



LECTURE NOTES ON
WATER SUPPLY AND WASTE WATER ENGINEERING(Th.4)
Diploma 5th Semester

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WATER DEMAND AND SUPPLY

Average domestic water consumption in Indian city=135lpcd

FIRE DEMAND

Empirical formulas:

(i) Kuichling's Formula

$Q=3182\sqrt{P}$ where, Q= Amount of water required in liters/minute.P= population in thousand.

(ii) Freeman Formula

$$Q = 1136 \left[\frac{P}{10} + 10 \right]$$

PER CAPITAL DEMAND (q)

$$q = \frac{\text{Total yearly water requirement of the city in litre}}{365 \times \text{Design population}}$$

Assessment of Variation in Demand

- (i) Maximum daily demand = 1.8 × Avg daily demand
- (ii) Maximum hourly demand = 1.5× maximum daily demand
- (iii) Maximum hourly demand or peak demand= 2.7 × Avg daily demand
- (iv) Maximum weekly demand = 1.48× Avg. weekly demand
- (v) Maximum monthly demand=1.28× Avg. monthly

POPULATION FORECASTING METHODS

(i) Arithmetic increase- This method is based upon the assumption that population increases at a constant rate.

$$P_n = P_0 + n\bar{x}$$

Where, P_n = Prospective or forecasted population after n decades from the present (i.e., last known census)

P_0 = Population at present (i.e., last known census)

n= Number of decades between now & future.

\bar{x} = Average (arithmetic mean) of population increases in the known decades

(ii) Geometric Increase Method In this method the per decade percentage increase or percentage growth rate is assumed to be constant. Also known as Uniform increase method

$$P_n = P_0 \left(1 + \frac{r}{100} \right)^n$$

Where, r= Assumed growth rate (%)

r can be calculated using

$$r = \frac{t\sqrt[t]{P_2}}{P_1} - 1$$

Where, P_2 = Final known population, P_1 = Initial known population, t= Number of decades (period) between P_1 and P_2

r can also be calculated as

$$r = t\sqrt[t]{r_1 r_2 \dots r_t}$$

(iii) Incremental Increase Method – The population for a future decade is worked out by adding the mean arithmetic increase to the last known population as in arithmetic increase method and to this is added the average of the incremental increase \bar{y} . Method is best for any city, whether old or new

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \bar{y}$$

Where, \bar{x} = Average increase of population of known decades

\bar{y} = Average of incremental increase of the known decades.

WATER DEMAND AND SUPPLY

(iv) Decreasing rate of growth method

Used where the rate of growth shows a downward trend (as the cities reach towards saturation, the rate of increase in population goes on reducing)

CHARACTERISTIC OF WATER

A) PHYSICAL CHARACTERISTICS

a) Turbidity :- If a large amount of suspended matter such as clay, silt or other organic material are present in water it will appear to be muddy or turbid in appearance.

- Amt of suspend matter. Unit-ppm or JTV or NTV

Measurement (i) field – Turbidity Rod,

Lab (i) Jackson's turbidity meter – candle test

Longer the light path – lower the turbidity 10.8cm \approx 200JTV

Can't measure Turbidity less than 25JTV

(ii) Nephelometer- Light reflection test

Can measure Turbidity less than 1ppm

NTV (unit) = Nephelomete Turbidity unit

PLD (Permissible limit for drinking water = 5 to 10 limit)

b) Colour :- Measured in "Burgress scale" with Nessler tubes or colour scale".

More precise instrument is –Tintometer

PLD on cobalt scale =20

c) Taste & Odour :- Taste and odour may be caused by presence of dissolved gases such as H₂S, CH₄, CO₂ etc. combined with organic matter

Test A ml of odour sample +B ml of dilute sample
A+B=200ml

Threshold odour No. (TON) = $\frac{A+B}{A} = \frac{200ml}{A}$

PLD = 1, should never exceed 3

d) Temperature:-

PLD = 10⁰c should never exceed 25⁰c

B) CHEMICAL CHARACTERISTICS

a) Total solid and suspended solids

Total solid measured by evaporation, the suspended solid can be found by filtering the water sample and weighing the residue left on the filter paper. The difference between total solid and suspended solid gives the dissolved solid

Dissolved solid = Total solid – suspended solid

PLD = 500ppm

b) pH = -log[H⁺]

$$p^{OH} = -\log_{10}[\bar{OH}]$$

$$[H^+][\bar{OH}] = 10^{-14}$$

$$p^H + p^{OH} = 14$$

The lower value of it (acidic) may cause corrosion and the higher value of it (alkaline) may produce incrustation.

Measurement is done by potentiometer

or by colour indicator generally 2 indicator used are

Methyl orange \rightarrow (2.8-4.4), original colour is red, finally converted to yellow

Phenolphthalein \rightarrow (8.6-10.3), original colour is yellow, finally converted to red

PLD = 6.6 to 8.5

c) Hardness :- If carbonate and bicarbonate of Ca & Mg present called temp. hardness, if

WATER DEMAND AND SUPPLY

sulphate, carbonate and nitrate present called permanent hardness

- Carbonate hardness → It is equal to total hardness or alkalinity whichever is less
- Non carbonate → only present if Total hardness is more than Alkalinity.

Ex. if T.H=150ppm, Alk=50ppm then carbonate =50ppm & non carbonate =[150-50]=100ppm

If hardness ≤ 75 ppm = softwater

Hardness between (75-200)=moderate water

Hardness >200=Hard water

CONSTITUENTS OF ALKALINITY

Major sources → CO_3^{2-} , HCO_3^- , OH^-

(a)

$$\text{Equivalent weight} = \frac{\text{Molecular weight}}{\text{valency}}$$

$$\text{Equivalent weight of CaCO}_3 = \frac{40+12+3 \times 16}{2} = 50$$

$$\frac{\text{gram equivalent or number of equivalent} = \frac{\omega t}{\text{equivalent} \omega t}}$$

PLD (75 – 115)PPM

Measurement by titration using EDTA also called 'versanate' solution.

T. H(ppm) as CaCO_3

$$\left[\text{Ca}^{2+} * \frac{\text{combining wt of CaCO}_3}{\text{combining wt of Ca}^{2+}} \right] +$$

$$\left[\text{Mg}^{2+} * \frac{\text{combining wt of CaCO}_3}{\text{combining wt of Mg}^{2+}} \right]$$

Combining wt. of, Ca, Mg & CaCO_3 are 20, 12, 50 respectively.

(d) Chloride content: - Large amount of chloride may enter from industries. Generally present in the form of NaCl

PLD = 250ppm

Test – Titration with silver nitrate using KMO_4 indicator.

(e) Nitrogen content: - It gives the indication of presence of organic matter, may present in any form

(a) Free Ammonia- Indicates the first stage of decomposition of organic matter or gives the indication of recent pollution

(b) Organic Nitrogen (Albuminoid)- Indicates quantity of nitrogen present in water before the decomposition of organic matter is started

(c) Nitrites – Indicates the presence of partially decomposed organic matter

(d) Nitrates- Indicates the presence of fully oxidized organic matter

- Excess of nitrate may cause Methemoglobinemia or blue baby disease
- Free Ammonia & org. Nitrogen called 'Kjeldahl Nitrogen'

PLD Ammonia = 0.15, org. Nitrogen = 0.3

Nitrite = zero, Nitrate = 45ppm

(f) PLD of other chemicals

(a) Mn= 0.05ppm

(b) Fluoride=(1-1.5)ppm, <1 cause –tooth decay
>1.5cause →spotting of teeth

(c) Iron =0.3ppm

(d) sulphate =250ppm

(g) BOD (Bio chemical oxygen demand):- BOD of water during 5 days at 20°C is generally taken as the std. demand required. It's a demand by Microorganism for the degradation of organic matter.

Test

WATER DEMAND AND SUPPLY

BOD 5day at 20°C = $[(D.o)_i - (D.o)_f] * \text{Dilution factor}$

- Condition $(D.o)_i$ should \nless 1ppm, $(D.o)_f$ should not more than 7ppm

PLD BOD = 0

Min. DO for survival of fish = 4ppm

$$\text{BOD } Y_t = L_0[1 - (10)^{-k_D t}]$$

Where $K_D=0.43K$, Deoxygenation constant or BOD constant

K =speed of reaction in day

L_0 =Ultimate D.O

The rate at which BOD is satisfied at any time depends upon temp and also on the amount and nature of organic matter present in water at any time. It can be calculated using:

$$K_D(T^0) = K_D(20^0)(1.047)^{T-20}$$

h) C.O.D:- Potassium dichromate ($K_2Cr_2O_7$) or Potassium permanganate ($KMnO_4$) which are oxidizing agents are used to destroy the organic matter. As the organic matter is of two types biologically degradable and non-bio degradable.

BACTERIAL CHARACTERISTICS

Most bacteria are harmless, and under certain conditions beneficial to human beings, animals and crops. Such bacteria or micro-organisms are called non-pathogenic bacteria or non-pathogens. Certain other bacteria are dangerous for and may cause serious water borne diseases, such as cholera, typhoid, infectious hepatitis, etc. such harmful bacteria or organisms are known as pathogenic bacteria or pathogens.

- (i) Aerobic- Oxygen is required for Survival
- (ii) Anaerobic- Don't require oxygen for survival
- (iii) Facultative- can survive with O_2 or without O_2

→Test by counting of Coliforms (harmless Aerobic m.o) found residing in the intestines of all warm blooded animals including human beings.

→life of coliform is higher than pathogenic bacteria, hence if no coliform present water will be safe and free from pathogen

PLD 1coliform per 100ml of water

→Determine using MPN (most probable number) test- By mixing different samples of water with lactose and incubating them with test tubes for 48 hr. The presence of acid or CO_2 in the test tube will indicate the presence of coliform bacteria, then referring to std. statistical tables the MPN of b.coli per 100ml of water can be found

→It can also be determined by membrane filter technique

- Diseases caused by Bacteria
 - a)Typhoid- caused by Salmonella Typhi (Bacteria, b)Cholera- caused by Vibrio – cholera, c)Bacillary dysentery – caused by Shiga bacillus
- Diseases caused by viral infection
 - (i) Hepatitis (infectious jaundice) – caused by Hepatitis virus
 - (ii) Poliomyelitis –caused by Polio virus

WATER TREATMENT

WATER TREATMENT

Purpose of water treatment

To remove color, turbidity, dissolved solid, suspended solid, objectionable taste and odour, excess hardness, salinity, toxic materials, various microorganism.

Theory of Sedimentation

It is the removal of suspended particles by gravitational settling. Sedimentation tanks designed to reduce velocity of flow so as to reduce turbulence sedimentation is based on Stokes law.

There are two type of sedimentation

1) Plain Sedimentation- Also called type 1 sedimentation, based on discrete settling where no coagulants are added

2) Coagulation Sedimentation- Also called type 2 sedimentation, based on colloidal settling where chemicals are added to form flocs

- Settling Velocity using Stokes Law- The settling velocity of discrete particle having d diameter can be computed using Stoke law

$$(a) \quad V_s' = \frac{g}{18} (G - 1) \frac{d^2}{\nu}$$

Valid for $d < 0.1 \text{ mm}$.

Where V_s = Velocity of settlement of particle in m/s., d = Diameter of the particle in meter. G = Specific gravity of the particle
 ν = kinematic viscosity of water in m^2/sec

$$(b) \quad V_s = \left[\frac{\frac{4}{3}gd(G-1)}{C_D} \right]^{1/2}$$

$$C_D = 0.4 \text{ for } Re > 10^4$$

And if $(Re < 0.5), C_D = \frac{24}{Re}$

And if $0.5 \leq Re \leq 10,000$

$$C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$$

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

For $d < 0.1 \text{ mm}$.

Where, T = temperature of water in $^\circ \text{C}$,
 V_s is in mm/sec. d is in mm.

$$(d) \quad V_s = 1.8\sqrt{gd(G-1)}$$

For $d > 0.1 \text{ mm}$

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

For $0.1 < d < 1 \text{ mm}$.

Types of sedimentation tanks

- Quiescent Type (Fill and draw type) –**
 Tank is filled with incoming water and allowed to rest, generally for 24hr. 6-8 hr required for removal of sludge. Tank is designed to treat maximum daily demand equals to 1.8 times of average daily demand.
- Continuous flow type-** It is designed to achieve ideal condition of equal velocity at all points. Depending on type of flow these may be of following 3 types- horizontal, circular and vertical flow.

Horizontal Flow (Rectangular Sedimentation Tank)

Assumptions- Settling of particles is same as in case of Quiescent type of equal depth

Flow is horizontal and steady and settling velocity is uniform

Concentration of suspended particles is same at all height

Particles are removed when they reach at bottom of the settling zone

Important terms in calculations

- Over flow rate-** Defined as settling velocity of that particle if introduced at the top most point at inlet will reach bottom most point at outlet

WATER TREATMENT

Over flow rate, $V_s = \frac{\text{Discharge}}{\text{surface area}}$

Or $V_s = \frac{Q}{BL}$

$V_s = 12000$ to 18000 lit/m²/ day for plain sedimentation, and $V_s = 24000$ to $30,000$ lit/m²/ day for sedimentation with coagulation.

(b) Velocity of flow, $V_f = \frac{Q}{BH}$

(c) Time of horizontal flow,

$$T = \frac{L}{V_f} = \frac{L}{Q/BH} = \frac{LBH}{Q}$$

(d) Time of falling through height 'H'

$$T = \frac{H}{V_s} = \frac{LBH}{Q}$$

(e) Detention time,

$$t_d = \frac{L}{V_f} = \frac{H}{V_s}$$

4 to 8 hr → For plain sedimentation

2 to 4 hr → For sedimentation with coagulation

(f) Percentage lighter particle-

$$P_l = \frac{V_s}{V_o} \times 100$$

Where, $P_l = \%$ of lighter particles (with setting velocity (V_s') is less than V_s) which shall be removed in an ideal settling basin.

(g) Percentage of particle removed

$$P_r = (1 - x_s) + \sum \frac{V_s'}{V_s} \cdot \Delta x$$

Where x_s is fraction of particles which have settling velocity less than v_s , it means $(1-x_s)$ is fraction of those particles which have settling velocity more than v_s

(h) Detention time 't' for circular tank

$$t = \frac{d^2(0.011d + 0.785 H)}{Q}$$

Where d= dia of the tank,
H= Vertical depth of wall

TYPE-2 SEDIMENTATION

It is also called sedimentation with coagulation. Coagulation is added to neutralize the -ve charge on colloidal particles and allow them to coagulate. Coagulant forms the precipitate known as flock.

