DEPARTMENT OF CIVIL ENGINEERING

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EN8592 –WASTEWATER ENGINEERING

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Semester-VI

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UNIT I
PLANNING AND DESIGN OF SEWERAGE SYSTEM

Characteristics and composition of sewage and their significance

1. Explain briefly the characteristics of wastewater/ sewage. (Or) Explain the various characteristics and composition of sewage and state their environmental significance

The characteristics or properties of wastewater can be classified under the following three heads:

(a) Physical Characteristics

(b) Chemical Characteristics

(c) Biological Characteristics

a) PHYSICAL CHARACTERISTICS

(i)Turbidity:

- The turbidity of wastewater depends upon the quantity of solid matters present in the suspension state.
- Sewage is normally turbid which having floating matter like pieces of paper, match sticks, greases, vegetable peels, soaps etc.

(ii) Color:

- If sewage color is yellowish, grey or light brown, it indicates fresh sewage.
- If it is black or dark brown, it indicates stale and septic sewage.

(iii)Odor:

Fresh sewage is odorless but after 4 hours it gives offensive odor because of H2S.

(iv)Temperature:

It has an effect on the biological activities of bacteria in sewage.

(b) CHEMICAL CHARACTERISTICS OF SEWAGE:

(i) pH:

Fresh sewage is alkaline in nature. As the time passes, pH value tends to fall due to production of acids by bacterial action and sewage tends to become acidic.

(ii) Chloride Content:

- Chlorides are generally present in municipal sewage.
- It is derived from the kitchen wastes, human feces and urinary discharges, etc.,
- The normal chloride content of domestic sewage is 120 mg/l, whereas the permissible chloride content for water supply is 250 mg/l.

(iii) Nitrogen Content:

- Presence of nitrogen indicates that the presence of organic matter in wastewater.
- Nitrogen is essential to the growth of protista and plants and it is known as nutrients or bio stimulants.

(iv)Fat, Grease and Oils:

It is mainly constituted from kitchen wastes because they are major components of food stuffs such as butter, vegetable oils and fats.

(v) Surfactants:

It comes primarily from the synthetic detergents. They are discharged from bathrooms, kitchen and washing rooms.

(vi) Phenol, Pesticides and Agricultural Chemicals:

- It is found in industrial wastewater.
- It causes serious taste problem in drinking water when the water is disinfected by chlorination.

(vii) Toxic Compounds:

Copper, Lead, Silver, Chromium, Arsenic and Boron are some of the cations which are toxic to microbes resulting in the malfunctioning of biological treatment plant.

(viii) Sulphate, Sulphide and H2S gas:

These are formed due to the decomposition of various Sulphur containing substances in sewage.

(ix) Other Gases:

Nitrogen, Oxygen, Carbon dioxide, Hydrogen Sulphide, Ammonia and Methane are the gases found in untreated wastewater.

(x) Dissolved Oxygen (DO):

- It is the amount of oxygen in the dissolved state in the wastewater.
- Though wastewater generally does not have DO, its presence in untreated wastewater indicates that the wastewater is fresh.

(xi) Total Oxygen Demand (TOD):

To measure the organic content of wastewater.

(xii) Theoretical Oxygen Demand(ThOD):

This is the theoretical method of computing the oxygen demand of various constituents of the organic matter present in wastewater.

(xiii) Total Organic Carbon (TOC):

- The TOC test is especially applicable to small concentration of organic matter.
- The TOC test consists of acidification of the wastewater sample to convert inorganic carbon to CO2 which is then stripped.

(xiv) Bio-Chemical Oxygen Demand (BOD):

It may be defined as the oxygen required for microorganisms to carry out biological decomposition of dissolved solids or organic matter in the wastewater under aerobic conditions at standard temperature.

(xv) Chemical Oxygen Demand (COD):

It may be defined as the amount of oxygen required for complete oxidation of organic and inorganic matter in presence of strong chemical agent.

(c) BIOLOGICAL CHARACTERISTICS:

- The biological characteristics are related to the presence of microorganisms such as (i) Groups of microorganisms found in wastewater (ii) Pathogenic Organisms, (iii) Microorganisms used as indicators for pollution.
- The various micro –organisms found in water or wastewater may be broadly classified under three categories (i) Aquatic plants, (ii) Aquatic Animals, (iii) Aquatic molds, bacteria and viruses

2. <u>Population Equivalent:</u>

Population equivalent or **unit per capita loading**, (**PE**), in waste-water treatment is the number expressing the ratio of the sum of the pollution load produced during 24 hours by industrial facilities and services to the individual pollution load in household sewage produced by one person in the same time.

For practical calculations, it is assumed that one unit equals to 54 grams of BOD per 24 hours.

$$PE = \frac{\text{BOD load from industry [kg/day]}}{0.054\ \text{[kg/inhab. Day]}}$$

Population equivalents of wastewater from some industries[2]		
Type	**Activity**	**BOD PE [inhab/(unit/d)]**
Food	Canning (fruit/vegetables)	500
	Pea processing	85-400
	Tomato	50-185
	Carrot	160-390
	Potato	215-545
	Citrus fruit	55
	Chicken meat	70-1600
	Beef	20-600
	Fish	300-2300
	Sweets/candies	40-150
	Sugar cane	50
	Dairy (without cheese)	20-100
	Dairy (with cheese)	100-800
	Margarine	500
	Slaughter house	10-100
	Yeast production	21000
Confined animals breeding	Pigs	35-100
	Dairy cattle (milking room)	1-2
	Cattle	65-150
	Horses	65-150
	Poultry	15-20
Sugar-alcohol	Alcohol distillation	4000
Drinks	Brewery	150-350
	Soft drinks	50-100
	Wine	5
Textiles	Cotton	2800
	Wool	5600
	Rayon	550
	Nylon	800
	Polyester	3700
	Wool washing	2000-4500
	Dyeing	2000-3500

	Textile bleaching	250-350
Leather and tanneries	Tanning	1000-3500
	Shoes	300
Pulp and paper	Pulp	600
	Paper	100-300
	Pulp and paper integrated	1000-10000
Chemical industrial	Paint	20
	Soap	1000
	Petroleum refinery	1
	PVC	200
Steelworks	Foundry	12-30
	Lamination	8-50

<u>Hydraulics of Flow in sewers</u>

3. **How to determine the flow velocities in sewers and drains?**
   Factors that influence flow of sewage in sewers.
   a. Slope of sewer
   b. Geometry of sewer
   c. Roughness of interior surface of sewer
   d. Bends, transitions, obstructions etc.
   e. Flow condition
   f. Characteristics of sewage.

Hydraulic Formulae.

(i) Chezy's Formula:

Velocity of flow, $= \sqrt{\;}\,.$

Where,

V= Velocity of flow in m/s

S= Hydraulic gradient of sewer

R= Hydraulic mean radius in m

Hydraulic mean radius, $\frac{}{} =$

Where,

C= Chezy's constant

A= Area of cross section in m^2

P= Wetted perimeter in m

Chezy's constant C is found using Bazin's formula:

Discharge, $=$

Where,

Q= Discharge in m^3/s

(ii) Kutter's Formula:

Chezy's coefficient, $= \dfrac{23 + 0.00155 + 1}{1 + (23 + 0.00155)\sqrt{\;}}$

Where,

R= Hydraulic mean radius

S= Slope

N= Rugosity coefficient (depends on nature of inner surface of sewer)

When N decreases, diameter increases.

Example: For cement concrete sewer of Ø600 , = 0.013

(iii) Bazin's Formula:

Chezy's constant, = $\frac{157.6}{181+\sqrt{}}$ =

Where,

K= Bazin's constant (depends on nature of inner surface of sewers).

(iv) Manning's Formula:

Velocity of flow, = 1 2/3 1/2

Where,

N, R, S have same meaning as given by kutter's formula.

(v) Crimp and Burge's Formula:

Velocity of flow, = 83.5 2/3 1/2

(Similar to Manning's formula, where 1 = 83.5 (or) N=0.012).

Example: For a circular pipe

Hydraulic mean radius, $R = \frac{A}{P} = \frac{\pi/4 D^2}{\pi D} = \frac{D}{4}$

Velocity of flow , $V= 83.5\ (D/4)^{2/3}.S^{1/2}$

Discharge, =

$= (\frac{}{4}^{2})\ 83.5\ (D/4)^{2/3}.\ S^{1/2}$

$Q= 26.02\ D^{8/3}.S^{1/2}$

(vi) William-Haizen Formula:

For flow under pressure for designing water pipes.

Velocity of flow, = 0.85 0.63 0.54

C value depends on the type of pipe material..

4. **What are the maximum and minimum velocities in sewer?**
   a. Minimum velocity of flow (Self Cleansing Velocity)
   b. Maximum velocity of flow (Non-Scouring Velocity)

Minimum velocity of flow (Self Cleansing Velocity):

c. Solid particles in sewage remain suspended only when minimum flow velocity is maintained in sewers. Otherwise the solid particles will settle and clog the sewers, such a minimum velocity is known as self-cleansing velocity.
d. It is not possible to maintain the self-cleansing velocity throughout the day because of fluctuations in sewage flow.
e. During minimum flow conditions, the velocity of flow is less than the self cleansing velocity.
f. The sewers are designed in such a way that the self cleansing velocity is maintained atleast once in a day.
g. The sewers are designed to flow half to $3/4^{th}$ full to prevent sewage becoming stale and to prevent foul gases (ventilation).

Table 1: Self cleansing velocities for various sewer sizes

S.No	Diameter of sewers (cm)	V (cm/s)
1.	15 to 25	100
2.	30 to 60	75
3.	Above 60	60

Maximum velocity of flow (Non-Scouring Velocity):

- At higher velocities, the sewage flow becomes turbulent and results in continuous abrasion of the interior surface of the sewer by the suspended solid particles. Hence maximum velocity of flow is also limited. Such limiting velocity is called non-scouring velocity.
- The non-scouring velocity can be defined as the maximum velocity at which no scouring action (or) abrasion takes place.
- The flow velocity should be within tolerable limits of pipe materials. Otherwise the wear and tear will reduce the life span and carrying capacity of sewer pipes.
- E.g., ceramic material (vitrified tiles and Glazed Bricks) are more resistant to wear and tear than bricks and concrete.
- Abrasion is maximum at the invert (bottom) of the sewer because of the heavy grit and sand and should be lined with ceramic material.

Effect of flow variation on velocity in sewers (→ →)

- The discharge in a sewer does not remain constant and it varies from time to time.
- Due to the variation in discharge, the hydraulic mean depth (R) also varies.
- Since the velocity of flow is a function of R, the velocity of flow also varies.
  $^{2/3}$ (Manning's formula)
- As the flow decreases, the velocity also decreases.
- Velocity should be within 40 cm/s (for Min flow)-90 cm/s (for Max flow) in sewers.
- Velocity should never exceed the scouring value.

Design of sewers: [Based on self cleansing and Non-scouring velocities]

(i) Based on discharge [Q], the velocity of flow and gradient are determined.

(ii) In flat country:

- The design of sewers should be done in such a way that self-cleansing velocity is achieved at maximum discharge.
- At maximum discharge, the velocity of atleast 40cm/s should be maintained.

(iii) In rough country:

- The design of sewers should be done in such a way that the self-cleansing velocity is achieved at minimum discharge.
- The non-scouring velocity is achieved at maximum discharge.
- Due to steep slopes, if the velocity is exceeded during maximum discharge, drop man holes should be provided to bring down the velocity within the non-scouring value.

(iv) In Combined sewers:

- It is difficult to achieve self-cleansing velocity during minimum flow/ Dry weather flow (DWF).
- Hence, special form of sewers sections [egg-shaped] should be adopted.

(d) Design a sewer running 0.7 times full at maximum discharge for a town provided with the separate system serving a population of 80,000 persons. The water supplied from the water works to the town is at a rate of 190 l/person/day. The sere is made up of brick work plastered smooth with cement mortar (n=0.013) and the permissible slope is

b) in 600. The variations of n with depth may be neglected. Assume any other data not given and needed.

Population=80,000

Rate of water supplied=190 liters/person/day

Average rate of daily water supplied to the town=80,000 X 190 l/d

Average water supplied (in cumecs) = $\frac{80000\times190}{24\times60\times60\times1000} = 0.176$

Assuming that 80% of water supplied to the town appears as sewage, we have

The average discharge of sewage produced=0.176x0.8 =0.14 cumecs

Assuming the maximum flow to be three times the average, we have

The maximum sewage discharge=3x0.14

=0.42 cumecs

Now since the sewer is to be designed as running 0.7 times the full depth at maximum discharge, from table, we have

(d/D)=0.7

We know that

$$\frac{\ }{\ } = \frac{1}{2}(1 - \cos \frac{\ }{2}) \quad \text{(iii)}$$

$$0.7 = \frac{1}{2}(1 - \cos \frac{\ }{2})$$

$$1.4 = (1 - \cos \frac{\ }{2})$$

$$\cos \frac{\ }{2} = -0.4$$

$$\frac{\ }{2} = \cos^{-1}(-0.4)$$

$$\frac{\ }{2} = 113.57$$

$$= 227.15$$

$$= \frac{\ ^2}{4}\left(\frac{\ }{360^0} - \frac{\sin\ }{2}\right) = \frac{\ ^2}{4}\left(\frac{227.15^0}{360^0} - \frac{\sin 227.15^0}{2}\right) = 0.59\ ^2$$

Hydraulic mean depth, $= \frac{\ }{\ } = \frac{0.59\ ^2}{3.14\times\ \times 227.15/360^0} = 0.30$

Manning's formula, $= \frac{1}{\ }\ .\ .\ ^{2/3}.\sqrt{\ }$

$$0.42 = \frac{1}{0.013}(0.59\ ^2) \times (0.30)^{2/3} \times \sqrt{(1/600)}$$

$$0.504=D^{8/3}$$

$$D=0.77$$

Self cleansing velocity, $= \frac{1}{n}(R)^{2/3} \times S^{1/2}$

$= \frac{1}{0.013} \times (0.3 \times 0.77)^{2/3} \times (1/600)^{1/2}$

V=1.19 m/s

V is more than self cleansing velocity

Hence ok.

Discharge, $= \frac{1}{n} \times R^{2/3} \times S^{1/2} \times A$

$= \frac{1}{n} \times (D/4)^{2/3} \times (1/600)^{1/2} \times \frac{\pi}{4}D^2 = 0.5\ m^3/s$

Discharge, Q=AV

V= (Q/A)=(0.5/0.465)=1.07 m/sec

(c) Design a sewer to serve a population of 36,000; the daily per capita water supply allowance being 135 liters of which 80% find its way into the sewer. The slope available for the sere to be laid is 1 in 625 and the sewer to be designed to carry 4 times the dry weather flow when running full. What would be the velocity of flow in the sewer when running full? Assume n = 0.012 in Manning's Formula.

Solution:

Population = 36,000

Per capita water supply = 135 l/p/d

Average water supplied daily = 36,000 X 135

Average water supplied in cumecs = $\frac{36,000 \times 135}{1000 \times 24 \times 60 \times 60} \approx 0.0562$ cumecs

Average sewage discharge = 80% of water supplied

Therefore, D.W.F = 0.8 X 0.0562 = 0.045

Maximum discharge for which sewers should be designed running full

(j) 4 X 0.045 = 0.18

cumecs We know that,

Discharge, $= \frac{1}{n} \times A \times R^{2/3} \times \sqrt{S}$

(jj) $0.18 = \frac{1}{0.012} \times \frac{\pi}{4}D^2 \times \left(\frac{D}{4}\right)^{2/3} \times \frac{1}{\sqrt{625}}$

$D^{8/3} = 0.173$

D = 0.31 m

Hence, we use 0.31m, diameter sewer pipe velocity of flow when running full.

Self cleansing velocity, $= \frac{Q}{A} = \frac{0.18}{\frac{\pi}{4}(0.31)^2} = 2.39\ m/s$

(iv) Design an outfall circular sewer of the separate system for a town with a population of 1, 00,000 persons with a water supply at 180 l/person/day. The sewer can be laid at a slope of 10 in 10,000 with n = 0.012. a self cleansing velocity of 0.75 m/sec is to be developed. The dry weather flow may be taken as 1/3 of the maximum discharge. Given the following table:

Proportionate depth	Proportionate velocity	Proportionate discharge
0.31	**0.7901**	**0.2086**
0.35	**0.8430**	**0.2629**
0.37	**0.8675**	**0.2981**
0.39	**0.8909**	**0.3217**
0.40	**0.9022**	**0.3370**
0.42	**0.9299**	**0.3682**

Solution:

Population = 1,00,000

Average rate of water supply = 180 litres/ person

Average rate of water supplied per day = 1,00,000 X 180 litres

Average rate of water supplied in cumecs $= \frac{1,00,000 \times 180}{1000 \times 24 \times 60 \times 60} = 0.20$

Maximum discharge = 3 X 0.208 = 0.624 cumecs

Let us design the sewer as running full at maximum discharge.

Using Manning's formula, we have

Discharge, $= \frac{1}{} \times \quad \times \ ^{2/3} \times \sqrt{}$

Assuming that the sewer is laid at the variable slope of 10 in 10,000 ie.,1 in 1000 Slope, $S = \frac{1}{1000}$

Putting the values in Manning's equation, we have

$$0.624 = \frac{1}{0.012} \times \frac{^{2}}{4} \times \frac{^{2/3}}{4} \times \frac{1}{\sqrt{1000}}$$

$$^{8/3} = \frac{0.624 \times 0.012 \times 4 \times 2.52 \times 31.6}{}$$

$$^{8/3} = 0.755$$

$$(0.758)^{3/8} = 0.915$$

Now, velocity of flow at full flow,

Velocity, $= \frac{}{} = \frac{0.625}{\frac{}{4}(0.915)^2} = 0.95$ /

This is more than 0.75 m/s, and hence satisfactory.

Let us check for the velocity at Dry Weather Flow

(DWF), At Dry Weather Flow = q / Q = 1/3 = 0.333

From the given table, corresponding to the discharge ratio, we find, Depth ratio d/D = 0.40

Velocity ratio = v/V = 0.9022 (given)

Hence, the velocity developed at Dry Weather Flow = 0.9022 X 0.95 = 0.855 m/s.

This is more than 0.75 m/s and therefore satisfactory.

Hence we use 0.915 m diameter pipes as worked out.

(viii) A 25cm diameter sewer with an invert slope of 1 in 400 is running full. Calculate the velocity and rate of flow in the sewer. Is itself cleansing? Take n= 0.015.

Solution:

D =diameter of sewer = 25 cm = 0.25 m

Area of the sewer when running full,

$$, = \frac{\ ^2}{4} = \frac{(0.25)^2}{4} = 0.049\ ^2$$

$$h, = \frac{\frac{\ ^2}{4}}{\ } = \frac{\ }{4} = \frac{0.25}{4} = 0.0625\ .$$

$$, = \frac{1}{400}$$

N = 0.015

Using Manning's equation, we have,

Velocity of flow, $= \frac{1}{\ } \times\ ^{2/3} \times\ ^{1/2}$

$$= \frac{1}{0.015} \times (0.0625)^{2/3} \times \frac{1}{\sqrt{400}} = 0.525\ /$$

Discharge, Q = V.A = 0.525 X 0.049 m^3/s = 0.0257 m^3/s.

The velocity in the above sewer is 0.525 m which is slightly more than 0.45 m /s, which is the numerical theoretical value of the self-cleansing velocity. Hence the sewer can be termed as self cleansing at full flow, although such self cleaning should be obtained at partial flow also such as at half full. In this case, the velocity at partial flow is likely to be lesser than 0.45 m/s or so, and hence sewer will no longer remain self cleansing at partial flow.

Sewer appurtenances:

13. Discuss about the sewer appurtenances.

Sewer appurtenances are those structures which are constructed at suitable intervals along a sewerage system, which helps in efficient operation and maintenance. These include:

(xii) Manholes

(xiii) Drop Manholes

- Lamp holes
- Clean-outs
- Street inlets(Gullies)
- Catch Basins
- Flushing Tanks
- Grease and oil traps
- Inverted siphons
- Storm Regulators.

(xv) Manholes:

- Manholes are Masonry (or) R.C.C chambers.
- Purpose - Provides access into sewers for inspection, cleaning and maintenance works.
- Location – provided at every bend, junction, change of gradient (or) change of sewer diameter at suitable intervals along sewer lines.

Spacing – Depends on sewer sizes (Large diameter – Greater spacing).

Sewer size	Spacing in straight stretches
Dia < 0.3	45m
< 0.6m	75m
< 0.9m	90m
< 1.2 m	120m
< 1.5m	250m
>1.5m	300m

Minimum internal diameter (IS 1742-1960)

Depth	Minimum Size Specified
0.8m (or) less	0.75m x 0.75m
0.8m and 2.1m	1.2m x 0.9m
>2.1m	Circular chamber diameter 1.4m
	Rectangular 1.2m x 0.9m
Wall thickness 20-30cm:	20cm
a) 1.5m depth	
b) >1.5m depth	30cm

Classification of Manholes:

Shallow Manhole:

- It is used as inspection chambers.
- It depths is 0.7m t0 0.9m.
- It is constructed at start of branch sewer and at places of minimum traffic.
- Light cover is provided at the top.

(d) Normal (or) Medium Manhole:

- Depth=1.5m
- Square (1m x 1m) / Rectangular 91.2m x 1m) shape.
- Heavy cover is provided at the top.
- Unlike shallow manholes, the section does not change with depth.

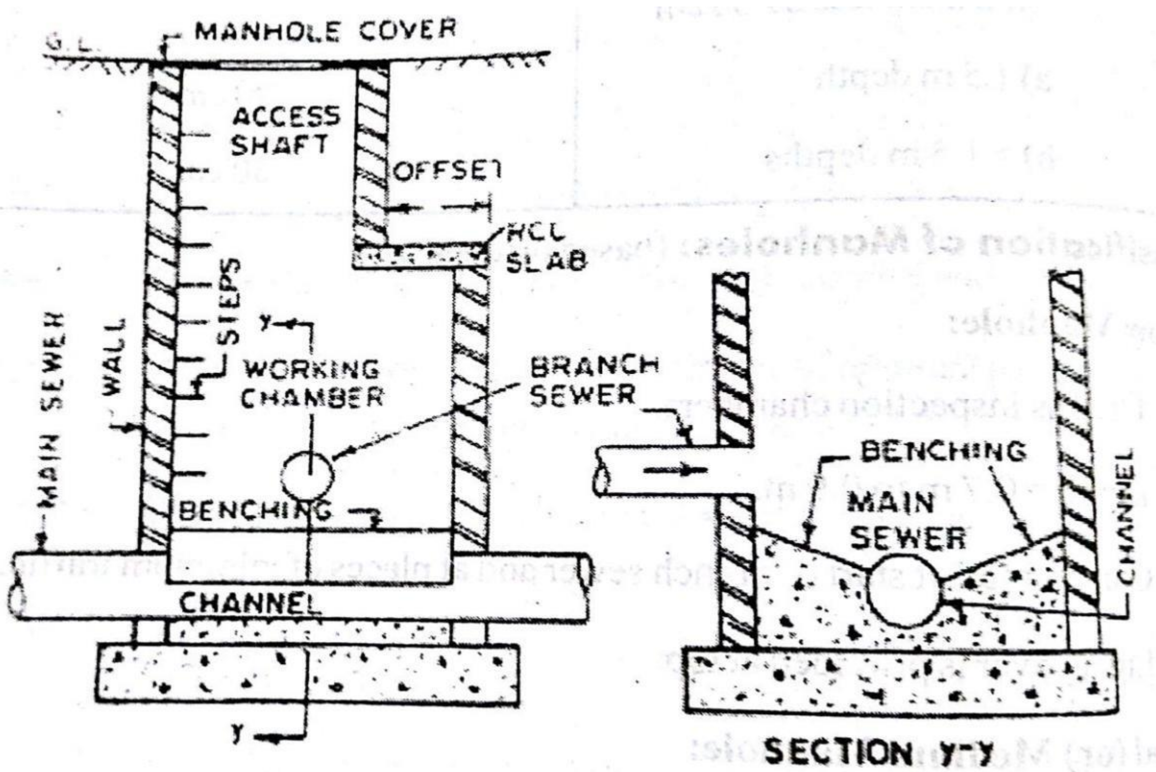
(iii) Deep manhole:

- Depth > 1.5m
- Section normally varies, the upper portion is reduced.
- Steps are provided to enable workers entry to bottom.
- Heavy cover is provided at the top.

Components parts of Manhole:

(i) Access shaft:

- It is the upper portion of deep manhole.
- For rectangular manhole – Size of access shaft is 0.75m x 0.6m.
- For Circular manhole – size is 0.6m to 0.7m.
- Depth of access shaft depends on the manhole depth.



Figureure.13:Deep manhole

(ii) Working chamber:

- It is the lower portion of manhole.
- It provided working space for inspection and cleaning operations.
- For rectangular manhole – Size of working chamber is 1.2m x 0.9m.
- For circular manhole – Size of working chamber is 1.2m diameter.
- The height of this chamber must not be less than 1.8m.

(iii) Benching/Bottom/Invert portion of Manhole:

- The bottom portion of the manhole is constructed in cement concrete.
- A semi-circular (or) U-shaped channel is generally constructed and the sides are made to slope towards it.
- The concreting is known as benching and facilities the entry of sewage from branch sewers into the main sewer.

(iv) Side walls:

- The side walls are made up of brick/stone masonry/R.C.C.
- The minimum thickness of the brick walls should be 22.5cm (9").
- The approximate thickness may be computed by using empirical thumb-rule.

$$= 10 + 4 \quad (\qquad)$$

Where,

t = thickness of wall in cm.

d = Depth of excavation in m.

- The thickness of R.C.C walls will however be much less as compared to that of brick wall, but R.C.C walls are costly than brick.

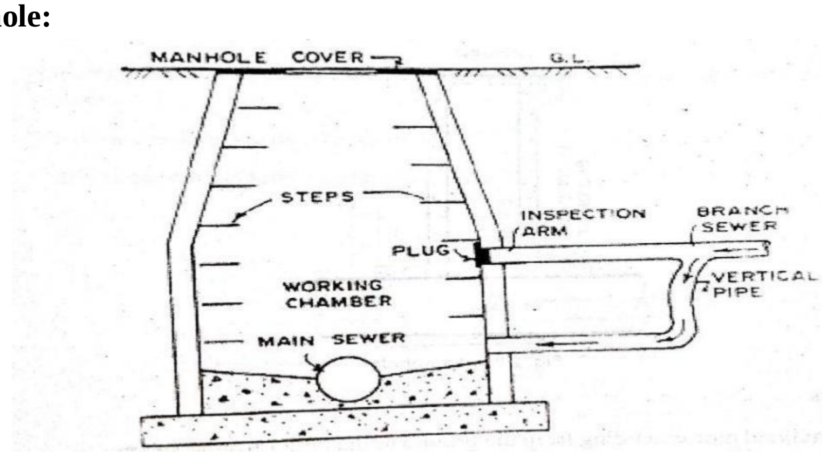
(v) Steps (or) Ladders:

- Steps are generally provided for descending into deep manholes.
- Steps are made of cast iron.
- It is placed at horizontal distance of about 20 cm and a vertical of about 30cm.
- Steps are embedded in walls.

(vi) Cover and frame:

- Cover is generally made of cast iron material.
- It is fixed at the top of the manhole embedded in pavements.
- The thickness of the frame is about 20 to 25 cm and the wide is 10cm.
- Circular or rectangular shape cover is provided of size 0.5 to 0.6m Ø or 0.6m x 0.45m respectively.
- The top surface of the cover also carries an arrow mark to mark the direction of flow of sewage.
- The weight of the cover and frame varies between 90 to 270kg which depends on traffic volume.

(2) Drop Manhole:



Figureure.14: Drop manhole.

- When a branch sewer enters a manhole by more than 05 to 0.6m above the main sewer, the sewage is generally not allowed to fall directly into the manhole, but is brought into it through a down pipe taken from the branch sewer to the bottom of the manhole.
- If the drop is only few meters, the down pipe can be kept sloping (at 45 deg. to the ground), and if the drop is more, a vertical pipe is found to be economical.

- The manhole, in which a vertical pipe, such as shown in Figure. is used, is called a drop manhole. Whereas, the one using an inclined pipe is called as a ramp.
- The construction of a drop manhole in place of an ordinary manhole in case a high leveled branch sewer enters a low leveled main sewer will thus serve the following purposes:

  (i) The steep gradients which otherwise would have to be given to the branch sewer (so as to bring it low will be avoided, thus avoiding a lot of work excavation).

  (ii) The sewage trickling into the manhole from the directly placed branch sewer is likely to fall on persons working in the manhole. This is avoided in drop manhole.
- The typical details of a drop manhole are shown in the Figure. the branch sewer is joined to the manhole through a vertical pipe.
- The sewage coming through the branch sewer drips in through the vertical pipe and trickles over the main sewer just above it as shown in the Figure.
- A plug is provided at the point where branch sewer if taken straight intersects the wall of the manhole.
- The length of the branch sewer between the vertical pipe and the plug is known as inspection arm and can be used for inspecting and cleaning the branch sewer after opening the plug.

Advantages:

- A steep gradient of branch sewer is avoided by providing vertical drop manhole.
- The cost of excavation is reduced.
- Sewage entering into the manhole is directly from branch sewers that are provided at certain height is likely to fall on the working personnel, which is prevented.

(3) Lamp holes:

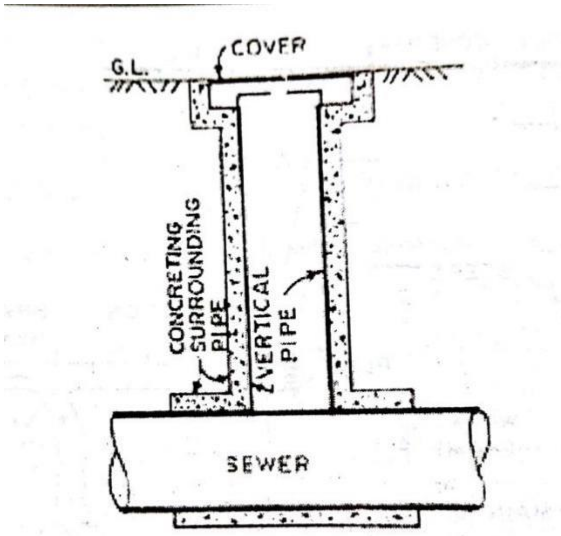
Openings or hole extending from ground to sewer line through T-Junction.

Purpose:

- For inspection.
- For flushing sewers.
- For ventilation of foul gases.
- These holes permit the insertion of lamp into sewers. The lamp light is viewed at upstream and downstream ends to find any obstructions.
- Lamp hole consists of a vertical pipe (20 to 30cm∅) made up of cast iron of stone-ware.
- The vertical pipe is surrounded by concrete.
- A manhole cover is provided at the top.

Location:

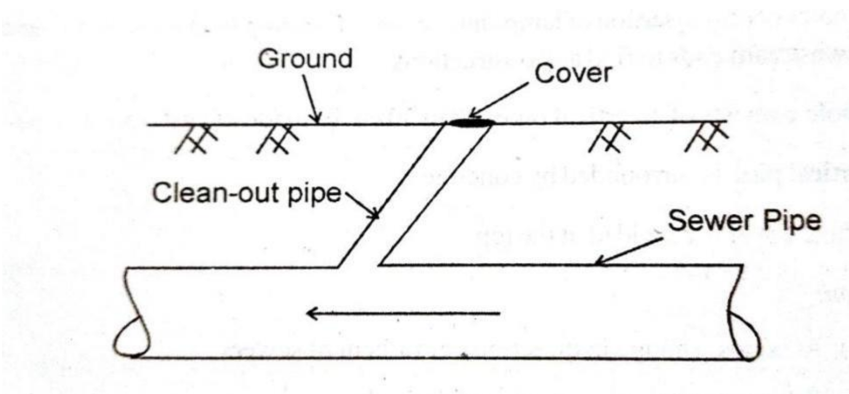
- At bends, change in direction or gradient of sewers.
- Where manhole construction is difficult.
- Where the manhole spacing is more.



Figureure.15:Lamp hole

(4) Clean-Outs:

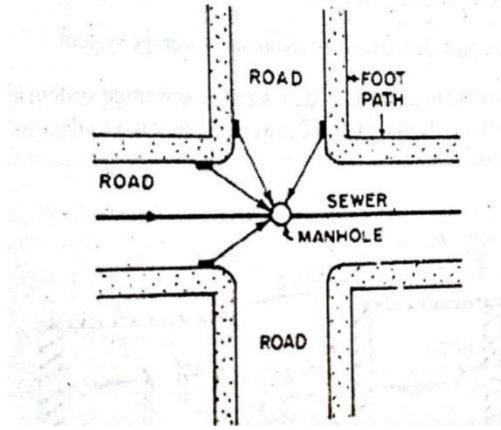
- An inclined pipe extending from the ground to the underground sewer.
- A clean out is used for cleaning sewer pipes – flushing sewers (laterals) to remove obstacles.
- A clean out is provided at the upper ends of lateral sewers in place of manholes.
- The functioning of a clean out is very simple.
- Removing the top cover and forcing water through the clean out pipe to lateral sewers to remove obstacle in the sewer line.
- If the obstruction is large, a flexible rod may be inserted and pushed forward and backward to remove the obstacles.



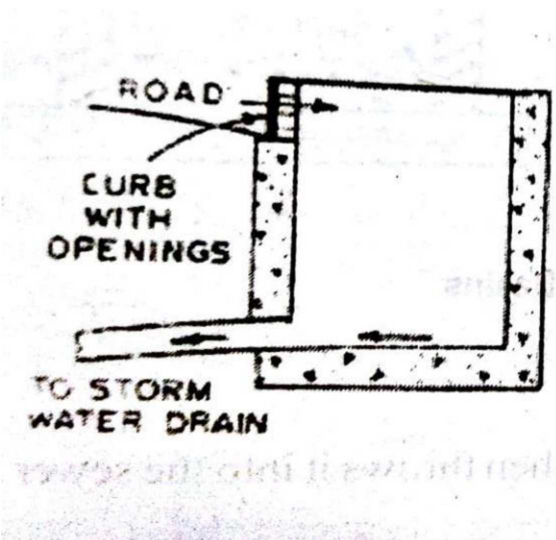
Figureure.16: Clean-outs

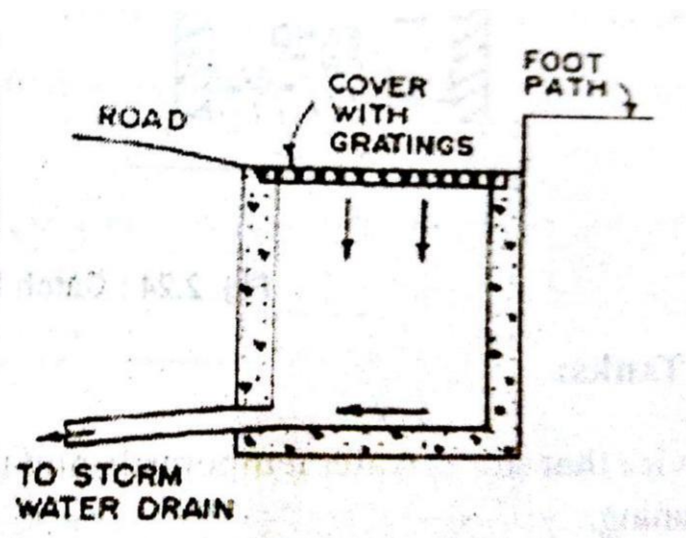
(5) Street Inlets (Gullies):

- Openings on road provided at lowest point which drains water into storm/Combined sewers.
- Provided at spacing of 30m to 60m.
- Gullies are connected to manhole by pipe lines.
- A street inlet is a simple concrete box with gratings (or) openings in vertical (or) horizontal direction.
- The inlet having vertical openings is vertical inlet and inlet having horizontal openings is horizontal inlets.



