon the extent of BOD desred to be removed. It is generally expressed as percentage of flow of sewage.

Extent of BOD removal desired in ppm	Quantity of returned sludge as % of sewage
150	25
250	30
300	35
400	40
500	48
600	53

Capacity of the aeration tank $= (V_1 + V_2)\dfrac{T}{24}$ **in cu-m**

where, V_1 = volume of sewage flow in m^3 per day

V_2 = volume of returned sludge in m^3 per day. It generally lies between 25 to 30% of sewage flow.

T = aeration period (4 to 8 hr).

(*ii*) **Mechanical Aeration:**

In mechanical aeration method, atmospheric air is brought in contact with the sewage. The sewage is stirred up by means of mechanical devices like paddles etc.; so as to introduce air into it from the atmosphere by continuously changing the surface of sewage by the circulation of sewage from bottom to top.

Secondary sedimentation Tank of an Activated sludge plant:

- For design a weir overflow rate, not exceeding 150 m^3/day per metre of weir. This value is based on average flow of sewage.
- The solid loading rate based on mixed liquor flow to the settling tanks, may be kept at about 100-150 kg./m^2 per day at average flow and should not excess 250 kg/m^2 per day at peak flows.
- The surface area for activated sludge settling tanks should be designed for both overflow rate and solids loading rate, and larger value is adopted.
- Detention time may be kept between $1\frac{1}{2} - 2$ hours.
- $\dfrac{\text{Length}}{\text{Depth}} = 5$ for circular tanks, and 7 for rectangular ones. The depth may be kept in the range of 3.5 to 4.5 m.
- Surface loading rate of 20 m^3/day/m^2
- A conventional activated sludge plant involves a mixing regime, which is essentially of plug flow type.

DESIGN CONSIDERATIONS INVOLVED IN AN ACTIVATED SLUDGE PLANT

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

(*i*) Aeration Period (*i.e.* Hydraulic Retention Time– H.R.T) $= \dfrac{V}{Q}$

(*ii*) BOD loading per unit volume of aeration tank (*i.e.* volumetric loading).

(*iii*) Food to Micro-organism Ratio (F/M Ratio); and

(*iv*) Sludge age.

(*i*) Aeration Period,

$$t = \frac{\text{Volume of the tank}}{\text{Rate of sewage flow in the tank}}$$

$$= \frac{V}{Q} \text{ day (excluding recycled sludge)}$$

(*ii*) *Volumetric BOD loading or Organic loading*

$$= \frac{\text{Mass of BOD applied per day to theaeration tank}}{\text{Volume of the aeration tank}}$$

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

where, Y_0 = BOD_5 of the influent sewage.

V = Aeration tank volume in m^3

(*iii*) *Food (F) to Micro-organisms (M) ratio, or F /M ratio:*

The BOD load applied to the system in kg. or gm. is represented as food (F) and the total microbial suspended solids in the mixed liquor of the aeration tank is represented by M.

∴ Food to Micro-organism ratio

$$= \frac{\text{Daily BOD load applied to the aerator system in gm.}}{\text{Total microbial mass in the system in gm.}}$$

$$= \frac{QY_0}{\text{MLSS} \times \text{Volume of the aeration tank}} = \frac{QY_0}{V.X_t}$$

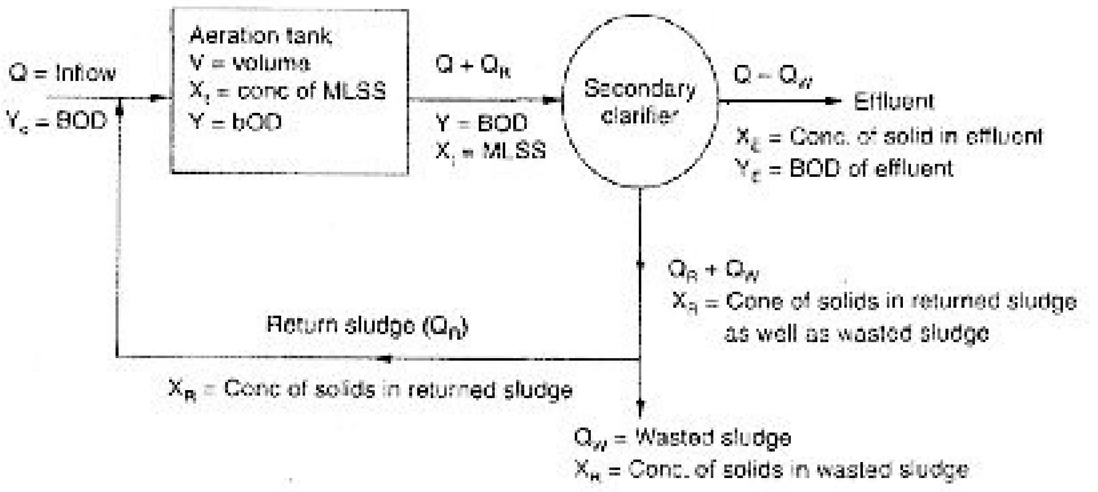
$$\frac{F}{M} \text{ ratio} = \frac{Q \cdot Y_0}{V \cdot X_t}$$