Chemical used for Coagulation

1) Alum ($Al_2(SO_4)_3 \cdot 18H_2O$)

- Alum reacts with bicarbonates to form $Al(OH)_3$ as a ppt.
- Addition of Alum imparts permanent hardness because it converts bicarbonate into sulphate.
- Addition of alum produces CO_2 which form carbonic acid which decreases pH and hence corrosiveness is increased, hence in order to increase the pH alkali may be required such as lime $Ca(OH)_2$ or Soda Na_2CO_3 .
- $Al_2(SO_4)_3 \cdot 18H_2O + 3 Ca(HCO_3)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3 \downarrow + 6 CO_2 \uparrow$
- $Al_2(SO_4)_3 \cdot 18H_2O + 3Ca(OH)_2 \rightarrow 3CaSO_4 + Al(OH)_3 \downarrow + 18H_2O$
- $Al_2(SO_4)_3 \cdot 18H_2O + 3Na_2CO_3 \rightarrow 3Na_2SO_4 + 2Al(OH)_3 \downarrow + 3CO_2 \uparrow + 15H_2O$

2) Copperas ($FeSO_4 \cdot 7H_2O$)

- Also called ferrous sulphate. Used with lime in order to increase the pH.
- Effective pH range is more than 8.5. Since value is more than the PLD for pH hence rarely used for drinking water treatment
- $FeSO_4 \cdot 7H_2O + Ca(OH)_2 \rightarrow CaSO_4 + Fe(OH)_2 + 7H_2O$
- Copperas + Hydrated lime = Ferrous hydroxide
- $FeSO_4 \cdot 7H_2O + Ca(HCO_3)_2 \rightarrow Fe(HCO_3)_2 + CaCO_3 + 7H_2O$
- $Fe(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Fe(OH)_2 + 2CaCO_3 + 2H_2O$
- $Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3 \downarrow$

WATER TREATMENT

3) Chlorinated Copperas: ($Fe_2(SO_4)_3$) and $FeCl_3$)

- When chlorine is added with iron slats Ferric Sulphate and Ferric Chlorides is formed
- Iron salts are more commonly used in treating sewage water, whereas alum is used treating the raw water
- Imparts bad taste to water
- Produces heavy flocks
- $6(FeSO_4 \cdot 7H_2O) + 3Cl_2 \rightarrow 2Fe_2(SO_4)_3 + 2FeCl_3 + 42H_2O$
- $Fe_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 3CaSO_4 + 2Fe(OH)_3 \downarrow$
- Ferric sulphate + Hydrated lime = Ferric hydroxide ppt
- $2FeCl_3 + 3Ca(OH)_2 \rightarrow 3CaCl_2 + 2Fe(OH)_3 \downarrow$

4) Sodium Aluminate ($Na_2Al_2O_4$)

- It reacts with permanent hardness present in water and gives ppt of Calcium aluminate. Since it removes permanent hardness hence it is often used treating boiler feed water
- Method is costlier as compare to Alum treatment
- $Na_2Al_2O_4 + Ca(HCO_3)_2 \rightarrow CaAl_2O_4 \downarrow + Na_2CO_3 + CO_2 \uparrow + H_2O$
- $Na_2Al_2O_4 + CaCl_2 \rightarrow CaAl_2O_4 \downarrow + 2NaCl$
- $Na_2Al_2O_4 + CaSO_4 \rightarrow CaAl_2O_4 \downarrow + Na_2SO_4$

MIXING BASIN

Mixing is done by mechanical Mixer. Raw water and coagulants are mixed vigorously. Intensity of mixing depends upon temporal mean velocity gradient (G). G is a measure of relative velocity of two particles of fluid and distance between them. Unit of G is sec^{-1} .

$$G = \left[\frac{P}{\mu V} \right]^{1/2}$$

Where, G = Velocity gradient (per second)

P= Power dissipated in watts i.e., N-m/s

V= Volume of tank in m^3 raw water to which P is applied in m^3 ; μ = Dynamic viscosity (N-s/ m^2)

G can also be calculated

$$G = \sqrt{\frac{C_D \rho_w A_P V_r^3}{2\mu V}}$$

Where C_D is coefficient of drag; ρ_w is density of water; A_P Area of plates; V_r is relative velocity; V volume of tank

FILTRATION

Filtration removes fine particles, turbidity, colloidal matter, dissolved minerals and Microorganism.

Types of Filters:-

A. Slow Sand Filter

- Generally designed rectangular having L/B ratio 1.5 to 3
- Depth of filter is 2.5 to 3.5 m.
- Plane area of filter is 100 to 2000 m^2 having its' size of the order of 30m *60m
- $0.2 \leq D_{10}$ of sand ≤ 0.4 mm.
- Coefficient of uniformity $\frac{D_{60}}{D_{10}} = 3$ to 5.
- Design period =10 years
- Depth of sand is 90 to 110 cm
- Below the sand gravel based of 30 to 75 cm thick is used.
- Frequency of cleaning is 1 to 3 months.
- Rate of filtration =very slow 100 to 200 lit/hr/ m^2 .
- Efficiency of bacteria removal = 98 to 99%
- It can be removed turbidity up to 50 ppm.
- Cleaning of filter is done manually once in 1-3 months in which top 1.5 cm to 3 cm layer is scrapped and washed manually.
- It is designed for maximum daily demand

WATER TREATMENT

- The number of filter beds required depend on total filter area but usually 1 filter bed is provided at stand by

B. Rapid Sand Filter

- Number of Filter unit is computed using as

$$N = 1.22\sqrt{Q}$$

where Q= Plant capacity in million lit/day

- $\frac{D_{60}}{D_{10}} = 1.3 \text{ to } 1.7$
- Water to be treated must be Coagulated and Sedimented
- Sand layer depth is about 75 cm.
- Below the sand gravel based of 60 to 90 cm thick is used.
- D_{10} of sand is 0.35 to 0.55 mm.
- Depth of tank = 2.5 m to 3.5 m.
- Area = 10 to 80 m² each unit.
- Rate of washing is 15 to 90 cm rise/ minute.
- Rate of filtration 3000 to 6000 lit/hr/ m² approx 30 times of slow sand filter.
- Less efficient in removal of bacteria (80-90%)

C) Pressure Filter

Pressure filters are just like small rapid gravity filters placed in closed vassals, and through which water to be treated is passed under pressure.

- Rate of filtration – 6,000 to 15, 000 liter/hr/m²

The pressure filter is less efficient than the rapid gravity filters, in removing bacteria and turbidities.

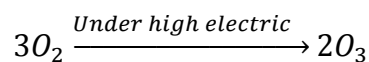
DISINFECTION OR STERILIZATION

Disinfection means killing of pathogenic bacteria whereas sterilization means killing of pathogenic and nonpathogenic bacteria both.

Methods of Disinfection

Minor Methods

- Boiling-** It is the best method which removes 100% bacteria and other microorganism. Since method is costly hence not suitable for mass public supply.
- Treatment with lime-** Lime increases the pH and when pH >11 then removes approx. 100% bacteria. Generally used for boiler feed after as it also removes hardness. Excess lime can be removed by carbonation of the water.
- Treatment with silver ions-** Also called electro catadion process. Metallic silver ions have strong killing action.
- Treatment with Iodine and Bromine –** It may be used for army troops and by private plants
- Treatment with UV light-** Efficient method for sterilization. Rays are generated using Mercury vapor lamp. Method is costly and often adopted for treating surgical water, swimming pool water.
- Treatment with KMnO₄-** This Pink in colour commonly used for open well in rural area. It can kill bacteria and can oxidise bad taste producing organic matter. If pink color disappears quickly then it indicates oxidation and presense of organic matter. Dose- 1-2 ppm
- Ozone-** Reaction is as follows



Arc voltage

Powerfull oxidising agent, it can be produced in a high voltage electrical field. Ozonised water is tasty and no residue is left and no color is produced. Method is very costly.

WATER TREATMENT

MAJOR METHODS

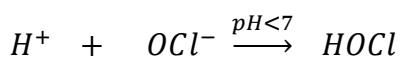
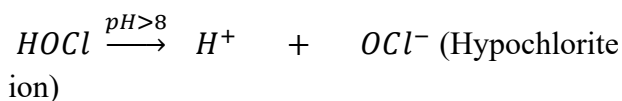
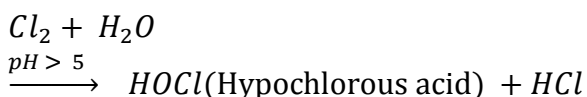
CHLORINATION

Chlorine in its various forms are almost used for disinfecting public water supply. As this method is very cheap, easy to handle and having residual disinfecting effects for long period.

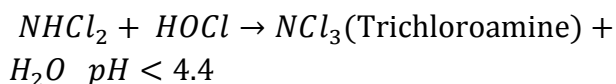
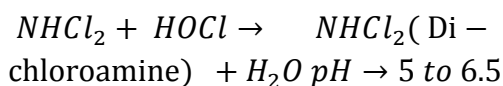
Forms of Chlorine – In the form of Liquid chlorine, Chloramine, Chlorine dioxide, hypochlorite or bleaching powder.

ii) Disinfecting Action of chlorine

When chlorine is added to water, it forms Hypochlorous acid or hypochlorite ions.



- $\text{NH}_3 + \text{HOCl}$ is called combined chlorine



- HOCl is most destructive form for this reason pH value of water is kept between 5-7
- NCl_3 has no disinfecting property

TYPE OF CHLORINATION

(i) Plain chlorination - No other treatment is given to water except chlorination. Dose 0.5mg/l. Removes bacteria, organic matter and colour

(ii) Pre-chlorination- Apply Chlorination before filtration. Normal dose 5-10mg/l

(iii) Post-chlorination- Apply Chlorine at the end. Dose should be such that around 0.1 to 0.2 mg/lit is left after a contact of 20 min.

(iv) Double chlorination- Pre and Post Chlorination applied

(iv) Break point chlorination- It gives an idea about extent of the chlorine added to water. Beyond the break point free residual appears. The difference between applied chlorine and residual chlorine is called chlorine demand of water.

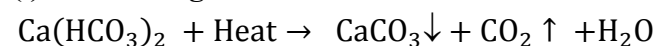
(v) Super chlorination – When excess chlorine is added say 5-15mg/l. Generally used in some special cases ex. Epidemic

(vi) Dechlorination- Required when super chlorination is done (Generally to remove excess chlorine) Agents used are SO_2 gas, activated carbon, Sodium Bisulphite (NaHSO_3), Sodium Thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$)

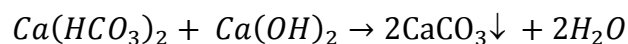
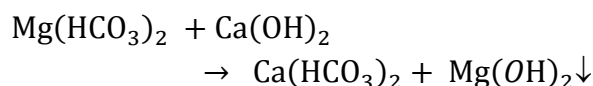
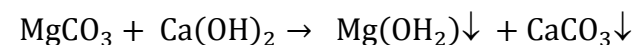
WATER SOFTENING

• Methods of Removing of Temporary Hardness

(i) Boiling

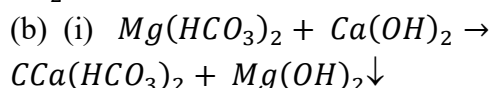
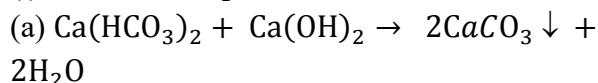


(ii) Addition of Lime

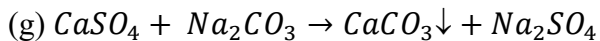
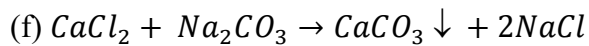
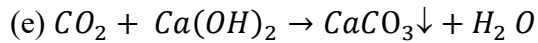
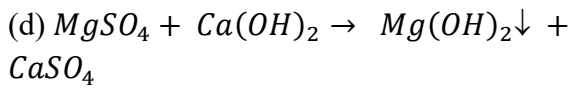
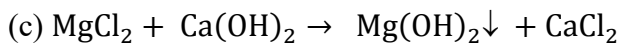
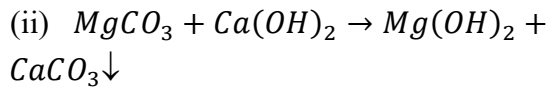


• Method of Removing Permanents Hardness

(i) Lime – soda process

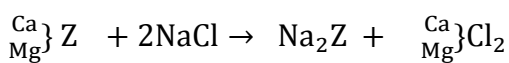
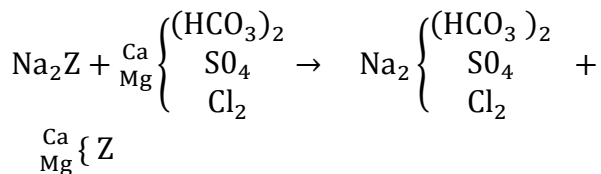


WATER TREATMENT



- Lime removes entire carbonate hardness
- Lime reacts with non-carbonate hardness of magnesium to convert non carbonate hardness of calcium
- Non Carbonate hardness of Calcium is further removed by Soda Ash
- Dry Sludge produced in mg/l = Ca removed + 0.58 Mg removed + Lime added

(ii) Zeolite or Base Exchange or Cation-Exchange Process for Removing Hardness



Used Sodium Regenerated
zeolite chloride zeolite

- This process is very effective and can produce zero hardness
- No sludge is formed
- Zeolite is a natural or synthetic cation exchange hydrated silicates of sodium and aluminum. Also called Green Sand.

FLOOD ROUTING & GROUND WATER HYDROLOGY

Flood Routing- Determination of flood hydrograph at downstream end using upstream data is called flood routing

Method 1) Hydrological (Lumped) Routing - a) Reservoir routing (ex. Level pool method), b) Channel Routing (ex. Muskingum method)

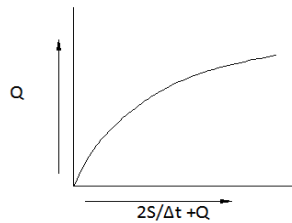
2) Hydraulic Routing- Distributed type, solved by Saint-Vaint Equation

a) Level pool method- Based on continuity equation

$\frac{ds}{dt} = I(t) - Q(t)$, method based on principle that if $Q = f(H)$ and $S = f(H)$ then $S = f(Q)$, where H is elevation. Max. Storage occur when $\frac{ds}{dt} = 0$ thn $I = Q$. Eqn used

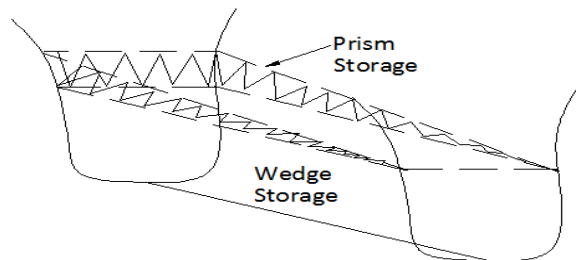
$$1) \frac{2S_{j+1}}{\Delta t} + Q_{j+1} = (I_{j+1} + I_j) + \left(\frac{2S_j}{\Delta t} - Q_j\right)$$

Curve used-



Channel routing or River Routing by

Muskingum method- Use to model volume storage of flooding by combination of wedge and prism storage. $S = f(Q, I)$



When $I > Q$, +ve wedge formed. Prism storage is denoted by $S_p = KQ$. Where $K =$ time of travel of flood wave routing through channel, also called proportionality constant.