Figureure.17: Location of inlets at street intersections

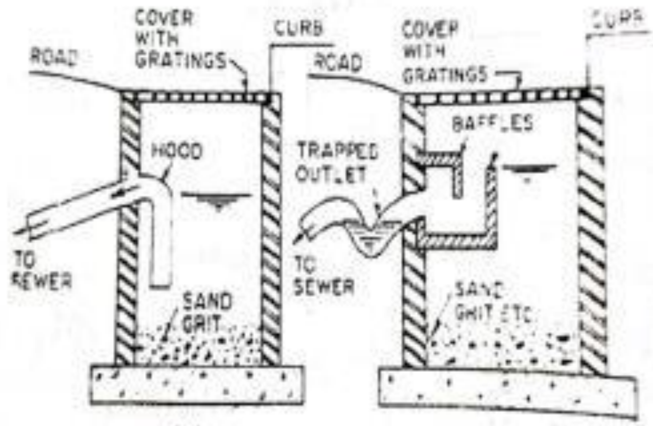




Figureure.18: Vertical inlet **Figureure.19: Horizontal inlet**

(6) catch basins (or) Catch pits:

- Catch basins are street inlets provided with small settling basins.
- Grit, sand, debris etc., do settle in these basins and their entry into the sewer is prevented.
- A hood is provided which prevents the escape of foul gases.
- Catch basins need periodical cleaning.
- Catch basins are provided only in old combined sewerage system.
- Catch basins are not required in modern separate sewerage system as the streets are paved and not much debris enters the sewers.
- Further the foul gases in storm water drains are also less.



Figureure.19: Catch basin

(7) Flushing Tanks:

- Device that stores water temporarily and then throws it into the sewer for flushing and cleaning.
- It can be operated either manually or automatically.
- Sewers that are laid on flat gradient or dead ends may not produce self cleansing velocity and may be frequently blocked.
- This can be cleaned with the help of flushing tanks.
- Quantity of water added in one flush is about 1600 liters.

Types:

(a) Hand operated flushing operation (Manual)

(b) Automatic Flushing Tanks

(a) Hand Operated Flushing Operation (Manual):

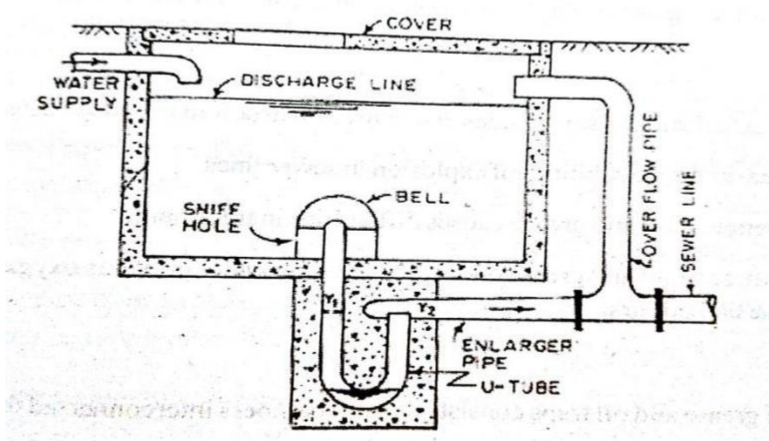
- A hope pipe is provided with once end connected to the nearest fire hydrant and another end is placed in the manhole to achieve flushing action.
- The outlet and inlet ends are closed by sluice or gate valve and the manhole is filled with water.
- When sufficient head builds up, both the inlet and outlet valves are opened and flushing is achieved.

(b) Automatic Flushing Tanks:

- Flushing action is achieved automatically at regular intervals.
- Entry of water is so regulated that the tank is filled in a period equal to the flushing interval.
- An overflow pipe is also provided to drain away excess water in case the tank overflows before the flushing action starts.
- The tank consists of a masonry (or) concrete chamber fitted with a water trap for filling water.
- A U-tube connects the chamber with the enlarged end of the sewer pipe.
- The bell cap has a sniff hole.

When water level is below the sniff hole, water level in the U-tube is at level [1 − 2] (along arm, short arm).

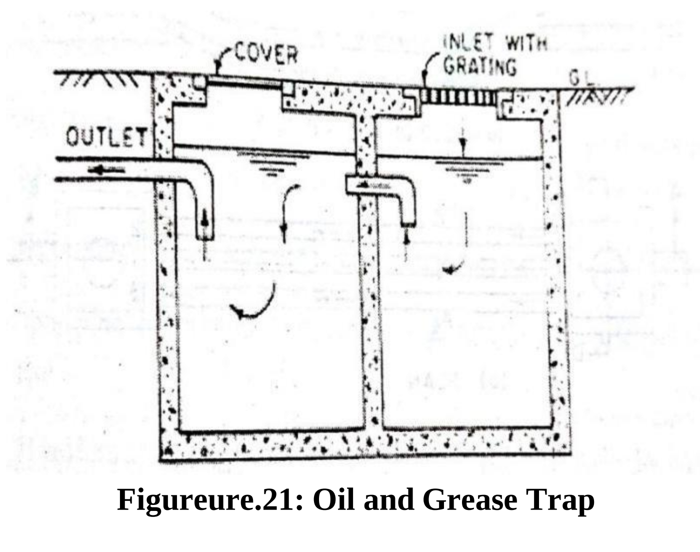
- As the water level in the tank rises above the sniff hole, the air caught up in the bell (compressed air) exerts pressure on water surface Y1 and the water level in the long arm is depressed.
- As water level rises in tank (up to discharge level) Y1 level in long arm of U-tube depressed more and more and the compressed air caught in bell is released through shorter arm. This siphonic action starts releasing water from the tank into the sewer till water level falls below sniff hole.
- When water level in tank falls down, air enters the bell cap and breaks the siphonic action.



Figureure.20: Automatic Flushing Tank

(8) Grease and Oil traps:

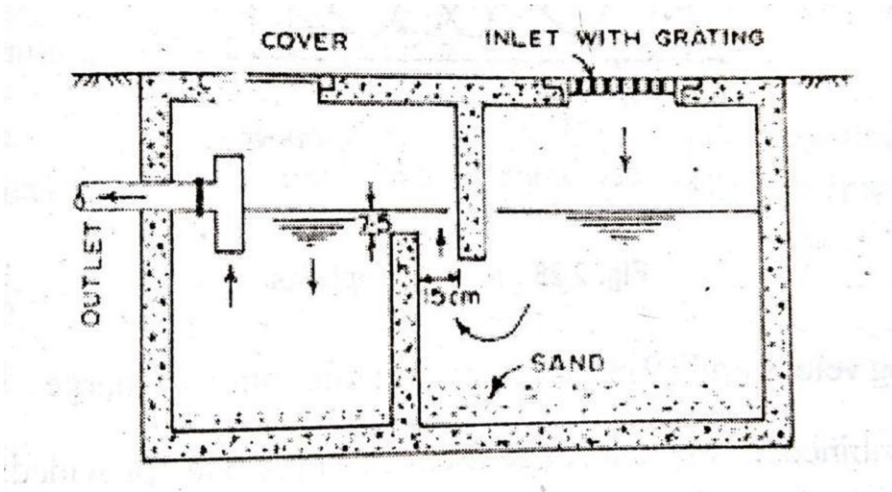
- Trap chambers are used to remove oil/grease from sewage, before entering sewer line.
- These are located near sources which generate grease and oil (automatic repair workshops, garages, kitchens of hotels, oil/grease industries etc.)



Figureure.21: Oil and Grease Trap

Necessity:

- Grease oil stick to sewer sides and cause obstruction or reduce sewer capacity.
- Increases the possibilities of explosion in sewer lines.
- Presence of oil and grease causes difficulties in treatment.
- Presence of oil and grease on surface of waste water prevents oxygen penetration and cause bad odors.

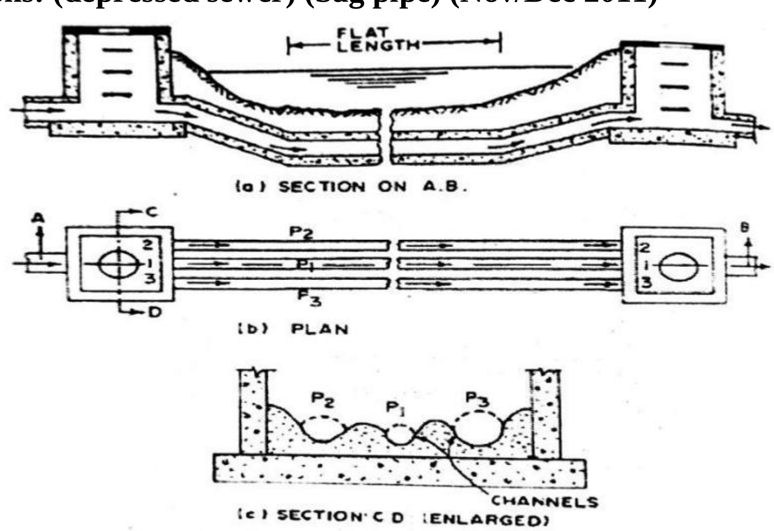


Figureure.22: Combined sand, Grease and oil trap

Principle:

- The grease and oil traps consist of two chambers interconnected through a pipe.
- The inlet is provided with a grating on the top.
- The oil and grease float on surface.
- The outlet is provided submerged to exclude oil and grease.
- Combined sand, grease and oil trap is also available.

(9) Inverted siphons: (depressed sewer) (Sag pipe) (Nov/Dec 2011)



Figureure.23: Inverted Siphon

- Inverted siphons are sewer sections that are provided lower than the adjacent sewers, (or) drops below the hydraulic gradient line (HGL).
- They are provided under the obstructions such as roadway, railway, stream, valley etc.
- Inverted siphons should be provided only in areas where other means of passing the obstructions are not feasible.
- They are siphon tubes or pipes made of cast iron or concrete.
- A Self cleansing velocity of 0.9m/s is achieved at minimum discharge.

- In the combined flow system, three channels or pipes are provided:
  a) Pipe 1: Carry minimum sanitary sewage (Channel 1)
  b) Pipe 2: Carry maximum sanitary sewage (Channel 2)
  c) Pipe 3: Carries combined flow during monsoons (Channel 3)
- When pipe/channel 1 overflows, the sewage enters channel 2 and 3.
- For a separate sewerage system, two channels are provided,
  a) Channel 1: For carrying minimum dry weather flow.
  b) Channel 2: For carrying maximum dry weather flow.

Designing siphon –Important points.

- The construction should be simple.
- Direction change should be easy and gradual.
- Self-cleansing velocity should be atleast 1m/s during minimum flow.
- Two or three parallel pipes are provided such that average flow happens in first pipe and any excess discharge (flow) goes to the second and third pipes.
- Selection of pipe size depends on both average and maximum flows.
- Total pipe length should consist of straight lengths and the length of falls, bends and rise.
- Head loss at bends, friction, silting and roughness should also be considered.
- Possibility of silting should be avoided by providing screens and grit (detritus) pits.
- Minimum diameter of siphon should be 15 to 20cm.
- Chambers should be provided with sufficient room for cleaning and maintenance.
- In the outlet chambers, any backflow of sewage should be prevented.

Demerits of siphons:

- Silting occurs because the down gradient pipe is not continuous and difficult to cleaning.
- Improper design of inlet chamber cause accumulation of floating matter and reduce efficiency.

(10) Storm water Regulator / Storm Relief Works:

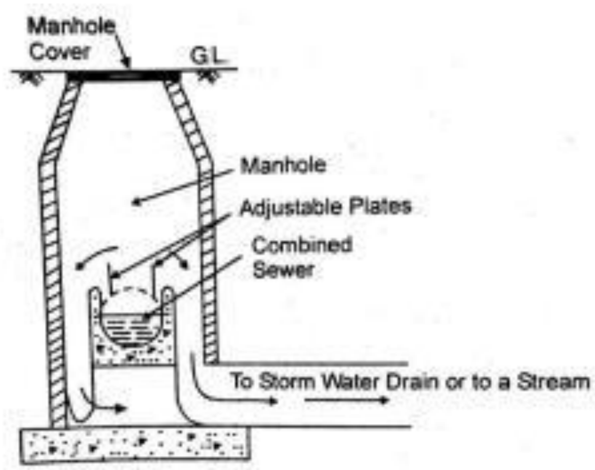
- Storm water regulators are provided in combined sewerage system to divert excess storm water into stream.
- These are overflow devices to prevent overloading of sewers, pumping stations, treatment plants etc.

Types:

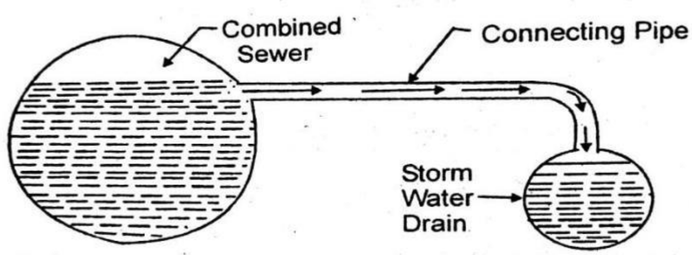
Overflow Weirs (Side Flow Weirs):

- Masonry chamber with overflow weir is the common type.
- Overflow weirs are located where sewer approaches a water course.
- Single acting (Single side) (or) double acting (double side) overflow weirs can be provided.

- Openings are provided at suitable height of combined sewer and joined to storm drains.
- Excess sewage flows to drains that are discharged to water course.
- Excess sewage overflows the combined sewer and enters channel, carrying storm water drains or into a stream.
- Adjustable plates are provided to prevent escape of floating matter.



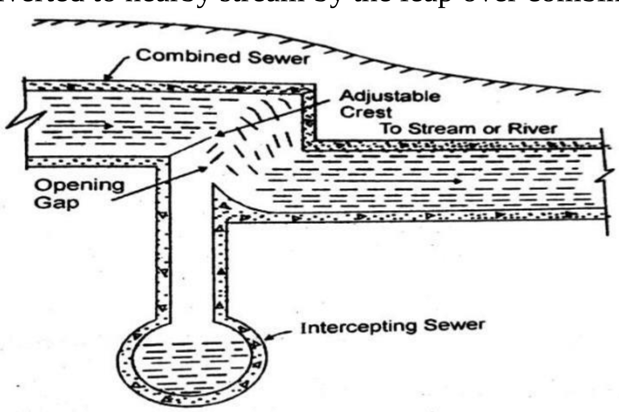
Figureure.24: Overflow weir



Figureure.25: Another type of overflow weir

Leaping Weir:

- An opening is provided at invert of storm drain (Combined sewer).
- Normal storm water flows in intercepting sewer.
- Excess flows are diverted to nearby stream by the leap over combined sewers.



Figureure.26: Leaping weir

14. What are the forces acting on Sewer Pipes? The forces acting on the sewer pipes are:

(i) Internal Pressure of sewage
(ii) Pressure due to External Loads
(iii) Temperature Stresses
(iv) Flexural Stresses

(i) Internal Pressure of sewage:

- The pressure exerted by the sewage from inside the pipe when running full is called internal pressure.
- Such a pressure may be exerted due to either surcharge or due to overflow of sewers flowing under gravity or it may be exerted in outfall sewer which has to flow full under pressure.

(ii) Pressure due to External Loads:

- Sewer pipes are mostly buried under the ground and placed in trenches which are back filled.
- The weight of the pipe, the weight of the backfill and the superimposed traffic loads if any, will then be transferred to the pipe.
- This will produce compressive stresses in the pipe material (when the pipe is flowing under no internal pressure) and the material may fail in compression.

(iii) Temperature Stresses:

- When pipes are laid above the ground, they are exposed to the atmosphere and are therefore subjected to temperature changes.
- They expand during day time and contract at night.
- If this expansion or contraction is prevented due to fixation or friction over the supports, longitudinal stresses are produced in the pipe materials.

(iv) Flexural Stresses:

- Sometimes, the sewer pipes may have to be carried supported between piers like beams.
- Similarly, sometimes the rain water etc., may wash off the ground from below the pipes resting on the ground thus exposing them like beams supported between the supports.
- Under all such circumstances, bending stresses get produced in the pipe, since pipe acts like a beam with loads resulting from the weight of the pipe, weight of the sewage in the pipe and any other superimposed loads.

Pumps, Selection of pumps and pipe drainage and pumping system for building

15. Explain in detail about the pumps and its type used for Pumping sewage? Necessity of pumping sewage:

- For lifting sewage from low lying areas [sewers run at higher elevation than the sources of sewage generation].
- In flat terrains, laying of sewers at deigned gradient requires large excavation and is expensive.
- To reduce the excavation cost, pumping is done at suitable intervals.

- Pumping is resorted to when outfall sewer is lower than the entrance of treatment works or receiving water bodies.
- For lifting sewage from basements of commercial buildings (since street sewers are higher than basement level of buildings).
- Instead of driving tunnel through ridges for sewer line, its economical to pump sewage into sewers laid across the slope of ridges.

Problems in pumping sewage:

- Sewage has foul characteristics.
- Suspended and floating matter in sewage clogs the pumps.
- Organic and inorganic waste in sewage cause corrosion and erosion of pump parts and reduce their life.
- Disease producing organisms (pathogens) in sewage cause health hazard to working personnel.
- Higher reliability pumps are required to prevent flooding nuisance.

Requirements of sewage lifting pumps:

(a) Pump capacity

- It must be able to handle peak flows.
- Two or more pumps and power sources are required.

(b) Clogging aspects.

- Special pumps which do not clog due to the floating and suspended solids in sewage are used.
- Pumps should be accessible for cleaning and removal of obstructions.

Types of pumps:

The different types of pumps used for sewage and storm water pumping area as follows:

(1) Centrifugal Pumps

(2) Reciprocating Pumps

(3) Propeller or axial flow pumps

(4) Air Pressure pump or

Ejectors. **l. Centrifugal pump:**

- Centrifugal pumps are most widely used for pumping sewage and storm water.
- These can be easily installed in pits and sumps, and can easily transport the suspended matter present in the sewage without getting clogged too often.
- These pumps works on the principle of centrifugal force. They essentially consists of two main parts.

  (i) Casing

  (ii)

  Impeller.
- There are three classes of centrifugal pumps

  (a) Disintegrator Pumps

  (b) Full way Pumps

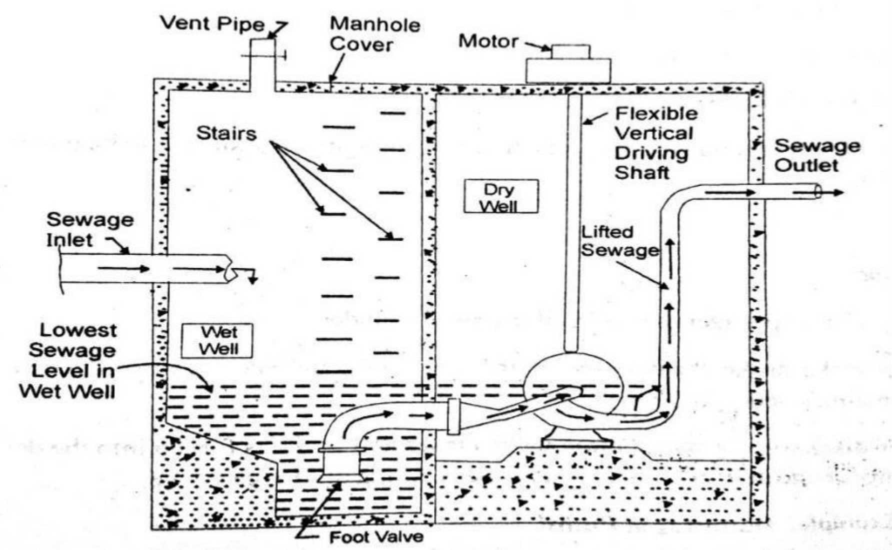
  (c) Freeway pumps.
- The disintegrator pumps are provided with conical shaped impeller having sharp edged groves, along with fixed knives set against the impeller which cuts the solids and disintegrated particles are discharged to sea.
- Full way pumps can pass down solids up to 1500 mm diameter through the pump casing into the rising main without getting chocked.

- Free way pumps are used when sewage containing solids of more than 150 mm diameter are required to pass through the pump casing.
- Centrifugal pumps can be classified under

  (a)Axial flow pumps

  (b) Mixed Flow pumps

  (c) Radial Flow Pumps.



Figureure.27: Typical centrifugal pump installation for sewage pumping.

2. Reciprocating pumps:

- They are more or less not in use in modern sewage pumping station since they are liable to be clogged by solids of fibrous material, even though sewage may have passed through coarse screens.
- Also their initial cost is higher and efficiency is lower than those of a centrifugal pump.
- However, in cases where it is required to deal with difficult sludge and where large quantity is to be pumped against low heads, these pumps may be used after passing the sewage through screen with 20 mm spacing.
- Reciprocating pumps used for pumping sewage are generally of two types.

  (a) Ram Type

  (b) Impeller Type.

(a) Ram Type:

- A piston or plunger moves inside a closed cylinder.
- On intake stroke, the liquid enters the cylinder through suction valve. The delivery valve remains closed.
- On discharge stroke, suction valve closes and liquid is forced into the delivery pipe through the delivery valve, which opens during discharge stroke.

(b) Impeller type:

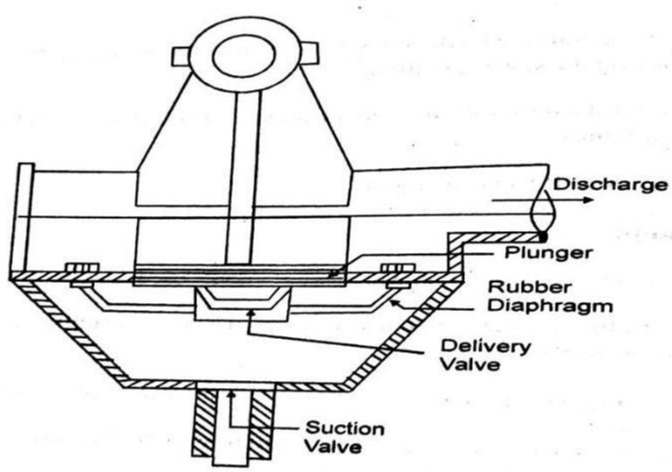
- It draws water through the inlet guide vanes and discharges through outlet guide vanes and this action is somewhat similar to that of ship propeller.
- Axial flow screw pump is an example of this type of pump.

3. Propeller or Axial flow pumps:
(b) Impeller type:

- In this pump, a multiple blade screw rotor or propeller moves vertically inside a pump casing, causing the sewage to lift up.
- The propeller draws water through the inlet guide vanes and discharges through the outlet guide vanes.
  Example: Axial-flow screw pump.

Diaphragm pump:

- Ram type reciprocating pump, which is commonly used.
- A piston or plunger is attached to the center of a circular rubber diaphragm, the outer edge is bolted to flange on pump.
- The up and down motion of plunger increases and decreases the capacity of pump.
- When the piston moves upward, the liquid flows into the pump through the suction valve, the delivery valve remains closed.
- When the piston moves downward, the suction valve closes and liquid is forced through delivery pipe by opening delivery valve.
- It is a simple, durable pump that needs no priming but may wear out and need replacement.

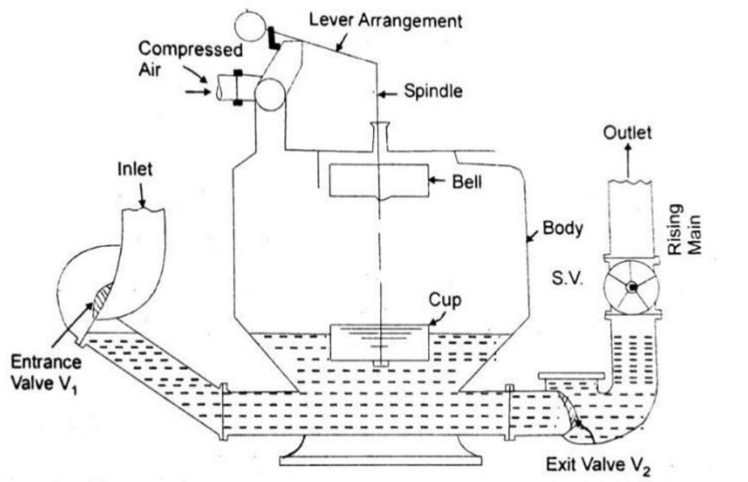


Figureure.28: Diaphragm pump

4. Air pressure pumps or Pneumatic ejectors:

- It is used for pumping smaller quantities of waste waters.
- Its works under the action of compressed air.
- It consists of an air-tight into which waste flows by gravity.
- The waste water is forced out automatically whenever sufficient waste water has accumulated to raise a float, which opens the compressed air inlet valve.
- A typical air ejector called **shone's ejector** consists of a cast iron chamber with a spindle having an upper and a lower cup.
- Two check valves V1 and V2 are provided at the entrance and exit points.
- The ejector chamber rests on a seat.
- A lever arrangement with a counter-weight is provided, so as to open the compressed air inlet valve (V3).
- The waste water enters the ejector chamber through V1 when exit valve V2 and compressed air inlet valve V3 remain closed.

- As waste water rises in chamber, the air from chamber escapes through exhaust.
- When waste water level reaches bottom of upper cup, air inside gets entrapped and exerts vertical pressure and lifts up the spindle closing the exhaust and opening compressed air inlet valve (V3).
- The air under pressure entering the chamber from valve (V3) forces the waste water from inside the chamber to rises up in the outlet pipe by opening the exit valve (V2).
- At this stage, the valves V2 and V3 remain open, but V1 is closed.
- The waste water is thus lifted up and discharged from the outlet, till the level of waste water falls below the bottom of upper cup.
- At this stage, exhaust opens and compressed air inlet valve (V3) closes.
- The exit valve V2 closes and entrance valve V1 opens to again admit the waste water.



Figureure.29: Shone's Pneumatic Ejector

Advantages:

- Automatic operation and require least supervision.
- It is used where centrifugal pumps get clogged.
- Only few parts come in contact with sewage.
- Ejectors do not get clogged.
- Economical where smaller quantities of sewage are required to be lifted.

Disadvantages:

- Low efficiency-15%.

<u>One pipe and two pipe system</u>

16. With help of neat sketch discuss various systems of plumbing used for drainage.

Following are the four principal systems adopted in plumbing of drainage work in a building:

(i) Two Pipe System
(ii) One Pipe System
(iii) Single Stack System
(iv) Partially ventilated single stack system

(i) Two Pipe System:

- This is the best and the most improved type of system of plumbing. In this system, two sets of vertical pipes are laid (i.e.,) one for draining night soil and the other for draining sullage.
- The pipes of the first set carrying night soil are called soil pipes and the pipes of the second set carrying sullage from baths etc., are called sullage pipes or waste pipes.
- The soil fixtures such as latrines and urinals are thus all connected through branch pipes (laterals) to the vertical soil pipe.
- Whereas, the sludge fixtures such as baths, sinks, wash basins are all connected through branch pipes to the vertical waste pipe.
- The soil pipe as well as the waste pipe are separately ventilated by providing separate vent pipes (or) antisiphonage pipes as shown in the Figure. this arrangement, thus requires four pipes.

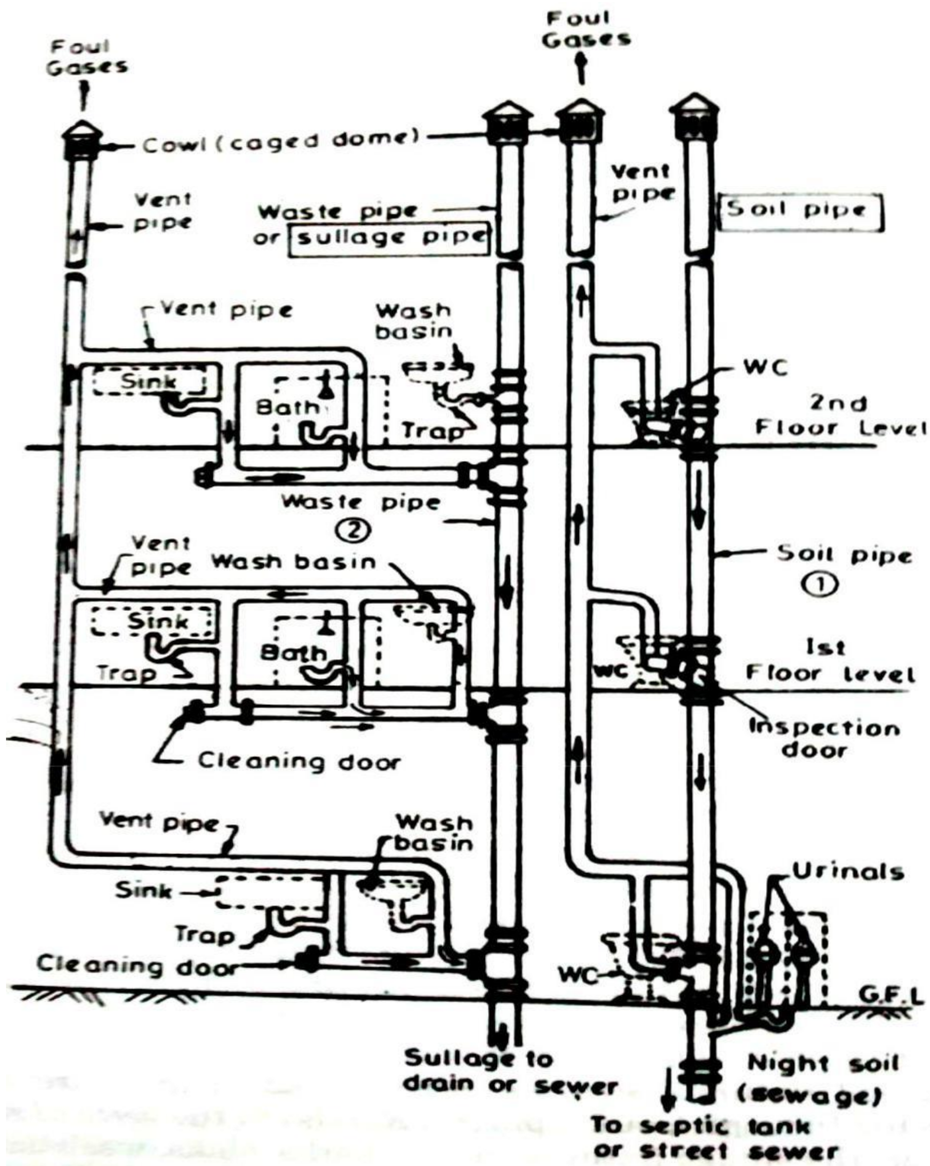


Figure.30:Two Pipe System

(ii) One Pipe System:

- In this system, instead of using two separate pipes (for carrying sullage and night soil as is done in the above described two pipe system), only one main vertical pipe is provided, which collects the night soil as well as the sullage water from their respective fixtures through branch pipes.
- This main pipe is ventilated in itself by providing cowl at its top, and in addition to this, a separate vent pipe however is also provided as shown in Figure.

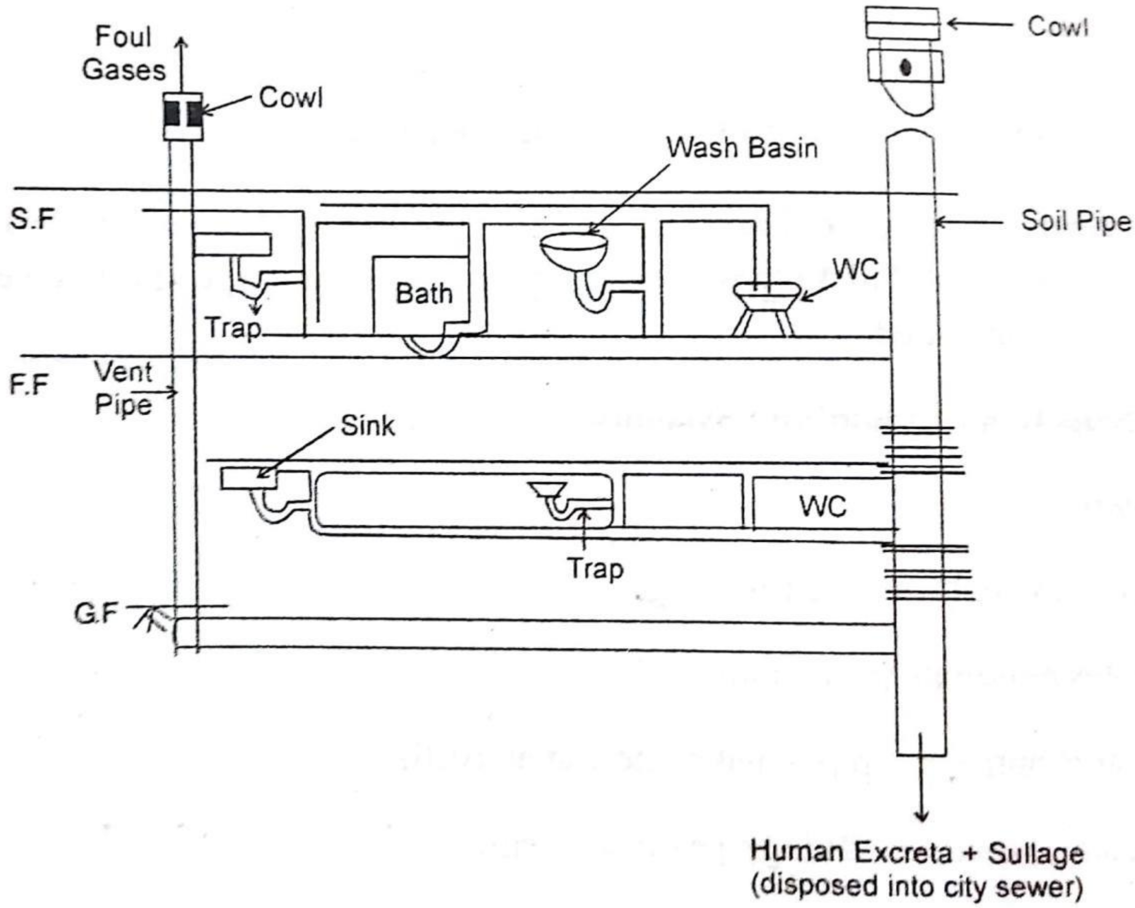


Figure.31. One Pipe System

UNIT-2
PRIMARY TREATMENT OF SEWAGE

Objective of wastewater treatment:

1. State the objectives of preliminary treatment.

- To remove solids in waste water.
- To prevent water pollution.
- To prevent environmental degradation.
- To avoid damage to soil structure.
- To minimize the discharge of wastewater into the environment

Unit Operations and Unit Processes:

(vi) Enumerate various unit operations and processes treatment systems used to remove major contaminants from wastewater.

S.No.	Contaminant	Unit Operation / Unit Processes
1	Suspended solids	(i) Plain Sedimentation (ii) Screening and Communition (iii) Filtration (iv) Floatation (v) Coagulation /Sedimentation (vi) Land treatment systems
2	Biodegradable Organics	(i) Activated Sludge Processes (ii) Trickling Filter (iii) Rotating Biological Contactor (iv) Lagoons (v) Intermittent sand filtration (vi) Land treatment systems (vii) Physical –chemical system
3	Pathogens	(i) Chlorination, (ii) Hypochlorination (iii) Ozonation (iv) Land treatment systems
4	Nitrogen	(i) Nitrification and Denitrification variations of suspended growth and fixed film processes (ii) Ammonia Stripping (iii) Ion Exchange Process (iv) Break point chlorination (v) Land treatment systems
5	Phosphorous	(i) Carbon Adsorption (ii) Lime Coagulation / Sedimentation

		(iii) Biological –Chemical Phosphorous removal (iv) Land treatment systems
6	Refractory Organics	(i) Carbon Adsorption (ii) Tertiary ozonation (iii) Land treatment systems
7	Heavy Metals	(i) Chemical Precipitation (ii) Ion Exchange (iii) Land treatment systems
8	Dissolved Inorganic Solids	(i) Ion Exchange (ii) Reverse Osmosis (iii) Electrodialysis

3. What do you understand by Physical Unit Operation? Write a note on applications of various physical unit operations employed in wastewater treatment.

- These operations used for the treatment of wastewater in which change is brought about by means of or through the application of physical forces are known as unit operations.
- Because they were derived originally from observations of the physical world, they were the first treatment methods to be used.
- Physical unit operations form the basis of most process flow diagrams.