where, X_t = mixed liguar suspended solid

= average concentration of solids in the mixed liguor of the aeration tank.

- Food to micro-organism ratio for an activated sludge plant is the main factor controlling BOD removal. Lower the food to micro-organism value, the higher will be the BOD removal in the plant.

(*iv*) Sludge age (θ_c) : It may be defined as the average time for which particles of suspended solids remain under aeration. It, thus, indicates the residence time of biological solids in the system.



$$\text{Sludge age}(\theta_c) = \frac{\text{Mass of suspended solids (MLSS) in the system (M)}}{\text{Mass of solids leaving the system per day}}$$

$$(\theta_c) = \frac{V.X_t}{Q_w X_R + (Q - Q_w) X_E}$$

where, V = volume of aerator,

xt = MLSS (mg/l)

XR = concentration of solids in the returned sludge (mg/l)

XE = concentration of solids in the effluent (mg/l)

Qw = volume of wasted sludge per day

Q = see wage in flow per day

- **Design parameters for a conventional Activated sludge plant:**

S.NO.	Parameter/Loading	Design Values
1.	MLSS	1500-3000 mg/l.
2.	MLVSS/MLSS	0.8
3.	Food to micro-organism (F/m) ratio	0.4 to 0.2
4.	Aeration Period (HRT)	4 to 8 hr.
5.	Volumetric loading as gm of BOD applied per m^3 of tank	300-700
6.	SRT or sludge age	5 to 15 days
7.	Volume of returned sludge/volume of influent sludge = (Q_R/Q)	0.25 to 0.5
8.	BOD removal efficiency	85 to 95 %
9.	kg of O_2 required per kg. of BOD removal	0.8 – 1.1
10.	Air required per kg. of BOD_5	40-100 m^3

- Activated sludge treatment plant are normally preffered for large size cities.

SLUDGE VOLUME INDEX (S.V.I)

It represents the degree of concentration of the sludge in the system and hence decides the rate of recycle of sludge (Q_R) required to maintain the desired MLSS and food to micro-organism ratio in the aeration tank to achieve the desired degree of purification.

$$\text{Sludge Volume Index (SVL)} = \frac{V(\text{ml/l})}{X(\text{mg/l})}$$

Sludge volume index is defined as the volume occupied in ml. by one gm. of solids in the mixed liquor after settling for 30 minutes and is determined experimentally

Rate of return sludge (Q_R) :

Empirical equation is $Q_R = Q\left[\dfrac{X_t}{\dfrac{10^6}{SVI} - X_t}\right]$

Return sludge ratio, $\dfrac{Q_R}{Q} = \dfrac{X_t}{\left(\dfrac{10^6}{SVI} - X_t\right)}$

where, X_t is MLSS in mg/l. $\dfrac{10^6}{SVI}$ is also in mg/l.

The excess sludge quantity will increase with the increasing food to micro-organism ratio and decreases with temperature.

Comparison of Activated Sludge Process and Trickling Filter Process

In a trickling filter, the bacterial film coating the grains of the filter media is stationary and likely to become clogged after sometimes; in the activated sludge process, On the other hand, the finer suspended organic particles of sewage are themselves coated with the bacterial film, which is kept moving by the constant agitation, therefore, the sludge flocs are coated with bacteria and they act like free moving organisms, which are being continuously swept through the sewage, and which in their search for food and work, oxidise organic matter present in sewage in a much more efficient way than that carried out in a filter by the bacteria coated around the particles of the filter media. As such, it can be stated that an activated sludge process is more efficient than a trickling filter.