Wedge storage $S_w = KX(I - Q)$ hence total storage is denoted as $S = K[XI + (1 - X)Q]$, where X is weighting factor varies ($0 \leq X \leq 0.5$) which depends upon shape of wedge. $X = 0$ for rectangular storage and $X = 0.5$ for full wedge.

To determine $Q_{j+1} = C_1 I_{j+1} + C_2 I_j + C_3 Q_j$,

Where $C_1 = \frac{\Delta t - 2KX}{2K(1-X) + \Delta t}$, $C_2 = \frac{\Delta t + 2KX}{2K(1-X) + \Delta t}$,
 $C_3 = \frac{2K(1-X) - \Delta t}{2K(1-X) + \Delta t}$, check is $C_1 + C_2 + C_3 = 1$

Distributed flow routing (Depth and velocity both varies)

Ex. St. Vt. Equation, Continuity eqn ($\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial x} - q = 0$), Q is discharge, q is lateral discharge, A is channel cross sectional area.

Momentum Eqn- $\frac{\partial v}{\partial x} + V \frac{\partial v}{\partial x} + g \left(\frac{\partial y}{\partial x} - s_o + S_f \right)$

Ground water flow (Sub Surface flow)

Terms- 1) Saturated zone- Subsurface zone in which all opening are filled with water.

2) Vadose zone- Generally unsaturated and partially filled with air

3) Capillary fringe- Lies just above saturated zone, also called transition zone. Water held by Capillary action

4) Specific yield (S_y)- Volume of water drained from a rock to the total volume of rock.

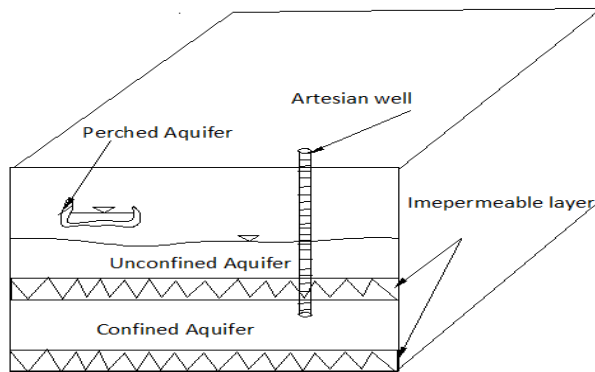
5) Specific Retention (S_r)- Volume of water retain to the total volume of rock.

6) Porosity (η) = $S_y + S_r$

FLOOD ROUTING & GROUND WATER HYDROLOGY

Ex-	$\eta\%$	$S_v\%$	K(Hyd. Conductivity)m/day
Clay	15-55	1-10	0.041
Sand	35-40	10-30	32.8
Gravel	30-40	15-30	2.5

	Aquifer	Aquitard	Aquiclude	Aquifuge
Permeability	High	Less	Less	Not present
Porosity	High	Less	High	Not present
ex	Gravel	Sandy Clay-Seepage	Clay	Rock



Confined Aquifer- Filled with pressurized water and separated from land surface by impermeable confining bed also called Artesian Aquifer

Unconfined Aquifer- Exposed to land surface consist water table

Darcy law- $Q=KiA$, K is permeability, I is hyd. Gradient, $Q/A = Ki=v$ (Apparent velocity, Actual vel. is higher than v)

Limitation- Valid for laminar flow, for Re. no <1 only. $Re=Vd_s/\nu$, where d_s is particle size representative d_{10} is 10% of aquifer material is of smaller than it.

Transmissibility-(Discharge for unit width) as $Q=Kia$, $T=KD$ (for unit gradient and unit width), D is height of fully saturated zone

Compressibility of aquifers- For confined aquifer

Compressibility of water (β)= $-\frac{dV_w}{V_w}/dp$

Compressibility of Pore (α)= $-\frac{dV_s}{V_s}/\sigma_z$

Specific storage (S), dimension(L^{-1})= S_s/B where S_s is storativity denoted as $S_s=v(\eta\beta+\alpha)$, defined as volume of water released from unit volume of water column due to unit decrease in piezometer head.

Groundwater equation of Motion

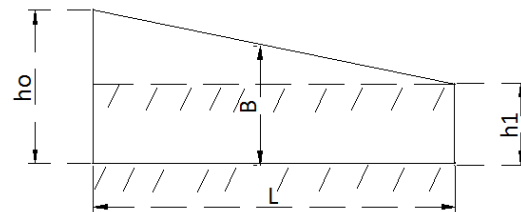
a)Confined Groundwater flow

$$\nabla^2 h = S/T \frac{\partial h}{\partial t}, \text{ where } \nabla^2 h = \frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2}$$

Where S is storage coefficient and T is Transmissibility. Above equation is valid for unsteady groundwater, Homogenous, Isotropic and Confined Aquifer.

When flow is Steady equation reduced to $\nabla^2 h = 0$.

b) Confined groundwater flow between 2 water body



Equation of discharge

$$q = \frac{(h_0 - h_1)}{L} KB$$

FLOOD ROUTING & GROUND WATER HYDROLOGY

Equation of head

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0, \text{ valid of Steady flow}$$

Unconfined flow using Dupit's assumption equation is $\nabla^2 h^2 = 0$.

Assumptions involved are

- 1) The curvature of the free surface is very small so that the streamline can be assumed to be horizontal at all sections
- 2) The hydraulic grade line is equal to the free surface slope and does not vary with depth

Unconfined flow with recharge

$$\frac{\partial^2 h^2}{\partial x^2} + \frac{\partial^2 h^2}{\partial y^2} = \frac{-2R}{K}, \text{ where } R \text{ is recharge in } (m^3/d)/m^2 \text{ of area}$$

Without recharge head equation would be

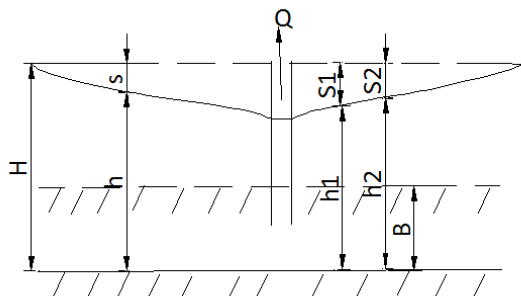
$$\frac{\partial^2 h^2}{\partial x^2} + \frac{\partial^2 h^2}{\partial y^2} = 0$$

Unconfined groundwater flow between 2 water body

Equation of discharge

$$q = \frac{(h_0^2 - h_1^2) K}{L} \frac{K}{2}$$

Steady flow into a well for confined flow

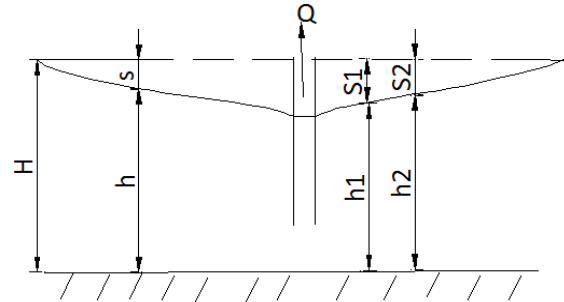


$$Q = \frac{2\pi KB(h_2 - h_1)}{\ln \frac{r_2}{r_1}}, \text{ called Thiem's eqn, Where}$$

$$T=KB \text{ or } Q = \frac{2\pi T(s_1 - s_2)}{\ln \frac{r_2}{r_1}}, \text{ at edge of zone of}$$

$$\text{Influence } S=0, r_2=R, h_2=H, \text{ hence } Q = \frac{2\pi T S_w}{\ln \frac{R}{r_w}}$$

Unconfined Flow



$$Q = \frac{\pi K(h_2^2 - h_1^2)}{\ln \frac{r_2}{r_1}} \text{ at edge or at } R,$$

$$Q = \frac{\pi K(H^2 - h_w^2)}{\ln \frac{R}{r_w}}$$

where $h_w =$
depth of water in pumping well of radius r_w



Environment Engineering

Environment Engineering 1

Water Supply Engineering
/ Raw Water Engineering

Environment Engineering 2

Waste Water Engineering

Solid Waste Management

Air Pollution and Noise
Pollution

Environment Engineering II

- 1. Waste Water Characteristics**
- 2. Biochemical Reactions in waste water**
- 3. Disposal of Sewage Effluents**
- 4. Design of Sewerage system**
- 5. Treatment of Waste water**
- 6. Solid waste management**
- 7. Air and noise pollution**

Some Important Terms

✓ DOMESTIC SEWAGE:

- It is the sewage obtained from the lavatory basins, urinals & water closets of houses, offices & institutions. It is highly foul on account of night soil and urine contained in it. Night soil starts putrefying & gives offensive smell. It may contain large amount of bacteria due to the excremental wastes of patients. This sewage requires great handling & disposal.

✓ INDUSTRIAL SEWAGE:

- It consists of spent water from industries and commercial areas. The degree of foulness depends on the nature of the industry concerned and processes involved.



Some Important Terms

✓ **RUBBISH**: It consists of sundry solid wastes from the residencies, offices and other buildings. Broken furniture, paper, rags etc are included in this term. It is **generally dry and combustible**.



✓ **SEWAGE**: It is a dilute mixture of the wastes of various types from the residential, public and industrial places. It includes waste water and foul discharge from the water closets, urinals, hospitals, stables, etc.



✓ **SANITARY SEWAGE** : It is the sewage obtained from the residential buildings & industrial effluents establishments.

Some Important Terms

- **REFUSE**: This is the most general term to indicate the wastes which include all the rejects left as worthless, sewage, sullage etc
- **GARBAGE**: It is a dry refuse which includes, waste papers, sweepings from streets and markets, vegetable peelings etc. The quantity of garbage per head per day amounts to be about 0.14 to 0.24 kg for Indian conditions. Garbage contains **large amount of organic and putrefying matter** and therefore should be removed as quickly as possible.



Some Important Terms

✓ **STORM WATER**: It is the surface runoff obtained during and after the rainfall which enters sewers through inlet. Storm water is not foul as sewage and hence it can be carried in the open drains and can be disposed off in the natural rivers without any difficulty.



Some Important Terms

✓ **SULLAGE**: It is the discharge from the bath rooms, kitchens, wash basins etc., it **does not** include discharge from the lavatories , hospitals , operation theaters , slaughter houses which has a high organic matter .



Some Important Terms

✓ SEWERS:

- Sewers are underground pipes which carry the sewage to a point of disposal.

✓ SEWERAGE:

- The entire system of collecting, carrying & disposal of sewage through sewers is known as sewerage.

✓ DRY WEATHER FLOW (DWF):

- Domestic sewage and industrial sewage collectively, is called as DWF. It does not contain storm water. It indicates the normal flow during dry season



Waste Water Characteristics

- Waste water is usually classified as
 - Industrial waste water and
 - Municipal waste water
- Industrial waste water with characteristics compatible with municipal water is often discharged into municipal sewer.
- Many Industrial waste waters require pretreatment to remove non compatible substances prior to discharge into the municipal sewers

Properties of Waste Water

Waste water = water + liquid waste originated from locality

1. **Domestic sewage**: It is a mixture of water and liquid waste originating due to domestic activities like washing, cooking, bathing, etc.
2. **Industrial sewage**: Waste water originated due to industrial activities
3. **Storm Water Drainage**: It is sewage that is originated due to rains.

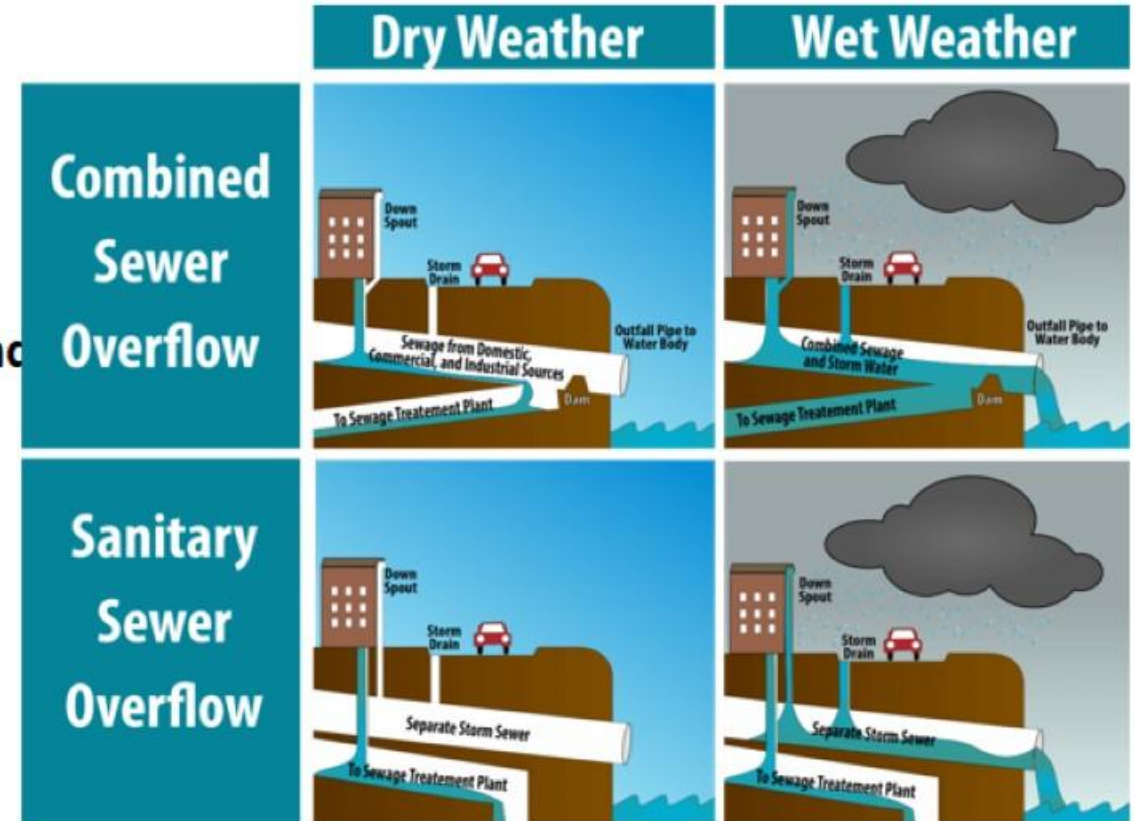
Note: Combination of kitchen and Bathroom waste is termed as **sullage**

SEWERAGE SYSTEM

- It is a system of collection, treatment and disposal of the treated sewage
- Sewerage system is of 3 types:
 1. Separate sewerage system
 2. Combined sewerage system
 3. Partially separate sewerage system

TYPES OF SEWERS

- Sanitary sewer
 - It carries sanitary sewage i.e. waste water from municipality including Domestic and Industrial wastewaters.
- Storm Sewer
 - It carries storm sewage including Surface Runoff and Street Wash.
- Combined Sewer
 - It carries domestic, industrial and storm sewage.
- House Sewer
 - It is the sewer conveying sewage from plumbing system of building to common/municipal sewers.