The unit operations most commonly used in wastewater treatment includes:

(i) Screening	(ii) Comminution	(iii) Flow equalization
(iv) Mixing	(v) Flocculation	(vi) Sedimentation
(vii) Floatation	(viii) Elutriation	(ix) Micro-screening

Applications of Physical Unit Operation in Wastewater Treatment

S.No.	Operation	Applications
1	Screening	Removal of coarse and settleable solids by surface straining
2	Comminution	Gridding of coarse solids
3	Flow Equalization	Equalization of flow and mass loading of Biological Oxygen Demand and Suspended solids

4	Mixing	Mixing of chemicals and gases with wastewater and maintain solids in suspension
5	Flocculation	Promotion of the aggregation of small particles into large particles
6	Sedimentation	Removal of settleable solids and thickening of sludge
7	Floatation	Removal of finely divided suspended solids and particles with densities close to that of water. Also thickens biological sludge.
8	Filtration	Removal of fine residual suspended solids remaining after biological or chemical treatment
9	Micro-screening	Same as filtration. Also removes algae from stabilization.

 What is meant by chemical unit processes? Enlist the applications of various chemical unit processes employed in wastewater treatment.

Chemical unit processes are those in which removal of contaminants are brought about by chemical activity. In the field of wastewater treatment, chemical unit operations are usually used in conjunction with physical unit operations and biological unit processes

Chemical unit processes are additive processes whereas physical unit operations and biological unit processes are subtractive processes. This is an inherent disadvantage of chemical unit processes.

The following are the chemical unit processes commonly used for wastewater treatment

(i) Chemical Precipitation	(ii) Gas Transfer	(iii) Adsorption
(iv) Disinfection	(v) Combustion	(vi) Ion Exchange
(vii) Electrodialysis	(viii) Dechlorination	(ix) Miscellaneous

<u>Application of Chemical Unit Processes in Wastewater Treatment</u>

S.No.	Processes	Application
1	Chemical Precipitation	Removal of phosphorous and enhancement of suspended solids removal in primary sedimentation
2	Gas Transfer	Addition and Removal of Gases
3	Adsorption	Removal of Organics
4	Disinfection	Disinfection of disease causing organisms.
5	Dechlorination	Removal of total combined chlorine residuals
6	Miscellaneous	Achievement of specific objectives in wastewater treatment

- **Write a detailed note on biological unit processes employed in wastewater treatment?**

Biological unit processes are those in which removal of contaminants are brought about by biological activity.

The objectives are to coagulate and remove the non settleable colloidal solids and to stabilize the organic matter.

Generally,the wastewaters from the sources are (i) Domestic, (ii) Agricultural return and (iii) Industrial wastewater.

- For domestic wastewater the objective is to remove various nutrients specially nitrogen and phosphorous which having capable of stimulating the growth of aquatic plants.
- For industrial wastewater the objective is to remove or reduce the concentration of organic and inorganic compounds which may otherwise be toxic.
- Biological processes are classified by the oxygen dependence of the primary microorganisms responsible for wastewater treatment.
- Biological unit processes are classified in the following heads (i) Aerobic Processes (ii) Anaerobic Processes and (iii) Aerobic –Anaerobic Processes

(v) Aerobic Processes:

- Aerobic processes are biological treatment which occurs in the presence of dissolved oxygen.
- The bacteria that can survive only in the presence of dissolved oxygen are known as obligated aerobes.
- The aerobic process includes the following:

(i) Activated Sludge Process
(ii) Aerobic Stabilization Pond
(iii) Trickling Filter
(iv) Aerated Lagoons.

(ii) Anaerobic Processes:

- Anaerobic treatment involves the decomposition of organic or inorganic matter in absence of molecular oxygen.
- They include (i) Anaerobic Sludge Digestion, (ii) Anaerobic Contact Processes (iii) Anaerobic Lagoons.

(iii) Aerobic –Anaerobic Processes:

Stabilization of waste is brought by a combination of aerobic, anaerobic and facultative bacteria.

(i) Gas transfer-Aeration
(ii) Ion transfer
   a) Chemical coagulation
   b) Ion exchange
   c) Adsorption
(iii) Solute stabilization
   a) Chlorination
   b) Liming
(iv) Solids transfer
   a) Screening
   b) Filtration
   c) Sedimentation
(v) Solids concentration/Stabilization.
   a) Sludge thickening
   b) Sludge digestion
   c) Chemical conditioning of sludge
   d) Elutriation.

Methods of treatment of waste water:

6. What are the various methods of treatment of wastewater? Distinguish clearly between them.

Methods of treatment of Wastewater:

1. Conventional Methods
(i) Preliminary Processes
(ii) Primary Treatment
(iii) Secondary (or) Biological Treatment

2. Advanced Wastewater Treatment
(i) Tertiary Treatment

Conventional Methods

(i) Preliminary Processes

- Pumping, Screening and Grit Removal.
- Remove floating material and heavy inorganic solids.
- Remove particles which otherwise interfere in subsequent processes.

- Reduces BOD load about 5 to 10%.
- Screens, Grit, Comminutors, Floatation, Flow measuring units, Pumping, Pre-aeration.
- Sometimes for high strength municipal wastewaters, chemicals added to prevent excess loads on secondary treatment processes.

(ii) Primary Processes

- Larger suspended solids are removed from wastewater.
- Organic and Inorganic solids are removed.
- Consists of Sedimentation and Chemical Coagulation.
- Primary clarifiers to remove fine suspended solids or precipitate phosphorus.
- They remove particles with settling rate of 0.3 to 0.7 m/s.
- Often stabilized by anaerobic digestion.
- Septic tank and Imhoff tanks incorporate organic solids separation and digestion in a single unit.

(iii) Secondary (or) Biological Treatment

- Removes soluble and colloidal organic matter which remains after primary treatment.
- Removes biodegradable organics and suspended solids.
- Maintains large active mass of bacteria Classification:
  - (a) Attached Growth Processes
  - (b) Suspended growth Processes
  - (c) Combined growth Processes

(a) Attached Growth Processes:

- Solid medium upon which bacterial solids are accumulated.
- It converts organic matter to gas and cell tissue.
- Includes sand filter, Trickling Filter(TF), Rotating Biological Contactor (RBC), Packed bed Reactors, Anaerobic Ponds, Fixed Film Denitrification.

(b) Suspended growth Processes:

- Bacteria in suspension by mechanical mixing.
- In most processes the required volume is reduced by returning bacteria from the secondary clarifier in order to maintain a high solid concentration.
- It includes Activated Sludge Process (ASP) [conventional, continuous flow stirred tank, step aeration, modifies serration, contact stabilization, extended aeration, oxidation ponds], Suspended growth Nitrification and Denitrification, Aerated Lagoon, Sludge Digestion Tank.

(c) Combined growth Processes:

- Both surface and suspended growth process.
- Sequence will be (i) Trickling Filter ,Activated Sludge Process (ii) Facultative Lagoons.

- All are secondary units.
- 90to 95% BOD is removed.

2. Advanced or Tertiary Wastewater Treatment

- In this process, pollutants not removed in before treatment.
- Typical of them are Phosphorus, Nitrogen, algae growth.
- Wastewater can be reused after this treatment process.
- Some of the process involved is Chemical Clarifier, Filtration, Activated carbon, Disinfection, Nitrogen, Phosphorous removal and Demineralization.

Septic tank with dispersion

7. Describe the on-site sanitation methods (or) with the help of neat sketch discuss the components parts, functioning, advantages and disadvantages of a septic tank. (Or) Explain about septic tank and advantages and disadvantages of septic tank, design consideration of septic tank.

- It is a primary treatment unit.
- It is similar to a horizontal flow primary sedimentation tank which directly admits raw sewage.
- It is a combined sedimentation digestion tank.
- It has larger capacity and extra provision for digestion and storage of settled sludge.
- It has longer detention time of 12 to 36 hours.
- It is provided in areas where sewers are not laid, in individual houses, small communities and institutions (hospitals, schools) with population not more than 300.

Construction:

- It is a rectangular tank constructed of brick or stone masonry or concrete with water tight cover.In highest building, the ventilation pipe is extended at least 2m above the top of the building which is used to remove foul gases.
- The tank may have one or two compartments.
- A partition wall is provided at $2/3^{rd}$ length of the tank.
- Inlet and outlet are located at opposite ends.
- Baffles are provided at both inlet and outlet.
- The floor tank is sloped to the outlet end.

- When raw sewage is allowed inside the septic tank, the solids settle to the tank bottom due to the long detention time.
- The settled sludge undergoes anaerobic decomposition by the anaerobic micro-organisms and gives rise to septic conditions.
- The digestion process releases foul gases (H_2S, CH_4, CO_2) which escapes through the ventilation shaft.
- There is appreciable reduction in the sludge volume.
- But the effluent produced foul in nature, it should be disposed either by sub-surface irrigation or in soak pits or in cesspools or treated in Trickling filters.

- The scum (oil and grease rising to surface) and sludge are retained in tank for several months.
- It is periodically removed either half yearly or yearly (Once in 6 to 12 months) but in no case cleaning period should not be exceed 3 years.

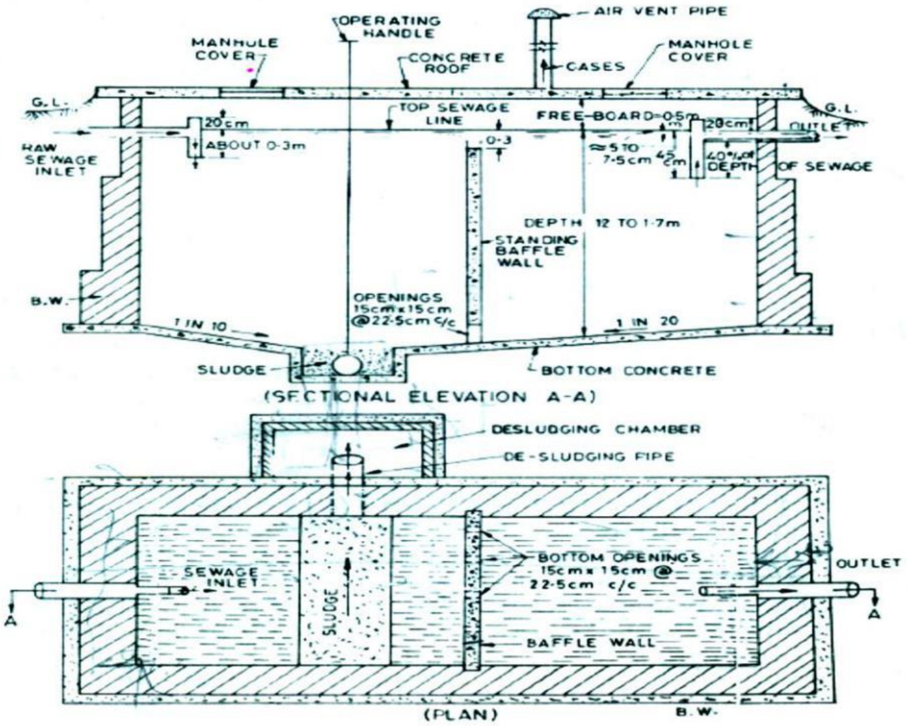


Figure.1: Cross-section of septic tank

Design considerations:

Function of a septic tank:

(i) Sedimentation – Removal of suspended solids from sewage by gravity settling.

(ii) Digestion of settled sludge – Reduction in sludge volume.

(iii) Storage of digested sludge and scum – Between successive cleaning intervals.

Tank dimensions are fixed based on these three functions.

(i) Sedimentation:

- Surface area = $0.92 m^2$ for 10 lpm peak flow rate.
- Depth= 25 to 30 cm.
- Length= 2 to 4 times width.
- Sludge digestion:
- A suspended solid entering the tank per capita is assumed as 70g/day.
- Volume of fresh sludge = $0.00083\ m^3$/capita/day.
- Volume of digested sludge = $0.0002\ m^3$/day.
- Volume of digestion zone = $0.000515\ m^3$/capita/day.
- Digestion period at 25^0c for average sludge = 63 days.
- Capacity of sludge digestion = 6 x 0.000515 = $0.032\ m^3$/capita.

(iii) Storage of digested sludge and scum: Sludge storage capacity = 0.002 x 365 x 100

= $7.3\ m^3$/ 100 persons for a cleaning interval of 1 year.

Total capacity of tank = Sedimentation + Sludge Digestion + Storage + Free Board(30cm) + Depth of sludge (25 to 50 mm).

Recommended size of septic tank

No. of Users	Length (m)	Breadth (m)	Liquid Depth (m) (Cleaning interval of)	
			2 years	3 years
5	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
15	2.0	0.90	1.3	2.00
20	2.3	1.10	1.3	1.80

Estimated peak discharge for residential housing colonies

No .of Users	No .of Households	No .of Fixture Units	Probable peak discharge (lpm)
100	20	40	240
150	30	60	360
200	40	80	480
300	60	120	720

Advantages of septic tank

- Easy construction.
- No maintenance problems.
- No skilled supervision or attention is required.
- The cost is reasonable in rural and urban areas, where no sewage system has been laid.
- Considerable reduction in suspended solids and Biological Oxygen Demand from sewage.
- Sludge production is less.
- The effluent from the septic tank can be disposed on land (or) in a soak pit without much trouble.
- They are best suited for isolated rural areas, and for isolated hospitals, buildings etc.

Disadvantages of septic tank

- Effluent has foul smell and high BOD, requires treatment before disposal.
- Tanks are large in size and uneconomical.
- Leakage of gases from septic tank may cause bad smell and environmental pollution.

- Periodical cleaning, removal and disposal of sludge remains at tedious problem.

8. Discuss various methods of disposal of tank effluent. (Or) Explain how the effluent from a septic tank is being disposed?

- The effluent coming out from a septic tank is not better than the effluent of an ordinary sedimentation tank.
- It contains large amount of putrescible organic matter (200 to 250 mg/l) and the BOD is quite high (100 to 200 mg/l)
- This effluent should therefore be disposed of carefully so as to cause minimum nuisance or risk to the health of the people.
- The following three methods of disposal of septic tank effluent are usually adopted.

(i) Soil absorption system
(ii) Biological Filter
(iii) Up flow Anaerobic Flow

(i) Soil Absorption System:

- The soil absorption system involves the disposal of effluent on the land.
- It can be adopted only, when sufficient land is available.
- This is adopted in porous soils where percolation rate is less than 25 minutes/cm and the water table is below 180 cm from ground level.
- Total subsurface soil area required for soak pits/dispersion trenches.

Maximum rate of effluent, $= \frac{130}{\sqrt{}}$

Where,

Q = Maximum rate of effluent application in

lpd/m^2. t = Standard percolation rate of soil in

minutes/cm.

Types of soil absorption system:

(a) Seepage Pit or Soak Pit
(b) Dispersion Trench

(a)Seepage Pit or Soak Pit:

- It is a circular shape pits.
- It preferred in low water table areas.
- Availability of land is less.
- Where porous layer is beneath impervious layer.
- It dimensions is 1m in length and the depth is below invert level at 1m.
- It should be covered at the top and the top raised above ground level to prevent damage by flooding.

- It is lined or unlined and filled with bricks or aggregates.

(b) Dispersion trenches:

- Effluent is distributed into large area of subsoil through open-jointed perforated drains housed inside dispersion trenches.
- It is used in areas, where percolation rate is not greater than 60 minutes.
- These are narrow and shallow trenches of 0.5 to 1m deep, and 0.3 to 1m width.
- Open-jointed earthen / concrete pipes of 70 to 100mm in diameter which are laid in trenches over a bed of 15 to 25cm crushed stone or gravel.
- Maximum length of trench – 30m.
- Spacing of trenches – 2m.
- One distribution box is provided for 3 to 4 trenches.

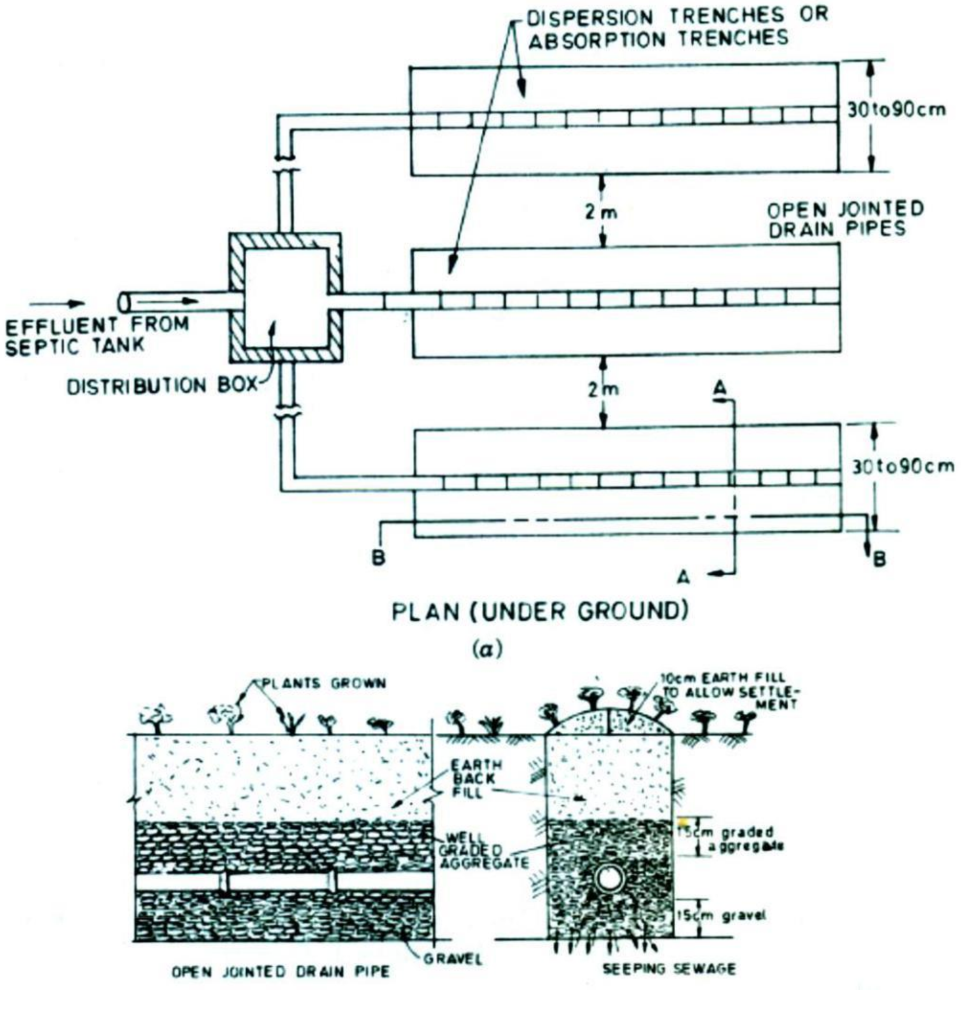


Figure.2: Absorption trench method of septic tank effluent.

(ii) Up flow Anaerobic Filters:

- Septic tank effluent undergoes secondary treatment in up flow filters.

- It is a submerged filter with stone media, 0.6 to 1.2m deep.
- Effluent is introduced from bottom of trench.
- Microbial growth happens on the stone media.
- Capacity = 0.04 to 0.05m^3 per capita (or) 1/3rd to 1/2 liquid capacity of septic tank.
- Its efficiency of BOD removal is 70%.

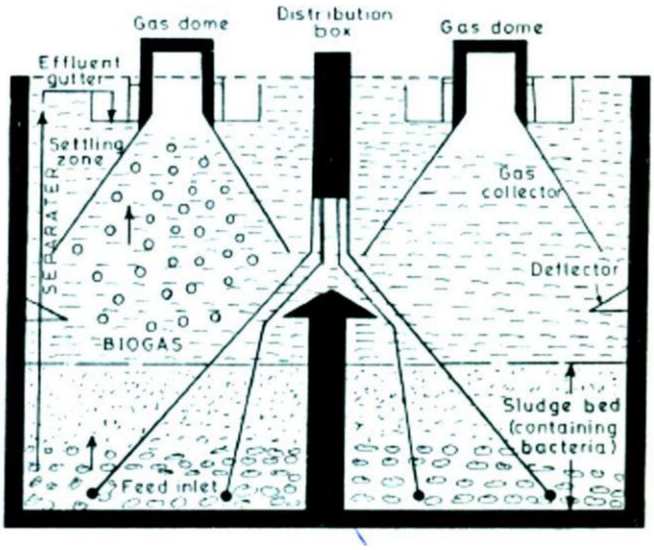


Figure.3:Upflow Anaerobic Filters

Advantages

- High stabilization – clear and odour free effluent.
- Little sludge is produced.
- Low capital and operating cost.
- Low loss of head.

(iii) Biological Filters

- It is similar to trickling filters.
- It is used in impervious soils with slow percolation rate > 60 minutes.
- Septic tank effluent is sprayed on filter by rotary distributors.
- A coarse stone 0.9m to 1.4m thickness is used as filter media.
- Microbial film grows on filter media requires oxygen which is supplied by the under drains connected to air vents.

9. Design a septic tank for an on-site sanitation of a housing colony with 120 populations. Assume suitable design criteria and draw a neat sketch of the designed tank.

Population of the colony = 150 persons.

Quantity of water supplied = Per capita water demand x Population

= 120 *l*pcd x 120 persons

= 14,400 *l*/d.

Quantity of sewage produced, Q = 0.8 x 14,400

Q = 11,520 *l*/d.

Assuming detention period to be 24 hours, we have,

Quantity of sewage produced during the detention period (i.e., capacity of the tank)

= Discharge x detention time

= 11,520 *l*/d x $\frac{24\ h}{24}$

= 11,520*l*

Now assuming the rate of deposited sludge as 30 liter/capita/year and also assuming the period of cleaning as 1 year, we have.

The volume of sludge deposited = 30*l*/c/yr x 120 persons x 1 yr = 3600 liter.

Total capacity of the tank = Capacity of sewage + Capacity of sludge

= 11,520 + 3600 = 15,120 *l* = 15.12m^3.

Assuming the depth of the tank as 1.5m, we have

Surface area of the tank = $\frac{15.12\ ^2}{1.5}$ = 10.08 ^{2}.

If the ratio of length to width is kept 3:1, we have,

Surface area = 10.08m^2.

× = 10.08 ^{2}

$\frac{}{} = \frac{3}{1}$

$$L=3B$$

$$3 \times \quad = 10.08 \quad ^{2}$$

$$2\ ^{2} = 10.08 \quad ^{2}$$

$$= \sqrt{\frac{10.08}{3}} = 1.8$$

Length of the tank, L = 3B = 3 x 1.8 = 5.5 m

Dimensions of septic tank:

Length, L = 5.5 m

Breadth, B = 1.8 m
Depth, D = Liquid depth + free board

= 2.0 + 0.3 m

= 2.3 m

Hence provide a septic tank of dimensions

Length x Breadth x Depth = 5.5m x 1.8m x 2.3m.

<u>Grey water Harvesting:</u>

10. Briefly explain the grey water harvesting. (On-site sanitation method)

- Greywater is any household wastewater with the exception of wastewater from toilets, which is known as blackwater.
- Typically, 50-80% of household wastewater is greywater from kitchen sinks, dishwashers, bathroom sinks, tubs and showers. The composting toilet has 100% of your household wastewater is greywater.
- Greywater decomposes at a much faster rate than blackwater and if stored for as little as 24 hours.
- The bacteria in it use up all the oxygen and the greywater becomes anaerobic and turns septic.
- After this point, it is more like blackwater - stinky and a health hazard.
- In fact, many jurisdictions havestrict regulations about disposal of greywater, some even require it to be treated as blackwater.
- Not all greywater is equally "grey". Kitchen sink water laden with food solids and laundry water that it has been used to wash diapers is more heavily contaminated than greywater from showers and bathroom sinks.
- Although greywater from these sources contains less pathogen than blackwater, many regulatory bodies consider it as blackwater.

Benefits of Greywater Recycling for Irrigation

- Reduce fresh water use
- Reduce strain on septic system or treatment plant
- Develop otherwise unsuitable real
- Groundwater Recharge
- Plant growth
- Maintain soil fertility
- Enhance water
- Satisfaction

Greywater Irrigation May Not Be A Good Choice If:

- Soil is not suitable - If your soil is either too permeable or not permeable enough, you may not be able to recycle your grey water, or you may need a system with some modifications.
- Area too small - You need enough soil to process the grey water and enough plants to use it.
- Climate unsuitable - If it's too wet to benefit from irrigating with grey water, there may be a better way to dispose of it. If it's too cold, you will only be able to recycle in the warmer months. In cold climates, the heat in grey water may be more valuable than the water itself. See Drain-water Heat Recovery.
- Permit hassles - Many jurisdictions in North America have no clear guidelines regarding grey water processing. With water shortages looming in the near future for many regions, this may change sooner than later. Health concerns are often cited as the reason for not allowing grey water recycling, although there has never been a documented case of somebody becoming sick as a result of exposure to grey water.
- Low cost/benefit ratio - Where legal requirements dictate a complex system and there is only a small flow of water, grey water recycling is not economically feasible.
- Inconvenience - If the grey water system you are considering is more expensive and requires more maintenance than a properly functioning septic or sewer system.
- To recycle grey water safely, users must understand the nature of the grey water itself as well as the natural cycles and processes involved in the purification of it. Each set of circumstances requires its own unique recycling system for optimum results.
- For most residential purposes, low-tech, homemade grey water systems tend to outperform and outlast expensive pre-made systems.

<u>Screens and Racks:</u>

11. Discuss the various types of screens adopted in sewage treatment. (Or) Explain the designing of a screen chamber.

Screening:

- Screening is the very first unit operation carried out in sewage treatment.
- A screen is a device with openings of uniform size. It may consist of parallel bars, rods, gratings, wire mesh or perforated plates. Screens are rectangular or circular-shaped.

- When waste water or sewage is passed through screens, they trap and remove the floating matter such as pieces of cloth, paper, wood, hair, fiber, and kitchen refuse etc. present in sewage. The waste material trapped on the screen is called screenings.
- These floating materials if not removed will choke the pipes and pumps (or) adversely affect the working of subsequent treatment units.

Types of screens

Depending upon the size of openings, screens may be classified as coarse screens, medium screens and fine screens.

(i) Course screens / racks / Bar screens

- A bar screen consists of vertical or inclined bars spaced at equal intervals.
- Coarse screens are also known as racks and the spacing between the bars (i.e., opening size) is about 50mm (or) more.
- The screens help in removing large floating bodies from sewage.
- The screens are placed at an inclination of 300 and 600 (normally 450) to horizontal to increase the effective cleaning surface and to improve the screening operations.
- Coarse screen will collect about **6 liters of solids per million liter of sewage.**
- The material separated by **coarse screens** usually consists of rags, wood, paper, etc.
- It may be disposed by incineration, burial (or) dumping.

(ii) Medium screens

- The spacing between bars is about 6 to 40 mm.
- Medium screens collect 30-90 liters of material per million liter of sewage.
- The screenings usually contain some quantity of organic material which may putrefy and become offensive.
- It must be disposed by incineration (or) burial.
- Rectangular shaped coarse and medium screens are widely used at sewage treatment plants.
- They are made up of steel bars, fixed parallel to one another at desired spacing on a rectangular steel frame called as bar screen.
- The screens are set in a masonry (or) R.C.C chamber called the screen chamber.
- These screens are kept inclined at about 30^0 to 60^0 to the direction of flow, so as to increase the opening area and reduce the flow velocity.
- The velocity through them is not more than 0.8 to 1 m/s.
- The material collected on bar screens can be removed either manually (or) mechanically.
- Large sewage treatment plants however use mechanically operated rakes, either continuously (or) intermittently.
- Screens are classified as fixed (or) movable depending upon whether the screens are stationary (or) capable of motion.
- Fixed screens are permanently fixed in position. Movable screens are stationary during operation and it can be lifted up for cleaning purpose.

(iii) Fine screens

- Fine screens have perforations of 1.5 mm to 3 mm in size.
- It is very effective.

- Fine screens remove 20% of the suspended solids from sewage.
- These screens however get clogged very often and need frequent cleaning.
- Fine screens are therefore used only for treating industrial wastewaters.
- Brass (or) Bronze plates (or) wire mesh is generally used for constructing fine screens.
- The metal used should be resistant to rust and corrosion.
- The fine screens may be disc (or) drum type which is operated by electric motors.

Cleaning frequency

- Cleaning frequency is governed by the head loss through the screen.
- If clogging of screens is more, head loss will be high.
- Generally, only 50% (one half) clogging of screens is allowed.
- Head loss is measured to find the clogging and cleaning frequency.
- Head loss through the screen, HL = 0.0729 (V^2-v^2)

Where,

V = Velocity through the screen.

v = Velocity above the screen.

Screenings and their Disposal

(e) The material separated by screens is called screenings which contain 85 to 90% moisture and floating matter.

(f) It may also contain traces of organic matter, which if not properly disposed will putrefy causes bad smells and nuisance.

(g) To avoid this, screenings are disposed by burning or burial or dumping.

(h) If screenings contain organic matter, then burning is done in incinerators at very high temperature of 760^0 to 815^0C.

(i) Burial (composting) is done in deep trenches (1 to 1.5m deep).

(j) It is covered with earth which becomes manure.

(k) Dumping in low lying areas, water bodies, sea or land is done when there is no organic matter in screenings.

(l) Digestion of screenings is also adopted in sludge digestion tanks.

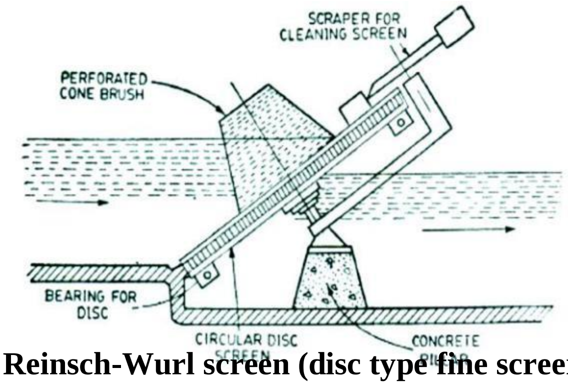
c) Velocity through screen = 0.75 m/s to 1 m/s.

d) Spacing between bars = 25 mm to 100 mm

e) Thickness of bars = 10 mm to 25 mm

f) Angle of inclination of bar to horizontal = 30^0 to 60^0

g) Material of bar = steel.



igure.5: Reinsch-Wurl screen (disc type fine screen)

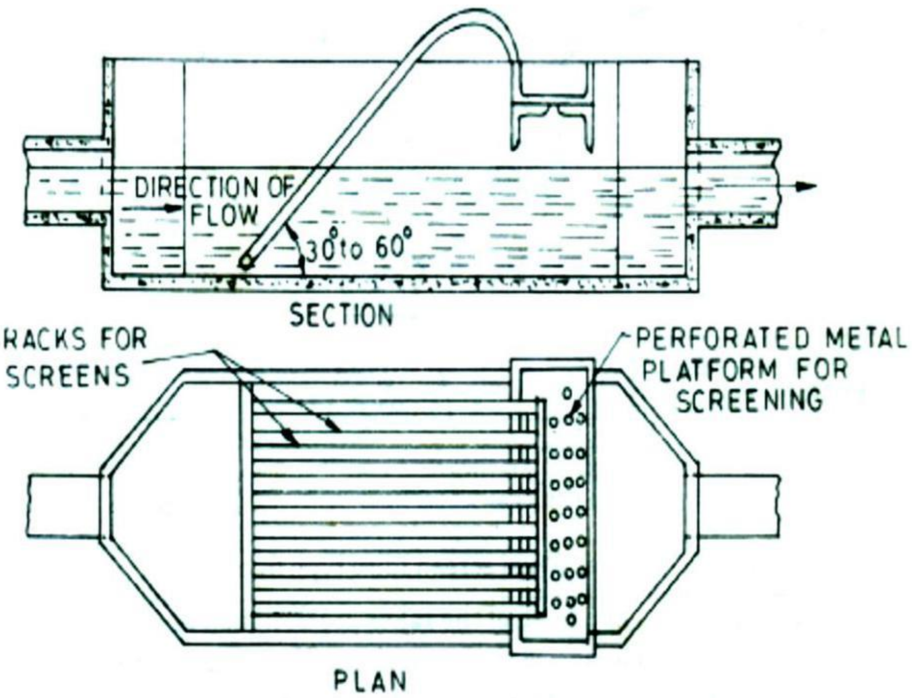


Figure.4:Fixed Bar type coarse or medium screen

(iv)Design a bar screen for a peak average flow of 30 million liters per day. **<u>Assumptions:</u>**

Bar Inclination = 45^0

Bar size = 9 mm x 50 mm (9 mm is facing flow direction)

Clear spacing of bars = 36 mm.

Velocity of flow through screen = 0.8 m/s at peak flow.

<u>Solution:</u>

Maximum rate of flow = 30 MLD = $\frac{30 \times 10^6}{10^3 \times 24 \times 60 \times 60}$ = 0.347 m^3/s.

Net area of screen [space where sewage flows] = A = $\frac{0.347}{0.8}$ = 0.434 ^{2}

Gross area of screen = $\frac{0.434 \times}{}$ = $\frac{0.434}{}$ = 0.543 ^{2}

$$\frac{(36+9)}{36} \quad \frac{\times 45}{36}$$

Since the screen is inclined at 45^0 with the horizontal, sin =

=

$$= \frac{0.543}{\sin} = \frac{0.543}{\sin 45^{\circ}} = 0.768^{2}$$

Grit Chamber:

(d) Explain about Grit Chamber and its types.

- The grit chambers (or) grit channels are the sedimentation basins placed after the screen chambers and before the primary sedimentation tank.
- Long narrow channels where flow velocity of 0.3m/s has to be maintained such that it carries away organic particles. It permits only heavier grit to settle out in the grit chamber.
- The depth and detention time provided for a grit basin are inter-reliantbased on the considerations of settling velocity of inorganic particles through water.
- A detention time of about 40 to 60 seconds is generally sufficient for a water depth of about 1 to 1.8 m.
- After fixing the depth and the detention time, we can easily design the tank dimensions as its length will then be equal to velocity X detention time.

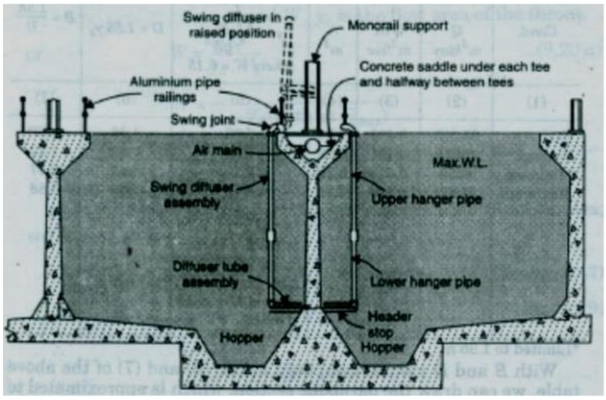
Types of Grit Chamber:

There are two general types of grit chambers.

- Horizontal flow grit chamber
- Aerated grit chamber

(k) Horizontal flow grit chambers are designed to maintain a velocity as close to 0.3 m/s as practical. Such velocity will carry most organic matters through the chamber and will tend to re-suspend any that settle but will permit the heavier grit to settle out. The most important point in the design of the grit chamber is that the flow velocity should neither be too low as to cause the settling of lighter organic matter nor should it be so high as not to cause the settlement of the entire silt and grit present in sewage.

(l) Fig. shows a grit chamber, consists of 10 to 18 meters long narrow open channel with depth of liquid between 1 to 1.3 m.