- Normally, it is found that for towns or small cities with medium sized plants, trickling filters are better; whereas big cities with large sized plants, the activated sludge plant is better.

OXIDATION PONDS AND AERATED LAGOONS

- The end products of the aerobic pond are carbon dioxide, NH_3 and phosphates, which are required by the algae to grow and continue to produce oxygen.
- In an anaerobic pond, the stabilisation of waste is mainly brought about by the usual anaerobic conversion of organic water to CO_2, CH_4, and gaseous end products, with erruption of foul odours and pungent smells.
- In a facultative pond, the upper layers work under aerobic conditions, while the anaerobic conditions prevail in the bottom layers. The upper aerobic layer of the pond acts as a good check against the evolution of the foul odours from such a pond.
- Practically difficult to construct and use purely aerobic ponds. The facultative ponds, with depth (1 to 1.5 m.) are thus most widely used for treatment of sewage.
- The term *oxidation pond* was originally referred to that stabilisation pond which received *partially treated sewage*; whereas the pond that received *raw sewage* was used to be called *a sewage lagoon*; but in recent years, the term oxidation pond has been widely used as a collective term for all types of ponds, and most particularly the facultative stabilisation ponds.
- The effluents from oxidation ponds can be easily used for land irrigation, particularly at places, where they cannot be discharged into river streams.

Design Criteria:

Oxidation ponds works on algal-symbiosis. In this symbiosis, the algae while growing in the precede of sunlight, presence oxygen by the action of photosynthesis and this oxygen is utilised by the bacteria for oxidising the waste organic water. The end products of the process are CO_2, NH_3 and phosphates, which are required by the algae to grow and continue to produce oxygen.

- Organic loading = 300 – 150 kg/hectors/day. In India to about 90 – 60 kg./ha./day.
- Each unit may have an area ranging between 0.5 to 1 hectare.
- L/B = 2, depth = 1 to 1.5 m., free board = 1m.
- Detention time = 20 – 30 days.
- Detention period in days = $\frac{1}{k_D}\log_{10}\left(\frac{L}{L-Y}\right)$

where, L = BOD of the effluent entering the pond.
Y = BOD removed, say 90% of L or 95% of L etc.

k_D at 20°C = 0.1/day,

- Properly operated ponds may be as effective as trickling filters in reducing the BOD of sewage. The BOD removal is upto 90%, and coliform removal is upto 99% or so.
- The biggest advantage of an oxidation pond treatment is that it is very cheap. The capital cost being 10 to 30% of that of the conventional plant. Their maintenance cost is also very minor, and no skilled supervision is required at any stage of construction and operation.
- The main disadvantage of oxidation ponds, is the nuisance due to mosquito breeding and bad odours. Order may also be kept under control by avoiding the over-loading. The algae growth may be stimulated by adding sodium nitrate, which is both a plant food and an oxidising agent.

OXIDATION DITCHES (Pasveer Type) or EXTENDED AERATION LAGOONS

The normal activated sludge plant has been modified to eliminate the primary sedimentation tank and sludge digestion tank, in a process, called *Extended aeration*, which aims at providing an aeration tank with a longer aeration time.