TYPES OF SEWERS

- Lateral Sewer

- This sewer carries discharge from two or more house sewers.

- Sub Main Sewer

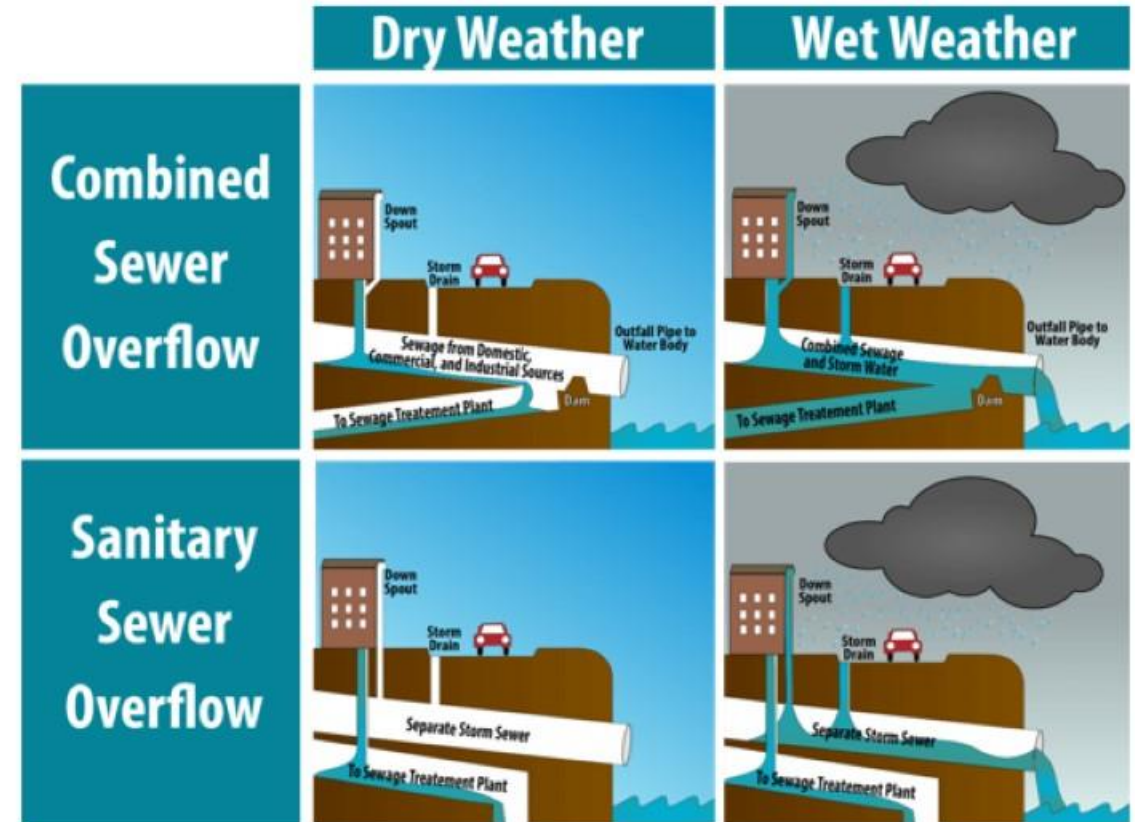
- This sewer carries discharge from two or more laterals.

- Main/ Trunk Sewer

- It receives discharge from two or more sub-mains.

- Outfall Sewer

- It receives discharge from all collecting system and conveys it to the point of final disposal.



TYPES OF SEWERS

- **Waste pipe**

- A pipe which carries only liquid waste from kitchens, wash basins etc.
- It also carries human excreta.

- **Vent pipe**

- A pipe which is provided for ventilation purpose to facilitate the exit of foul gases into atmosphere.

- **Soil pipe**

- A pipe which carries human excreta from water closet to septic tank.



Physical Waste Water Parameters

- All physical water quality parameters like **total solids, suspended solids, Turbidity, colour, Temperature**, etc. are applicable here also.
- Sewage Consists of Both Organic & Inorganic particles
- Average temperature of sewage in India is 20° C.
- As per GOI manual, 80% of water supplied goes into the sewage.

Chemical Parameters of Waste Water

Solids present in waste water can be of four forms:

- 1. Suspended solids**
- 2. Dissolved solids**
- 3. Colloidal solids**
- 4. Settleable solids**

Chemical Parameters of Waste Water

1. **Suspended solids** are those which remain floating in water. (**>100nm**)
2. **Dissolved solids** are these which dissolve in waste water. (**< 1 nm**)
3. **Colloidal solids** are those which have particle size in between dissolved and suspended. (**1-1000nm**)
4. **Settleable solids** are that portion of solid matter which settles out if the waste water is allowed to remain undisturbed for 2 hours.

Chemical Parameters of Waste Water

The amount of various kinds of solids present in waste water can be determined as below:

- Total amount of solids can be determined by evaporating a known volume of waste water and weighing the residue left. The mass of residue left divided by the known volume of water is expressed in mg/L
- The suspended solids are also called as Filterable Solids that are retained on a filter of **2 μm pore size**.
- The quantity of settleable solids with the help of Imhoff Cone.
 - Waste water is allowed to stand in the cone for 2 hours and the quantity of solids settled down in the bottom is directly read out.



Chemical Parameters of Waste Water

2. pH Value

- The alkalinity of fresh waste water is **alkaline** but as time passes it becomes **acidic** because of the bacterial action in anaerobic processes

3. Chloride content: The normal chloride content of waste water of domestic nature is taken as **120 mg/L**.

4. Dissolved oxygen (DO)

- Respiration of aerobic microorganisms
- The dissolved oxygen in fresh waste water depends upon temperature. If the temp of sewage is more, DO content will be less.
- **For survival of fish, 4ppm (4mg/L) DO is required**
- **DO content of waste water is found out by Winkler's method**

Chemical Parameters of Waste Water

5. Chemical Oxygen Demand (COD)

- COD is used to measure the content of Biodegradable as well as Non biodegradable organic matter
- The oxygen equivalent of organic matter that can be oxidized is measured by using a strong oxidizing agent in an acidic medium ($K_2Cr_2O_7$). This COD test is also called as Dichromate Test
- $COD - BOD = \text{non biodegradable organic matter}$

6. Theoretical Oxygen Demand (ThOD)

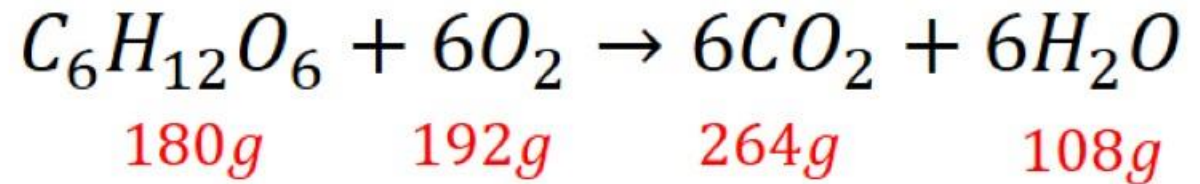
- Amount of oxygen required to oxidize the quantity of all organic matter
- $ThOD > COD > BOD$

Que.

What is theoretical oxygen demand of 300mg/L glucose solution?

- a) 300 mg/L
- b) 320 mg/L
- c) 350 mg/L
- d) 400 mg/L

For oxidation of Glucose



180g of glucose requires 192g of oxygen

For 1 g of glucose $\rightarrow \frac{192}{180}$ oxygen

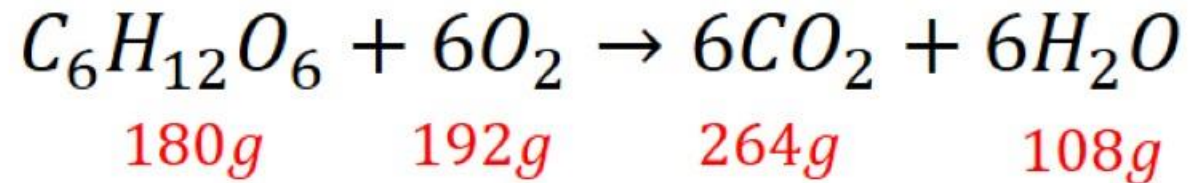
For 300 g of glucose $\rightarrow \frac{192}{180} \times 300$ oxygen

Que.

What is theoretical oxygen demand of 300mg/L glucose solution?

- a) 300 mg/L
- b) 320 mg/L**
- c) 350 mg/L
- d) 400 mg/L

For oxidation of Glucose



180g of glucose requires 192g of oxygen

For 1 g of glucose $\rightarrow \frac{192}{180}$ oxygen

For 300 g of glucose $\rightarrow \frac{192}{180} \times 300$ oxygen

= 320 mg/L

Chemical Parameters of Waste Water

7. Biochemical Oxygen Demand (BOD)

- BOD is used as a measure of the quantity of oxygen required for oxidation of Biodegradable organic matter present in water sample by aerobic biochemical reactions.
- BOD of water during **5 days at 20° c** is taken as standard BOD and is approx., equal to **67% of ultimate BOD**
- The BOD is determined by diluting a known volume of a sample of waste water with a known volume of Aerated water and then calculating DO of the diluted sample.
- The diluted sample is then incubated at 20° c for 5 days the DO at the end of 5 days is again calculated.
- The difference between initial DO and final DO will indicate the oxygen consumed



Chemical Parameters of Waste Water

7. Biochemical Oxygen Demand (BOD)

- $BOD = (DO_i - DO_f) \times D.F$

$$\text{Dilution factor } DF = \frac{\text{volume of diluted sample}}{\text{volume of undiluted sample taken}}$$

Que 1. If initial DO = 5 mg/L, final DO = 2 mg/L.

5ml of sample is mixed to form 100 ml of diluted sample. Find BOD.

5ml of sample is mixed with 95ml of aerated water

$$BOD = (5 - 2) \times \frac{100}{5}$$

$$\Rightarrow BOD = 60mg/L$$

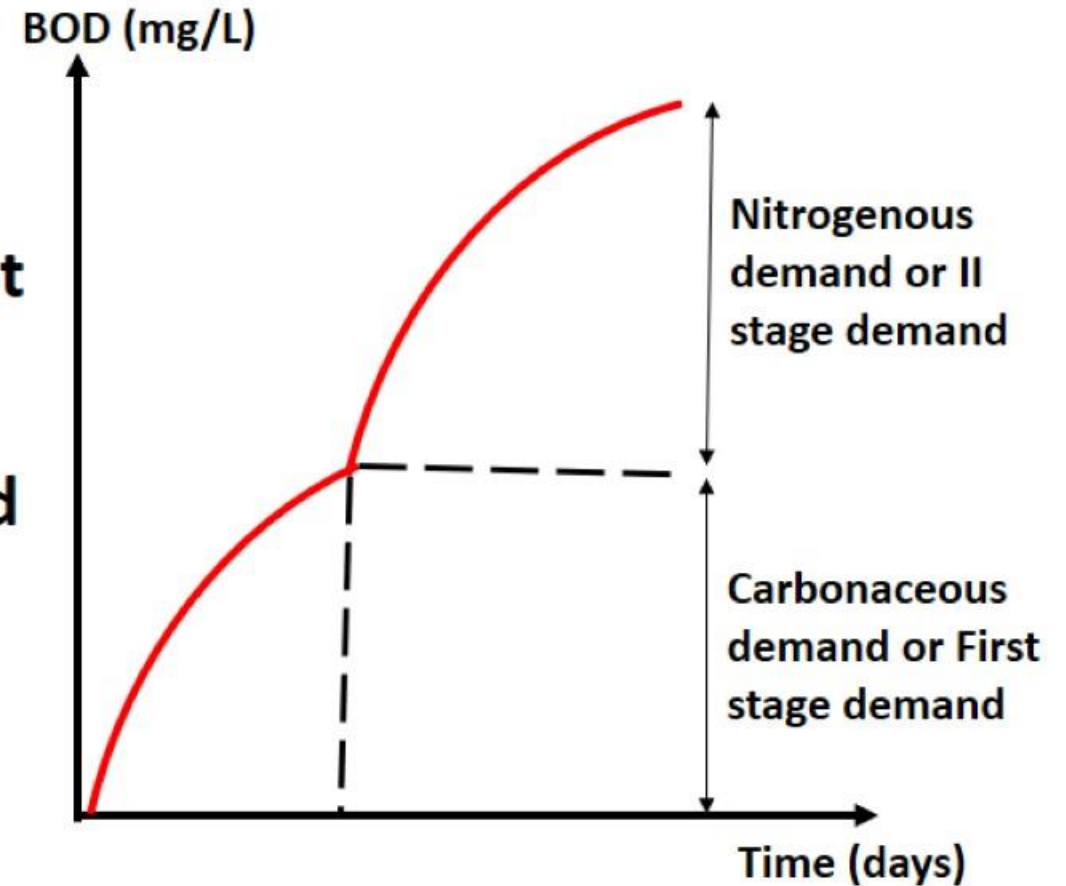
**Que 2. If initial DO = 5 mg/L, final DO = 0 mg/L at the end of 5 days.
5ml of sample is mixed with 95 ml of aerated water. Find BOD after 5 days.**

Can not be determined as we do not know when it became 0

Chemical Parameters of Waste Water

7. Biochemical Oxygen Demand (BOD)

- The first Demand occurs due to oxidation of organic matter and is called Carbonaceous demand or First stage demand.
- The later demand occurs due to biological oxidation of Ammonia and is called Nitrogenous demand or II stage demand
- Nitrogenous demand starts only after 8 days because the reproduction rate of Nitrification bacteria is very slow.