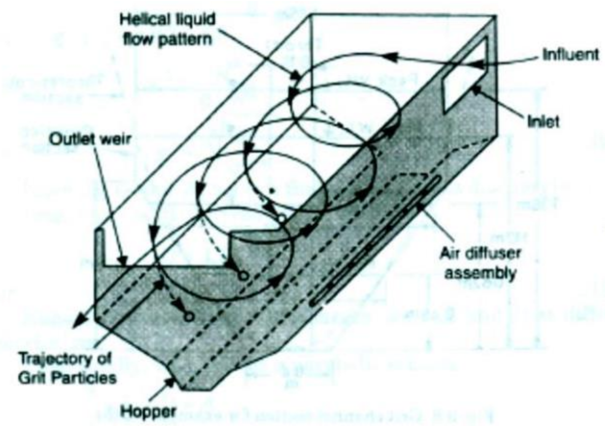
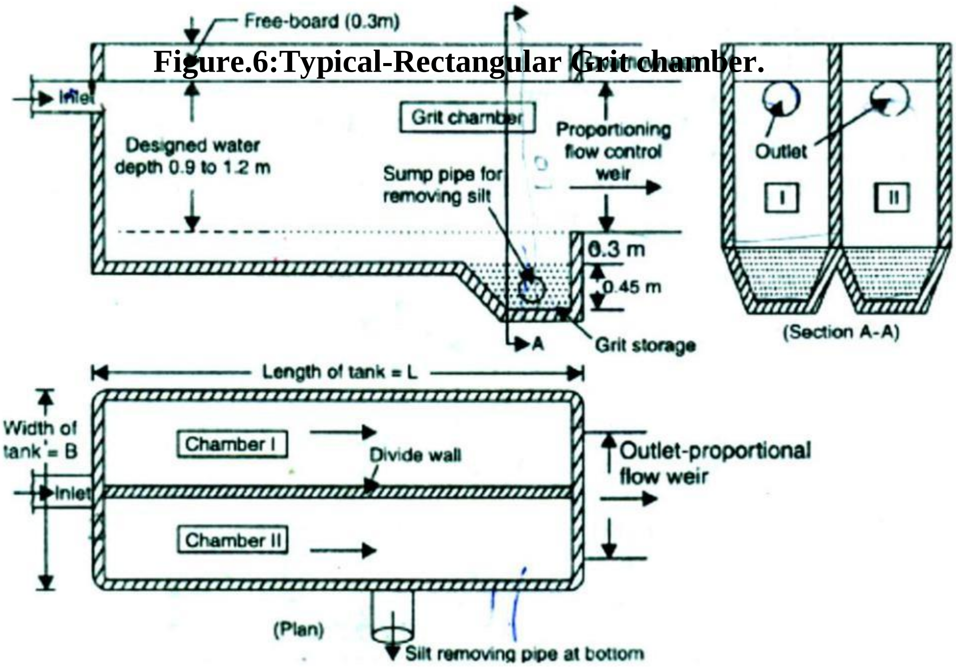


Figure.6:Typical-Rectangular Grit chamber.



- In order to maintain a constant velocity of flow, within the recommended range a control section is placed at the end of the channel.
- Such control system varies the cross section areas of flow in the section in direct proportions to the flow.
- Such control sections includes (i) Proportional Flow weir, (ii) Sutro weir, (iii) Parshall flume and (iv) Palmer Bowlus flume etc.,
- Grit chamber may be either mechanically cleaned or manually cleaned. The choice depends upon (i) quality and quantity of grit to be handled. (ii) Space, (iii) Topography,

  (v) Economic consideration with respect to capital costs as well as maintenance costs.

(kk) State the design criteria for a grit chamber.

(v) Settling velocity:

- The settlement of a particle depends upon the following factors:
- Velocity of flow
- Viscosity of wastewater
- Size and shape of particle
- Specific gravity of the particle (> 2.4 to 2.65)

(ix) Stoke's Law:

If particle diameter < 0.1 mm and the flow is laminar (stream line).

Particle settling velocity == $\frac{\ }{18} \left(\frac{-}{\ } \right) . \ ^2$

$= \frac{\ }{18} \left(\frac{-1}{\ } \right) . \ ^2$

Where,

− Settling velocity in cm/s

d – diameter / size of particles in cm.

- Dyanmic / Absolute viscosity of liquid in centipoises.

- Mass density of liquid in g/cm^3

–Mass density of particles in g/cm^3

= Acceleration due to gravity in cm/s^2.

(xvi) If particle diameter > 1 mm – Turbulent settling:

Newton's formula

Settling velocity = $= \sqrt{3.33 \ (-)}$

(e) Grit diameter between 0.1 mm to 1 mm – Transition Zone:

Hazen's modified equation

$$= 60.6 (S_s - 1)d \left[\frac{3t + 70}{100} \right]$$

Where,

= Settling velocity in cm/s.

t = temperature of liquid in degree Celsius.

If Grit has specific gravity = 2.65

$$= 60.6 (2.65 - 1)d \left[\frac{3t + 70}{100} \right]$$

(or) = (3 + 70)

(d) Organic solids with sp .gravity = 1.2

$$= 60.6\,(1.20 - 1)d\left[\frac{3t + 70}{100}\right]$$

(or) = 0.12 (3 + 70)

The settling velocity (the rate of subsidence) of a particle in liquid medium is denoted as **hydraulic subsidence value (HSV).**

(iv) Overflow rate:

- The efficiency of grit removal can be expressed as percentage removal of grit above a specified particle size.
- A grit chamber is designed to remove 100% of grit particles of the smallest size.
- When 100% of the smallest size grit particle is removed, it also removes all grit particles larger in size.

Settling velocities and Overflow Rates for Grit chamber (Temperature = 10^0C)

Diameter of particles (mm)	**Settling Velocity (cm/s)**		**Overflow Rate in an ideal Grit chamber $m^3/d/m^2$**	
	Ss = 2.65	**Ss = 1.20**	**Ss = 2.65**	**Ss = 1.20**
0.20	2.0	0.24	1700	210
0.18	1.8	0.22	1600	190
0.15	1.5	0.18	1300	160

For temperature other than 10^0C, correction of $\frac{3 + 70}{100}$ to be applied.
Where,

t = Temperature

(ii) Detention Period:

- The detention period for grit chambers vary from 45 to 90s.
- A detention period of 60 seconds is usually adopted.

(iii) Bottom Scour and Flow through Velocity:

The critical velocity for scour may be calculated from the modified shields formula

$$= \quad . \quad \sqrt{(\quad - \quad)}$$

(iv) Length = Velocity x Detention Time

(v) Flow Velocity of 0.25 to .3 m/s. is adopted.

(vi) Number of units:

- If manual cleaning is adopted, minimum 2 units are required.
- If mechanical cleaning is adopted, 1 unit which is manually cleaned is provided.

(vii) Dimensions of Tank:

- Surface area is found based on overflow rate.
- Width of section depends on velocity control device adopted.
- Length depends on overflow rate.
- In mechanized cleaning units, size of cleaning equipment should be considered.
- Depth of flow depends on the horizontal velocity at peak flow.
- Additional depth depends on the storage of grit and cleaning interval.
- Free board = 150 to 300 mm.
- Bottoms slopes depend on the type of scraper provided.

(viii) Loss of Head:

It may vary from 0.06 m to 0.6m depending upon the velocity control device adopted.

(v) Disposal of Grit:

- Grit particles like sand and gravel that settle in grit chamber may also have traces of organic matter.
- The organic matter may attract rodents and insects and produce odors.
- The grit requires washing before disposal by dumping, burying or by sanitary landfilling.
- The disposal method adopted depends on the quantity and characteristics of grit, land availability for dumping, filling or burial.
- For unwashed grit either burial is adopted or it is mixed with soil and used as a soil conditioner.

(vii) Explain the Constructional details of the sedimentation tanks. Inlet and Outlet arrangements of a settling tank and their purposes and requirements.

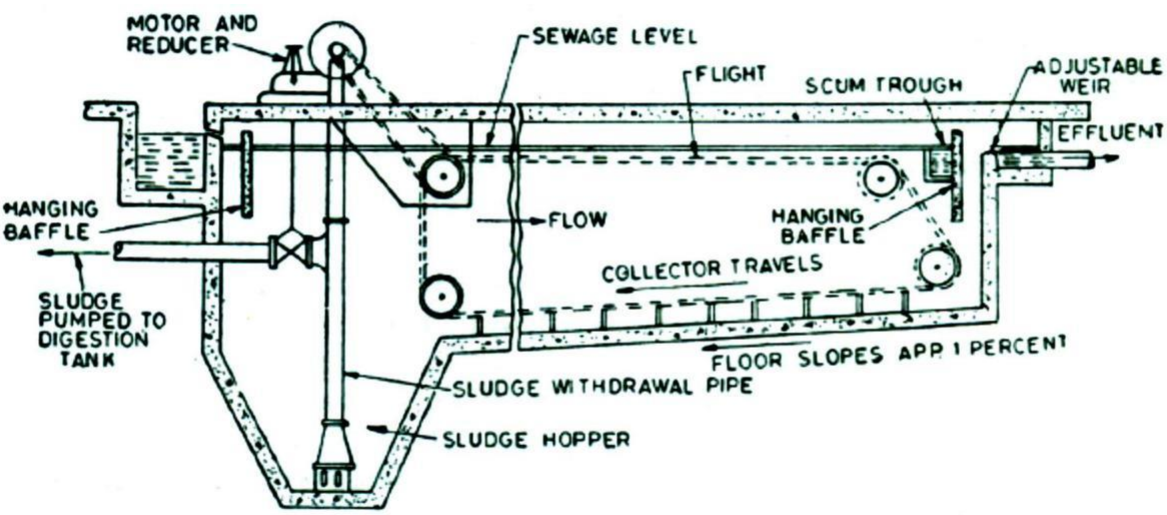
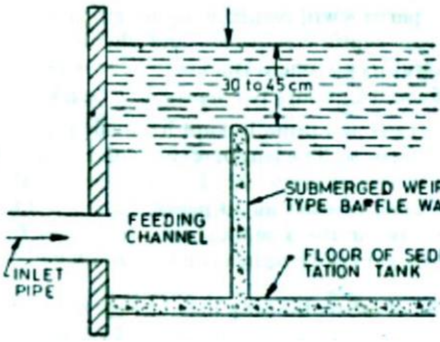
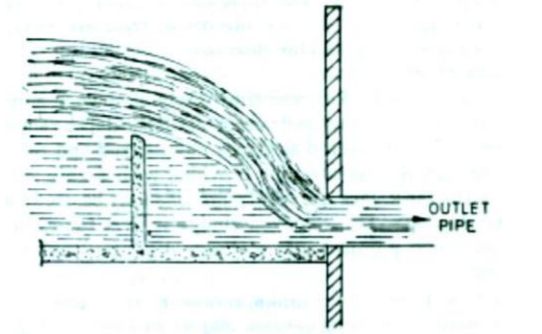


Figure.9: Rectangular sedimentation tank.





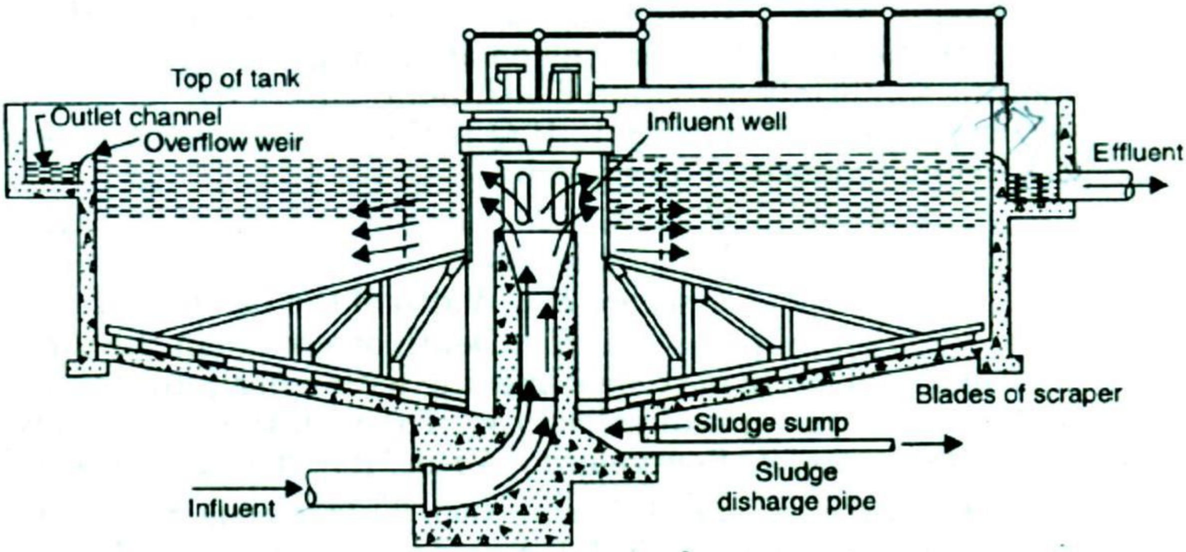


Figure.10:Circular sedimentation tank.

Figure.11:Submerged or Weir type inletFigure.12:Submerged or Weir type outlet

- **Inlet and outlet arrangement:**
  (i) In order to short circuiting and to distribute the flow uniformly proper arrangement must be made for smooth entry of water.
  (ii) 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 the submerged weir type baffle wall.
  (iii)A similar type of outlet arrangement is also used these days.

- **Baffles:**

These are required to prevent the movement of organic matter and its escape along with the effluent and to distribute the sewage uniformly through the cross section of the tank, and thus to avoid short circuiting.

(4) Skimming troughs:

- When the amount of oils and greasy matter present in sewage is small, it is generally uneconomical to provide a separate skimming tank.
- In such cases, a skimming trough is generally provided in the sedimentation tank itself near its outlet end.

(5) Cleaning and sludge removal

- Suspended solids needs to be cleaned due to prevent stale condition and gas formed due to anaerobic decomposition.
- They are cleaned manually or mechanical means. In manual cleaning a duplicate tank is provided when the supply stopped for cleaning.
- In mechanical means the sludge is scrapped by scrappers and are brought to the outlet end and is removed daily or often.

 Discuss in brief the various types of settling and design consideration of sedimentation tanks. (Or) Name various types of settling and discuss the significance of surface overflow rate in the design of sedimentation tank.

Particle may settle out of a liquid suspension in the following four ways (depending upon the concentration of the liquid and the properties of the suspended particles).

- Type I Sedimentation (Discrete settling)
- Type II Sedimentation (Flocculants settling)
- Type III Sedimentation (Hindered (or) Zone settling)
- Type IV Sedimentation (Compression settling)

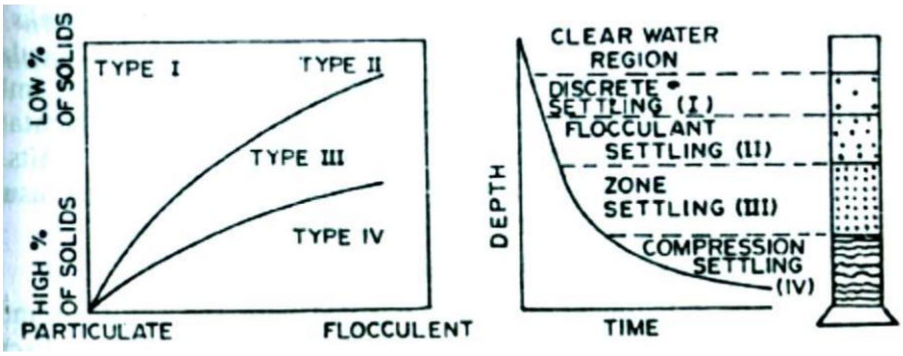


Figure.14:Types of Settlings

Type I Sedimentation – Discrete settling:

(5) It is the free settling or sedimentation of discrete particles in a liquid suspension of flow solids concentration.
(6) A particle that does not alter its shape, size and weight while settling (or) rising in water is known as discrete particle.
(7) These discrete particles due to their high specific gravity settle easily. It have less tendency to flocculate. E.g. settling of grit and sand.

Type II Sedimentation – Flocculants settling:

(6) This refers to dilute suspension of particles that flocculate, agglomerate, increase in mass and settle faster during the sedimentation process.
(7) It removes suspended solids and chemical flocs in settling tanks.

Type III Sedimentation – Hindered (or) Zone settling:

- This refers flocculants suspension of particles and of intermediate concentration.
- Inter – particle forces hold the particles together and they settle as a whole mass.
- It is used with biological treatments units (Secondary settling tank).

Type IV Sedimentation – Compression settling:

(7) This refers to flocculants suspension of high concentration.

(8) The particles come in contact with each other, resulting in the formation of a structure.

(9) Settling happens by compression of structure due to weight of particles added continuously to the structure. e.g., bottom layers of secondary settling tanks and sludge thickeners.

Design of sedimentation Tank:

1. Removal of suspended organic solids with specific gravity 1.01 to 1.20.

2. Overflow rate / Surface loading rate which is the hydraulic loading per unit surface area of tank expressed as $m^3/d/m^2$.

	Overflow rate ($m^3/d/m^2$)	
	At average flow	**At peak flow**
For primary settling tank	25-30	50-60

3. Detention period – 2 to $2\frac{1}{2}$ hours.

- Rate of BOD/Suspended solids removal is maximum during the initial $2\frac{1}{2}$ hours period.

(8) Weir Loading Rate:

$$= \frac{h}{h}$$

- Primary sedimentation tank – Not greater than $100 m^3/d/m$.
- Secondary sedimentation tank – Not greater than $150 m^3/d/m$.

Outlet weirs of sedimentation tank draw off clear waste water and take it out without disturbing the quiescent conditions in the tank.

This withdrawal of clear effluent per unit length of outlet weir is called weir loading rate.

(c) Depth of sedimentation tank is 3 to 3.5m.

(d) Performance:

(i) Primary Settling Tanks

- Efficiency of suspended solids removal – 45 to 60%
- Efficiency of BOD removal - 36 to 45%

(c) Secondary Settling tanks

- It has high efficiency of about 99% BOD removal.

7. Tank Dimensions.

- **Rectangular Sedimentation Tank:**

Length of tank, L = 90 m

Width of tank, B = 30 m

L:B = 1.5 to 7.5

L/D = 5 to 25

Minimum depth = 2m.

Bottom slope = 1%

(9) Circular Sedimentation Tank:

- Diameter of tank = 3 m to 60 m. commonly used 12 m to 30 m.
- Depth of water = 2 m.
- Floor step = 7.5 to 10%.

UNIT-III

SECONDARY TREATMENT OF SEWAGE

1. Explain the components and the operational principles of Activated Sludge Process.

- The activated sludge process provides an excellent method of treating either raw sewage or more generally the settled sewage.
- The sewage effluent from primary sedimentation tank, which is thus normally utilized in the process, is mixed with 20 to 30 percent of own volume of active aerobic micro-organisms.

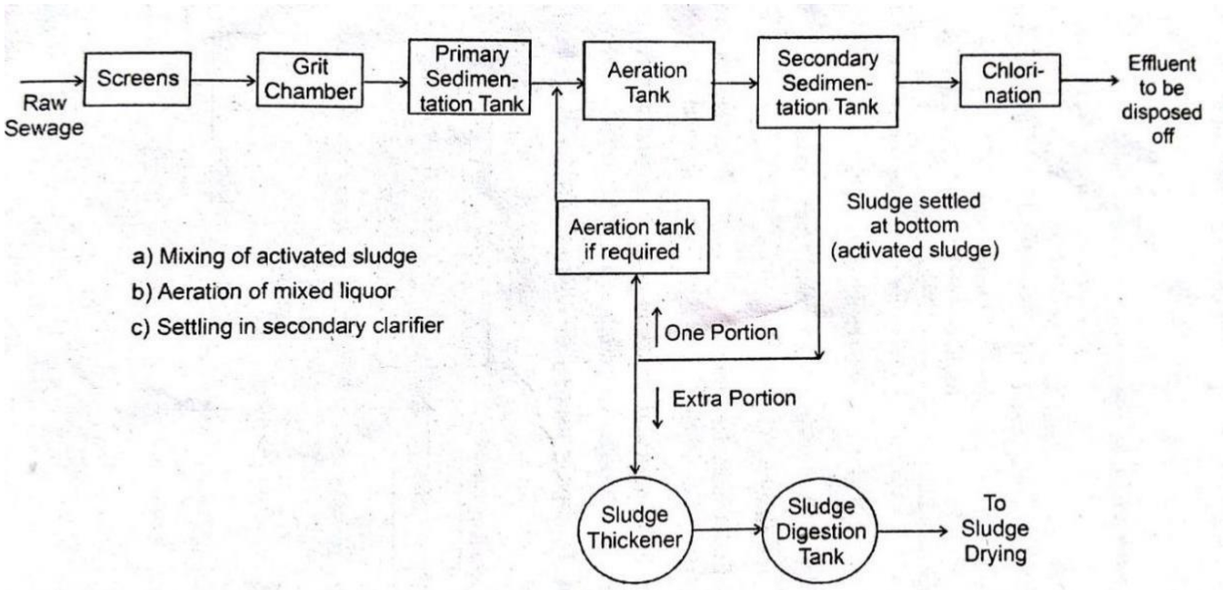


Figure.1: Conventional Activated sludge plant

- The mixture enters an aeration tank, where the micro-organisms (coated around the sludge solids) 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 oxidize the organic matter, and the suspended and colloidal matter tends to coagulate and form a precipitate, which settles down readily in secondary settling tank.
- The settled sludge called activated sludge, is then recycled to the head of the aeration tank, to be mixed again with the sewage being treated.
- Now, Activated sludge is continuously being produced by this process, and a portion of it being utilized and sent back to the aeration tank, whereas the excess portion is disposed of properly along with the sludge collected during primary treatment, after digestion.

- The effluent obtained from a properly operated activated sludge plant is of high quality, usually having a lower BOD than that of a trickling filter plant.
- BOD removal is up to 80-95%, and bacterial removed is up to 90-95%. Moreover, land area required also quite less.
- But, however, in this process, a rather close degree of control is necessary operation to ensure (i) that an ample supply of oxygen is present, (ii) that there is intimate and

continuous mixing of the sewage and the activated sludge added to the volume of sewage being treated is kept practically constant.

- Moreover, there is the problem of obtaining activated sludge, at the start of new plant. Hence, when a new plant is put into operation, a period of about 4 weeks may be required to form a suitable return sludge, and during this period, almost all the sludge from the secondary sedimentation tank will be returned through the aeration tank. 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.

2. What are the various methods of aeration? Explain.

There are two basic methods of introducing air into the aeration tanks, i.e.

(1) Diffused air aeration or Air diffusion; and

(2) Mechanical aeration

(3) Sometimes, a combination of both may also be used which may then be called as combined aeration.

(1) Diffused Air Aeration

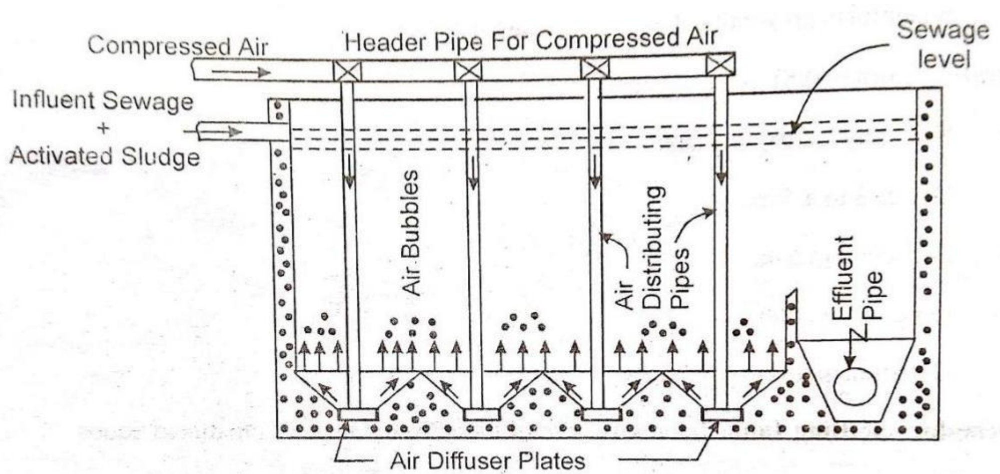
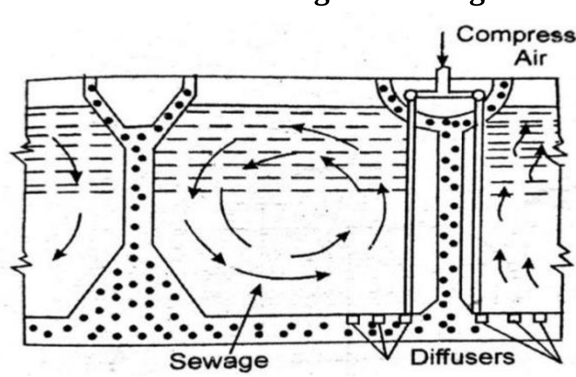


Figure.2: Ridge & furrow type aeration tank



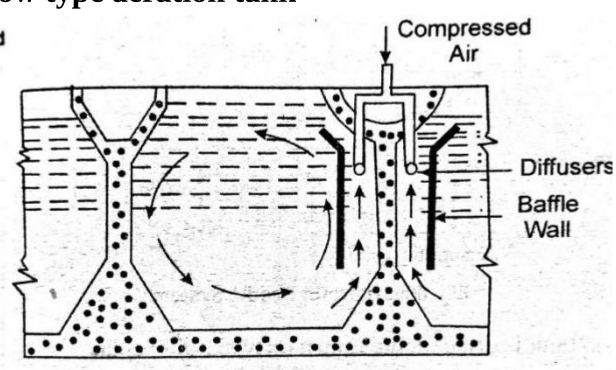


Figure.3: Spiral aeration using plate diffusers Figure.4: Spiral flow type aeration tan

- In the diffused air aeration method compressed air undera pressure of 35 to 70 kN/m^2 (0.35 to 0.7kg/cm^2).
- It is introduced into the aeration chamber, through diffusion plates or other devices, called diffusers.

- The main criteria for selection of a particular diffuser are that it should be capable of diffusingair in small bubbles, so as to provide the greatest possible efficiency of aeration.

- Porous plates and porous tubes, made of quartz or crystalline alumina (Aluminium oxide) are generally used as diffusers.
- Plates are generally square in shape with dimensions of 30 cm x 30 cm, and they are usually 25 mm thick.
- These plates are fixed at the bottom ofaeration tanks. Tube diffusers are generally 60 cm long with internal dia of 75 mm and thickness of wall equalto 15 mm.
- The effective areas for the above standard plate and tube diffusers work out to 780 cm^2 and 1160 cm^2respectively.

(2) Mechanical aeration:

- In the air-diffusion method, as pointed out above, a lot of compressed air (90 to 95%) gets wasted.
- It simply escapes through the tank without giving oxygen to the sewage.
- Although it helps in bringing about the required agitation of sewage mixture.
- In order to affect economy, atmospheric air is brought in contact with the sewage in the mechanical aeration method.
- In this mechanical aeration method, the sewage is stirred up by means of mechanical devices, like paddles, etc. (called surface aerators).

Types:

(a) Haworth Paddle System:

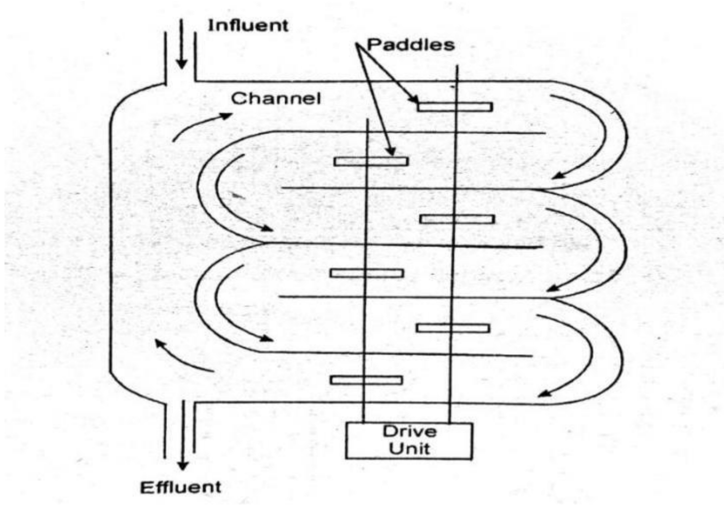


Figure.5: Haworth paddle system

- The aeration tank is divided into long narrow parallel channels.
- Two paddles are provided between channel which rotates at 15 rpm and it causes spiral motion of sewage.

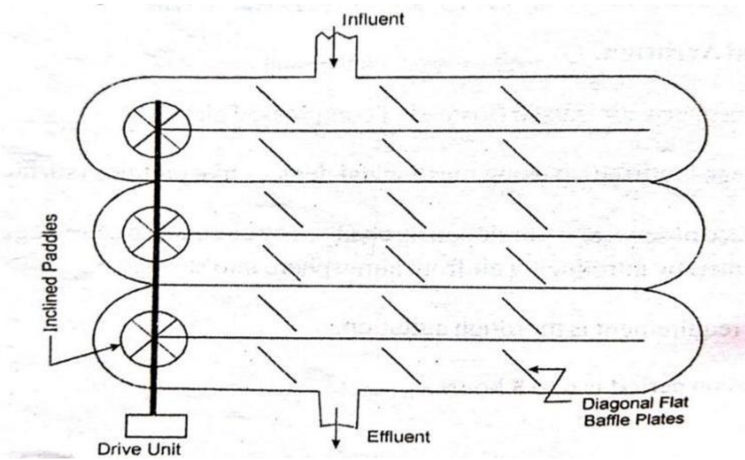


Figure.6: Hartley system

(b) Simplex system: (Bio-Aeration system)

- It is a square hopper bottom vertical flow tank.
- At the centre, a hollow uptake draft tube is suspended from the top.
- A steel cone with spiral vanes is provided at the top of the uptake tube and is driven by motor.
- The cone revolves at a speed of 60 rpm which sucks the mixed liquor sewage through the uptake tube by creating suction at the bottom and sprays it at the top surface.
- The spray then absorbs oxygen from the atmosphere.

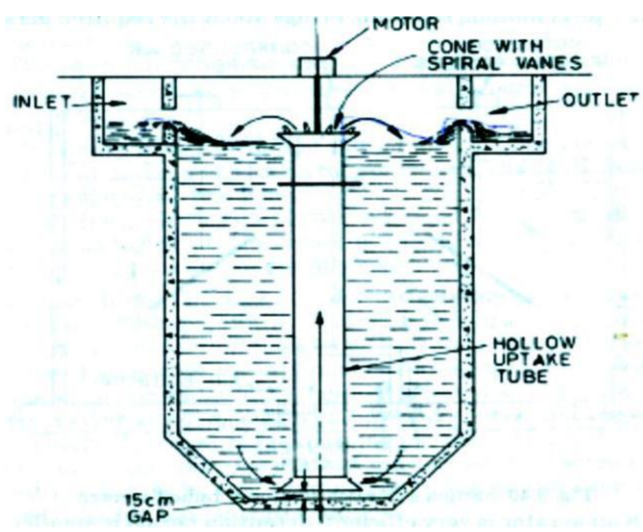


Figure.7: Simplex aerator

(3) Combined Aeration:

- In combined aerators, the diffused-air aeration as well as the mechanical aeration are combined together in a single unit, Awell known type of such an aerator unit is called Dorr aerator.
- In this type of an aerator the aeration of sewage is achieved by diffusing air through bottom diffuser plates, as well as by rotating paddles @ 10 to 12 r.p.m., as shown. Spiral

motion, so set up, brings about the required aeration. Such an aerator is very efficient; detention period is smaller (3 to 4 hours).

- It requires less amount of compressed air as compared to the diffused-air aeration.

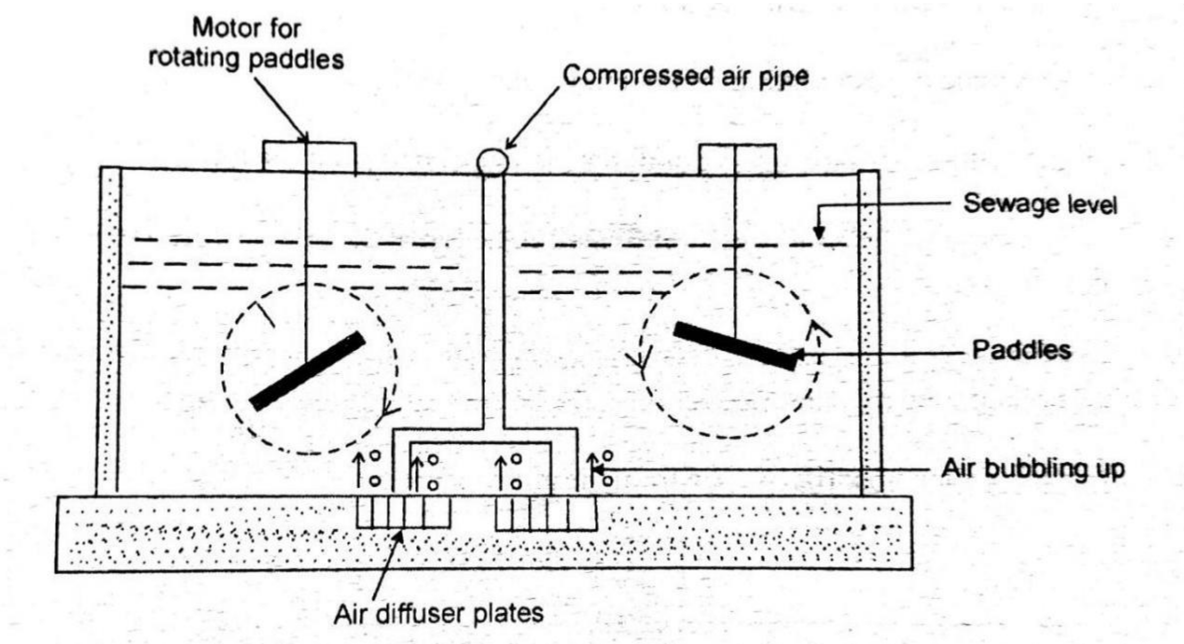


Figure.8: Dorr Aerator

3. Define and explain the different loading criteria, based on which aeration tank of ASP is operated.

Definition:

- Aeration is the most important operation in the Activated Sludge Process.
- In addition to supplying to the aeration devices have also to provide adequate mixing and agitation so that the mixed liquor suspended solids do not settle down.

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

1. Aeration period [i.e. Hydraulic Retention Time (H.R.T)]
2. BOD loading per unit volume of aeration tank (i.e. Volumetric Loading)
3. Food to Micro-organism ratio (F/M ratio)
4. Sludge age

1) The Aeration period (H.R.T):

- The aeration period (t) empirically decides the loading rate at which the sewage is applied to the aeration tank.
- For continuous flow aeration tank, this value is determined in the same manner as it is determined for and ordinary continuous sedimentation tank, as per equation as,

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

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

$$t = \frac{V}{Q} \text{ day}$$

$$t = \frac{V}{Q} \cdot 24 \text{ hour}$$

where t = aeration period in hours

V = Volume of aeration tank

Q = Quantity of waste water flow into the aeration tank, excluding the quantity of recycled sludge

2) Volumetric BOD loading:

Another empirical loading parameter is volumetric loading, which is defined as the BOD5 load applied for unit volume of aeration tank. This loading is also called Organic loading

∴ Volumetric BOD loading or organic loading

$$= \frac{\text{Mass of BOD loading per day to the aeration tank through influent sewage in gm}}{\text{Volume of the aeration tank in } m^3}$$

$$= \frac{Q.Yo \text{ (gm)}}{V}$$

Where Q = sewage flow into the aeration tank in m^3

Yo = BOD5 on mg/l (or gm/m^3) of the influent sewage

V = Volume of aeration tank in m^3

This loading is quite similar to the BOD loading rate per cum of filter volume, as used an adoption in biological filtration and discussed.

3) Food (F) to Micro-organisms(M) ratio:

F/M ratio is an important rational organic loading rate, adopted for an activated sludge process.

- It is a manner of expressing BOD loading with regard to the microbial mass in the system.
- 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.

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

- If Yo (mg/dl) represents the 5day BOD of the influent sewage flow of Q m^3/day, then eventually, the BOD applied to the aeration system = Yomg/l or gm/m^3.
- BOD load applied to the aeration system = F = Q.Yogm/day
- The total microbial mass in the aeration system(M) is computed by multiplying average concentration of solids in the mixed liquor of the aeration tank, called Mixed liquor suspended solids(MLSS) which the volume of aeration tank(V)

$$M = MLSS \times V$$

$$M = X_t \times V$$

Where X_t is MLSS in mg/l.

Dividing (i) by (ii) we get,

$$\frac{F}{M} \text{Ratio} = \frac{F}{M} = \frac{Q.Yo}{V.X_t}$$

$\frac{F}{M}$ Ratio for an activated sludge plant is the main factor controlling BOD removal.