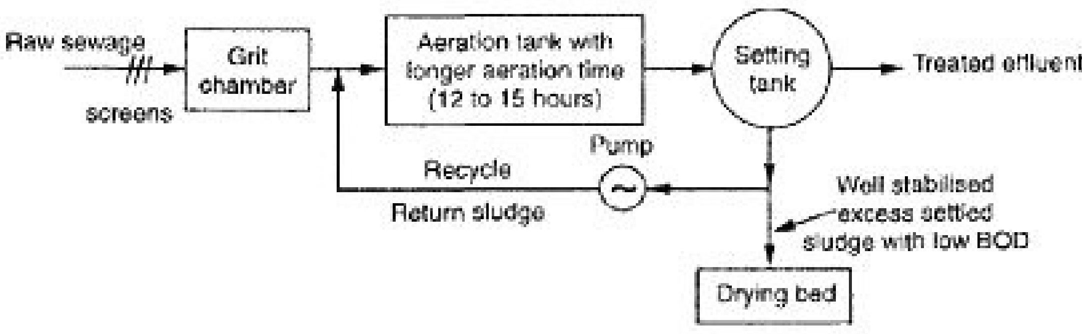


Fig: Extended Aeration process

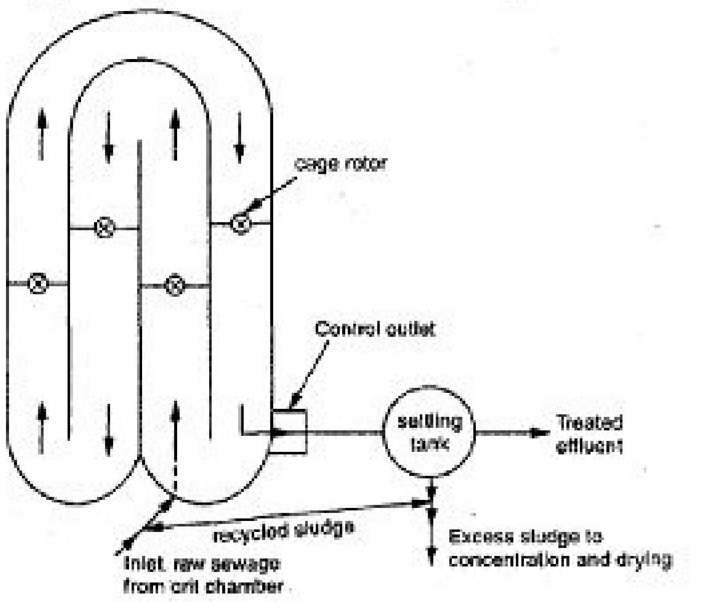


Fig: Plane view of a typical oxidation ditch

Design Considerations:

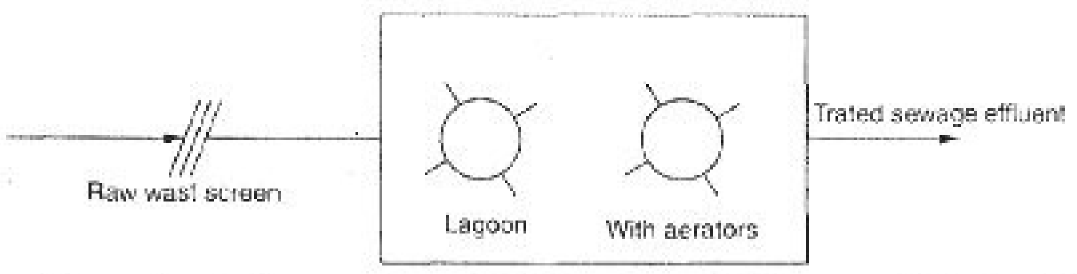
- D.T. = 12 to 15 hours, depth of about .1 to 1.5 m.

  The width of the ditches is limited to the type and availability of the aeration rotors used, and may vary between 1 to 5 m. The length may vary from, say 150 m to 1000 m or so.

- The concentration of the suspended solids in the mixed liquor should be high say about 4000 to 5000 mg/I.
- The quality of the effluent obtained is quite good, with suspended solids removal at about 95% and BOD removal at about 98%.

MECHANICALLY ARENTED LAGOONS

It is a deeper oxidation pond with oxygen induced by mechanically aerated.



- Depth =2.4 to 3.6 m., D.T. = 4 to 10 hours. The land area required is about 5 to 10% of that required for an equivalent oxidation pond. The aerated lagoons are frequently used for treating industrial waste waters.

ANAEROBIC STABILISATION UNITS

(*i*) Anaerobic stabilisation Ponds or Lagoons

(*ii*) Septic Tanks

(*iii*) Imhoff tanks; and

(*iv*) High rate anaerobic systems.

- Anaerobic treatment of complex waste involves two distinct stages:
  (*i*) Acid fermentation, and
  (*ii*) Methane fermentation.

SEPTIC TANKS

- A septic tank may be defined as a primary sedimentation tank, with a longer detention period (12 to 36 hr.) and with extra provisions for digestion of the settled sludge.
- The septic tank unit is generally classified under the units which work on the principle of anaerobic decomposition. It is completely covered and provided with a high vent shaft for escape of gases.
- A septic tank is a horizontal continuous flow type of a sedimentation tank, directly admitted raw sewage, and removing about 60 to 70% of the dissolved matter from it. The effluent from such a tank will be sufficiently foul in nature, and will have to be disposed off either for sub-surface irrigation or in cess-pools or soakpits or to be treated in trickling filter before disposed it off in water courses.
- Septic tanks are generally provided in areas where sewers have not been laid.