Chemical Parameters of Waste Water

Let L_t = amount of organic matter present at any time t
 t = time in days

K = rate constant (unit = per day) or deoxygenation constant

L_0 = maximum or total amount of organic matter present

$$\frac{dL_t}{dt} = -KL_t$$

$$\Rightarrow \frac{dL_t}{L_t} = -K dt$$

$$\Rightarrow [\ln L_t]_{L_0}^{L_t} = -K [t_2 - t_1]$$

$$\Rightarrow L_t = L_0 e^{-kt}$$

$$BOD_t = L_0 - L_t$$

$$= L_0 - L_0 e^{-kt}$$

$$BOD_t = L_0(1 - e^{-kt})$$

Chemical Parameters of Waste Water

7. Biochemical Oxygen Demand (BOD)

- Deoxygenation constant for given system depends on type of impurities present in waste water.
- For sample impurities exp-sugar, deoxygenation constant will be more and for complex impurities like phenol, toluene , aldehydes, ketones, etc K will be less.
- In general, deoxygenation constant can be under base e or base 10

$$BOD_t = L_0(1 - e^{-kt})$$

- *When it is not given in question whether base e or base 10, then we will use base e.*

$$K_D^{T^{\circ}C} = K_D^{20^{\circ}C} (1.047)^{T-20^{\circ}}$$

This equation is called as Vanthoff's Aeheniers Equation

Population Equivalent

- It indicates strength of industrial waste water for estimating the treatment required at the municipal treatment plant
- Average BOD of domestic sewage is 80g/capita/day
- *Population equivalent* =
$$\frac{\text{total } BOD_5 \text{ of the industry in kg/day}}{0.08 \text{ kg/day}}$$

Biochemical reactions in Waste Water

- The aerobic and anaerobic are the two basic forms of Biological stabilization reaction whose occurrence is dependent upon the availability or non-availability of oxygen.
- Aerobic Reactions taken place in the presence of free oxygen and produce Stable inorganic end products with relatively low energy content.
- Anaerobic reactions occur in the absence of free oxygen.
- Anaerobic reactions are slow and do not remove the organic content completely.

Biochemical reactions in Waste Water

- **Bacteria are primary decomposers of organic material**
- **Bacteria require energy and material for growth and reproduction**
- **Energy for bacteria is derived from biological oxidation or reduction of organic or inorganic compounds**
- **Material is derived from organic or inorganic compounds. Bacteria are classified according to the energy source**

Various Types of Bacteria

1. **AUTOTROPS:** They derive both energy and material from inorganic substances.
2. **HETEROTROPHS:** They derive both energy & material from organic substances
3. **PHOTOTROPS:** They utilize sunlight as energy source and inorganic substances as material source
4. **FACULTATIVE HETROTROPS:** They are capable of functioning both in the presence and in the absence of oxygen to oxidize organic matter.
5. **AEROBIC HETROTROPS:** They utilize organics in the presence of oxygen.
6. **ANAEROBIC HETROTROPS:** They utilize organics in the absence of oxygen.

DESIGN AND CONSTRUCTION OF SEWERS

The major roles of a sewer system :

- Improvement in the environment by removing the sewage as it originates
- Preventing inundation of low lying areas that may be otherwise caused by not providing sewers
- Prevention of sewage stagnations
- Avoiding cross connections with freshwater sources by seepage

Flow formulas for Sewer Design

1. Hazen-William's formula

$$V = 0.85 C r^{0.63} S^{0.54}$$

2. Manning's formula

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$R = \frac{\text{wetted area}}{\text{Wetted Perimeter}}$$

where, V= velocity, m/s;

R= hydraulic radius,

S= slope,

C= Hazen-William's coefficient,

n = Manning's coefficient.

3. Darcy-Weisbach formula

$$hL = \frac{fLV^2}{2gd}$$

Pipe Size and Design Condition

- Sanitary Sewers are designed to run partially full and under gravity

<i>Pipe Size</i>	<i>Design Condition</i>
$D < 0.4m$	$D/2$ or half full at maximum discharge
$D = 0.4 - 0.9m$	$2D/3$ or $2/3$ full at maximum discharge
$D > 0.9m$	$3D/4$ or $3/4$ full at maximum discharge

Design Data

- Sewer should be designed to carry peak discharge i.e. maximum hourly discharge and should be checked to ensure that at minimum discharge i.e. minimum hourly discharge velocity generated should be greater than self cleansing velocity
- Self Cleansing Velocity is the minimum velocity at which no solid gets deposited at the bottom of the sewer
- To avoid erosion of pipe material, maximum velocity should be limited as follows:
 - For concrete sewer, 2.5 - 3 m/sec
 - For Cast iron, 3.5 - 4.5 m/sec

PEAK SEWAGE FLOW

$$Q_{max} = \left(\frac{18 + \sqrt{P}}{4 + \sqrt{P}} \right) q$$

- Where **P** is population in thousand
- **q** is the average sewage flow

Minimum Velocity

- The flow velocity in the sewers should be such that the suspended materials in sewage do not get silted up; i.e. the velocity should be such as to cause automatic self-cleansing effect
- The generation of such a minimum *self cleansing velocity* in the sewer, at least once a day, is important, because if certain deposition takes place and is not removed, it will obstruct free flow, causing further deposition and finally leading to the complete blocking of the sewer.
- For impurities like sand up to 1 mm diameter with specific gravity 2.65 and organic particles up to 5 mm diameter with specific gravity of 1.2, it is necessary that a minimum velocity of about 0.45 m/sec and an average velocity of about 0.9 m/sec should be developed in sewers.
- When finalizing the sizes and gradients of the sewers, Sewers must be checked for the minimum velocity that would be generated at minimum discharge, i.e., about 1/3 of the average discharge

Maximum Velocity

- The smooth interior surface of a sewer pipe gets scoured due to continuous abrasion caused by the suspended solids present in sewage. It is, therefore, necessary to limit the maximum velocity in the sewer pipe.
- This limiting or non-scouring velocity will mainly depend upon the material of the sewer.

Maximum Velocity

Sewer Material	Limiting velocity, m/sec
Vitrified tiles	4.5 – 5.5
Cast iron sewer	3.5 – 4.5
Cement concrete	2.5 – 3.0
Stone ware sewer	3.0 – 4.5
Brick lined sewer	1.5 – 2.5

Partial Flow Characteristics of Circular Sewer

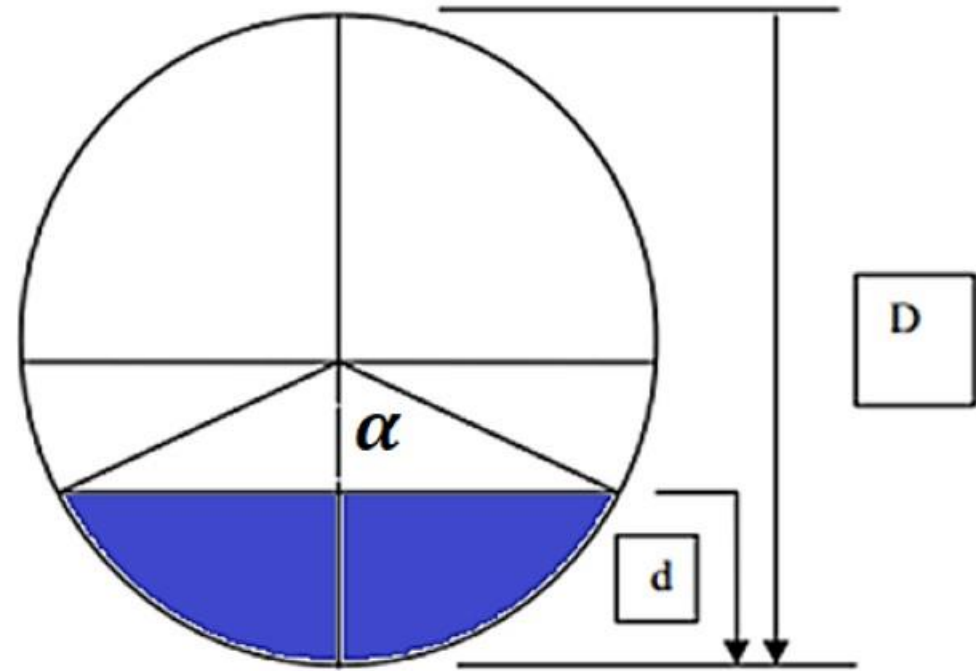
Let

- a = area of flow under partial flow condition
- A = area of flow under full flow condition

$$\frac{d}{D} = \frac{1}{2} \left(1 - \cos \frac{\alpha}{2} \right)$$

$$\frac{a}{A} = \frac{\alpha}{360^\circ} - \frac{\sin \alpha}{2\pi}$$

$$\frac{p}{P} = \frac{\alpha}{360^\circ}$$



d = depth of flow

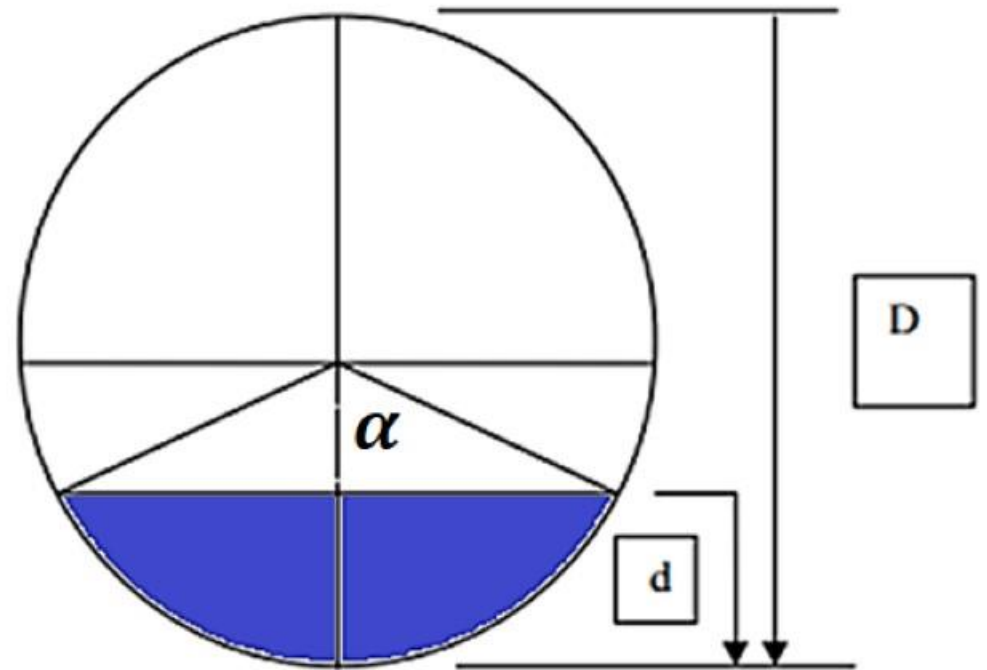
D = diameter of sewer

Partial Flow Characteristics of Circular Sewer

Hydraulic Mean Radius

$$R = \frac{\text{Flow Area}}{\text{Wetted Perimeter}}$$

$$\frac{r}{R} = \frac{(a/p)}{(A/P)} = \frac{(a/A)}{(p/P)}$$



Partial Flow Characteristics of Circular Sewer

Velocity

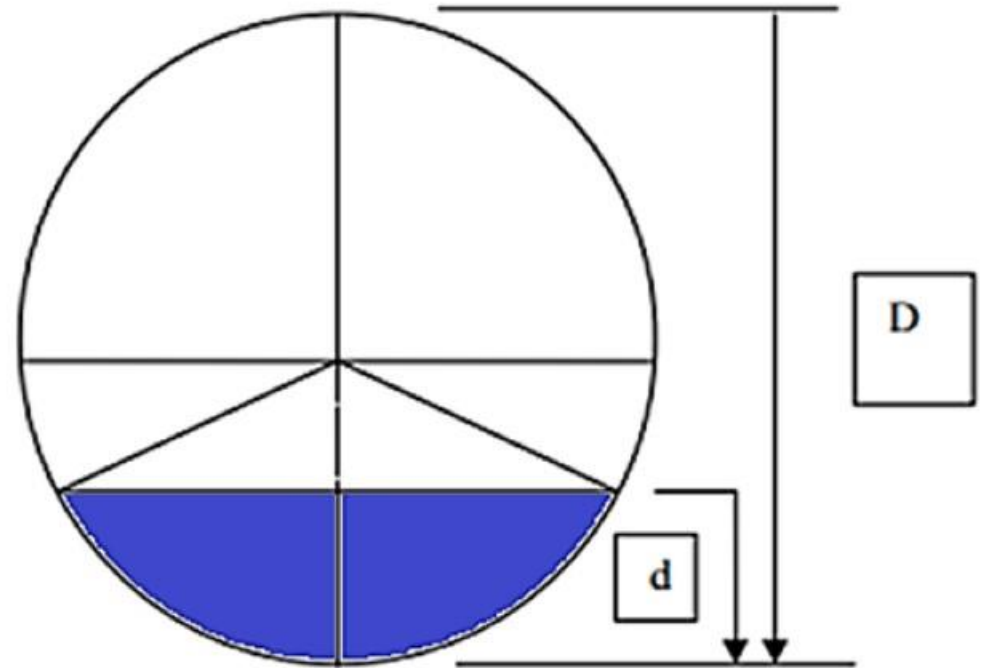
$$\frac{v}{V} = \frac{1/n r^{2/3} s^{1/2}}{1/N R^{2/3} S^{1/2}}$$

If pipe material of both sewers is same,

then $n = N$

If slope is also same, then $s = S$

$$\frac{v}{V} = \frac{r^{2/3}}{R^{2/3}}$$



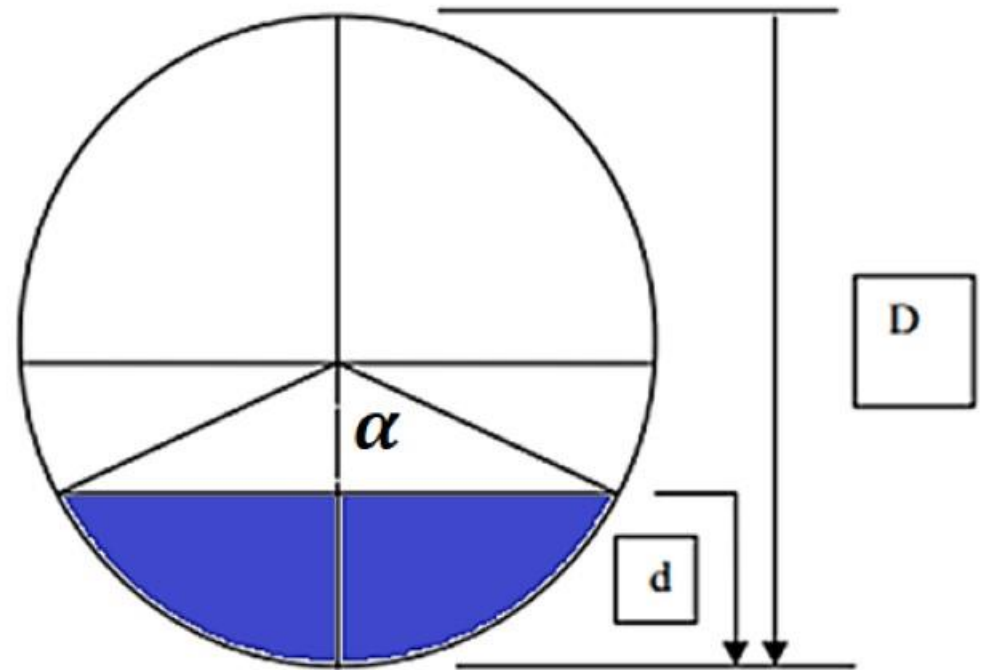
Partial Flow Characteristics of Circular Sewer