- Lower the F/M value; the higher will be the BOD removal in the plant. The F/M ratio can be varied by the MLSS concentration in the aeration tank.

4) Sludge Age:

- The sludge age is an operation parameter related to the F/M ratio. 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, while aeration period (i.e. liquid retention time) may be short as 3 to 30 hour, the residence time of biological solids in the system is much greater, and is measured in days.
- While sewage passes through the aeration tank only once and rather quickly, the resultant biological growths and the extracted waste organics are repeatedly recycled from the secondary clarifier back to the aeration tank, thereby increasing the retention time of solids.
- This time is called Solids Retention Time (SRT)orMean Cell Residence Time (MCRT)or sludge age.
- The most common method of expressing sludge age, usually represented by Oc in days, is to express it as the ratio of the mass of MLSS in the aeration tank relative to the mass of suspended solids leaning the per day.

  $\therefore$ Sludge age (θc) = $\frac{\text{Mass of suspended solids (MLSS)in the system(M)}}{\text{Mass of solids leaning the system}}$

- For conventional activated sludge plant, with the flow (Q), concentration of solids (Xt), and BOD5(Y) as marked in fig. we can easily write,

  (a)Mass of solids in the reactor.

  M = V×(MLSS)

  M = V× Xt.

  WhereXt is MLSS in the aeration tank (mg/l).

  (b)(i)Mass of solids removed with the wasted sludge per day = Qw× Xr (ii)Mass of solids removed from the system per day =(Q−Qw)Xe

  $\therefore$Total solid removed from the system = (i) + (ii)

  = Qw.Xr + (Q−Qw) Xe

  $\therefore$Sludge age (θc)= $\frac{V.Xt}{Qw.Xr+(Q-Qw)E}$

Where V = Volume of Aerator

Xr= Concentration of solids in the returned sludge/ waste sludge (mg/l)

Xt= Concentration of solids in the influent of the aeration tank called the MLSSi.e. Mixed Liquor Suspended Solids in mg/l

Q = Sewage inflow per day

Xe= Concentration of solids in the effluent in mg/l

- When the value of Xe (Suspended solids concentration in the effluent of activated sludge plant) is very small, then the term (Q−Qw)Xe is ignored, leading to

  $\theta c = \frac{V.Xt}{Qw.Xr}$

- In addition to use sludge retention time (θc) as a rational loading parameter, another rational loading parameter which has found wider acceptance is the specific substrate utilization rate (U) per day, and is defined as

  $U = Q \times \frac{(Yo-Ye)}{V.Xt}$

- Under steady operation, the mass of waste activated sludge is further given by

$$Qw.Xr = \propto y.\ Q(Yo - Ye) - Ke.Xt.V$$

Where $\propto y$= max. yield co-efficient

$$\propto y = \frac{\text{Microbial mass synthesised}}{\text{Mass of substrated utilised}}$$

$\propto y$ = 1.0 w.r.t TSS (i.e. MLSS)

$\propto y$ = 0.6 w.r.t VSS (i.e. MLVSS)

Ke= Endogenous respiration rate constant (per day)

Ke= 0.006 per day

$$\therefore \frac{1}{\theta_c} = \propto y.U - Ke$$

Since both $\propto y$&Ke are constant for a given waste water, it becomes necessary to defined either θc or U.

5) Sludge Volume Index (S.V.I.)

- The term sludge volume index or sludge index is used to indicate the physical state of the sludge produced in a biological aeration system.
- It represents the degree of concentration of the sludge in the system.
- It decides the rate of recycle of sludge (QR) required to maintain the desired MLSS and F/M ratio in the aeration tank to achieve the desired degree of purification.
- The standard test which is performed in the laboratory to compute SVI of an aeration system involvescollection of one liter sampleof mixed liquor from the aeration tank from near its discharge end in a graduated cylinder.
- This 1litre sample of mixed liquor is allowed to settle for 30 minutes and the settled sludge volume (Vob)in ml is recorded as to represent sludge volume.
- This volume Vobinml per litre of mixed liquor will represent the quantity of sludge inthe liquor in ml/l.

$$= \frac{(\ /\ )}{(\ /\ )} = \frac{}{} \ /$$

- The usual adopted range of SVI is between 50-150 ml/gm and such a value indicates good settling sludge.

6) Sludge Recycle and Rate of return sludge:

$$\frac{Q_R}{Q} = \frac{X_t}{X_R - X_t}$$

Where QR = Sludge recirculation rate in m^3/d

Xt = MLSS in the aeration tank in mg/l

XR = MLSS in the returned or wasted sludge in mg/l

$$\frac{Q_R}{Q} = \frac{X_t}{\frac{10^6}{SVI} - X_t}$$

7) Wasting of Excess Sludge (Qw)

- The aeration tank has to be partly discharged and wasted out of the plant to maintain a steady level ofMLSS in the system.

- The excess sludge quantity will increase with the increasing FIM ratio, and decrease with temperature.
- In thecase of domestic sewage, Qw will be about 0.50-0.75 kg per kg BODremoved for the conventional sludge plants (having F/M ratio varyingbetween 0.4 to 0.3).

8) Size and Volume of the Aeration Tank:

$$V.\ X_t = \frac{\alpha_y.(Y_O - Y_E)\theta_c}{1 + K_e.\theta_c}$$

9) Oxygen Requirement of the Aeration Tanks:

$$O_2 \text{ required} = \left[\frac{Q(Y_o - Y_E)}{f} - 1.42\ Q_w.X_R\right] \text{gm/day}$$

4. Explain about the advantages and disadvantages of Activated Sludge Plant Advantages of ASP:

- Lesser land area is required.
- The head loss is in the plant is quite low.
- There is no fly or odour nuisance.
- Capital cost is less.
- Greater flexibility of operation, permitting, control on the quality of effluent is possible.

Disadvantages of ASP:

- High cost of operation, with greater power consumption.
- A lot of machinery to be handled.
- A sudden change in the quantity and character of sewage may produce adverse effects on the working of the process, thus producing inferior effluent.
- Bulking of sludge is a common trouble, which has to be controlled, especially when industrial waste wasters with high carbohydrate content or antiseptic properties are present. In any case, if such bulking is not there, comparatively larger sludge volume is to be handled.
- The quantity of returned sludge has to be adjusted every time as and when there is a change in the quantity of sewage flow. Thus making the operation a little cumbersome.

5. Explain Bulking and Foaming Sludge in an Activated Sludge Treatment Plant

- Foam formation and poorly settling sludge are the two most common problems of the activated sludge process.
- A sludge that exhibits poor settling characteristics is called a bulking sludge. Filamentous micro-organisms have been found to be responsible for a bulked sludge.
- Large surface area tovolume ratios of these microorganisms retards their settling velocities.
- Fungi are the most familiar filamentous micro-organisms.
- Bacteria are usually found to develop in activated sludge systems which are characterized by the low or variable nutrient concentrations. These bacteria may live on variety of carbon and nitrogen sources present in the activated sludge system.

- Organic acids form an important class of carbon sources for the growth of filamentous sulphur bacteria.
- These bacteria, however, do not develop well at low pH values.
- The most successful methods to control these organisms, as per latest research, are: (i) reduction of the sludge age to less than 6 days and (ii) chlorination of return activated sludge.
- Foam removal is also a logical and beneficial control measure.
- Carbohydrate-rich waters are more prone to give rise to filamentous populations. Exclusion of such wastewaters may, therefore, sometimes help in controlling sludge bulking.
- One of the first check made on a bulking activated .plant, therefore, is to measure concentrations to determine whether they are sufficient for the amount of sludge being produced. If not, the problem is readily solved by addition of nutrients to the waste water.

6. What is meant by rising Sludge?

- The rising sludge is caused by denitrification in the secondary clarifier.
- Denitrification results in the formation of nitrogen gas bubbles, which lifts up the settled sludge, thereby deteriorating the quality of the clarified effluent.
- High temperatures (above 20°C) do accelerate the rate of denitrification.
- when the nitrates concentration in the influent of the secondary clarifier of an activated plant exceeds 6-8 mg/l and temperatures are more, then enough nitrogen gas (due to denitrification) would be produced the secondary clarifier during its usual 1 hour detention time, causing rising sludge.
- Plants in areas of warm climates will be susceptible to this problem and the only practical solution to be problem is to denitrify the effluent of the activated sludge process before allowing its entry into the secondary clarifier.

7. An average operating data for conventional activated sludge treatment Plant is as follows:

(1) Wastewater flow I = 35000 m31d
(2) Volume of aeration tank = 10900 m3
(3) Influent BOD = 250 mg/l
(4) Effluent BOD = 20 mg/l
(5) Mixed liquor suspended solids (MLSS) = 2500 mg/l
(6) Effluent suspended solids = 30 mg/l
(7) Waste sludge suspended solids = 9700 mg/l
(8) Quantity of waste sludge = 220 m3ld.

(a) Aeration period (hrs)
(b) Food to microorganism ratio (F/M) (kg BOD per day I kg MLSS)
(c) Percentage efficiency of BOD removal
(d) Sludge age (days).

Q = 35000 m3/d;   V = 10900 m3

Y_o = 250 mg/l; Y_E = 20 mg/l /

X_t = 2500 mg/l; X_E = 30 mg/l

X_R = 9700 mg/l; Q_w = 220 m3/d

These values are now used to calculate the desired factors, as below **(a) Aeration period(t) in hr is given by**

$$t = \frac{V}{Q} . 24 = \frac{10900}{35000} \times 100 = 7.47 \text{ hrs} = 7.5 \text{ hrs}$$

(b) F/M ratio

F = Mass of BOD removed = Q. Yo = 35000 X 250 gm/day

$$F = \frac{35000 \times 250}{1000} \frac{kg}{day} = 8750 kg/day$$

M =Mass of MLSS = V. Xt = 10900 m^3 X 2500 gm/m^3

$$M = \frac{10900 \times 2500}{1000} kg = 27250 \text{ kg}$$

$$\frac{F}{M} \text{ ratio} = \frac{8750}{27250} = 0.32 \text{ kg BOD per } \frac{day}{kg} \text{ of MLSS}$$

(c) Percentage efficiency of BOD removal

$$= \frac{\text{Incoming BOD} - \text{Outgoing BOD}}{\text{Incoming BOD}} = \frac{250-20}{250} \times 100 = 92\%$$

(d) Sludge age (days)

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

$$\Theta_c = \frac{27250 \text{ kg}}{(220 \text{ m}^3/d \times 9700 \text{ mg/l}) + (35000 \text{ m}^3/d - 220 \text{ m}^3/d) \times 30 \text{ mg/l}}$$

$$\Theta_c = \frac{27250 \text{ kg}}{\frac{220 \times 9700}{1000} kg/d + (35000 - 220) \times \frac{30}{1000} kg/d} = \frac{27250}{2134+3177.4} = 8.58 \text{ days}$$

__**Trickling Filter:**__

8. Explain Construction and Operation of Trickling Filters

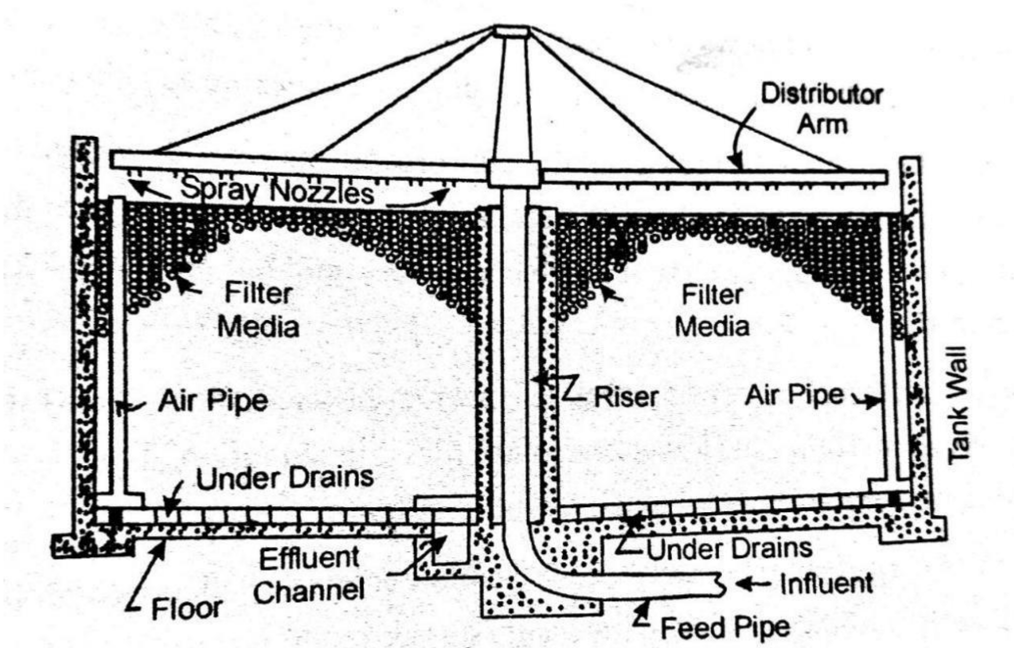


Figure.9: Typical cross-section.

- It is an anaerobic and attached growth process (the micro -organisms remain attached to the filter media).
- Trickling filter are also known as percolating filters (or) sprinkling filters
- Sewage is allowed to sprinkle (or) trickle over a bed of coarse, rough, hard filter media and it is then collected in the under-drainage system.
- Spray nozzles (or) rotary distributors provided on top are used for sprinkling sewage on filter media.
- The biological purification is brought about mainly by aerobic bacteria, which form a bacterial film (biofilm) around particles of filter media.
- The color of this film is blackish, greenish and yellowish and apart from bacteria it may consist of fungi, algae, protozoa etc.
- Sufficient O2 (oxygen) is supplied inside filter for the existence of this bio -film.
- Organics are removed by Bisorption.
- The trickling filter is always proceeds by primary sedimentation tank along with the skimming devices to remove the scum.
- This will prevent the clogging of the filter by settleable solids.
- The effluent from the filter is then taken to secondary sedimentation tank for settling out organic solids oxidized while passing through the filter.
- The microbial film (or biofilm) (or) the slim film formed on the filter medium is aerobic to a depth of only 0.1 to 0.2mm, and the remaining part of the film is anaerobic.
- As the waste water flows over the microbial film, the soluble organic material in the sewage is rapidly metabolished while the colloidal organics are absorbed onto the surface.
- In the organic layer of the biological film, the organic matter is degraded by the aerobic micro-organisms. The food concentration and oxygen supply is high at the outer layer, which leads to rapid growth of aerobic microbes and thereby the thickness of slime layer increases.
- The D.O is therefore consumed at the upper layer itself and prevents its penetration to lower zone.
- Hence, the lower zone of the film is in starvation of oxygen and food due to whi ch anaerobic environment is established.
- The micro-organisms in the lower zone therefore enter into endogeneousphase of growth and lose their ability to stick to the media surface.
- Eventually there will be scouring of the slim layer and new fresh slime lay er begins to grow again on the media.
- This phenomenon of scouring of the slime layer is called sloughing.

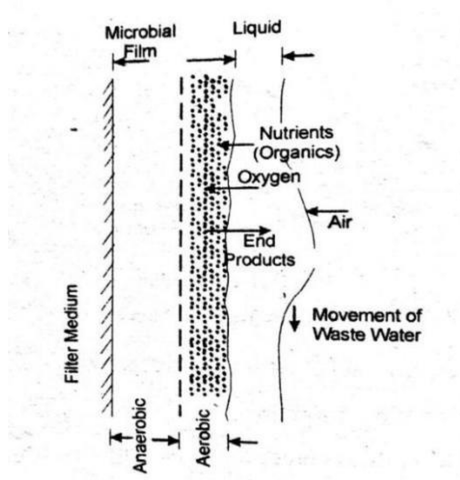


Figure.10: Attached Growth Process in a Trickling Filter

<u>Classification of Trickling filters:</u>

9. What are the different types of trickling Filters?

(i) Low Rate Trickling Filters (or) Standard Rate Trickling Filter (SRTF)

(ii) High Rate Trickling Filter (HRTF)

- A water tight holding tank made of masonry or concrete walls.
- Distribution system
- Filter media and
- Under-drainage system.
- Tank is either square, rectangular or circular in shape.
- Influent to the trickling filter is from the primary sedimentation tank.

Filter media:

- The filter media used should have high surface area, high void space, resistance to abrasion and insoluble.
- Particles of filter media should be round (or) cubical in shape.
- The filtering media should be free from flat (or) elongated pieces and should not contain dirt.
- The most commonly used filter media is broken stone, slag (or) gravel of size 25 to 75mm.
- The media should be packed atleast 30cm height above the under drainage.
- The filter depth varies from 1.8m to 3.0m.
- The purpose of under-drainage system:
- To carry the liquid effluent and sloughed biological solids.
- To distribute air throughout the bed.
- They are formed of precast vitrified clay (or) concrete blocks with perforated cover.
- The slope of the under drain should be same as that of floor sloping towards a common collection point.
- At design flow, the velocity of drains may be 0.6 to 0.9m/s.

Main collecting channel:

- The main collecting channel is provided to carry away the flow from the under drains and to admit air to the filter.
- The main collecting channel shall have semi-circular (or) other rounded inverts.
- The velocity shall not be less than 0.6m/s.
- The filter floor should be strong enough to support the under -drainage system.
- An R.C.C. slab of 10 to 15cm thick is provided.

Filter Walls:

- Filter walls may either be fully plastered stone (or) brick masonary (or) R.C.C.

Ventilation:

- Natural ventilation is ensured by providing under drains or forced ventilation is done with air flow of $1m^3/min/m^2$ of filter area.

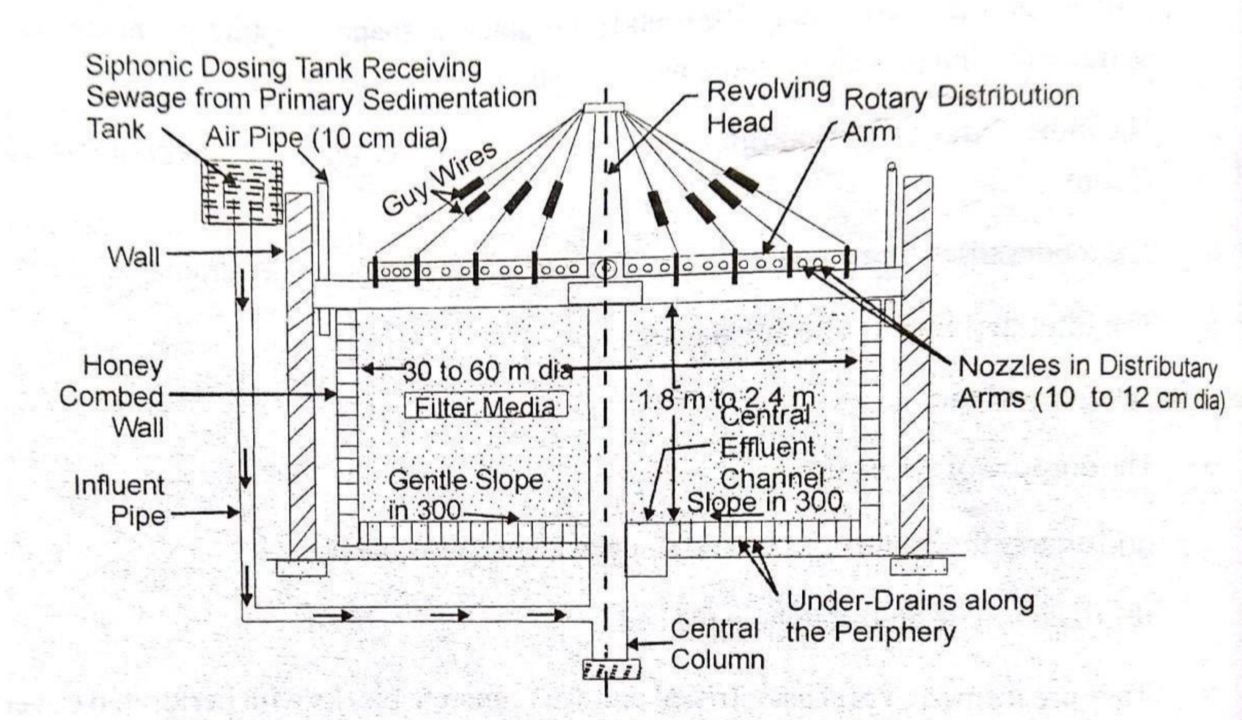


Figure.11: Conventional circular trickling filter with rotary distributors.

10. List out the Merits and Demerits of trickling filters?

Merits

1. Rate of filter loading is high, as such requiring lesser land areas and smaller quantities of filter media for their installations.
2. Effluent obtained from the trickling filters is sufficiently nitrified and stabilized.They can remove about 75% of BOD and about 80% of suspended solids. Theeffluent can, therefore be easily disposed of in smaller quantity of dilution water.
3. Working of tricking filters is simple, and does not require any skilled supervision.
4. They are flexible in operation, and they can, therefore, withstand the application of variety of sewages having different concentrations and compositions. Even if they are over-loaded, they can recoupe after rest.
5. They are self-cleaning.
6. Mechanical wear and tear is small, as they contain less mechanical equipment.
7. Moisture content of sludge, obtained from trickling filters, is as high as 99% or so.

8. Trickling filters have been found to operate more efficiently in warm weather, and produce an effluent appreciably lower in BOD. Hence, they are of immense -use in hot countries like India.

Demrits

1. The head loss through these filter is high, making automatic dosing of the filters necessary (through siphonic dosing tanks).
2. Cost of construction of trickling filters is high.
3. These filters cannot treat raw sewage, and primary sedimentation is a must.
4. These filters pose a number of operational troubles such as fly nuisance.
5. Odor nuisance and Ponding Trouble.

Design of Trickling filter.

11. Explain the design considerations in Trickling Filters?

Loading:

Hydraulic loading:

- Quantity of sewage per hectare of surface area per day.
- Loading varies from 25 to 40 million liter per hectare of surface area per day.
- SRTF = 1 to 4 $m^3/d/m^2$.
- HRTF = 10 to 30 $m^3/d/m^2$.
- Loading varies from 1000 to 2200kg of BOD5 per hectare meter of filter volume of per day.
- SRTF = 80 to 320 $g/d/m^3$.
- HRTF = 500 to 1000 $g/d/m^3$.
- Number of persons served per hectare of filter surface area.
- Number of persons served per unit volume of filter media.

Efficiency:

Based on NRC equation (USA).

$$(\%) = \frac{100}{1 + 0.0044\sqrt{\ }\ \_} \ (\ ) \ \frac{100}{1 + 0.44\sqrt{\ }\ \_}$$

$$= \frac{-}{\quad} \times 100$$

E = Efficiency of filter and its secondary clarifier in terms of percentage BOD in removal.

Ci = Influent BOD concentration.

Ce = Effluent BOD concentration.

u = Organic loading in kg/ha-m/day applied to filter (unit hydraulic loading). U = Unit hydraulic loading in kg/m3/day.

$$= \frac{\quad}{\quad}$$

W = Total BOD in kg.

V = Filter volume in m3 (or) ha-m.

F = Recirculation factor.

Performance:

The trickling filter has high efficiency in removal of BOD and other organic matter.

- Suspended solids and BOD are reduced by 90% each.
- BOD left in the effluent is less than 20 ppm.
- Effluent is highly stabilized.
- Conventional Trickling Filter/Ordinary/Sandard/Low rate – No recirculation of sewage.
- High Rate Trickling Filter – Recirculation of sewage (as in ASP), greater loading, less space requirements and less filter media.

12. Compare conventional and high rate trickling filters.

Sl.No.	Characteristics	Conventional or Standard Rate Filters	High Rate Filters
1	Depth of filter media	1.6 – 2.4m	1.2 – 1.8m
2	Size of filter media	25 – 75mm	25 – 60mm
3	Land required	More as filter loading is less	Less land area is required. More loading of filters
4	Cost of operation	More	Less
5	Method of operation	Continuous and less flexible	Continuous and more flexible (skilled attention is required)
6	Sloughing	Intermittent	Continuous
7	Type of effluent produced	Highly stabilized, nitrified BOD < 20ppm	Less stable and inferior quality, BOD > 30ppm
8	Dosing interval	3 – 10 min	>15 seconds
9	Hydraulic loading	20 to 44 ML/hectare/day	110 to 330 ML/hectare/day
10	Organic loading	900 to 220 kg of BOD5 per ha-m of filter media/day	6000 to 18000 kg of BOD5 per ha-m of filter media/day
11	Recirculation system	Not provided	Always provided
12	Quality of secondary sludge	Black, highly oxidized	Brown, not fully oxidized

13. What is the need of recirculation of treated sewage in high rate trickling filters?

- Recirculation of sewage is an essential and important feature of high rate filters.
- 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, or to, the dosing tank of the filter, as shown in Fig.3.
- Sometimes, the effluent from the filter itself, before it enters the secondary clarifier, may be sent back to the primary clarifier.

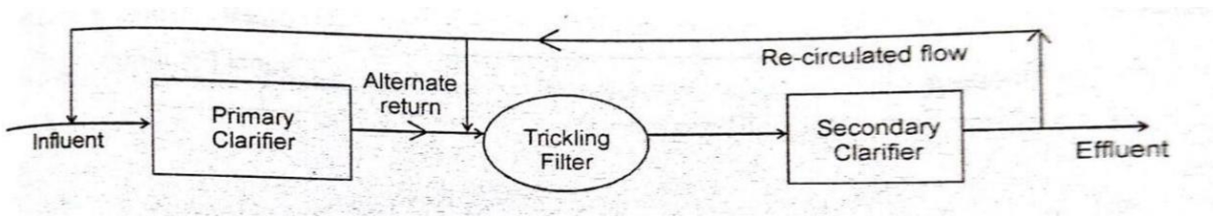


Figure.12:Single Stage commonly adopted Recirculation Process.

- In some other cases, and to obtain better efficiency, two stagerecirculation process may be adopted.
- A two stage recirculationprocess consists of having two filters arranged in series, as shown in Fig.4. Various other combinations are possible.

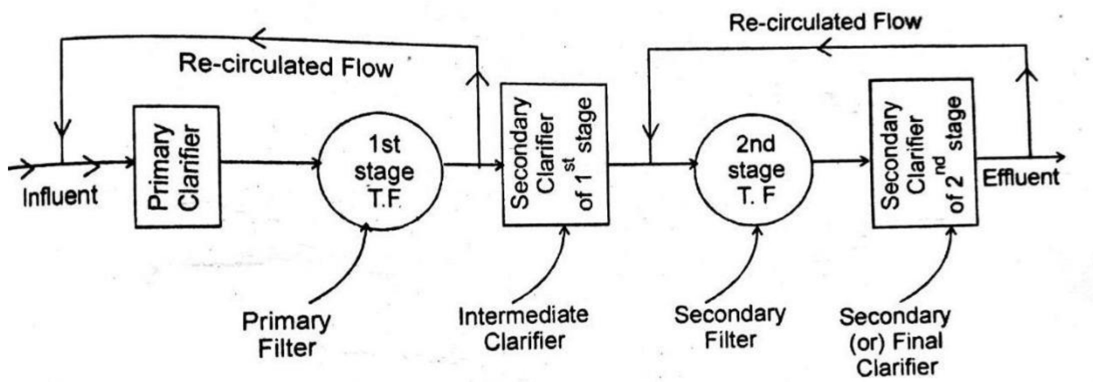


Figure.13:Two stage commonly adopted Recirculation Process.

- Recirculation improves the operating results of filters, because of the following reasons:

(i) Recirculation allows continuous dosing of the filters, irrespective of the fluctuations in flow.

(ii) Recirculationequalizes and reduces loading, thereby increasing the efficiency of the filter.

(iii) Recirculationprovides longer contact of the applied sewage with the bacteriafilm on the contact media, thereby seeding it with bacteria, 'and accelerating the biological oxidation process.

(iv) Theinfluent remains fresh all the time, and also helps in reducing odours. The fly nuisance is also comparatively less.

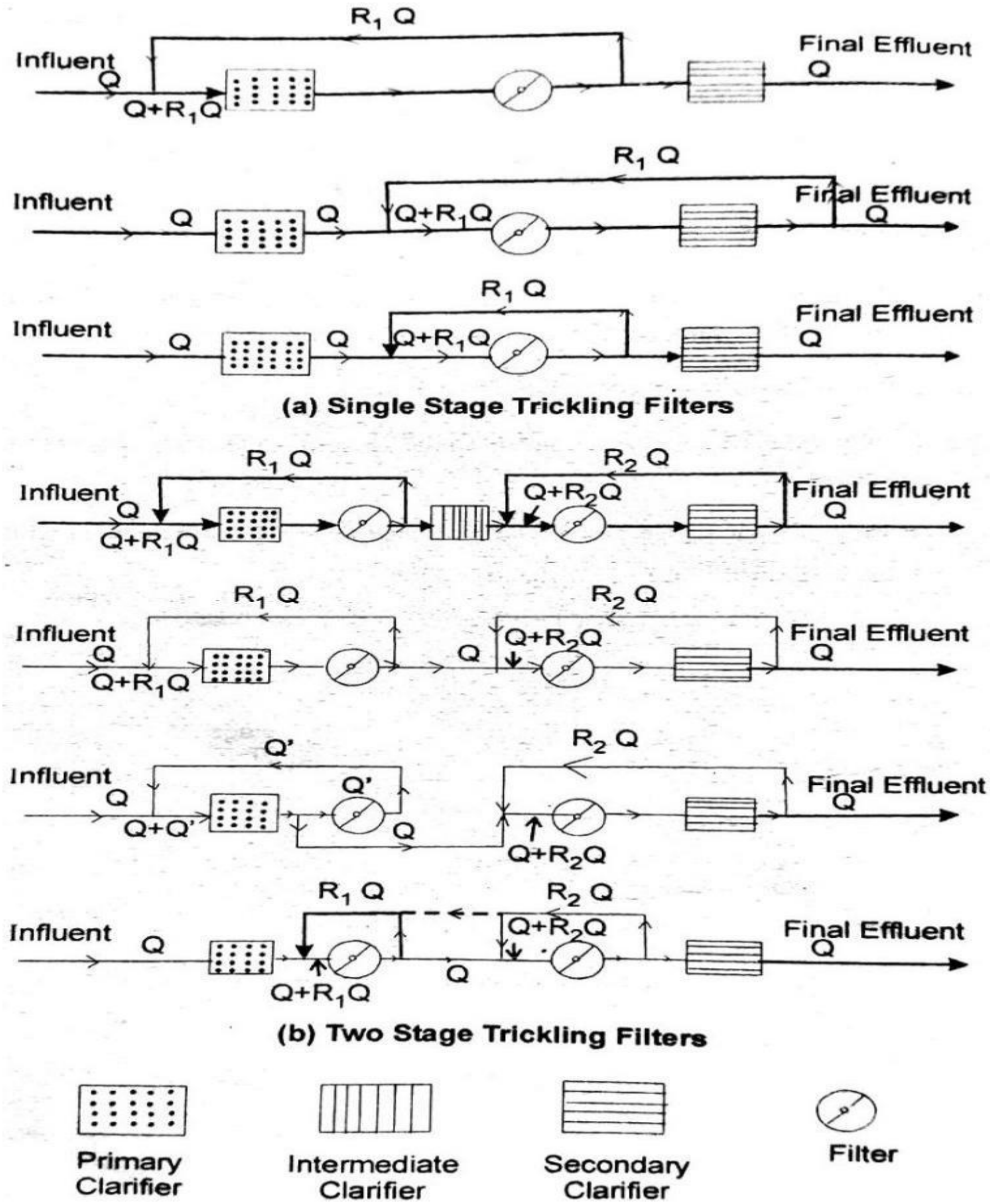


Figure.14: Flow diagrams for High Rate Trickling Filte

Efficiency of High rate filters:

The ratio (R/I) of the volume of sewage recirculated (R) to the volume of raw sewage (I) is called recirculation ratio. The recirculation ratio is connected to another term, called recirculation factor (F) by the relation

$$F = \frac{1+\frac{R}{I}}{\left(1+0.1\frac{R}{I}\right)^2}$$

The recirculation factor (F) also represents the number of effective passages through the filter. Thus, when there is no recirculation and (R/I) is zero, F" is unity.

The efficiencyofthe single stage high rate trickling filter can then be worked out by using the equation,

$$\eta(\%) = \frac{100}{1+0.0044\sqrt{\frac{Y}{V.F}}}$$

where Y = the total organic loading in kg/day applied to the filter, i.e. the total BOD in kg. The term $\frac{Y}{V.F}$ is also called unit organic loading on filter, i.e., u.

V = Filter volume in hectare-meters.

F = Recirculation factor

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 second stage filter.

η' = Final efficiency obtained after two stage filtration.

Effects 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 some conditions.

- The size of the secondary sedimentation tanks may also have to be increased.
- The volume of the filter, no doubt, will not be affected by recirculation, but the distributor will have the capacity to handle the increased flow.

14. Determine the size of a high rate trickling filter for the following data.

Sewage flow = 4.5 Mld

Recirculation ratio = 1.5

BOD of raw sewage = 250 mg/l

BOD of removal in primary tank = 30%

Final effluent BOD desired = 30 mg/l

SOLUTION:

Quantity of sewage flowing into the filter per day =

4.5Ml/d BOD concentration in raw sewage = 250 mg/l

∴Total BOD present in raw sewage = 4.5Ml × 250 mg/l = 1125 kg

BOD removed in primary tank = 30%

BOD left in the sewage entering per day in the filter unit

= 1125 × 0.7= 787.5 kg

BOD concentration desired in final effluent = 30 mg/l

∴ Total BOD left in the effluent per day = 4.5 × 30 kg = 135 kg

BOD removed by the filter = 787.5 – 135 = 652.5 kg

Efficiency of the filter = $\frac{\text{BOD removed}}{\text{Total BOD}} \times 100$

$= \frac{652.5}{787.5} \times 100$

= 82.85 %

Now, using equation we have

$$\eta = \frac{100}{1+0.0044\sqrt{\frac{Y}{V.F}}}$$

Where η = 82.85 % ; Y = Total BOD in kg = 787.5 kg

$$F = \frac{1+\frac{R}{I}}{\left(1+0.1\frac{R}{I}\right)^2};$$

Here $\frac{R}{I}$ = 1.5 (given)

$$F = \frac{1+1.5}{(1+0.1\times 1.5)^2} = 1.89$$

$$\therefore 82.85 = \frac{100}{1+0.0044\sqrt{\frac{787.5}{V\times 1.89}}}$$

V = 0.2 hectare-m

V = 2000 m^3

Assuming depth of the filter as 1.5m, we have

Surface area required = $\frac{2000}{1.5}$ m^2= 1333.3 m^2

∴Diameter of the circular filter required = $\sqrt{1333.3 \times \frac{4}{\pi}}$

= 41.2 m

Hence, use a high rate trickling filter with 41.2m diameter, 1.5m deep filter media, and with recirculation (single stage) ratio of 1.5.

15. Determine the surface area of a flow rate trickling filter to treat 10MLD of average sewage flow with a BOD of 300 mg/l at an organic loading rate of 0.2 kg BOD/m^3/day.

SOLUTION:

Average sewage flow = 10MLD

BOD of sewage = 300 mg/l

Organic loading = 0.2 kg BOD/m3/day

Total BOD per day = (10×106×300×10-6)

=3000 kg/day

$$\therefore \text{Volume of filter media required} = \frac{\text{Total BOD}}{\text{Organic loading}} = \frac{3000}{0.2}$$

$$= 15000\ m^3$$

The depth of the filtering media may vary between 2 to 3m

$$\therefore \text{Surface area} = \frac{15000}{2.5}$$

$$= 6000\ m^2$$

16. A single stage filter is to treat a flow of 3.79 M.l.d. of raw sewage with BOD of240 mg/l. It is to be designed for a loading of 11086 kg of BOD in. raw sewage per hectare meter, and the recirculation ratio is to be 1. What will be the strength of the effluent?

Solution:

Total BOD present in raw sewage = 3.79 ML x 240 mg/l= 909.6 kg

$$\text{Now, filter volume required} = \frac{\text{Total BOD in raw sewage in kg}}{\text{Given BOD loading rate of } 11086\ \text{kg/ha}-\text{m}}$$

$$\text{Volume required} = \frac{909.6}{110`86} \text{ha} - \text{m} = 0.082\ \text{ha} - \text{m}$$

Now, assuming that 35%ofBOD is removed in primary clarifier, we have

The amount of BOD applied to the filter= 0.65 x 909.6 kg= 591.24 kg.