Design considerations:

(*i*) Capacity of septic tanks = Quantity of sewage produced during the detention periods + volume of sludge for 6 months to 3 years, depending upon the periodicity of cleaning.

The rate of accumulation of sludge has been recommended as 30 lit./person/years. A free board of about 0.3 m. may be provided above the top sewage line in the tank.

(*ii*) *Inlet and outlet baffles*: The inlet should penetrate by about 30 cm below the top sewage line, and the out let should penetrate to about 40% of the depth of sewage.

(*iii*) *Detention Period*: The detcution period for septic tank generally varies between 12 to 36 hr. but is commonly adopted as 24 hours.

(*iv*) *Length to width ratio*: L/B = 2 to 3, The width should not be less than 90 cm. Depth of the tank generally ranges between 1.2 to 1.8 m.

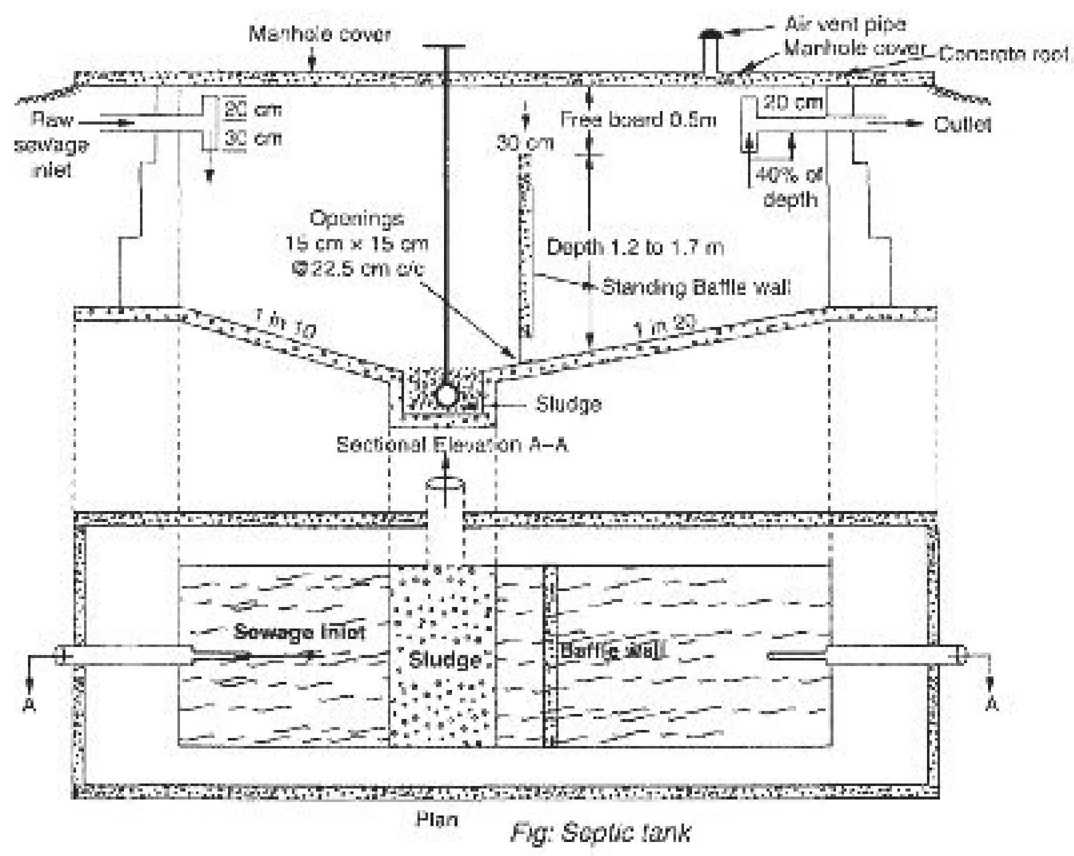


Fig: Septic tank

Disposal of the Effluent from the Septic Tanks:

(*i*) Sub-surface irrigation method using dispersion trenches;

(*ii*) Disposal in Soak-pits.

(*iii*) Disposal in a Leaching cess-pool.

Design of soak-well

The soak-well or soak-pit can be designed by assuming the percolating capacity of the filtering media, say as 1250 lit/m^3/day.

IMHOFF TANKS OR TWO-STOREY DIGESTION TANKS

Imhoff tank is a two storeyed tank in which upper portion is sedimentation tank and lower portion is called *digestion chamber*.