- For maximum velocity,

$$\frac{d}{D} = 0.81$$

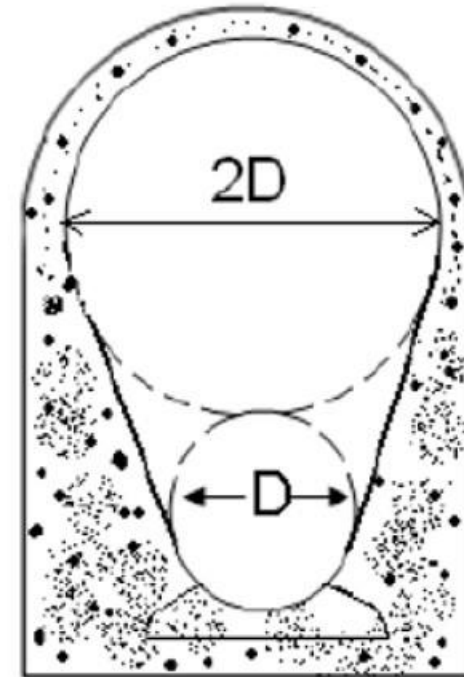
- For maximum discharge

$$\frac{d}{D} = 0.95$$



Egg Shaped Sewers

- Circular Sewers are mostly used for separate Sewerage System
- But the advantage of Circular Sewer is obtained only when the sewer runs at least half full.
- When the depth goes below half depth, the velocity reduces significantly
- If a circular sewer is used for combined system, it will be effective only during maximum rain and during dry weather flow, velocity generated would be very less
- Thus to take advantage of a circular sewer, two such circular sewers are combined to form an egg shaped sewer, in which smaller circular portion will be effective during dry weather and larger circular section is effective during maximum rainfall



LAYING OF SEWERS

Priorities of works shall be followed during execution in sequence as:

- (1) Sewage treatment plants**
- (2) Trunk mains**
- (3) Sewage pumping stations (if required)**
- (4) Main sewers**
- (5) Sub main sewers**
- (6) Sewers (Laterals)**

SEWER CONSTRUCTION

1. Removing pavement
2. Removal of the material from the ground, and its separation, its classification where necessary, and its final disposal
3. Sheet piling and bracing the sides of the trench
4. Removal of water (if any) from the trench
5. Protection of other structures, both underground and on the surface, whose foundations may be affected
6. Backfilling, and
7. Replacement of the pavement.

ESTIMATION OF DESIGN FLOWS

- a) DESIGN PERIOD: The length of time up to which the capacity of a sewer will be adequate is referred to as the design period.

Sl. No	Component	Design Period, Years (from base year)
1	Land Acquisition	30
2	Conventional sewers (A)	30
3	Non-conventional sewers (B)	15
4	Pumping mains	15
5	Pumping Stations-Civil Work	30
6	Pumping Machinery	15
7	Sewage Treatment Plants	15
8	Effluent disposal	30
9	Effluent Utilization	15 or as the case may be

(A) Typical underground sewers with manholes laid in the roads

(B) All types such as small bore, shallow sewers, pressure sewers, vacuum sewers

Central Public Health and Environmental Engineering Organization (CPHEEO)

ESTIMATION OF DESIGN FLOWS

b) POPULATION FORECAST:

- Arithmetic increase method
- Geometrical increase method
- Incremental increase method

SEWER APPURTENANCES

- The structures, which are constructed at suitable intervals along the sewerage system to help its efficient operation and maintenance, are called as sewer appurtenances.
- These include:
 - (1) Manholes
 - (2) Drop manholes
 - (3) Lamp holes
 - (4) Clean-outs
 - (5) Stormwater Inlets
 - (6) Catch basins
 - (7) Inverted Siphons
 - (8) Storm Regulators



SEWER APPURTENANCES

1. MANHOLES:

- The manhole is masonry or R.C.C. chamber constructed at suitable intervals along the sewer lines, for providing access into them.
- It helps in inspection, cleaning and maintenance of sewer.
- These are provided at every bend, junction, change of gradient or change of diameter of the sewer.
- The sewer line between the two manholes is laid straight with even gradient.
- For straight sewer line manholes are provided at regular interval depending upon the diameter of the sewer.
- The spacing of manhole is recommended in IS 1742-1960.

DIAMETER OF PIPE	SPACING
Upto 0.3m	45m
Upto 0.6m	75m
Upto 0.9m	90m
Upto 1.2m	120m
Upto 1.5m	250m
Greater than 1.5m	300m

TYPE OF MANHOLE	DEPTH
Shallow	0.7 – 0.9m
Normal	1.5m
Deep	>1.5m

SEWER APPURTENANCES

2. DROP MANHOLES:

- When a sewer connects with another sewer, where the difference in level between invert level of branch sewer and water line in the main sewer at maximum discharge is greater than 0.6 m, a manhole may be built either with vertical or nearly vertical drop pipe from higher sewer to the lower one.
- The drop manhole is also required in the same sewer line in sloping ground, when drop more than 0.6 m is required to control the gradient and to satisfy the maximum velocity i.e., non-scouring velocity.
- The diameter of the drop pipe should be at least equal to incoming pipe.

SEWER APPURTENANCES

3. LAMP HOLES

- It is an opening or hole constructed in a sewer for purpose of lowering a lamp inside it.
- It consists of stoneware or concrete pipe, which is connected to sewer line through a T-junction.
- The pipe is covered with concrete to make it stable.
- An electric lamp is inserted in the lamp hole and the light of lamp is observed from manholes.
- If the sewer length is unobstructed, the light of lamp will be seen.
- It is constructed when construction of manhole is difficult.
- This lamp hole can also be used for flushing the sewers.
- If the top cover is perforated it will also help in ventilating the sewer, such lamp hole is known as fresh air inlet.

SEWER APPURTENANCES

4. CLEAN OUTS:

- It is a pipe which is connected to the underground sewer.
- A clean-out is generally provided at the upper end of lateral sewers in place of manholes.
- During blockage of pipe, the cover is taken out and water is forced through the clean-out pipe to lateral sewers to remove obstacles in the sewer line.
- For large obstacles, flexible rod may be inserted through the clean-out pipe and moved forward and backward to remove such obstacle.



SEWER APPURTENANCES

5. STORMWATER INLETS:

- Storm water inlets are provided to admit the surface runoff to the sewers.
- These are classified in three major groups as curb inlets, gutter inlets, and combined inlets.
- They are provided either depressed or flush with respect to the elevation of the pavement surface.
- The clear opening shall not be more than 25 mm.
- The connecting pipe from the street inlet to the sewer should be minimum of 200 mm diameter and laid with sufficient slope.
- A maximum spacing of 30 m is recommended between the inlets, which depends upon the road surface, size and type of inlet and rainfall.



SEWER APPURTENANCES

6. CATCH BASIN

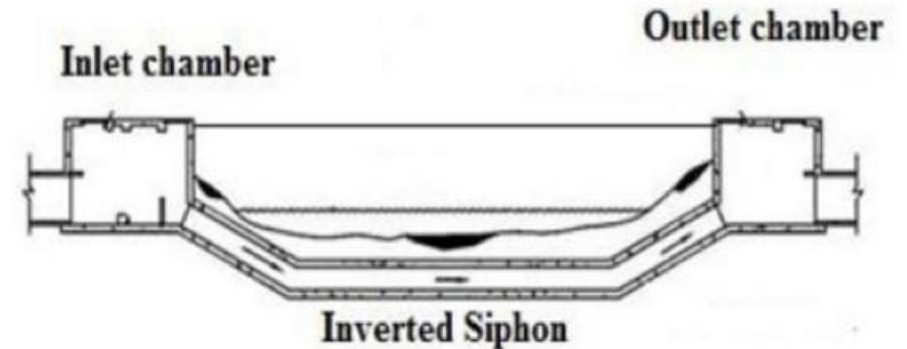
- Catch basins are provided to stop the entry of heavy debris present in the storm water into the sewers.
- However, their use is discouraged because of the nuisance due to mosquito breeding apart from posing substantial maintenance problems.
- It allows the storm water to enter the sewer by eliminating silt, grit etc. at the bottom of the basin.



SEWER APPURTENANCES

7. INVERTED SIPHON

- An inverted siphon or depressed sewer is a sewer that runs full under gravity flow at a pressure above atmosphere in the sewer.
- Inverted siphons are used to pass under obstacles such as buried pipes, subways, etc



8. REGULATORS

- These are used for preventing overloading of sewers, pumping stations, treatment plants or disposal arrangement, by diverting the excess flow to relief sewer.

FUNCTIONS AND TYPES OF TRAPS BEING USED IN SANITARY PLUMBING SYSTEM

- **Traps**: These may be defined as fittings, placed at the ends of the *soil pipes* or the *sullage pipes* (*waste pipes*) to prevent the passage of foul gases from the pipes to the outside. This is possible because traps do enclose or maintain water seal between the pipe and the outside
- **Soil pipes**: These are the pipes which carry the night soil, and
- **Sullage pipes** are the pipes which carry the sullage from bathrooms and kitchens

TYPES OF TRAPS

- Depending upon their shapes.

i. P –traps ii) Q–traps iii) S–traps.

- Depending upon their use.

1. **Floor traps or Nahani trap:** A floor trap or Nahani trap is provided at the head of each house drain.
2. **Gully trap:** A gully trap is provided at the junction of an unfoul roof or room drain and a foul bath or a kitchen drain.
3. **Intercepting trap:** An intercepting trap is provided at the junction of a house sewer and a municipal sewer.

Corrosion of Concrete Sewers

- **Hydrogen Sulphide is produced in Sewer lines and it gets oxidized to Sulphuric acid H_2SO_4 which reacts with the constituents of Cement which forms $CaSO_4$ to occupy greater volume than the compounds they replace. This leads to increase to expansion and disruption of concrete sewers.**

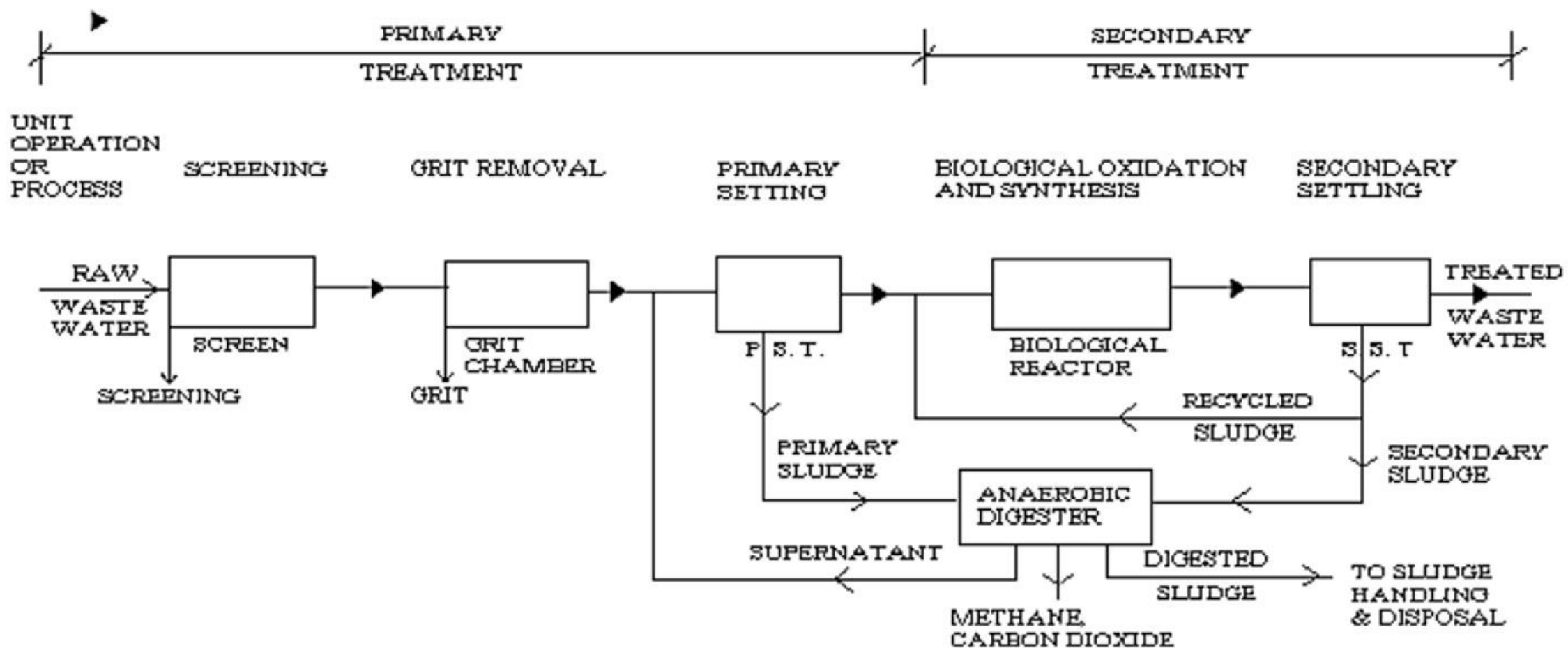
Chapter - Sewage Treatment

UNIT OPERATIONS AND UNIT PROCESSES

- **Unit Operations** are the application of Physical forces. In this, no other external forces are required.
 - Example: Screening, aeration, sedimentation, etc.
- **Unit processes** are the types of treatment in which removal of contaminants is brought about by the addition of chemicals or by microbial activities.

Based on the type of agent used, biological unit process are

 1. **Suspended Growth Process** (activated sludge process, oxidation pond, aerated lagoon, etc)
 2. **Attached Growth Process** (trickling filters, rotating biological contractors, biofilters, etc)



Sewage Treatment Process

- The sewage treatment process comprises of several steps. With each step serving a definite purpose.