Now, using equation

$$\eta(\%) = \frac{100}{1+0.0044\sqrt{\frac{Y}{V.F}}}$$

Y = Total BOD applied to the filter in kg = 591.24 kg

V = Vol. of the filter in ha-m. = 0.082 ha-m.

$$F = \frac{1+\frac{R}{I}}{(1+0.1\frac{R}{I})^2} \qquad \text{Here } \frac{R}{I} = 1$$

$$F = \frac{1+1}{(1+0.1\times 1)^2} = \frac{2}{1.21} = 1.65$$

$$H(\%) = \frac{100}{1+0.0044\sqrt{\frac{591.24}{0.082\times 1.65}}} = \frac{100}{1+0.291} = 77.45\%$$

The amount of BOD left in the effluent = 591.24 [1– 0.7745] kg. = 133.32 kg.

$$\text{BOD concentration in the effluent} = \frac{\text{Total BOD}}{\text{Sewage volume}}$$

$$\text{BOD concentration in the effluent} = \frac{133.32\times10^{6}}{3.79\times10^{6}} = 35.15\ mg/l$$

<u>Up flow Anaerobic Sludge Blanket</u>

17. With the help of neat sketch explain the function and operation of UASB. High rate anaerobic system

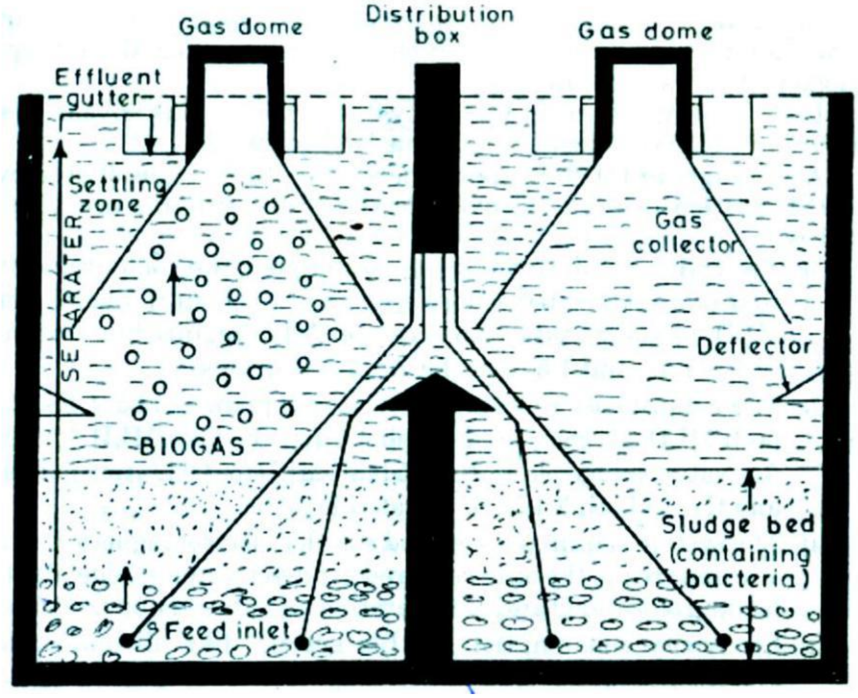


Figure.15: UASB Reactor

- The UASB reactor maintains a high concentration of biomass through the formation of biomass through the formation of highly settleable microbial sludge aggregates.
- Waste water flows upwards through a layer of very active sludge (sludge bed) to cause anaerobic digestion of organics of the waste water.
- At the top of reactor, three phases separation between gas-solid liquid takes place.
- This process is suitable for both soluble waste water as well as waste waters containing particulate matter.
- The waste water enters the tank from the bottom and flow upwards through the sludge bed, which is formed during the process itself.
- The sludge bed consists of anaerobic and facultative micro-organisms capable of flourishing in a oxygen deficient environment.
- The sludge bed (blanket) traps the suspended organics from the upflowingsewge which are degraded by anaerobic and facultative bacteria, which produce methane (CH4) and carbondioxide (CO2) (Biogas).
- The biogas produced helps in gentle mixing and stirring of biomass thereby increasing the efficiency of decomposition and reducing the BOD and suspended solids concentration of the waste water.

- The gas produced is sufficient to keep the sludge fully mixed.
- The biogas consists of 65 to 70% CH_4 and 30 to 35% CO_2.
- The methane (or) biogas is collected at the top of the tank in a gas collector.
- The water sludge mixture is made to enter a settling tank, where the sludge settles down and flows back into the bottom of the reactor.
- The sludge has good settling properties.
- There is no packing material. The microbes attach to each other or to small particles, agglomerate, granulates to form sludge bed or blanket.
- Retention time is about 6-8 hours with continuous bacterial process.
- The treated effluent is collected in gutters and discharged out of the reactor.
- The methane generated can be used for generating electricity to run the plant.
- The sludge is dewatered in drying beds and used as soil enricher.

Advantages :

- Space required is less compared to ASP/Oxidation pond/Aerated lagoons.
- Capital cost is less.
- System requires lesser/simpler electromagnetic parts.
- Low operation and maintenance cost.
- Electricity consumption is low and can withstand power failures.
- Low sludge production.
- Sludge has quick dewatering properties.
- Quicker sludge digestion.
- Biogas produced as by-product is used for electricity generation.
- It is used for treatment of high strength waste waters like those from municipalities and industries like food processing, distilleries, dairies etc.

Disadvantages:

- System lowers only two parameters of waste water.
- BOD
- Suspended solids.
- It does not remove heavy metals and toxic pollutants.
- Require larger quantity of organic matter (20 to 30 minutes) for growth of anaerobic bacteria.
- Acids produced by breakdown of organic matter in UASB may cause corrosion of reactor.
- Efficiency of BOD/SS removal is low.
- Pretreatment (Screening/Grit removal) is necessary.

18. Explain the working principle of waste stabilization ponds and mention their classification. (<u>Stabilization Ponds:</u>

- Stabilization ponds are open flow through earthen basins, specifically designed and constructed to treat sewage and biodegradable industrial waste waters.
- Such ponds provide comparatively long detention periods, extending from a few days to several days, during which time the wastes get stabilized by the action of natural forces.

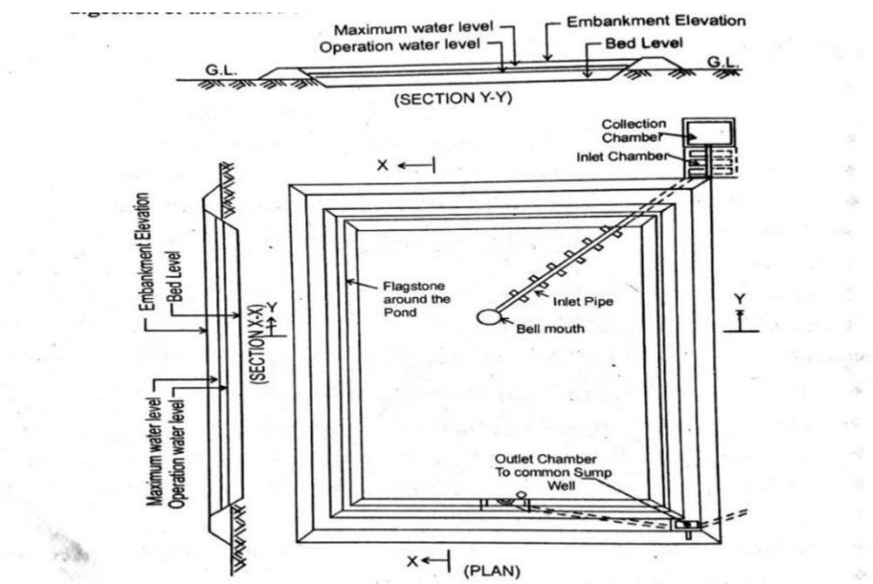


Figure.16: Oxidation pond

- Stabilization ponds may be classified as aerobic, facultative or anaerobic, depending upon the mechanism of purification.
- The term oxidation pond was originally referred to that stabilization 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 stabilization ponds.
- The results of the oxidation pond treatment are: the oxidation of the original organic matter and the production of algae, which are discharged with the effluent.
- This results in a net reduction in BOD, since the algae are more stable than the organic matter in waste water and degrade slowly in the river stream into which the effluent is discharged.
- The oxidation ponds, throwing their effluents in rivers, just upstream of some lake or reservoir are therefore, generally not preferred as the discharged algae may settle in the reservoir, and cause anaerobic decomposition and other water quality problems.
- However, the effluents from oxidation ponds can be easily used for land irrigation, particularly at places, where they cannot be discharged into river stream.

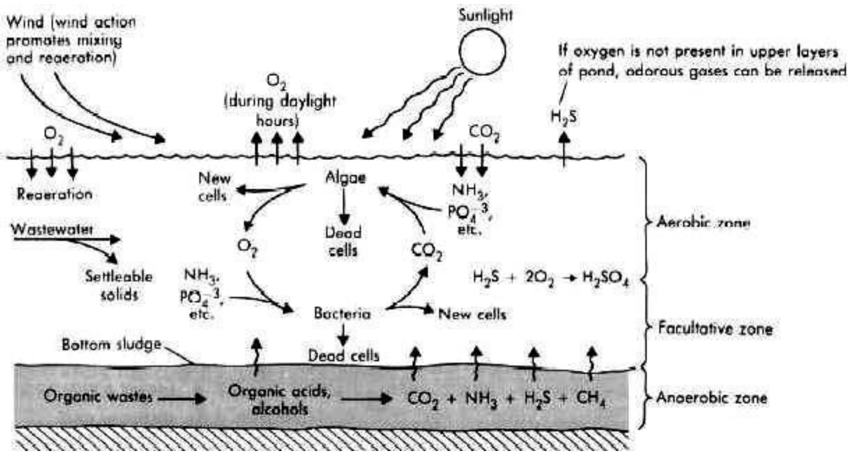


Figure.17: Process in Oxidation pond

Aerobic Ponds:

In a totally aerobic pond, the stabilization of wastes is brought about by aerobic pond bacteria, which flourish in the presence of oxygen.

- The oxygen demand of such bacteria which flourish in the presence of oxygen.
- The oxygen demand of such bacteria in such a pond is met by the combined action of algae and other micro-organisms, called algal photosynthesis, or **algal symbiosis**.
- In this symbiosis, the algae (which are microscopic plants) while growing in the presence of sunlight, produce oxygen by the action of photosynthesis; and this oxygen is utilized by the bacteria for oxidizing the waste organic matter.
- The end products of the process are CO2, ammonia and phosphates which are required by the algae to grow and continue to produce oxygen.

Anaerobic Ponds:

- In an anaerobic pond, however, the stabilization of waste is mainly brought about by the usual anaerobic conversion of organic wastes to carbon dioxide, methane and gaseous end products, with exception of foul odour and pungent smells.
- In a facultative pond, the upper layer 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 odour from such a pond.
- The treatment affected from such a pond is comparable to that of conventional secondary treatment process.
- The totally aerobic ponds will have to be of very small depths such as below 0.5m and still then may require occasional stirring, to prevent anaerobic condition in the settled sludge.
- It is therefore practicing difficult to construct and use such purely aerobic ponds.

Facultative Ponds:

- The facultative ponds, with depths varying between 1m to 1.5m, are thus most widely used for treatment of sewage.
- Deeper ponds in the depth range of 2.5m to 4m also sometimes are constructed to work anaerobically.
- Treatment ponds have been used to treat waste water for many years, especially for small communities.

Oxidation Ditch:

19. Explain Oxidation ditch/ Pasveer ditches / Extended Aeration in detail? It is a modified activated sludge process (ASP).

- It eliminates primary sedimentation and sludge digestion.
- As the aeration time is longer, it is called extended aeration process.
- Oxidation-ditch plant is economical for population upto 1.5 lakh, compared to ASP or trickling filters.
- Land requirement is less.
- Oxidation ditch plant involves the construction of number of ditch channels, placed side by side having depth of 1-1.5m, width of 1-5m based on the rotors used. The length may vary from 150m to 1000m.
- The oxidation ditches may be constructed either in earthwork with earthern embankments (or) in brick (or) in stone masonry walls.
- Each ditch channel is equipped with a horizontal axis rotor for agitating and circulating the sewage and thereby oxygenating the sewage and keeping the sewage-solids in suspension.
- The velocity of sewage is 0.3m/s.
- The aerated sewage is then settled in a settling tank by stooping the rotors for 2 hours.
- When rotors are stopped, the supernatant liquor is taken out.
- A part of settled sludge is recirculated and the excess sludge (stabilized) is easily dried in sand beds and disposed suitably.

Types of oxidation ditches:

(i) Intermittent Flow type:

- There is no separate settling tank.
- When the rotor is stopped, the sludge get settled and the supernatant is withdrawn.
- The surplus sludge is removed and disposal after treatment.

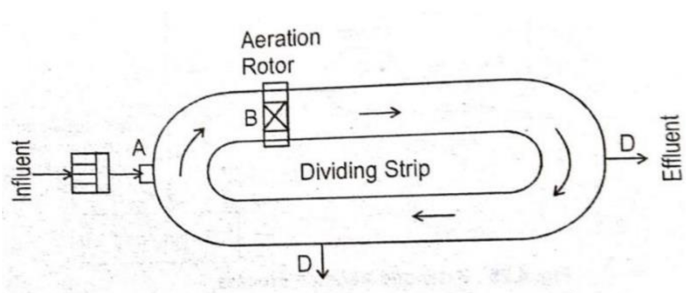


Figure.18: Intermittent Flow type.

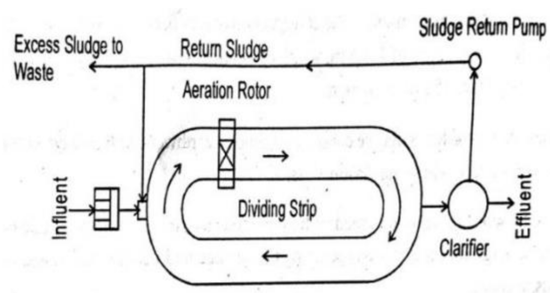


Figure.19: Continuous Flow type

(ii) Continuous Flow type:

- There is continuous operation.
- The mixed liquid gets settled in a separate settling tank.

Design considerations:

- Long aeration basin to carry MLSS concentration – 3000 to 8000mg/l.
- F/M ratio (loading factor) is low – 0.03 to 0.1.
- Efficiency – 95% for suspended solids removal.
- 98% for BOD removal.
- Settled sludge which is mineralized is dried without odours.
- Detention of period = 12 to 15 hours (or)

= 0.8 to 2.5m^3 per kg of BOD5 load in sewage.

- Volume of ditch = 150m^3 per meter length of rotor.

Kinetic Equations (Similar to ASP):

- Normally MLVSS is taken as the mass of active micro-organisms in reactor, but in oxidation ditch, it includes inactive volatile suspended solids also.

Influent soluble BOD S0 = La – BOD of suspended solids in

influent (0.25 kg/kg of SS)

BOD of SS escaping with effluent = 0.45 kg/kg of SS.

Microbial mass conc = 60% MLSS.

.

$$- = \frac{}{(\overline{100}) \times 0}$$

Sludge return ratio, $- = \frac{1 6}{0} -$

$$= \frac{(\ .\ (0-\ )}{1+\ .}$$

SS – Suspended solids

MLVSS – Mixed Liquor Suspended Solids
Microbial mass in excess sludge, = __

Wasting of excess sludge = __

Active microbes in return sludge.

(+)= .

Hydraulic retention time = _
Process loading = (0–) kg total BOD/kg of MLSS.
.

Where,

X = MLVSS mg/l.

Q = Sewage inflow.

V = Volume of aeration tank/ Oxidation ditch.

= MCRT (days).

Y = Growth yield co-efficient.

$_0$= Influent soluble BOD (mg/l)

S = Effluent soluble BOD (mg/l)
=Return sludge flow.

SVI = Sludge volume Index.

20. Explain the Design Considerations in Oxidation Ditch.

- The volume of the aeration channel required under Indian climates should be such as to give a detention period of 12 to 15 hours, or 800 to 2500 litres per kg of BOD load present in the sewage admitted.
- The concentration of the suspended solids in the mixed liquor should be high, say about 4000 to 5000 mg/l.
- The volume of the ditch approximates 120 to 150 cum per metre length of the rotor.
- The length of the standard horizontal axis cage type rotor used is 1 m.
- The rotor is in the form of a cylindrical cage of 0.7 m in diameter, and is rotated at a speed of 75 RPM, while dipping 10 cm into the liquid.

21. Describe in detail the mechanically Aerated Lagoons.

- A mechanically aerated lagoon is a deeper oxidation pond, with oxygen introduced by mechanical aerators rather than relying on the photosynthetic oxygen production alone.
- These ponds are deeper than the oxidation ponds, and as they are artificially aerated, less detention time and areas are required.
- The depth of these basins normally ranges between 2.4 to 3.6 m,
- Detention time between 4 to 10 hours.
- The land area required is about 5 to 10% of that required for an equivalent oxidation pond. The efficiency obtained ranges between 65 to 90%.
- The aerated lagoons are frequently used for treating industrial waste waters as well as city sewage.

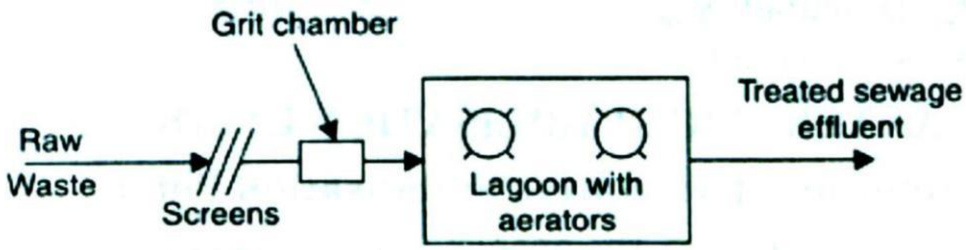


Figure.20:Aerated lagoon

22. Explain Rotating Biological Contactors (RBCs).

- A rotating biological contactor (RBC) is a cylindrical media made of closely mounted thin flat circular plastic sheets or discs of 3 to 3.5 m in diameter, 10 mm thick, and placed at 30 to 40 mm spacing mounted on a common shaft.
- Thinner materials can be used by sandwiching a corrugated sheet between two flat discs and welding them together as a unit.
- The R.B.C. are usually made in up to 8 m length, and may be placed in series or parallel in a specially constructed tank(s) through which the wastewater is allowed to pass.
- The RBC's are kept immersed in wastewater by about 40% of their diameter.
- The RBC's are rotated around their central horizontal shaft, at a speed of l-2 rpm by means of power supplied to the shaft.
- Approximately 95% of the surface area is thus alternately immersed in the wastewater and then exposed to the atmosphere above the liquid.
- When the process is operated, the microorganisms of the wastewater begin to adhere to the rotating surfaces and grow there, until the intersurface area of the disc gets covered with 1 to 3 mm layer of biological slime.
- As the discs rotate, they carry a film of wastewater into the air, where it trickles down the surface of the discs absorbing oxygen.
- As the discs complete their rotation, this film mixes with the wastewater in the tank, adding to the oxygen of the tank and mixing the treated and partially treated wastewater.
- As the attached microorganisms pass through the tank, they absorb other organics for breakdown. The excess growth of microorganisms is sheared from the discs, as they move through the wastewater tank.
- The dislodged organisms are kept in suspension by the moving discs. This suspended growth finally moves down with the sewage flowing through the tank to a downstream settling tank for removal.
- The effluent obtained is of equal or even better quality than what is obtained from other secondary treatments.
- The quality of the effluent can further be improved by placing several contractors in series along the tank.
- The method can thus provide a high degree of treatment, including biological conversion of ammonia to nitrates. As is evident, a given set of discs (i.e. an RBC) serves the following purposes:
  - ❖ They provide media for buildup of attached microbial growth.

- They bring the growth of microbes in contact with the wastewater.
- The aerate the wastewater and the suspended microbial growth in the wastewater tank.

- In this process, the attached growths are similar in concept to a trickling filter, except that here the microorganisms are passed through the wastewater, rather than the wastewater passing over the microbes, as happens in a trickling filter.
- The hydraulic loading rates may vary between 0.04-0.06 m/day
- Organic loading rates between 0.05-0.06 kg BOD/m^2/ day, based upon the disc surface area.

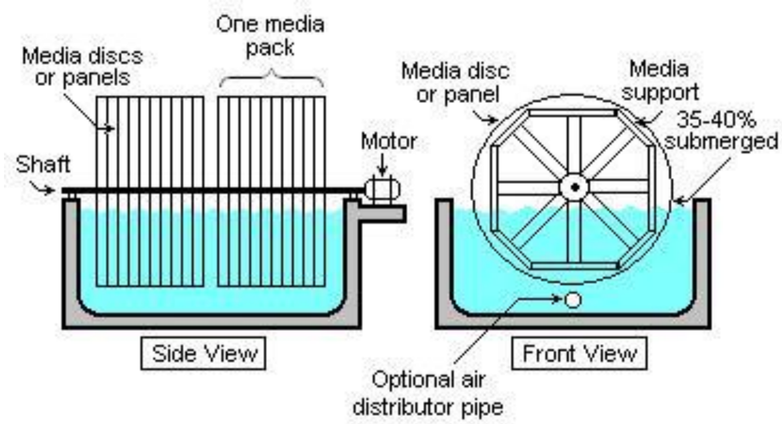


Figure.21: Rotating biological contactor

23. Discuss the operational problems of standard high rate trickling filter and their remedies.

Trickling filters

(i) Fly Nuisance

- The filter fly, psychoda, which develops in the filter particles, may prove to be nuisance, as the same may be carried away into the habitation.
- This problem may be controlled by flooding the filter with sewage for 24 hours or more.
- The flooding will destroy the larvae, and usually interfere slightly with the results of operation.
- Another method of controlling fly nuisance is by using insecticides, such as D.D.T., and benzene hexachloride, etc. in the filter plant.

(ii) Odour Nuisance

- When fixed nozzles are used, H2S and other odour gases are frequently released from the sprays into the atmosphere.
- The usual remedy is to chlorinate the sewage to prevent formation of H 2S gas, or to neutralize that already formed.
- The remedy is to chlorinate the sewage, and to keep sewage fresh by recirculation, as is done in rapid filters.

(iii) Ponding trouble

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

- This may result in Ponding of the sewage over the filter bed.
- This trouble, posed by algae and fungi, can be controlled by chlorinating the sewage, which kills the algae, thus causing unloading of the accumulated material.
- Other methods of controlling algae are to add copper sulphate to the sewage, and resting the bed for some time.

24.Design an oxidation pond for treating sewage from a hot climatic residential colony with 5000 persons, contributing sewage at 120 liters per capital per day. The 5-day BOD of sewage is 300mg/l

Solution:

The quantity of sewage to be treated per day = 5000×120 = 6,00,000litres = 600 cu.m

The BOD content per day = 0.6 ML × 300 mg/l = 180 kg

Now, assuming organic loading rate in the pond (in hot climates as say 300kg/hec/day) we have,

$$\text{Surface required} = \frac{180\ \text{kg/d}}{300\ \text{kg/hec/day}} = \frac{180}{300}\ \text{hec} = \frac{180}{300} \times 10^4 m^2$$

$= 6000 m^2$

Assuming the length of the tank(L), as twice the width(B), we have $2B^2 = 6000$

B = 54.7m ~ 55m

∴ Use $L = \frac{6000}{55} = 110m$

Using a tank with effective depth 1.2m, we have

The provided capacity = 110×55×1.2 = $7260 m^3$

Now, Capacity = Sewage flow per day × Detention time(days)

$$\text{Detention time in days} = \frac{\text{Capacity in cu.m}}{\text{Sewage flow per day in cu.m/day}} = \frac{7260}{600}$$

= 12 days

Hence, use an oxidation pond with length = 100m, width = 55m and Overall depth = (1.2+1) = 2.2m and Detention period of 12 days.

Design of Inlet Pipe:

Assuming, an average velocity of sewage as 0.9 m/sec, and daily flow for 8 hours only.

$$\text{Discharge} = \frac{600}{8\times60\times60}\ \text{Cumecs}$$

Area of inlet pipe required,

$$= \frac{\text{Discharge}}{\text{Velocity}} = \frac{600}{8\times60\times60} \times \frac{1}{0.9} m^2 = 0.0232\ m^2$$

$= 232\ cm^2$

Diameter of inlet pipe,

din $= \sqrt{\frac{4\times232}{\pi}} = 18$ cm

Diameter of outlet pipe may be taken as 1.5 times that of the inlet pipe diameter. dout = 1.5×18 = 27 cm

∴ Diameter of Inlet pipe =18 cm Diameter of Outlet pipe = 27 cm

25. Design an oxidation ditch for a community of 7500 with a per capita sewage contribution of 90 lpcd and BOD 250 mg/l. The desired BOD of the treated sewage is 30 mg/l.

Solution:

Population = 7500

Per capita sewage = 90 lpcd

Influent BOD = 250 mg/l

Effluent BOD = 30 mg/l

(i) Inflow rate & BOD removal efficiency:

Waste water flow = 7500 X 90 = 675000 lit/d = 675 m^3/d

BOD removal required $= \frac{250-30}{250} \times 100 = 88\%$

(ii) Volume of ditch:

$$\frac{F}{M} = \frac{Q.Y}{\left(\frac{V}{1000} \times X_t\right)^o}$$

Choosing $\frac{F}{M} = 0.1$ Xt = 4000 mg/l

$$0.1 = \frac{675 \times \times 250}{V}$$

$$V = \frac{1000 \times 675 \times 250}{0.1 \times 4000} = 421.875\ m^3$$

(iii) Volumetric loading rate:

Q in terms of MLD

Volumetric loading rate $= \frac{Q \times Y_o}{V} = \frac{0.675 \times 250}{421.875} = 0.4$ kg BOD/m^3

(iv) Hydraulic retention time:

$HRT = \frac{V}{Q} = \frac{421.875}{675} = 15$ hours

(v) Return sludge ratio:

$$r = \frac{Q_r}{Q} = \frac{X_t}{\frac{10^6}{SVI} - X_t}$$

Adopting value of SVI = 100,

$$r = \frac{Q_r}{Q} = \frac{4000}{\frac{10^6}{100} - 4000} = 0.667$$

Which is within prescribed range of 0.35 to 1.5

(vi) Oxygen requirement & no. of rotors

O2 required = 1.2 kg/kg of BOD removed

= 1.2 (250-30) X 0.675 = 186.3 kg/day

= 7.7625 kg/hr

Oxygenation capacity of cage rotor of dia. 70 cm, @ 75 rpm, at immersion depth of 10 cm = 2.8 kg of O2/hr/m length.

$$= \frac{7.7625}{2.8} = 2.77 \text{ m; say } 2.8 \text{ m}$$

Length of rotor needed d=from velocity consideration of 0.3 m/s (assuming 150 m^3 of ditch volume per m length of rotor for adequate circulation)

$$= \frac{421.875}{2.8} = 2.8125 \text{ m}$$

Hence adopt 2 rotors of 1.4 m length each. Giving a clearance of 0.25 m on either side, width of ditch = 1.4+2X0.25 = 1.9 m

Let us keep a depth of 1.5 m

Surface area required $= \frac{421,875}{1.5} = 281.25\ m^2$

Adopting one ditch, surface area of ditch = 281.25 m^2

Length of ditch $= \frac{281.25}{1.9} = 148$; say 150 m

(vii) Power required:

Power required for each rotor @ 1.35 kW/m length = 1.35 X 1.4 = 1.90 kW

(viii) Design of settling tank:

Let us SOR of 20 $m^3/m^2/day$ and detention time for 2 hours

Surface area $A = \frac{Q}{SOR} = \frac{675}{20} = 33.75\ m^2$

$V = \frac{675}{24} \times 24 = 56.25\ m^3$

Depth of tank $= \frac{56.25}{33.75} = 1.67$ m

Dia of tank $= \sqrt{\frac{33.75 \times 4}{\pi}} = 6.55$ m

Provide 6.6 m dia. tank of 1.7 m depth with hopper bottom,

Actual area $A = \frac{\pi}{4}(6.6)^2 = 34.21\ m^2$

Actual SOR $= \frac{675}{34.21} = 19.73\ m^3\ /m/day$

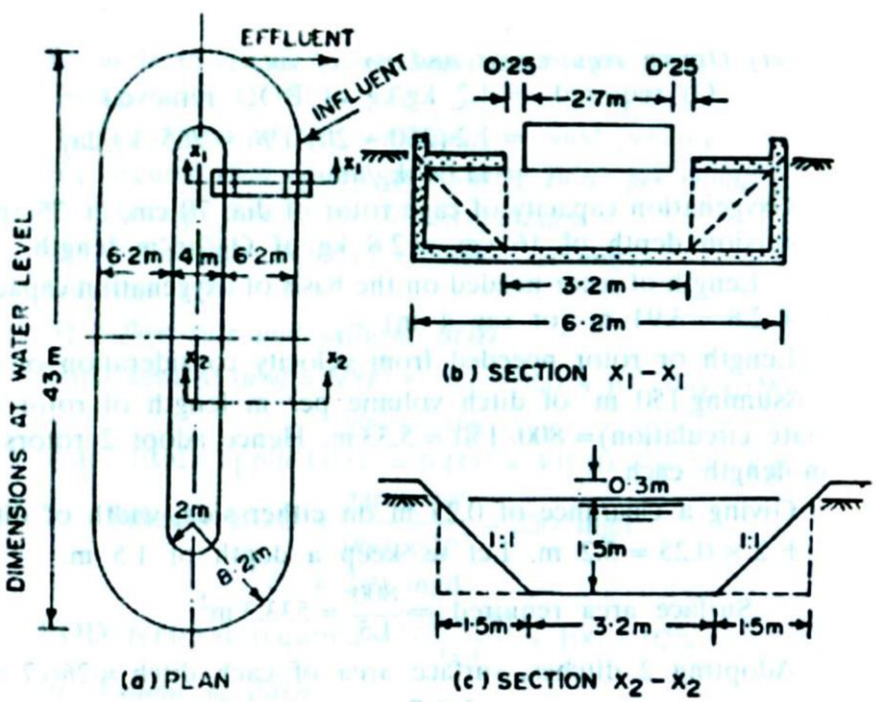


Figure.22: Designed Oxidation ditch

26.What are the basic requirements of successful operation of sewage treatment plant?

1. Thorough knowledge of processes
2. Knowledge of plant and machinery
3. Proper and adequate tools in the work place
4. Adequate spare parts and chemical goods stocks to be maintained
5. Specific maintenance responsibility to the plant operator
6. Training all the operators
7. Good housekeeping of the plant
8. Systematic and periodic maintenance schedule

27. Explain about the sewage recycle in residential complex

Sewage Treatment & Recycle Technologies

- Sewage treatment and recycle plants are usually divided into primary, secondary and tertiary treatment.
- Whatever the technology that is selected, primary and tertiary treatment requirements are more are less similar.
- Primary treatment includes screens for removing floating and large sizes objects from sewage which may otherwise choke the pipe lines and pumps in the subsequent treatment process.
- Grit chambers are also provided to remove particles such as sand, bone chips, etc. which would otherwise increase the wear and tear of moving mechanical equipment.
- In small sewage treatment plants, however, many designers avoid grit chambers for simplicity of the scheme.
- Also, the quantity of grit from housing complexes or commercial complexes is usually low.
- One of the important primary treatment units in the case of small sewage treatment systems is the equalization tank.
- As most of the secondary treatment systems are biological, they need to be operated continuously.
- The size of the treatment system can also be small when designed as a continuous process.
- Continuous treatment also increases efficiency of the system. Sewage generation from housing complexes is not continuous and will be more in morning and evening hours.
- In case of commercial complexes, sewage generation is limited to the working hours.
- Hence, the equalization tank acts like a buffer tank, which stores sewage during peak hours and supplies the same continuously into the biological treatment unit.
- Aeration of equalization tank is important to avoid septic conditions, thereby avoiding bad odour.
- Tertiary treatment at the end of secondary treatment is provided to further treat the sewage to make it suitable for recycle.
- Tertiary treatment units generally include chlorination, sand filtration and activated carbon.
- For treating sewage from toilets, a wide range of commercially available technologies exists.
- These include the age-old activated sludge process, compact high rate fixed film biological systems and state-of-the-art submerged membrane systems.
- Based on the economics and end use of the treated sewage, different schemes can be adopted.
- Usually treated sewage is used for gardening after tertiary treatment.
- The state-of-the-art technology adopted for sewage treatment these days is usually the membrane bio-reactor (Fig. 3).
- Membrane bio-reactors use bacteria to digest the organic matter in the sewage, and membranes to separate the water from the contaminants.
- The treated water from the membrane bio-reactor can be further treated using the reverse osmosis process, to produce high quality water suitable even for drinking.

- But the human mind rejects treated sewage even though the quality is much better than raw water available from many sources.
- But these kinds of systems can be used in industries for producing process quality water.

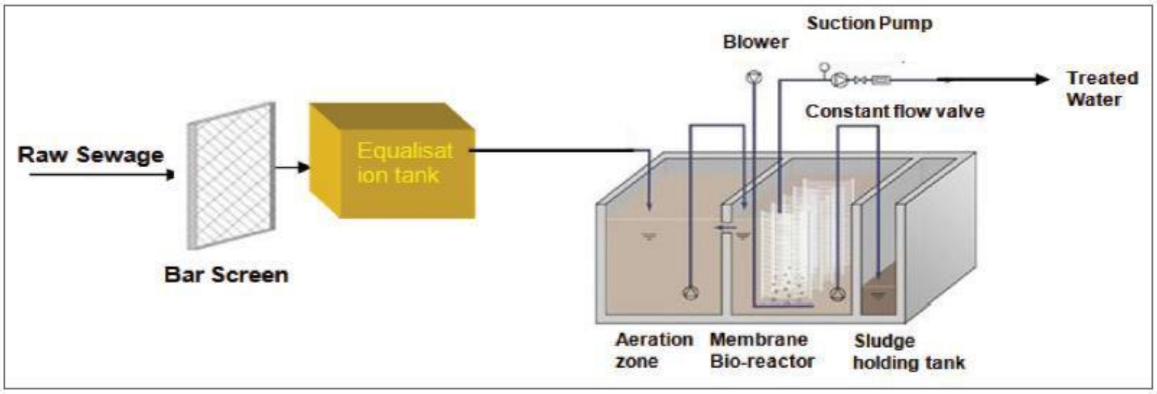


Figure.23: Treatment of Sewage Using Membrane Bio-reactor

UNIT-4
DISPOSAL OF SEWAGE

Standards for disposal

1. State the Indian standards for sewage disposal on land and conditions favouring it.

Table: BIS (ISI) Standards for discharge of sewage and Industrial Effluent in surface water sources and public sewers.

S.No	Characteristics of the effluent	Tolerance Limit for sewage effluent discharged into surface water sources as per IS 4764-1973	Tolerance Limit for Industrial Effluents Discharged into	
			Inland surface waters, as per IS 2490-1974	Public sewers as per IS 3306-1974
1.	BOD_5	20 mg/l	30 mg/l	500 mg/l
2.	COD	-	250 mg/l	-
3.	pH value	-	5.5 to 9.0	5.5 to 9.0
4.	Total suspended solids (TSS)	30 mg/l	100 mg/l	600 mg/l
5.	Temperature	-	40^0C	45^0C
6.	Oil and Grease	-	10 mg/l	100 mg/l
7.	Phenolic compounds (as Phenol)	-	1 mg/l)	5 mg/l
8.	Cyanides (as CN)	-	0.2 mg/l	2 mg/l
9.	Sulphides (as S)	-	2 mg/l	-
10.	Fluorides (as F)	-	2 mg/l	-
11.	Total residual chlorine	-	1 mg/l	-
12.	Insecticides	-	Zero	-
13.	Arsenic (as As)	-	0.2 mg/l	-
14.	Cadmium (as Cd)	-	2 mg/l	-
15.	Chromium, hexavalent (as Cr	-	0.1 mg/l	2 mg/l
16.	Copper	-	3 mg/l	3 mg/l
17.	Lead	-	0.1 mg/l	1 mg/l
18.	Mercury	-	0.01 mg/l	-
19.	Nickel	-	3 mg/l	2 mg/l
20.	Selenium	-	0.05 mg/l	-
21.	Zinc	-	5 mg/l	15 mg/l
22.	Chlorides (as Cl)	-	-	600 mg/l
23.	% sodium	-	-	60%
24.	Ammoniacal Nitrogen	-	50 mg/l	50 mg/l

	(as N)			
25.	Radioactive Material i) - ii) -	-	10^{-7} / (micro curie/ml) 10^{-6} /	- -

Methods of disposal:

2. Explain the methods of disposal and dilution.

Methods of Disposal of wastewater	Dilution
(i) Natural methods	i) By Dilution ii) By Land treatment
(ii) Artificial methods	i) Primary treatment ii) Secondary treatment
(iii) Combined methods	i) Primary treatment ii) Effluent disposal by natural methods.

Disposal by dilution (Natural Methods):

- Dilution is a method of natural disposal, discharging the waste water into the receiving water bodies (river, sea, lake etc.)
- Disposal by dilution is the process whereby the treated effluent (or) waste water from the treatment plant is designed either in static water bodies (lake (or) ponds) (or) in moving water bodies such as rivers (or) streams.
- It is based on the assumption that sufficient dissolved oxygen (DO) is available in the receiving water body so that the BOD of waste water is satisfied to stabilize the organic waste.
- If the diluting water is not sufficient to supply the dissolved oxygen (DO) to oxidize organic matter, there will be foul smell due to half-digested putrefying matter.
- The depletion of oxygen in surface waters kills aquatic life and the water will be unfit for drinking and pose danger to public health.
- Hence, atleast primary treatment of waste water is required.
- The discharged waste water (or) effluent is purified in due course of time by self purification process of natural waters.

Conditions favouring dilution "Without treatment".

- When waste water is fresh and it is discharged within 2 to 3 hours of its collection.
- The floating matter and settleable solids have been removed.
- Volume of receiving water body is comparatively larger than the volume of waste water.
- Where the diluting water has high content of D.O to satisfy BOD and also to support aquatic life.
- Where it is possible to thoroughly mix the waste water in the water body.

- Where it is possible to thoroughly mix the waste water in the water body.
- Where swift forward currents are available so that there is no deposition of sewage.
- When waste water does not contain industrial or toxic waste.
- Where receiving water body is not a source of drinking water at downstream side.

Conditions essential for treatment before dilution:

- Where the waste water discharge is dangerous to aquatic life.
- Where the waste water contains industrial or toxic waste.
- Where the volume of diluting water is not sufficient.
- Where the receiving waters are used for inland navigation.
- Where the receiving water is a source of drinking water.
- Where waste water is not fresh but is stale.

Standards of dilution:

$$\text{Dilution Factor} = \frac{\text{Quantity of receiving (or) diluting water}}{\text{Quantity of wastewater / Effluent discharged}}$$

Table: Standards of Dilution

Dilution factor	**Standards of purification required**
Above 500	• No treatment is required. • Raw sewage is discharged into water body.
300 to 500	• Primary treatment (Plain sedimentation) is required. • Effluent > 150 ppm of suspended solids.
150 to 300	• Treatments like sedimentation, screening and chamber precipitation are required. • Effluent > 60 ppm of suspended solids.
Less than 150	• Thorough treatment is required. • Effluent > 30ppm of SS and BOD_5 > 20ppm.

Self purification of rivers

2. Discuss the principle of the self-purification process of stream and factors influencing the process. (Or) What do you mean by "Self purification of stream"?(Or) Explain various actions involved in the self purification process of a stream. (Or) Explain the self purification process of rivers and the various stages of oxygen sag curve.

Dilution in Rivers (Self purification)

When sewage is discharged into water body, it gets polluted, but in due course of time, due to dilution, sedimentation, oxidation-reduction, the water gains its original condition. This is known as self purification phenomenon.

Natural forces of purification:

1. Physical forces

- i) Dilution and Dispersion
- ii) Sedimentation
- **iii)** Sunlight (Biochemical reactions**)**

2. Chemical forces + Biological forces (Biochemical)

- i) Oxidation
- ii) Reduction

Actions involved in self purification:

Dilution:

- When waste water is discharged into large volume of receiving water body, the concentration of the organic matter is reduced and the potential nuisance of sewage is reduced.
- If C_S and C_R are the concentrations of any impurity in sewage and river stream and Q_S and $Q_R$are the rates of sewage flow and rate of stream flow, then the resulting mixture concentration.

$$C = \frac{C_S Q_S + C_R Q_R}{Q_S + Q_R}$$

Dispersion due to currents:

- Self purification of stream largely depends on the current which will disperse the waste water in the stream, preventing locally high concentration of pollutants.
- High velocity improves re-aeration which reduces the concentration of pollutant.

b) Sedimentation:

- If the stream velocity is less, sedimentation will take place which will have two effects.
- The suspended solids, which contribute largely to O2, demand will be removed by settling and hence water quality at the downstream is improved.
- Due to settled solids, anaerobic decomposition takes place.

c) Sunlight:

- Stimulate growth of algae which produce oxygen during day light.
- The water body will be super saturated with dissolved oxygen, due to algal growth.

d) Oxidation:

- The organic matter present in the waste water is oxidized by aerobic bacteria utilizing the dissolved oxygen present in the natural water.
- Oxidation continues till organic wastes are completely stabilized.

e) Reduction:

- Reduction occurs in the stream due to hydrolysis of the organic matter biologically (or) chemically.
- Anaerobic bacteria split the organic matter into liquid and gases, causing complete stabilization.

Natural forces of purification depend on:

(i) Temperature:

- Temperature decides the dilution and sedimentation rate.
- Rate of biological and chemical activity also depends on temperature.
- At high temperature, the bacteria activity is high and the rate of decomposition of organic matter is also high.
- But dissolved oxygen is less at high temperature.
- At high temperature, self-purification takes lesser time.

(ii) Turbulence:

- Turbulence in water body helps in aeration and re-aeration of water surface and maintains aerobic conditions.
- Too much turbulence, however increases turbidity and scours away the settled sediments and retards self-purification.

(iii) Dissolved oxygen:

- If the amount of dissolved oxygen in water body is large, self purification will be faster.

(iv) Hydrography:

- Hydrography affects the velocity and surface area of river stream.
- High velocity and large surface area cause turbulence and rapid re-aeration.

(v) Amount and Types of organic matter and Biological growth:

- Algae absorb CO_2 and releases O_2 which helps in the self-purification process.

(vi) Rate of Reaeration:

- Rate of which reaeration or dissolved oxygen is replenished govern the self-purification process.

- Greater the rate, quicker will be the self-purification.

3. What are the various zones of pollution in a river – stream.

Explain. Zones of pollution in a River stream

- Zone of degradation / Zone of pollution.
- Zone of active decomposition
- Zone of recovery
- Zone of clear water

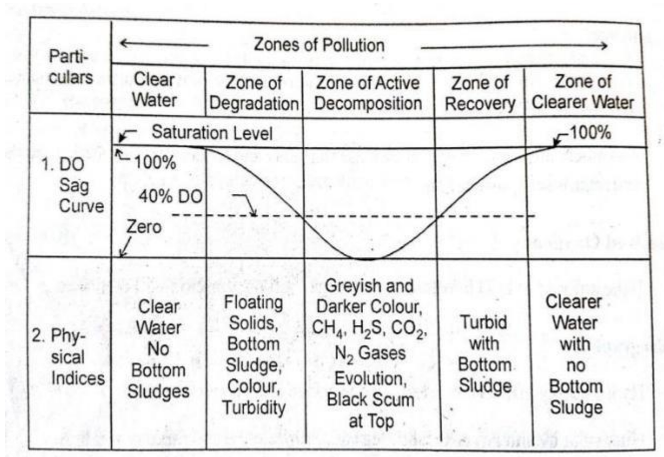


Figure.1: Zone of pollution along a stream

(i) Zone of degradation:

- This zone is situated just below the outfall sewer (Near discharge point).
- Water is dark and turbid, sludge deposits form at the bottom.
- Dissolved oxygen is reduced to 40% of the saturation value.
- CO_2 increases in water.
- Dissolved oxygen depletion (de-oxygenation) is faster than re-aeration.
- Conditions are unfavorable for aquatic life, algae dies but fish lives on the organic waste.

(ii) Zone of Active decomposition:

- This zone is marked by heavy pollution.
- Water becomes greyish and darker than previous develop.
- Active anaerobic organic decomposition takes place, with evolution of CH_4, H_2S, CO_2, N_2.
- The gases and sludge forms ugly scum on surface.
- Fish life is absent in this zone. Algae is also absent.
- When the organic matter is decomposed and stabilized, re-aeration starts and dissolved oxygen increases upto 40%.

(iii) Zone of Recovery:

- The process of recovery starts in this zone and the river recovers its original condition.
- Complete stabilization of organic matter takes place.
- The stabilized or organic matter settles down as sludge, BOD falls and DO content rises above 40% of saturation value. The water becomes clearer.
- The organic matter is mineralized into nitrates, sulphates, phosphates, carbonates etc.
- Near the end of this zone, microscopic aquatic plants reappear, fungi decreases and algae reappears.

(iv) Clearer water zone:

- In this zone, the natural condition of stream is restored.
- Water becomes clearer.
- Dissolved oxygen rises to its saturation level.
- Game fish which survives at D.O of 4 to 5 mg/l and other aquatic life reappears.
- River attains its original condition.

Indicators of self-purification:

Physical Indicators - Color, Turbidity

Chemical Indicators - D.O., BOD, Suspended solids

- Biological Indicators- Growth of different micro and macro-organisms.

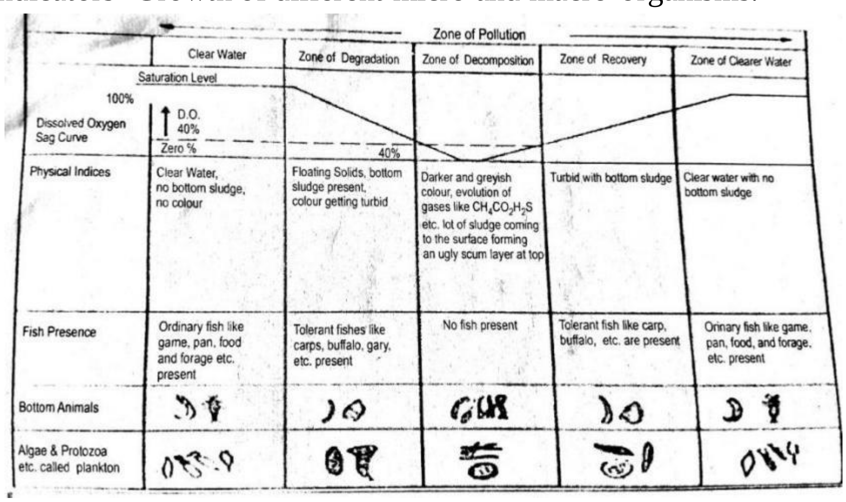


Figure.2: Zones of pollution in a river or stream.

O_2 sag curve / Oxygen deficit of polluted river – Stream /Oxygen sag analysis

4. Draw a typical oxygen sag curve and explain its meaning. (Or) Explain about oxygen sag curve and its importance. (Or)Explain the streeter phelps equation and its application.

The oxygen deficit 'D' at any time in a polluted river-stream is the difference between the saturation D.O and the actual D.O of water at that time.

Oxygen Deficit, D = Saturated D.O of water at specific temperature – Actual D.O of water

- The oxygen deficit is nil for clear waters.
- The oxygen deficit depends on the rates of de-oxygenation and re-oxygenation.

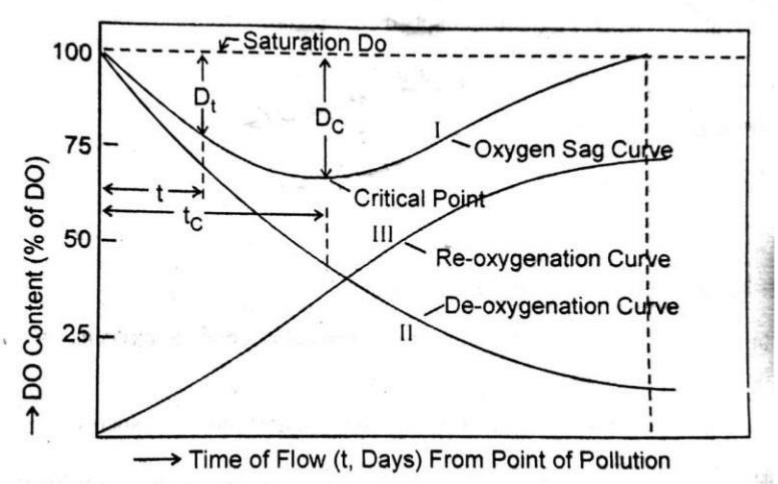


Figure.3 : Deoxygenation, Reoxygenation and Oxygen sag curves

De-oxygenation curve (similar to BOD curve):

- In a polluted stream, D.O goes on reducing due to decomposition of organic volatile matter.
- At any time, the rate of de-oxygenation depends on the amount of organic matter which is remaining to be oxidized (L_t) and temperature.
- De –oxygenation curve is similar to the first stage BOD curve.

$$\frac{dL_t}{dt} = -k \times L_t$$

Where,

L_t = Oxygen equivalent carbonaceous oxidizable organic matter present in the sewage after t days from the start of oxidation in mg/l.

Re –oxygenation Curve:

- In order to counter balance te deoxygenation or D.O lost due to the decomposition of organic waste in sewage, the atmosphere supplies oxygen to the water body which is called as re-oxygenation.
- The rate at which the oxygen is supplied depends on:
- Depth of receiving water (more at shallow depth)
- Condition of water body (running/stagnant).
- Oxygen deficit.
- Temperature of water.

Oxygen Deficit Curves / Oxygen-Sag Curve:

- In a running polluted stream exposed to the atmosphere, both de-oxygenation as well as re-oxygenation.
- If the de-oxygenation rate exceeds the re-oxygenation rate, it results in oxygen deficit.
- The amount of oxygen deficit can be obtained by adding the de-oxygenation and re-oxygenation curves. The resultant is called oxygen sag curve.
- From this curve the O_2 deficit and O_2 balance (100-D) present in a stream at any point of time can be found out.

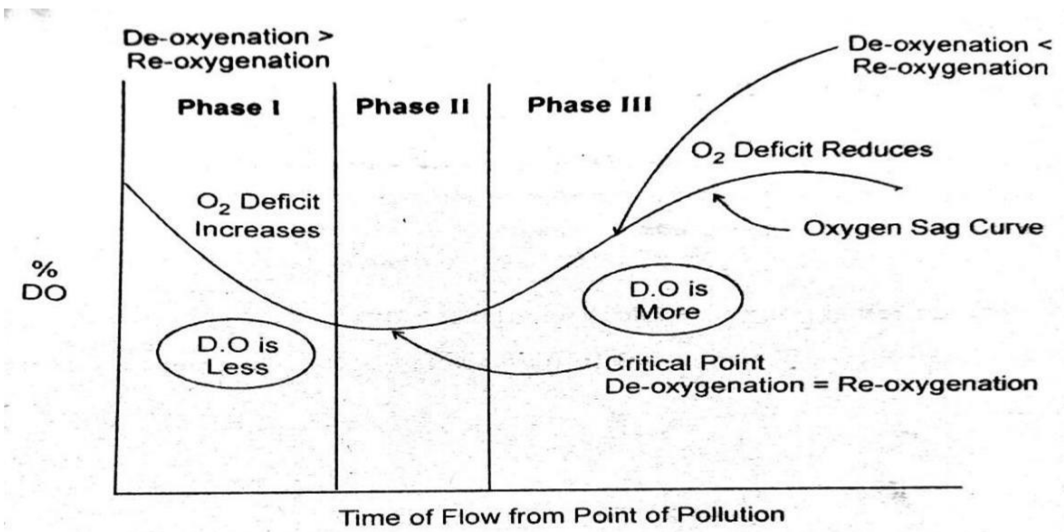


Figure.4: Oxygen sag curve

Streeter-Phelps Analysis:

Streeter-Phelps equation is a mathematical analysis to determine the degree of treatment required or degree of dilution required.

$$D_t = \frac{K_D \times L_0}{K_R - K_D}\left[(10)^{-K_D \times t} - (10)^{-K_R \times t}\right] + \left[D_0 \times (10)^{-K_R \times t}\right]$$

Rate of deoxygenation = $\gamma_D = K_{D \times L_t}$

Rate of reoxygenation = $\gamma_R = K_R \times D_t$

K_D = Deoxygenation co-efficient

= BOD rate constant = 0.1 to

0.2 $K_D = K20\ (1.047)T-20$

L_t = Amount of first stage BOD remaining in the sample at any time

t. K_R = Reoxygenation constant

$K_R = K_{20}\ (1.016)^{T-20}$ (or)

$K_R = K_{20}\ (1.024)^{T-20}$

K_R = 0.05 to 0.5

D_t = D.O deficit in mg/l after t days

$$\frac{dD_t}{dt} = rate\ of\ change\ of\ D.O\ deficit$$

$$\boxed{\frac{dD_t}{dt} = \gamma_D - \gamma_R = K_D \times L_t - K_R \times D_t}$$

We know,

$$L_t = L_0 \times e^{-K_D \times t}$$

D_0 = Initial O2 deficit at point of waste discharge at time, t=0.

L_0 = BOD remaining at the time, t=0 (Initial BOD)

$$\frac{dD_t}{dt} = K_D L_0 e^{-K_D \times t} - (K_R \times D^t)$$

$$\frac{dD_t}{dt} + (K_R \times D^t) = K_D L_0 e^{-K_D \times t}$$

Solving and changing to base 10, we get.

$$\boxed{D_t = \frac{K_D L_0}{K_R - K_D}[10^{-K_D \times t} - 10^{-K_R \times t}] + [D_0 \times 10^{-K_R \times t}]}$$

At the point X_c, critical oxygen deficit D_c occurs.

$$D_C = \frac{K_D L_0}{K_R}(10)^{-K_D \times tc}$$

$$f = \frac{K_R}{K_D} = Self\ purification\ constant.$$

$$\boxed{D_C = \frac{L_0}{f}(10)^{-K_D \times t_c}}$$

t_c = time required to reach critical point.

$$t_c = \frac{1}{[K_D - K_D]}\log\left[\left\{\frac{K_D.L_D - K_R.D_0 + K_D.D_0}{K_D.L_0}\right\}\frac{K_R}{K_D}\right]\ (or)$$

$$\boxed{t_c = \frac{1}{K_D(f-1)}\log\left[\left\{1 - (f-1)\frac{D_0}{L}\right\}f\right]}$$

Land Disposal:

5. What is sewage farming? List the methods and state its advantages over the method of disposal of sewage by dilution.

When waste water either raw (or) partly treated is applied (or) spread on the surface of land, the method is called as disposal by land treatment.

- When sewage is spread on land, it partly evaporates and partly percolates into ground.
- During percolation, the suspended solids are trapped in soil voids and are oxidized by bacteria under air, heat and light.
- However, clogging of voids by excess sewage solids should be prevented.
- Sewage adds to the fertilizing value of the land and crops can be raised.
- Disposal by land treatment is also called be sewage farming.

Methods of Land treatment:

- Broad Irrigation (or) Sewage farming.
- Rapid Infiltration
- Overland runoff.

(i) Broad Irrigation:

- The rate of sewage application on land depends on the percolation of waste water downward through the soil.

The percolation capacity of soil depends on:

- Soil characteristics (Pore size, void space, etc.)
- Infiltration capacity
- Degree of clogging
- The process by which purification of sewage takes place is called mechanical straining or filtration.
- The complex organic matter in sewage is converted into harmless mineral salts that serve as fertilizers.
- The nutrients in sewage like nitrogen, phosphorous and potassium NPK add fertility to the soil and improve water content.
- But sewage farming needs to be scientifically and carefully done to prevent soil pollution and assume hygienic safety of the employed staffs against infection by pathogens.

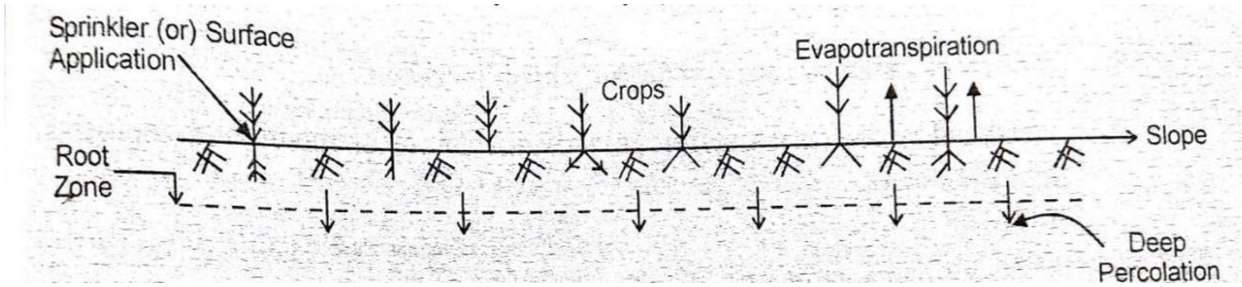


Figure.8: Broad Irrigation

(ii) Rapid Infiltration:

- Waste water is discharged into a large basin lined by sand or soil having high permeability.
- The bottom of the basin is covered with Bermuda grass which helps in removal of nitrogen and to maintain the infiltration capacity of the surface.
- This grass can grow in both dry and wet conditions.

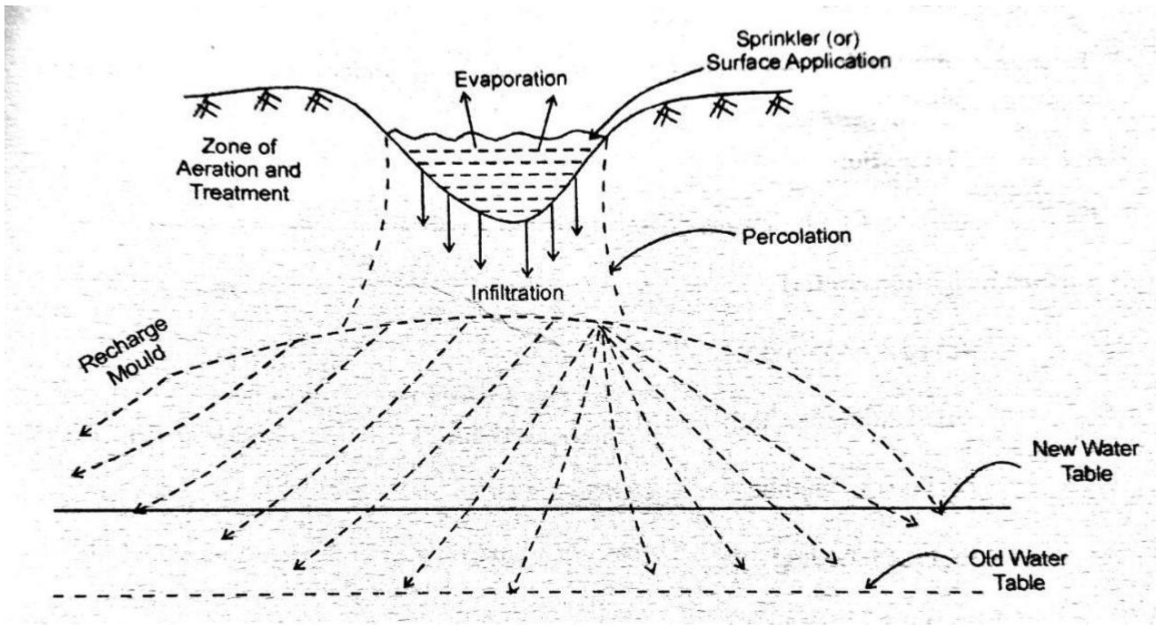


Figure.9: Rapid Infiltration

(iii) Overland runoff:

- It is used in soils with poor permeability.
- Waste water after passage over the soil surface is collected.
- Plants and trees (Hay grasses) are grown which removes or minimize the nutrients in waste waters.

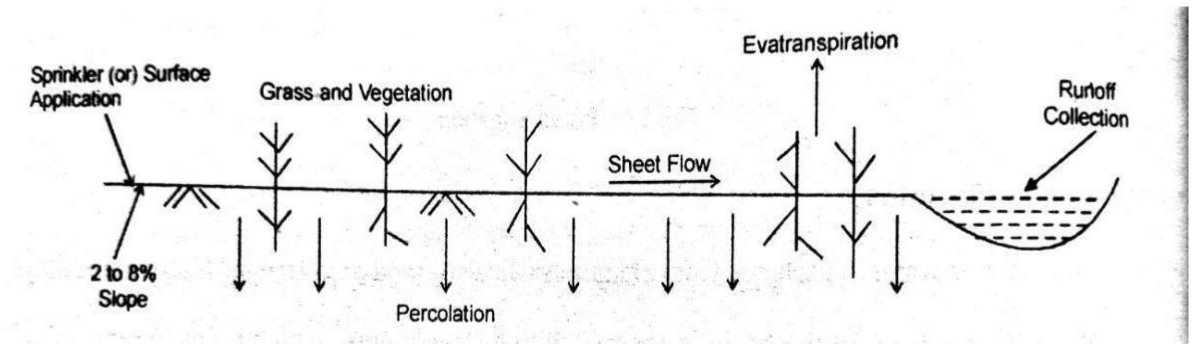


Figure.10: Overland Runoff

Methods of application of waste water

(i) Sprinkler or Spray Irrigation:

Sewage is sprayed or sprinkled through nozzles that work under pressure. Costly used in western countries.

(ii) Subsurface Irrigation:

Underground pipes supply sewage directly to the root zone.

(iii) Surface Irrigation (India)

- Basin method
- Flooding method
- Furrow method
- Free flooding
- Border flooding

Water Quantity considerations:

The quantity of irrigation water may affect the soil and crops.

The adverse effects on the plant growth are:

- Osmotic effects of salts in preventing water uptake by plants.
- Chemical (Toxins) effects on plants.
- Indirect effect- change in soil structure, permeability and aeration.

The suitability of irrigation water used depends on:

a) Quality of irrigation water (constituents).
b) Salt tolerance of crops.
c) Soil properties.

The sewage requires primary and secondary treatment before application on sewage farms.

Conditions favourable for Land treatment:

- When natural water bodies are not located nearby.
- When plentiful land with sandy, loamy soil is available (Easy aeration and aerobic conditions).
- Arid climates.
- Water table is low even during wet season.
- Low rainfall and there is demand for irrigation.
- Large open land is available.

Effluent Irrigation / Broad Irrigation:

- It is the successful disposal of sewage on vacant land.
- Crop growth is secondary.

Sewage farming:

- It is the successful growing of crops.
- Sewage disposal is secondary.
- Only treated sewage is used.

Sewage sickness:

- Due to continuous application of sewage on land, the soil pores get clogged, preventing oxidation and causing bad smells.
- The land becomes unsuitable to take further load of sewage. This phenomenon of soil is known as sewage sickness.

Sewage sickness can be prevented by:

(i) Pretreatment of sewage:

- Suspended solids are removed, which prevents clogging of soil pores.
- BOD load is reduced by 30%

(ii) Provision of extra land:

- Extra land (or) reserve land should be available so that the land with sewage sickness can be given rest.
- During the rest period, the sick land should be properly ploughed so that it is broken and aerated.

(iii) Under-Drainage of soil:

Subsoil drains should be provided to collect the percolating effluent to minimize sickness.

(iv) Proper choice of land:

- The chosen land should be sandy or loamy having high permeability.
- Clayey soil should be avoided.

(v) Rotation of crops:

Rotation of crops will minimize sewage sickness.

(vi) Shallow depth application:

Sewage should be applied in shallow depths. At greater depths, sewage sickness increases.

Comparison of Disposal methods:

Dilution	Land Application
• Requires large volume of water • Adopted in urban areas where land is costly. • Sewage from urban areas is diluted (99.9% water and 0.1% solids) • No management is required. • Only pretreated sewage is disposed. • No pumping is required. • Not preferred where receiving water body is a source of water supply. • Recreational use of natural water is affected.	• Requires large area of pervious land • Adopted in rural areas where land cost is less. • Sewage from rural areas is more concentrated and dilution cannot be adopted. • Efficient land management is required. • Raw or treated sewage is disposed. • Requires gradients / slopes and pumping. • It is used in hot climates where natural waters have low flows. • Increases crop yield. • It may cause health hazards. • It may pollute ground water.

UNIT 5
SLUDGE TREATMENT AND DISPOSAL

Sludge characterization:

1. Briefly outline the characteristics of sludge.

The two end products of waste water treatment are:

i) Effluent
ii) Sludge

- The treated effluent is discharged into water bodies or on land.
- The sludge is the solids that settle to the bottom of sewage treatment units.
- The sludge contains 90 to 95% moisture content and only 5 to 10% solids.
- Because it is bulky, difficult to handle and transport for disposal, the primary objectives of sludge treatment is to reduce the moisture content.

Types of sludge:

i) Raw or Primary sludge - Solids / Sludge from primary settling tank.
ii) Secondary or Humus sludge- sludge from secondary settling tank of trickling filter.
iii) Activated sludge - Sludge from secondary settling tank of ASP.

The sludge contains organic and putrescible matter and therefore requires treatment before disposal.

Characteristics of sludge:

Sludge contains both organic and inorganic solids.

(a) Specific gravity
Inorganic solids - 2.5
Organic solids - 1.06

(b) Moisture content -90 to 95%

(c) Color

(d) Odour

(e) Volatile and Fixed solids:After ignition at high temperature, the residue left is called fixed solids and weight lost is called volatile solids.

(i) Primary sludge – Sludge from primary settling tank.
Characteristics:

- Grey coloured.
- Greasy and sticky
- Odour slurry
- It consists of faecal matter, vegetable parings and fine silt
- Solids concentration – 6 to 8%
- Volatile solids - 60 to 80%
- It does not drain water easily.
- Chemical conditioning is adopted.

(ii)Sludge from chemical precipitation:

- Similar to primary sludge but less odour, heavy sludge.
- It contains colour of chemicals.
- It contains precipitated chemicals and entangled solids.

(iii) Secondary sludge / Humus sludge – sludge from trickling filter

- Dark brown
- Flocculent
- Less offensive when fresh.
- It contains suspended particles which are fragments of biological growth washed from filter media.
- Good settleability.
- Sludge is less dense due to irregular sloughing.
- Solids content is 4 to 6%.

(iv) Activated sludge – Sludge from ASP

- Golden brown
- It contains flocculent suspension of active microbial mass.
- Not offensive, when it fresh.
- Large volume
- Large moisture (98 to 99%).

Volume-Mass Relationship:

Total solids = fixed solids + Volatile solids

$$\frac{W_S}{S_S} = \frac{W_f}{S_f} + \frac{W_f}{S_v}$$

Where,

W_s = Weight of dry solids.
W_f = Weight of fixed solids.
W_v = Weight of volatile solids.
S_s = specific gravity of solids.
S_f = specific gravity of fixed solids.
S_v = Specific gravity of volatile solids.

$$\frac{100}{S_{sl}} = \frac{\%\ of\ moisture}{sp.gr.of\ water} + \frac{\%\ of\ solids}{S_s}$$

Volume of wet sludge:

$$V_{sl} = \frac{W_s}{\rho_w S_{sl} \rho_s}$$

Where,

W_s = Weight of dry solids.
S_{sl} = Sp.gr.of wet sludge.
= Percent solids in decimal.
= Density of water (10^3 kg/m^3)

Sludge Thickening (or) Concentration:

2. Discuss the sludge thickening.

- Sludge volume is reduced by.
- Moisture reduction
- Increasing solids concentration.

Purpose of sludge thickening:

- To permit increased loadings on sludge digester.
- To increase feed solids.
- To economize on transport cost of sludge.
- To minimize the land requirements for sludge disposal.
- To save fuel cost for incineration of sludge.
- Sludge thickening is commonly achieved by:
  - i) Gravity Thickening.
  - ii) Air Floatation.
  - iii) Centrifugation.

(i) Gravity Thickening:

- It is common , simple and least expensive method.
- It is adopted for primary sludge and combination of primary and activated sludge but not successful for activated sludge alone.
- Resembles a circular clarifier except that the depth / diameter ratio is greater and hopper bottom has steeper slope.
- Dilute sludge is fed to a central feed well. The feed sludge is allowed to settle and compact and the thickened sludge is withdrawn from the bottom of the tank.
- The slow motion of the scraper dislodges gas bubbles and prevents bridging of solids and moves the sludge toward a central well for withdrawal.
- The water (supernatant) escapes out through weirs and promotes densification. It is then returned to the primary settling tank.
- Gravity thickeners are either continuous flow (or) fill and draw type.
- Feed is continuous but underflow / sludge withdrawal is intermittent.
- The recommended solids loading for primary and activated sludge are 40 to 100kg/d/m^2. The underflow solids concentration is 8 to 10%.
- Gravity thickeners have a depth of 3m. Three settling zones occur:
  - i) Clear supernatant on top.
  - ii) Feed zone (hindered settling)
  - iii) Compression zone at the bottom (Where consolidation occurs).
- A sludge blanket is maintained on the bottom of the thickeners to aid in concentrating the sludge.
- The underflow solids concentration depends on:
  - i) Depth of sludge blanket at bottom (1m)
  - ii) Sludge detention time (24 hours or more).

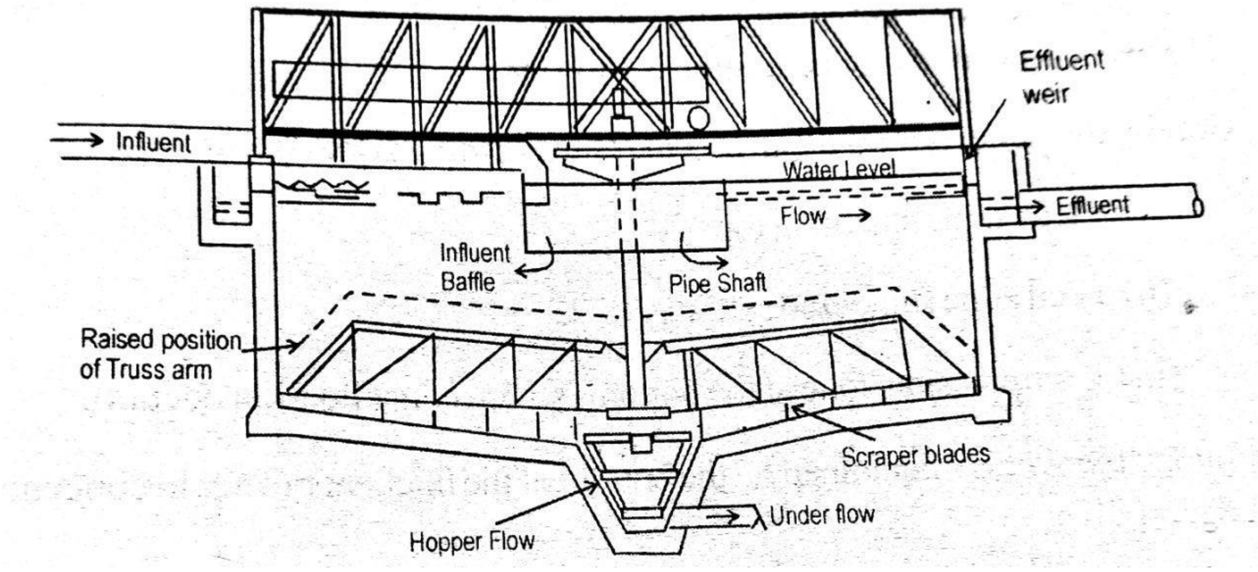


Figure.11: Gravity sludge thickener

(ii) Floatation Thickening:

- Air floatation units (dissolved air or pressure type) are used which float the sludge under pressure or vacuum.
- It is used for thickening light sludge (activated sludge) of flow density which can be easily buoyed (lifted) to surface.
- Chemicals like alum and polyelectrolytes if added will increase the efficiency.
- In the pressure tank or air dissolution tank, a portion of subnatant is pressured and saturated with the air and mixed with influent sludge just before releasing it into floatation tank.
- The sludge particles thus rise up with dissolved excess air.
- Thickened sludge blanket on surface (0.2 to 0.6m) is skimmed off and unrecycled subnatant returned to plant.
- Effluent is recycled at 30-150% of influent flow in air dissolution tank.
- Recycle ratio depends on:
  - i) Detention time (30 minutes to 1 hour).
  - ii) Feed solids concentration.
  - iii) Air solids concentration.
  - iv) The surface overflow rate varies from 10 to 45m/day.

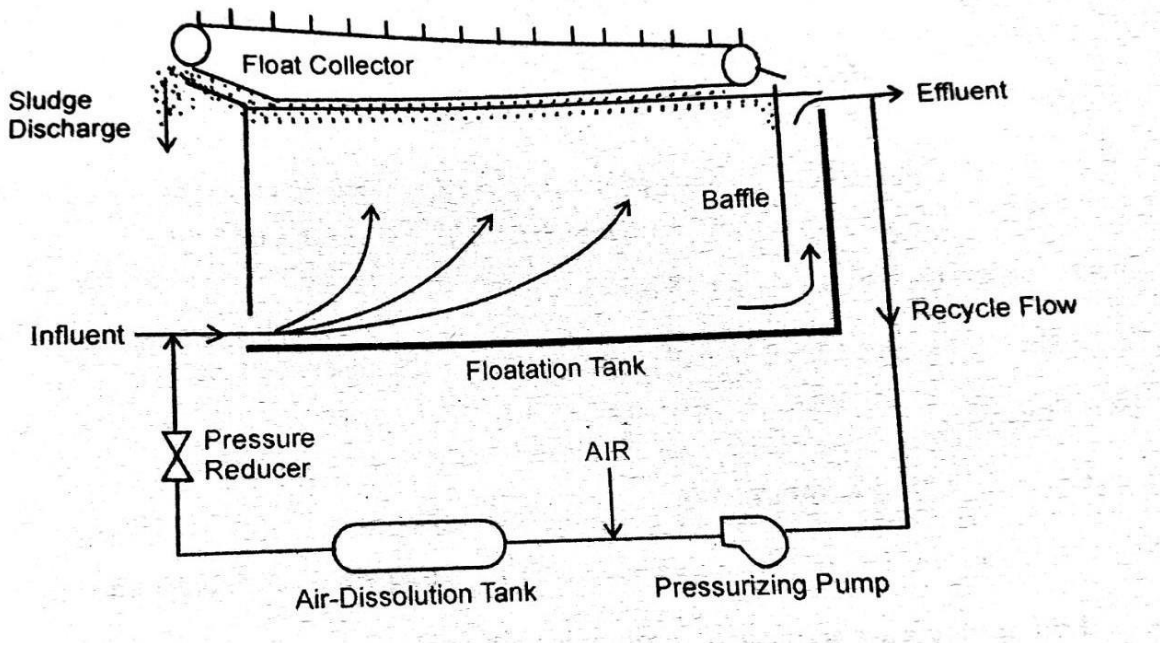


Figure.12: Schematic diagram of a dissolved air floatation system

(iii) Centrifugal Thickening:

- Centrifuges are used both to thicken and to dewater sludge.
- It is used only for waste activated sludge.
- It involves settling of sludge particles under centrifugal force.
- It is used only when there is a space limitations or when sludge characteristics does not permit the above methods.

Types:

- Nozzle Disc
- Solid Bowl
- Basket centrifuges

<u>Sludge Treatment Process</u>:

3. Enumerate various processes involved in sludge treatment.

Sludge treatment may include all or a combination of the following unit operations and unit process. They are:

1. Thickening
2. Digestion
3. Conditioning
4. Dewatering
5. Drying
6. Incineration

Figure shows the flowchart for sludge treatment and disposal. The arrows in the diagram indicate the possible flow path.

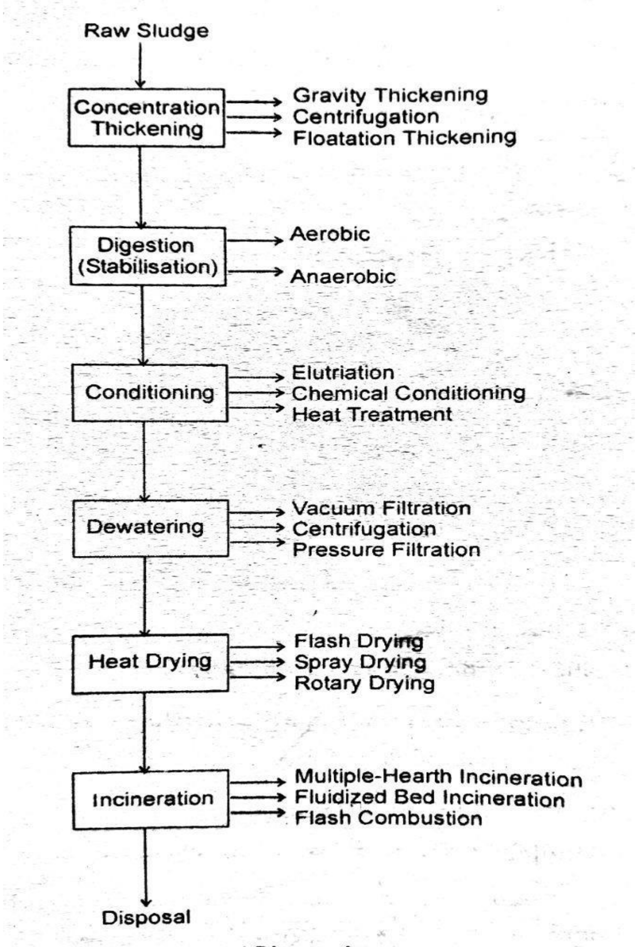


Figure.13: Sludge Treatment and Disposal

1. <u>Thickening:</u>

- The purpose of thickening is to reduce moisture content of the sludge, and consequently to increase the solid concentration.
- This process is adopted for the separation of greater amount of water from the sludge solids that can be attained in settling tanks.
- Three types of thickening commonly practiced are
  - (i) Gravity thickening
  - (ii) Centrifugation
  - (iii) Flotationthickening

2. <u>Digestion:</u>

- The principle objective of sludge digestion is to subject the organic matter present in the settled sludge to anaerobic or aerobic decomposition so as to make it amenable to dewatering on sand beds or mechanical filters before final disposal.

3. <u>Conditioning:</u>

- Conditioning improves the drainability of digested sludge. Prior conditioning of sludge before application of dewatering methods renders it more amenable to dewatering.
- This can be achieved by various methods such as elutriation, chemical conditioning, heat treatment, freezing, etc.. Chemical conditioning of sludge with or without elutriation is necessary when dewatering of sludge is accomplished by vacuum filtration.

4. **<u>Dewatering:</u>**

- The purpose of dewatering is to further reduce the volume of sludge and thereby increasing the solids concentration. Most of the digested primary or mixed sludge can be compacted to a water content of about 90% in the digester itself by gravity.
- However, further dewatering is accomplished either by air drying on sand drying beds or by a mechanical means such as vacuum filtration, centrifugation, pressure filtration, etc.,

5. **<u>Heat Drying:</u>**

- The purpose of heat drying is to reduce further the moisture content and volume of dewatering sludge, so that it can be used after drying without causing offensive odors or risk to public health. Several method such as sludge drying under controlled heat, flash drying, rotary kiln, multiple hearth flume etc,.have been used in combination with incineration devices.
- Drying is brought about by directing a stream of heated air or other gases at about 350°C.
- The hot gases dust and ash release during combustion are to be removed by suitable control mechanism to minimize air pollution.
- The dried sludge removed from the kilns is granular and clinker like which may be pulverized before use as soil container.

6. **<u>Incineration:</u>**

- Incineration involves the combustion of the sludge in a reactor under high temperature along with auxiliary fuels, if needed.
- The purpose of incineration is to destroy the organic material, the residual ash being generally useful as land fill. During the process all the gases are released from the sludge are burnt off and all the organisms are destroyed.
- Dewatered or digested sludge is subjected to temperature between 650°c to 750°c. Cyclone or multiple hearth and flash type furnaces are used with proper heating arrangements with temperature control and drying mechanism.

<u>Sludge Digestion</u>

4. **Explain the mechanism of anaerobic and aerobic sludge digestion with their relative merits and demerits?**

- Sludge digestion is defined as the organic matter present in the settled sludge to aerobic decomposition to make it amenable to dewatering.
- Sludge digestion is reduction in sludge volume.
- Anaerobic digestion produce gas (CH4) as by product, whereas aerobic digestion does not produce any utilizable byproduct other than well stabilized sludge.

(A) Anaerobic Digestion (Biogas Recovery).

- Biological decomposition of organic matter in the absence of oxygen.

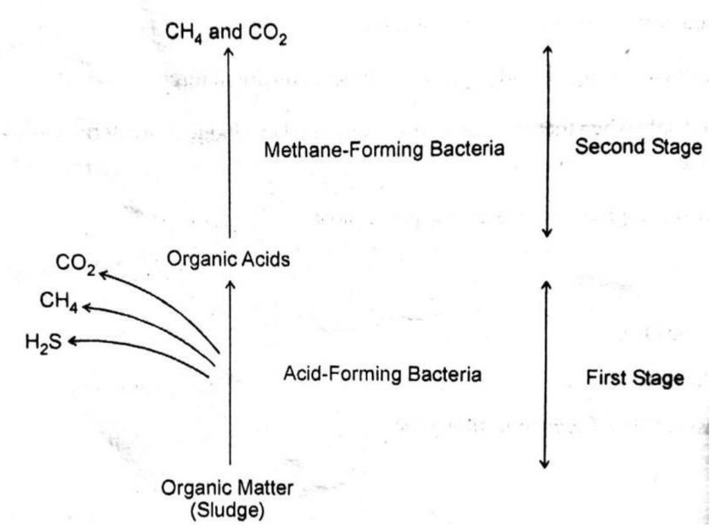


Figure.14: Anaerobic Digestion

Two stages:

(i) First stage – Acid Fermentations.

- Acid forming bacteria hydrolyses high molecular organic compounds into organic acids.
- End products are acetic acid, propionic acid and butyric acid.

(ii) Second stage – Methane Fermentation.

- Gasification of organic acids (formed in first stage) into methane and carbondioxide by acid splitting methane-forming bacteria.
- These reactions reduce the biodegradable volatile solids in sludge.
- Due to very low microbial growth rate, the production of biological sludge in anaerobic process is very low.
- Major portion of organic waste is converted into gas. Hence the effluent is more stabilized.

Types of Digestors

(i) Low rate or Conventional Digestor.

(ii) High rate digestor.

- Conventional sludge digestion is carried out in a single stage, where digestion, storage, sludge thickening and supernatant formation takes place in a single stage or two-stage.
- In the high digestion, the solids loading is high, sludge is intimately mixed and heated to achieve optimum digestion.
- Capacity of digester depends on:
    - i) Daily volume and moisture content of sludge.
    - ii) Temperature of digestion.
    - iii) Percentage volatile matter in sludge.
    - iv) Detention time.
    - v) Storage of digested sludge.

(i) Conventional standard-rate digestors.

- The raw sludge is pumped into digestor through pipes at the center of tank. The digested sludge is withdrawn from the tank bottom.
- Supernatant is drawn from series of pipes extending out of the tank wall.
- Digestion gas is collected in the gas dome and taken out through gas pipe.
- Three functions occur in a digestor:
    - i) Anaerobic digestion of volatile solids.
    - ii) Gravity thickening
    - iii) Storage of digested sludge.
- Lack of proper mixing in the conventional digester leads to stratification leading to layers of scums, supernatant, actively digesting sludge and digested sludge.
- In this type of digestor, the digestor capacity is wasted and methane fermentation is confined to the lower layers.

(ii) High rate digestors

- The solids loading rate is high.
- Sludge is continuously added and vigorously mixed either mechanically (impellers) or by recirculation of digestion gases.

Gas mixing is of three types:

- By injection of compressed gas through series of pipes hanging from cover.
- By use of draft tube in the centre of tank, with compressed air which would lift recirculating sludge from bottom and spill it on top.
- By diffusers at bottom of tank to supply compressed gas.
- Because of good mixing, there is no stratification, no dead pockets and no loss in digestor capacity.
- The digestor is also heated to maximize biological activity.
- High –rate digestion systems normally consist of two tanks in series.
- In the first stage, complete mixing, heating and anaerobic digestion of volatile solids occur.
- In the second stage digestor, separation of supernatant, gravity thickening, reduction in sludge volume takes place.

Design of Digestors:

- Number of units / capacity
- Conventional – Single or multiple units of 3 MLD each.
- High rate - Primary and secondary digestion tanks of 20 MLD.
- Tank shape - Circular.

Tank size not greater than 55m diameter.

- Water depth - 4.5m to 6m.
- Free board - 0.4 to 0.8 (depending on floating or fixed cover).
- Roofing - Floating or fixed with gas domes.
- Mixing - Mechanical stirring with revolving arms.

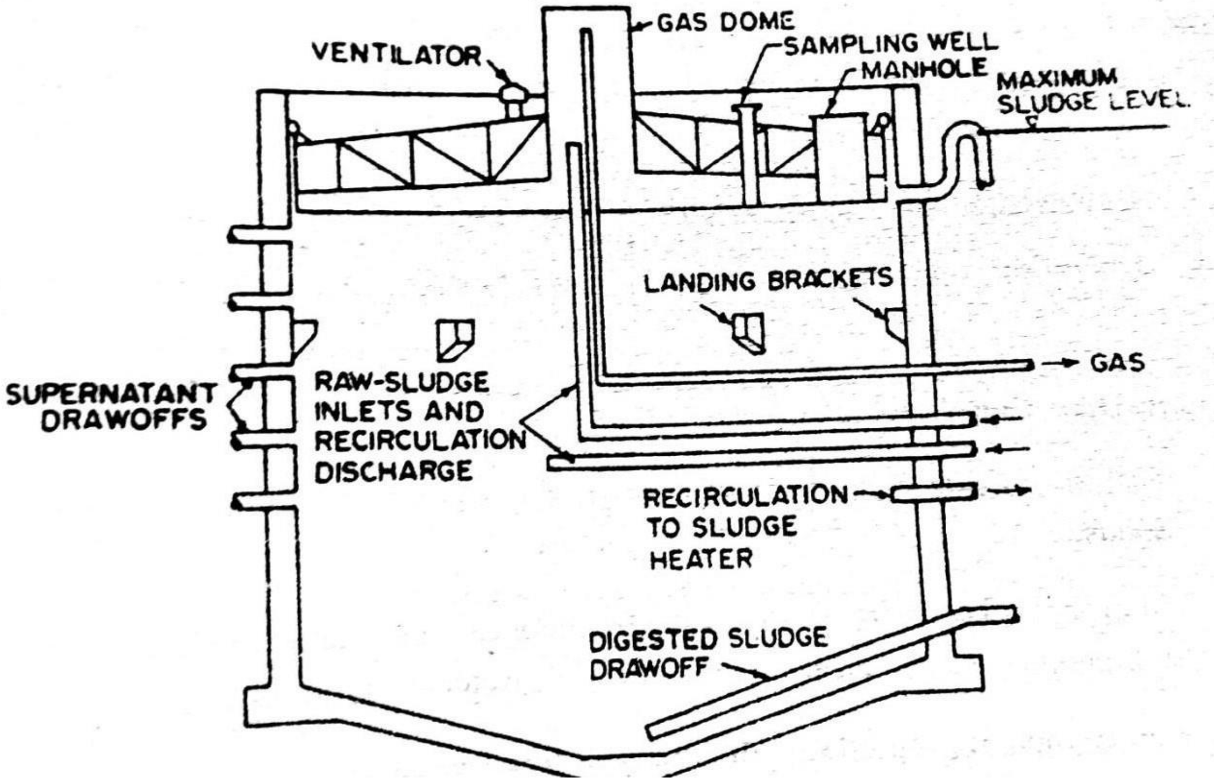


Figure.15: Cross-section of a Typical Floating Cover Digestor

Gas composition and collection:

- Sludge gas – 60 to 70% Methane(CH_4)
  - 25 to 35% carbondioxide (CO_2)
  - Other gases

H_2S - Hydrogen sulphide
H_2 - Hydrogen
N_2 - Nitrogen
O_2 - Oxygen

- The combustible gas is methane.
- Sludge gas with 70% methane has fuel value of 5800 Kcal/m^3.
- Average gas production is 0.9m^3/kg of volatile solids destroyed.
- Depending upon sulphate content of sludge, H_2S is produced which is corrosive and causes nuisance.

Advantages	Disadvantages
• Methane production as a by-product. • Biological sludge production is less. • Operation cost is less.	• Construction of cover increases cost. • It creates odour (H_2S, CO_2,CH_4). • Operational problems – It takes time to start operation.

(B) Aerobic Digestion:

- Stabilizes waste sludge by long-term aeration, reducing BOD and destroying volatile solids.
- Micro-organisms obtain energy by endogeneous or auto-oxidation of their own cellular protoplasm releasing carbondioxide, water and ammonia.
- One or more units used with mixing by diffused aeration.
- Long-term aeration of sludge creates bulking material difficult to thicken.
- It used for secondary or combined sludge.
- It cannot be used for primary sludge.
- Design parameters include:
    i) Detention time
    ii) Loading criteria
    iii) Oxygen requirements
    iv) Mixing
    v) Operation
    vi) Temperature

Advantages	Disadvantages
• Low BOD in supernatant. • Odourless, easily dewaterable, stable digested sludge is produced. • Fertilizer value of digested sludge. • Low capital cost. • Fewer operational problems.	• High power-operation cost. • Dewatering of sludge is difficult using vacuum filtration. • No useful byproduct is recovered.

5. **What are the different methods for disposal of digested sludge? a) Disposal of digested sludge:**

- The sewage sludge from the digestion tank is brought and spread over the top of drying bed to a depth of about 20 to 30cm, through distribution through having opening of about 15cm x 20cm @ 2m.
- Sludge should never be applied to a bed until the preceding dose has been removed.
- Hence several drying bed will generally be required, with an increase in the no of days for which the sludge is kept on the beds.
- Normally sludge removed from the beds after a period of about 7-10 days, within the period 30% moisture goes away and the surface of sludge cracked.
- The dried sludge are removed and dumped into a pit for further drying.

b) Disposal of dewatered sludge:

- The dewatered sludge obtained from mechanical devices of western countries is generally heat dried so as to produce fertilizers.
- The wet sludge after mechanical dewatering is sometimes directly disposed of either in sea or in underground trenches or burnt.

c) Disposal by dumping into the sea:

- The dewatered wet sludge may, sometimes be discharged at a sea from hopper barrages or through outfall sewers.
- This method can, however be adopted only in cases of cities situated on sea shores and where the direction of normal winds are such as to take the discharged sludge into the sea away from the shore line.

d) Disposal by burial into the trenches:

- In this method digested sludge without dewatering is run into trenches which are 0.9m wide x 0.6 m deep and rectangular spaced at 1 to 1.5m apart in parallel rows.
- When the sludge has dried to a firm state it is covered at top with a thin layer of a soil. After about a month, the land is ploughed up with powdered lime and planted with crops.

e) Disposal by incineration:

The dewatered wet sludge produced in waste water treatment plant may also be disposed of by burning, in suitably designed incinerator when sufficient space is not available for its burial near the plant site or the sludge cannot be dried and used as manure.

a. Multiple-hearth furnace
b. Fluid-bed furnace
c. Flash-type furnace
d. Infra-red furnace

<u>Sludge dewatering:</u>

6. **Discuss the need for sludge dewatering and explain the various sludge dewatering methods.**

α. Physical unit operation is used to reduce moisture content of the sludge and thus increase the solids concentration.

- **Methods:**
  - i) Air Drying in sludge drying beds
  - ii) Mechanical means - Vacuum filtration
    - Centrifugation
    - Pressure filtration

Purpose of Dewatering:

- Cost of transportation of sludge to ultimate disposal site is reduced (volume reduction).
- Ease in handling dewatered sludge.
- Increase in calorific value of sludge. Incineration cost is less due to moisture reduction.
- Rendering sludge odourless and putrescible.
- Reduce leachate production when disposed in landfills.

Sludge Drying Beds:

- It is suitable for location where temperature is high (India).
- Sludge is applied on specially prepared open beds of land.
- A sludge bed consists of bottom layer of gravel of uniform size and depth 30cm over which is laid a bed of clean sand of depth 15 to 30cm.
- Clean sand of effective size of 0.5 to 0.75mm and uniformity co-effective not greater than 4 is placed over the gravel.

- Open jointed pipes are provided as under drains in gravel layer to provide drainage to the liquid that passes through the sand and gravel layers.
- Under drains are made of vitrified clay of atleast 10cm diameter at a spacing of 6m apart.
- Graded gravel is provided around the under drains in layer upto 30cm with a minimum of 15cm above the top of under drains.
- Drying beds adopted are 6 to 8m wide and 30-45m long.
- Minimum of two drying beds should be provided.
- The area needed for dewatering digested sludge is dependent on total volume of sludge, climate, temperature and location.
- Sludge should be deposited evenly to a depth of not greater than 20cm.
- When digested sludge is deposited on a well drained bed of sand, the dissolved gases tend to buoy up and float the solids leaving a clear liquid at the bottom which drains through the sand rapidly.
- Major portion of liquid drains off in few hours and evaporation starts. The sludge cakes shrink.
- With good drying condition, the sludge will dewater and become fit for removal in 2-3 weeks with volume reduction of 20 to 40%.
- Dried sludge cake is removed by showel when moisture is less than 70%.
- Pick up trucks are used for hauling of sludge cakes.

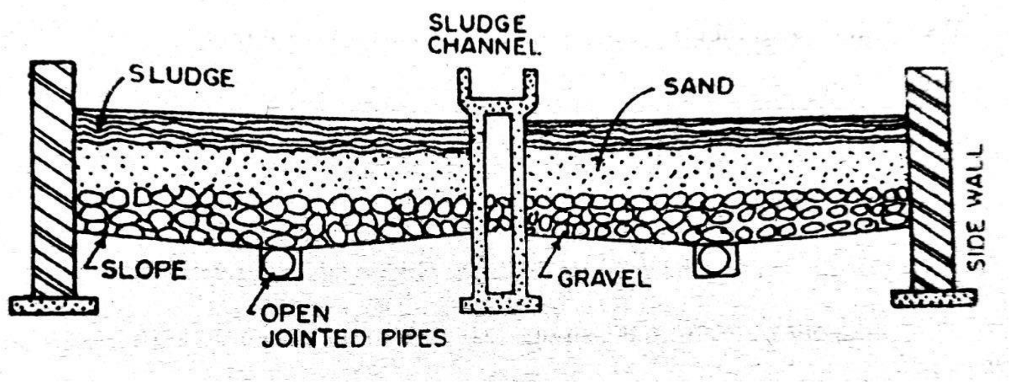


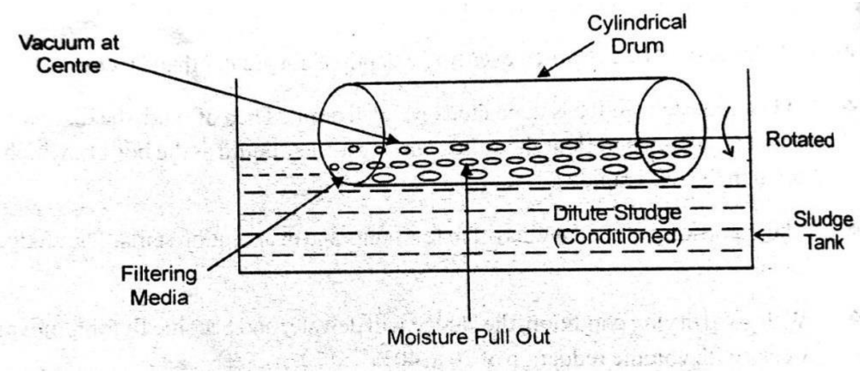
Figure.16: Sludge Drying Beds

Mechanical methods:

- Vacuum filtration (common)
- Filter press
- Centrifugation
- Chemical conditioning is normally done prior to mechanical dewatering.
- It is used to dewater raw or digested sludges.

Vacuum filters:

- Vacuum filter consists of cylindrical drum over which is laid a filter medium of wool, cloth, synthetic fibre, plastic, stainless (mesh) (or) coil spring.
- The drum is suspended horizontally so that one half is submerged in sludge tank.
- Valves and pipes are arranged to produce vacuum on the inner side of filter medium.
- When the drum enters the sludge tank, the conditioned sludge is spread in thin layer over the filter media.
- As the drum rotates, the vacuum holds the sludge against the drum.
- This pulls out water from the sludge leaving moist cake mat at the outer surface.
- The sludge cake on the filter media is scraped out before the drum enters again in the sludge tank.
- The rate of filtration is 10 to 50kg/m^2/hr.



UNIT-4

DISPOSAL OF SEWAGE

PART-A

1) Define the term "Dilution Factor"? (May/Jun-16)

The ratio of the quantity of the diluting water to that of the sewage is known as the Dilution Factor..

2) What are the methods adopted for sewage disposal? (May/Jun-16, Apr/May-18)

1. Dilution is disposal in water.
2. Effluent Irrigation or Broad Irrigation or Sewage forming is disposal on land.

3) What are the conditions adopted for disposal by dilution? (Nov/Dec-15)

1. When sewage is comparatively fresh (4 to hr old) and free from floating and settleable solids.
2. When the dilution water has high dissolved oxygen (D.O.) content.

4) What are the natural forces of purification?(Nov/Dec-15)

1. Dilution and dispersion, Sedimentation ,Oxidation – reduction in sun-light, Oxidation, Reduction

5) What are the factors affecting self purification of polluted streams? (May/Jun-15)

a) Temperature
b) Turbulence
c) Hydrography such as the velocity and surface expanse of the river stream.

6) What are the types of self purification? (May/Jun-15)

1. Zone of degradation.
2. Zone of active decomposition.
3. Zone of recovery
4. Zone of Cleaner water

7) What is meant by "Self purification phenomenon"? (Nov/Dec-14)

When sewage is discharged into a natural body of water, the receiving water gets polluted due to waste products, present in sewage effluent. The natural forces of purification such as dilution, sedimentation, and oxidation – reduction in sun light go on acting upon the polluted elements and bring back the water into its original condition. This automatic purification of polluted water, in due course is called the self purification phenomenon.

8) What is meant by photosynthesis? (Nov/Dec-14)

The sun light has a bleaching and stabilizing effect of bacteria. It also helps certain micro organisms to derive energy from it and convert themselves into food for other forms of life, thus absorbing CO_2 and releasing O_2 by a process known as Photosynthesis.

9) What do you mean by Oxidation? (May/Jun-14)

The oxidation of the organic matter present in sewage effluents will start as soon as the sewage out falls into the river water containing dissolved oxygen. The deficiency of oxygen so created will be filled up by the atmospheric oxygen. The process of oxidation will continue till the organic matter has been completely oxidized. This is the most important action responsible for effecting self purification of rivers.

10) What do you understand by Reduction? (May/Jun-14)

Reduction occurs due to hydrolysis of organic matter settled at the bottom either chemically or biologically. Anaerobic bacteria will help in splitting the complex organic constituents of sewage into liquids and gases and thus paving the way for their ultimate stabilization by oxidation.

11) Define the term Re-oxygenation curve. (Nov/Dec-13)

In order to counter – balance the consumption of D.O, due to de-oxygenation, atmosphere supplies oxygen to the water and the process is called re-oxygenation.

12) What is mean by "Oxygen sag curve"? (Nov/Dec-13)

The amount of resultant oxygen deficit can be obtained by algebraically adding the de-oxygenation and re-oxygenation curves. The resultant curve so obtained is called the oxygen sag curve or the oxygen deficit curve.

13) Define the term "limnology".

The study of the biological, chemical, and physical features of lakes and other bodies of fresh water is called limnology.

14) What is meant by epilimnion zone? (May/Jun-13)

The water of a lake gets stratified during summers and winters. Since such turbulence extends only to a limited depth from below the water surface, the top layers of water in the lake become well mixed and aerobic. This warmer, well mixed and aerobic depth of water is called epilomnion zone.

15) What is meant by hypolimnion zone? (May/Jun-13

The lower depth of water in the lake which remains cooler, poorly mixed and an aerobic, is called hypolimnion zone.

16) What do you understand by monocline? Give example. (Nov/Dec-12)

The water of a lake gets stratified during summers and winters. The change from epilimnion to hypolimnion can be experienced while swimming in a lake. When you swim in top layers horizontally you will feel the water warmer and if you dive deeper, you will find the water cooler. The change line will represent monocline.

17) What are the classification of biological zones in lakes? (Nov/Dec-12)

Euphotic zone, Littoral zone, benthic zone

18) What do you understand by "Euphotic Zone"? (May/Jun-12)

The upper layer of lake water through which sunlight can penetrate is called the euphotic zone. All plant growth occurs in this zone. In deep water, algae grow as the most important plants, whole rooted plants grow in shallow water near the shore.

UNIT-4

DISPOSAL OF SEWAGE

PART – B

1. A large stream has a rate of reaeration constant, kr = 0.24 per day (to base 10) and deoxygenation constant, kd = 0.1 per day (to the base 10). The initial deficit of the mixture of stream and waste water at the point of reference Do = 4 mg/l and the ultimate 5 day BOD, Lo = 35 mg/l. Find the DO deficit and critical time. (**CO4)(BTL-K4) (May/Jun-16, Nov/Dec-12)**
2. Outline about (a) Wastewater reclamation (b) Sewage disposal to sea water. (**CO4) (BTL-K2) (May/Jun- 16)**
3. List the various actions involved in the self-purification process of a stream and explainbriefly. (**CO4) (BTL-K4) (Nov/Dec-15)**
4. Explain the methods available and limitations of land disposal of sewage. (**CO4) (BTL-K2) (May/Jun-15)**
5. (i) Solve the Streeter Phelps equation and show itsapplication. (**CO4) (BTL-K3) (May/Jun-15)**

   (ii) A town discharges 14 million litres per day sewage at a temperature of 23^0C into a river having flow of 1.7 m^3/sec and water temperature of 20^0 C. BOD at 20^0 C for the waste water is 160 mg/l and k (base 10) is 0.1 per day. If R is 0.2 per day what is the critical oxygen deficit and the distance at which it occurs. Assume the stream as 92% saturated with oxygen before sewage addition the solubility of oxygen at 20^0 Cas 0.9mg/l an driver flow velocity as 0.12m/s **(CO4)(BTL-K1) (Nov/Dec-14)**
6. (i) Explain the principle of the self-purification process of stream and factorsinfluencingthe process. (**CO4)(BTL-K2)(Nov/Dec-14,May/Jun-12, Apr/May-17,Apr/May-18)**
7. (i) Draw a typical oxygen sag curve and explain its meaning. (**CO4)(BTL-K2) (Nov/Dec-14, May/Jun-12, Apr/May-17,Apr/May-18)**

   (ii) Determine the BOD of river water at the discharge point of the treated sewage from a town having a BOD of 30 mg/l discharged at the rate of 5 m^3/s into a river having a flow of 30m^3/s and no BOD.(**CO4) (BTL-K5)**
8. Summarize about lagooning dumping landfilling and incineration of solid wastes. (**CO4) (BTL-K2)(Nov/Dec-18)**

UNIT-5

SLUDGE TREATMENT AND DISPOSAL

PART – A

1) What are the distinct stages in the sludge digestion processes? (May/Jun-16)

1) Acid fermentation 2) Acid repression 3) Alkaline fermentation

2) Define the term ripened sludge? (Nov/Dec-15)

This digested sludge (from Alkaline fermentation stage)is collected at the bottom of the digestion tank and is also called repented sludge.

3) What are the factors affecting sludge digestion(Nov/Dec-15)

- Temperature Thermopolis
- Pit Value
- Seeding digested sludge
- Mixing and stirring the raw sludge with digested sludge.

4) List the methods of sludge thickening or concentration?

1. Gravity Thickening 2. Air floatation 3. Centrifuging

5) Compare the methods of sludge digestion

Anaerobic Digestion	Aerobic Digestion
• Biological decomposition of organic matter in sludge by anaerobic microorganism in the absence of oxygen	Biological decomposition of organic matter in sludge by aerobic microorganism in the presence of oxygen
• Operation cost is low	Operation cost is more
• Sludge production is less	Low capital cost
• Construction cost is more	Construction cost is more
• Odour nuisance	No Odour nuisance
• It takes time to start the operation	It takes time to start the operation
• By product biogas is recovered which can be used for power generation	Odourless stable digestion sludge obtained and no by product is recovered

6) What is the objective of sludge treatment?

Reduce sludge volume, moisture reduction, increasing solids concentration, reduce transportation cost of sludge, minimize land requirement for sludge disposal, save fuel cost for incineration of sludge.

7) Define the term Eutrophication? (Nov/Dec-15)

The excess growth of algae and other aquatic plants in a river stream is called eutrophication

8) What is meant by sludge conditioning? What are the methods of conditioning? (Apr/May-17, Nov/Dec-17)

Sludge conditioning is a process whereby sludge solids are treated with chemicals or various other means to prepare the sludge for dewatering processes, in other words, to improve dewatering characteristics of the sludge. The methods of sludge conditioning are Chemical conditioning, thermal conditioning and Freeze-Thaw conditioning.

9) What is meant by dewatering? (Apr/May-17)

Dewatering of residuals is the physical process of removing the water content of the sludgemaking it easier to handle and less expensive to transport, to compost to incinerate or to dispose of in a landfill. Dewatering can be done with the help of presses or centrifuges, filtration or physical processes in drying beds

10) Give out the advantages of sludge thickening? (Apr/May-18)

1) Reduction of load on digesters, improved digestion and higher gas yield due to longer solids retention times
2) The costs of the labour management and energy consumptions.

UNIT-5

SLUDGE TREATMENT AND DISPOSAL

PART – B

1. (i) Explain the mechanism of biogas recovery from sludge.**(CO5)(BTL-K2) (Nov/Dec-15)**
   (ii)A wastewater treatment plant produces sludge of 1000 kg dry solids per day with a moisture contentof97%.Thesolidsare65%volatilewithspecificgravity1.05andinorganicsolidsof specific gravity 2.55. Determine the sludge volume of raw sludge, after dewatering to 70% and after incineration.**(CO5) (BTL-K5)**
2. (i) Explain various process involved in sludge treatment anddisposal with the help of flow chart. (**CO5) (BTL-K2) (Nov/Dec-17)**
   (ii) Explain the mechanism of anaerobic and aerobic sludge digestion with their relative merits and demerits. (**CO5)(BTL-K2) (May/Jun-13,Nov/Dec-12)**
3. (i) Explain the various process involved in sludge treatment anddisposal. (**CO5) (BTL-K2)**
   (ii) A wastewater treatment plant produces sludge of 1000 kg dry solids per day with a moisture contentof97%.Thesolidsare65%volatilewithspecificgravity1.05andinorganicsolidsof specific gravity 2.55. Determine the sludge volume of raw sludge, after dewatering to 70% and after incineration.(**CO5) (BTL-K5)**
4. (i) Explain the mechanism of anaerobic and aerobic sludge digestion with their relative merits and demerits. (**CO5)(BTL-K2) (May/Jun-13,Nov/Dec-12)**

(ii)Explain the anaerobic sludge digestion process and also the effects of pH and temperature on it. (**CO5)(BTL-K2) (May/Jun-13Apr/May-18)**

5. Explain the working of a standard rate sludge digester with the help of a neat diagram.(**CO5)(BTL-K2)(Apr/May-17)**
6. Explain the characteristics of sludge and how biogas can be converted(**CO5)(BTL-K2)** (**Nov/Dec-17)**
7. Explain the various advances in the treatment of sludge and mode of disposal (**CO5) (BTL-K2)**(**Nov/Dec-17)**
8. Explain in detail about the working of biogas plant in your locality along with the neat sketch.(**CO5) (BTL-K2)**
9. With the help of flow chart explain various process involved in dairy industry sludge treatment and disposal.(**CO5) (BTL-K2)**
10. Draw a neat sketch of a high rate two – stage anaerobic sludge digester and explain its working principle. (**CO5)(BTL-K2) (Apr/May-19)**