1. Preliminary Treatment:

- It is also called as One Degree treatment when used along with primary sedimentation tank .
- It removes floating materials and large inorganic particles of waste water
- It comprises of screens (screen chamber), grit chamber, skimming tank and oil and grease traps

Sewage Treatment Process

2. Primary Treatment:

- It includes all the treatment units of preliminary system and Primary Sedimentation tank.

Note: Primary Sedimentation Tank is also called as Primary Clarifier.

- Purpose of Primary Treatment is to remove suspended solid materials from incoming waste water.
- It does not remove the colloidal and dissolved organic content of waste water.
- Large Debris are removed by Screens.
- **Inorganic solids** are removed in **Grit chambers**
- **Organic solids** are removed in **Sedimentation tank**

Sewage Treatment Process

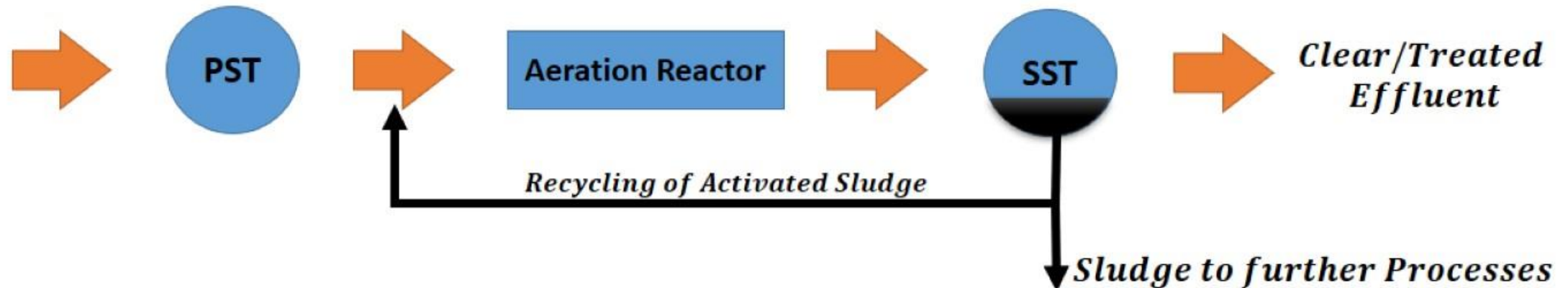
2. Primary Treatment:

- Disposal of inorganic Matter is convenient because it does not decompose but disposal of organic material is difficult because if it is disposed untreated, it will create nuisance
- Hence it is desired that inorganic and organic matters are removed in two separate units
- Primary Sedimentation Tank removes 60-70% of suspended organic matter.

Sewage Treatment Process

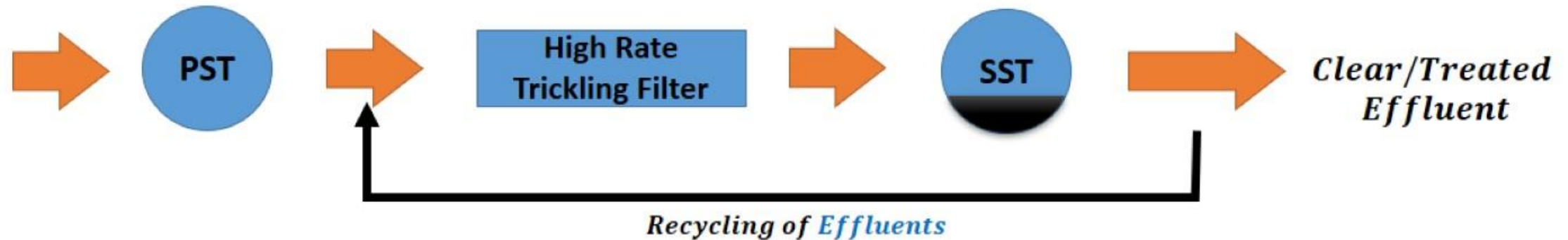
3. Secondary Treatment System or Two Degree Treatment System:

- After primary treatment, its waste water is further treated for the removal of Colloidal and Soluble organic matter present in waste water. This is called as **Secondary Treatment System**.
- It consists of biological conversion of organics into **biomass (bacteria)** that can be subsequently removed by sedimentation in Secondary Sedimentation Tank.
- Contact between microorganisms and the organic matter is optimised by suspending the biomass or by passing waste water over a film of biomass attached to solid surfaces
- The most common biomass system is the **Activated Sludge Process**



Sewage Treatment Process

- A part of settled Sludge in Secondary Clarifier/ SST is recycled back to aerator
- Recirculating a portion of biomass maintains a large number of organism in contact with the waste water and speeds up the conversion process
- The most common attached biomass system is the **Trickling Filter**



Sewage Treatment Process

- Stones or other media are used to increase the surface area for biological growth
- The old films of bacteria peel off the surface and are washed out.
- This effluent is rich in bacteria and a part of this effluent can be used as an additional bacterial source to maintain optimum amount of bacteria
- When effluent is recycled, trickling filter is called as High Rate Trickling filter
- Secondary System Produces excess biomass that is biodegradable by microorganisms
- Secondary sludge are usually combined with primary sludge and further treated aerobically or anaerobically
- When treated anaerobically, gaseous end products are formed (exp CH_4 , CO_2 , H_2S and inert gases)
- The methane has significant heating value and may be used to meet a part of the power requirement

Sewage Treatment Process

4. Tertiary Treatment System:

- Tertiary Treatment involves further clarification and disinfection
- In India tertiary treatment is generally not done except in case of epidemics some other emergency conditions

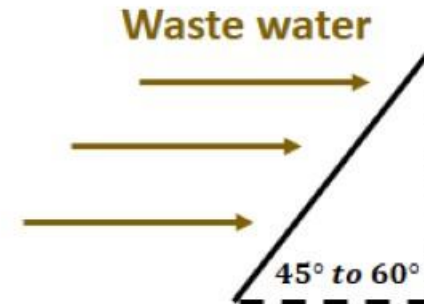
Primary Treatment System

1. Screening:

- It is the first Operation performed for the incoming waste water. Screens are classified as Coarse Screen Medium and Fine Screen

Screen	Clear Spacing
Coarse	45° to 60° > 50 mm
Medium	20-50 mm
Fine	< 20 mm

- Bars are 10 mm thick and screens are placed at an inclination of 45° to 60°



Primary Treatment System

2. Grit Chamber:

- They are located before pumps to prevent clogging, damage to the pumps.
- Removal of grit reduces the frequency of cleaning of other units
- They are provided in the form of channels of long length and smaller cross sectional area.
- They do not allow settlement of organic matter or if it has settled, the velocity should be sufficient to scour away the settled organic matter
- In grit chamber, velocity control devices are provided

Primary Treatment System

2. Grit Chamber:

Design of Grit Chamber:

- Grit chamber removes particles of size greater than or equal to 0.2 mm
- Specific gravity will be taken as 2.65
- Surface overflow rate is taken as $2160 \text{ m}^3/\text{m}^2/\text{day}$
- Stokes's law can not be applied in grit chamber because particle size is greater than 0.2 mm
- Horizontal velocity of flow is 0.15 to 0.3 m/sec
- Detention time is 40 to 60 sec
- Depth is 1 to 1.5m
- Free board is 0.3 m
- Length of channel is generally increased by 20% for inlet and outlet turbulence

Primary Treatment System

2. Grit Chamber:

Design of Grit Chamber:

- The settling velocity is determined by using appropriate equation depending upon the Reynold's number

$$R_e = \left(\frac{\rho V}{\mu} \right) x \quad ; \quad \text{where } x = \text{characteristic dimension of channel}$$

For this, transition flow holds good when Reynold's number lies between 1 to 1000

- So in this range, coefficient of discharge can be applied as $C_d = \frac{18.5}{R_e^{0.6}}$
- Settling Velocity $v_s^2 = \frac{4}{3} \frac{(\gamma_s - \gamma_w)d}{C_d \rho_w}$
- Reynold's number is defined as $R_e = \frac{v_s d}{\nu}$ where $d = \text{diameter of particle}$

Primary Treatment System

NOTE:

Detritus Tank:

It is similar to grit chamber, the only difference is that Detritus Tank is meant for removing more finer particles as compared to Grit Chamber

Primary Treatment System

3. Skimming Tanks

- These are used for removal of Oils and Grease, soaps, etc
- Skimming Tanks are provide before sedimentation tanks
- If oil, grease and soaps are not removed, the it forms scum on the surface and interfere with the activated sludge process by hindering the passage of O_2 and also inhibits biological growth on trickling filter
- In these tanks, compressed air is blown from below, the rising air coagulates the grease and causes it to rise to the surface from where it can be skimmed off.
- Skimming tanks are not suitable in India as Grease do not coagulate at higher temperature, so we try to remove oil and grease by using oil and grease trap before they enter the municipal sewer

Primary Treatment System

3. Sedimentation Tanks

- In primary sedimentation, organic suspended solids are settled.
- They have specific gravity normally 1.2
- Types of settling
 - Basically 4 types of settling occurs depending on the tendency of particles to interact and the concentration of solids.
 - They are –
 1. Discrete settling
 2. Flocculent settling
 3. Hindered or zone settling
 4. Compression settling

Primary Treatment System

TYPES OF SETTLING

1. DISCRETE SETTLING –

- This occurs when particles do not change their size, shape or mass during settling.
- Grit, in waste water behaves like discrete particle.
- Settling velocity of discrete particle is determinable using Stokes or Transition Law.
- Organic solids in raw water and bioflocs in biologically treated waters cannot be considered as discrete particles and hence Stokes Law is not applicable to these particles.

Primary Treatment System

TYPES OF SETTLING

2. FLOCCULENT SETTLING –

- Flocculent particles coalesce during settling increasing the mass of particles which settle faster.
- Flocculent setting refers to settling of flocculent particles of low concentration usually less than 1000mg/l .
- The degree of flocculation depends on the contact opportunities which in turn is affected by the surface overflow rate, the depth of basin, the concentration of particle, the range particle size and the velocity gradient of the system.
- No adequate mathematical equations exist to describe the flocculent settling and therefore overflow rates to achieve a given removal efficiency are determined using data obtained from sedimentation analysis.
- Example of flocculent setting - Removal of raw sewage organic suspended solids in PST, settling of chemical flocs in settling tank and bioflocs in the upper portion of SST

Primary Treatment System

TYPES OF SETTLING

3. HINDERED OR ZONE SETTLING –

- When concentration of flocculated particles is in the intermediate range, they are close enough together so that their velocity fields overlap causing hindered settling.
- The settling of particles resulting in significant upward displacement of water.
- Particles maintain their relative positions with respect to each other and the whole mass of particles settles as a unit.
- This type of settling is applicable to concentrated suspension found in SST following ASP (Activated Sludge Process).
- In hindered settling zone, the concentration of particles increases from top to bottom leading to thickening of sludge.
- Such secondary clarifier where zone settling occurs are designed on the basis of solid loading rate and checked for surface over flow rate.

Primary Treatment System

TYPES OF SETTLING

4. COMPRESSION SETTLING –

- In compression zone, the concentration of particles becomes so high that particles are in physical contact with each other, the lower layers supporting the weight of upper layers.
- Consequently any further settling results due to compression of the whole structure of particles and is accompanied by squeezing out of water from the pores between the solid particles.
- This settling phenomenon occurs at the bottom of deep sludge mass such as in the bottom of SST following TF, ASP and in tanks used for thickening of sludge.
- In PST, over flow rate and detention time are important

Primary Treatment System

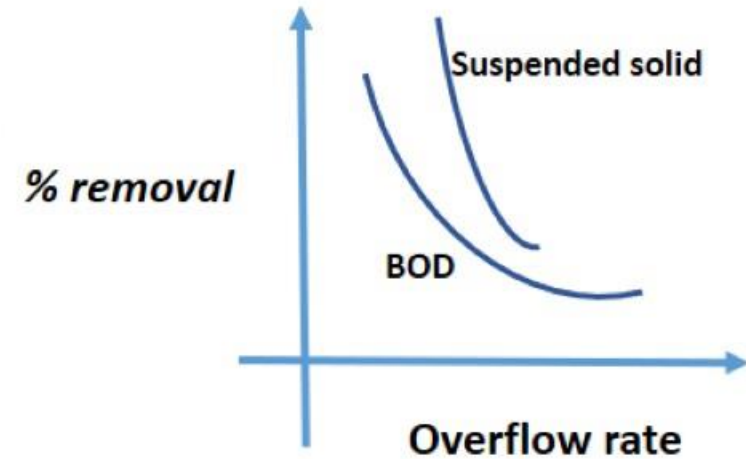
- Horizontal flow velocity = 0.3m/min
- Width = 6m
- Length = 4 – 5 times width

S.No.	PST	OVERFLOW RATE (AVG) $m^3/m^2/day$	OVERFLOW RATE (PEAK) $m^3/m^2/day$	DEPTH (METRE)	DETENTION TIME (HOUR)
1.	1° settling only	25-30	50-60	2.5-3.5	2-2.5
2.	1° settling followed by secondary treatment	35-50	80-120	2.5-3.5	2-2.5
3.	1° settling with ASP	25-35	50-60	3.5-4.5	2-2.5

Primary Treatment System

Primary Sedimentation Tank

- **Overflow rate can also be found out from % removal efficiency. From the above table, the surface area is calculated for both average and peak flow and larger value is adopted.**



$$\text{surface area for average flow} = \frac{\text{average discharge}}{\text{average overflow rate}}$$

$$\text{surface area for peak flow} = \frac{\text{peak discharge}}{\text{peak overflow rate}}$$

Primary Treatment System

SEDIMENTATION WITH COAGULATION

- It is not used generally in sewage treatment because –
 1. Chemical added in this process destroys certain bacteria which are useful for sludge digestion.
 2. It is costly.
 3. Large sludge volume produced in this process is difficult to be dispose off.
- It may however be provided in hilly areas because space requirement for coagulation and sedimentation is lesser.
- Coagulation process removes phosphate from sewage which help in controlling eutrophication of lakes.

SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

- Secondary treatment is generally carried out **aerobically**.
- It leads to stable end product.
- No foul gases are evolved in the process and rate of reaction is faster (almost 3 times faster than the anaerobic process in domestic sewage)
- Units based on **aerobic** treatment are –
 1. Trickling filter
 2. Activated sludge process
 3. Oxidation pond
- Units based on **anaerobic** treatment are –
 1. Septic tank
 2. Imhoff tank
 3. UASB reactor

SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

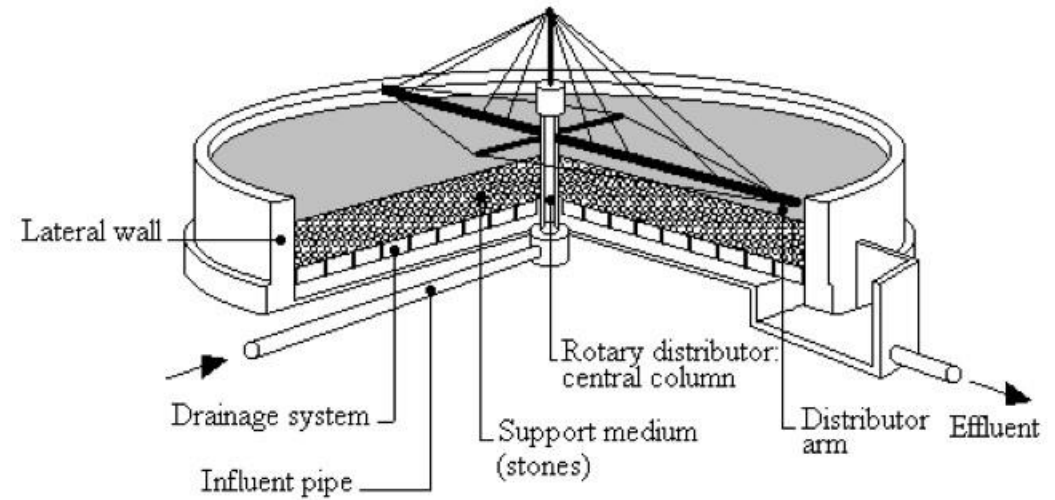
ATTACHED GROWTH SYSTEM & SUSPENDED GROWTH SYSTEM

- In attached growth system, biomass is attached to a medium and sewage containing organic matter is passed through the medium.
- In suspended growth system, biomass is in suspension in the liquid containing organic matter.

SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

1. STANDARD RATE TRICKLING FILTER

- Trickling filter is the most common biological process for small and medium works in temperate climates.
- Filters are constructed as beds of stone or gravel onto the surface of which settled sewage is sprinkled (so attached Growth System).
- Air for the oxidation process enters the bed through vents at the base.
- The filter usually consist of a 2m deep circular bed of random packed angular stone about 50mm in size and supported on a tile floor which allows the treated liquid to escape freely and ventilate air to enter the bed.



SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

1. STANDARD RATE TRICKLING FILTER

- Circular beds permit the use of reaction jet distributors in which the discharge under a head of 0.5 to 0.8m is sufficient to cause the arms to rotate.
- This provides an effective and inexpensive way of distributing the feed over a large area
- Sewage trickles through the interstices and the natural bacteria and other microorganisms like protozoa and fungi become attached to the surface of media
- The attached film is able to obtain food from the liquid and also obtain oxygen which flows up through the bed
- The attached biomass is called as Biological Film or the *slime layer*

SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

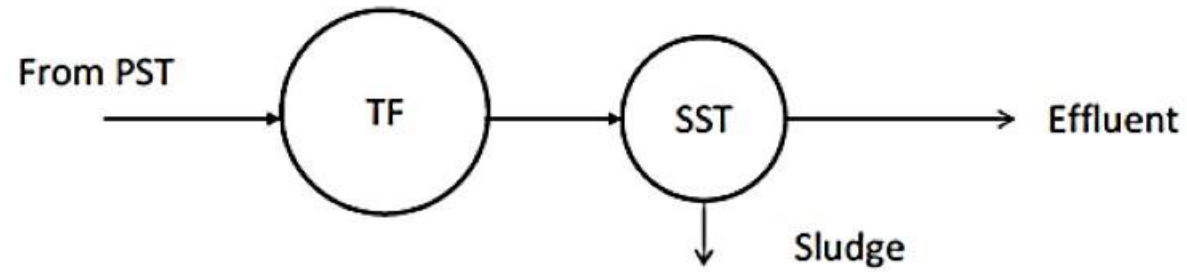
1. STANDARD RATE TRICKLING FILTER

- In standard rate trickling filter, screening and primary sedimentation is must before sewage is applied through the trickling filter
- **Facultative** bacteria are predominant organism in Trickling Filter

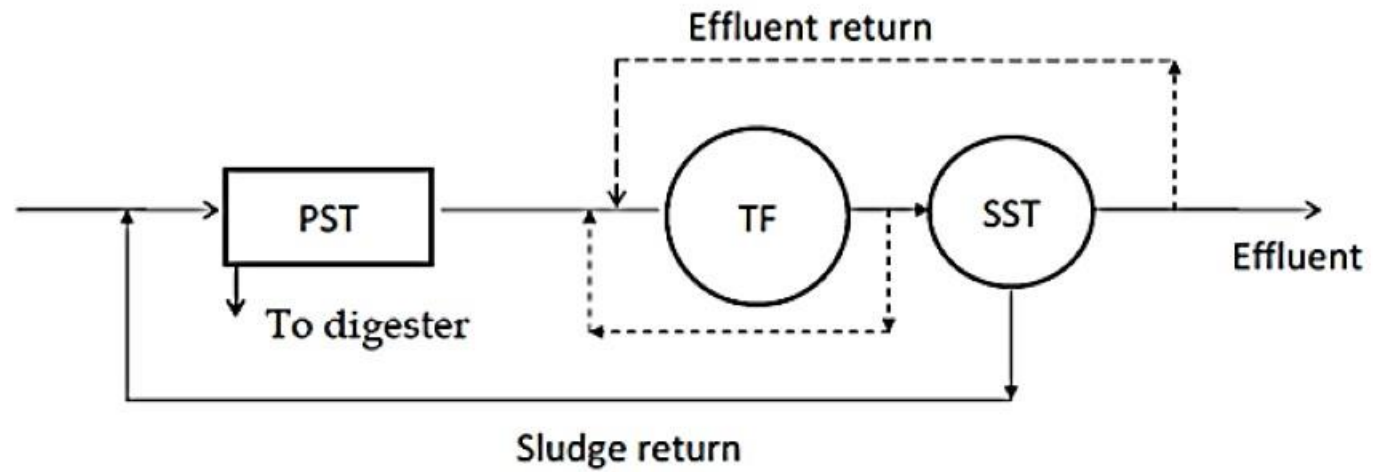
SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

1. HIGH RATE TRICKLING FILTER

- All other things are same as standard rate filters except that recirculation is done by pumping the effluent of trickling filter to influent of trickling filter or to the primary sedimentation tank
- High Hydraulic loading reduces filter clogging
- Recirculation permits higher organic loading



(a)



(b)

(a) Low rate trickling filter and (b) High rate trickling filter

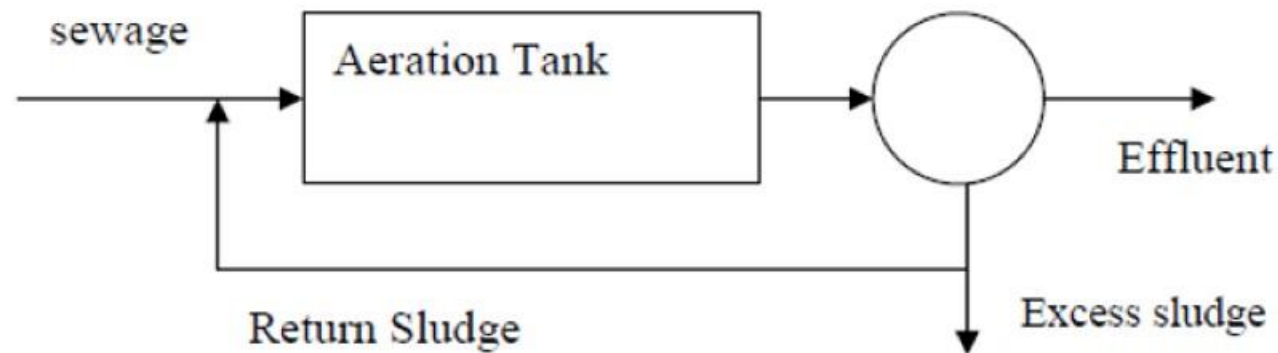
DESIGN CRITERIA FOR TRICKLING FILTERS

	Standard	High Rate	Super High Rate
Hydraulic Loading ($m^3/m^2/day$)	1-4	10-40 (including recirculation)	40-200 (including recirculation)
Organic Loading (in kg BOD5 / m^3/day)	0.08-0.32	0.32-1.0 (excluding recirculation)	0.6-0.8 (excluding recirculation)
Depth (m)	1.8-3.0	0.9-2.5m	4.5-12m
Recirculation Ratio (discharge from PST/Recycled Discharge)	0	0.5-3.0	1-4

SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

2. ACTIVATED SLUDGE PROCESS (SUSPENDED GROWTH SYSTEM)

- It is an aerobic suspended growth type biological process that uses the active microorganisms kept in suspension in the reactor to decompose and stabilize the soluble and particulate (colloidal and suspended) organic matter present in wastewater.



Some Terms

1. **Loading Rate:**

- The organic matter loading rate applied to the reactor is quantified as kg of BOD applied per unit volume of the reactor per day, called as volumetric loading rate, or
- Kg of BOD applied per day per unit mass of microorganisms present in the reactor (i.e. in the aeration tank), called as organic loading rate

Some Terms

2. **Solid Retention Time (SRT) or Mean Cell Residence Time (MCRT):**

- ASP in terms of organic matter removal depends on the duration for which the microbial mass is retained in the system.
- The retention of the sludge depends on the settling rate of the sludge in the SST.
- If sludge settles well in the SST proper recirculation of the sludge in aeration tank is possible, this will help in maintaining desired SRT in the system. Otherwise, if the sludge has poor settling properties, it will not settle in the SST and recirculation of the sludge will be difficult and this may reduce the SRT in the system.

Some Terms

3. Sludge Volume Index:

- The quantity of the return sludge is determined on volumetric basis.
- The sludge volume index (SVI) is the volume of the sludge in mL for one gram of dry weight of suspended solids (SS), measured after 30 minutes of settling.
- The SVI varies from 50 to 150 mL/ g of SS.
- Lower SVI indicates better settling of sludge.

Some Terms

4. Quantity of Return Sludge:

- Usually solid concentration of about 1500 to 3000 mg/L (MLVSS 80% of MLSS) is maintained for conventional ASP and 3000 to 6000 mg/L for completely mixed ASP.
- Accordingly the quantity of return sludge is determined to maintain this concentration.
- The sludge return ratio is usually 20 to 50%.
- The F/M ratio (mass of BOD applied per day/ mass of biomass) is kept as 0.2 to 0.4 for conventional ASP and 0.2 to 0.6 for completely mixed ASP.

MLSS (mixed liquor suspended solids) represents both living and dead bacteria.

MLVSS (mixed liquor volatile suspended solids) represents living bacteria only. MLVSS = 80% MLSS

Some Terms

5. **Mixing Conditions:**

- The aeration tank can be of plug flow type or completely mixed type.
- In the plug flow tank, the F/M and oxygen demand will be highest at the inlet end of the aeration tank and it will then progressively decrease.
- In the completely mix system, the F/M and oxygen demand will be uniform throughout the tank.

Some Terms

6. Sludge Bulking:

- The sludge which does not settle well in sedimentation tank is called as bulking sludge.
- It may be due to either (a) the growth of filamentous microorganisms which do not allow desirable compaction; or (b) due to the production of non-filamentous highly hydrated biomass.

7. Flow Scheme:

- Sewage addition may be done at a single point at the inlet end of the tank or it may be at several points along the aeration tank.

SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

2. ACTIVATED SLUDGE PROCESS (SUSPENDED GROWTH SYSTEM)

1. Conventional aeration

In conventional ASP the flow model in aeration tank is plug flow type. Both the influent wastewater and recycled sludge enter at the head of the tank and are aerated for about 4 to 8 hours for sewage treatment.

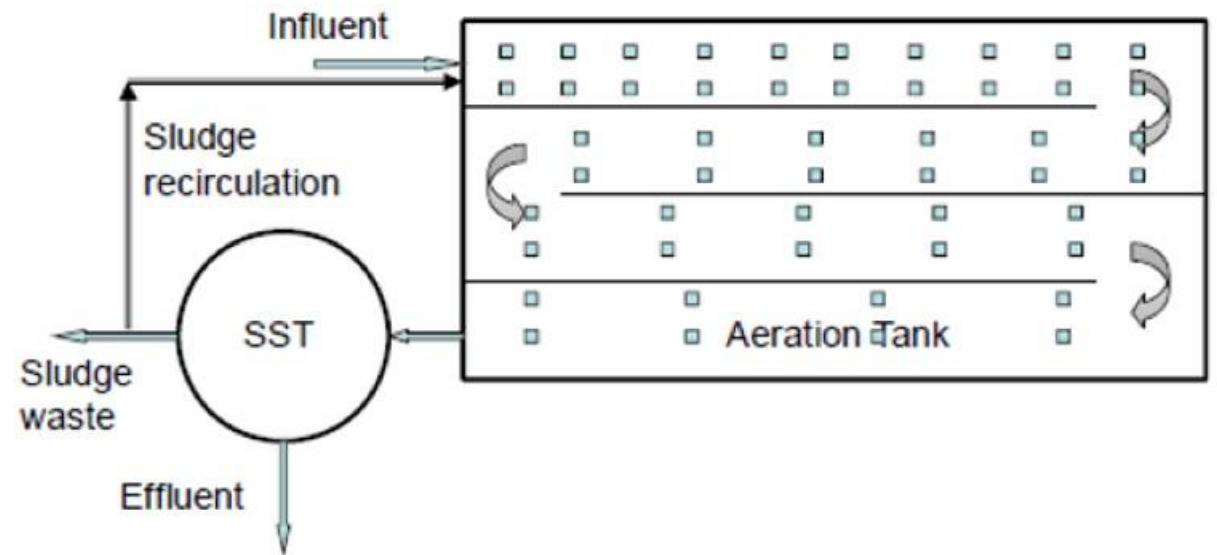
Rate of aeration is constant throughout the length of the tank. During the aeration period the adsorption, flocculation and oxidation of organic matter takes place.

SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

2. ACTIVATED SLUDGE PROCESS (SUSPENDED GROWTH SYSTEM)

2. Tapered Aeration

- In plug flow type aeration tank BOD load is maximum at the inlet and it reduces as wastewater moves towards the effluent end.
- Hence, accordingly in tapered aeration maximum air is applied at the beginning and it is reduced in steps towards end, hence it is called as tapered aeration.
- By tapered aeration the efficiency of the aeration unit will be increased and it will also result in overall economy.

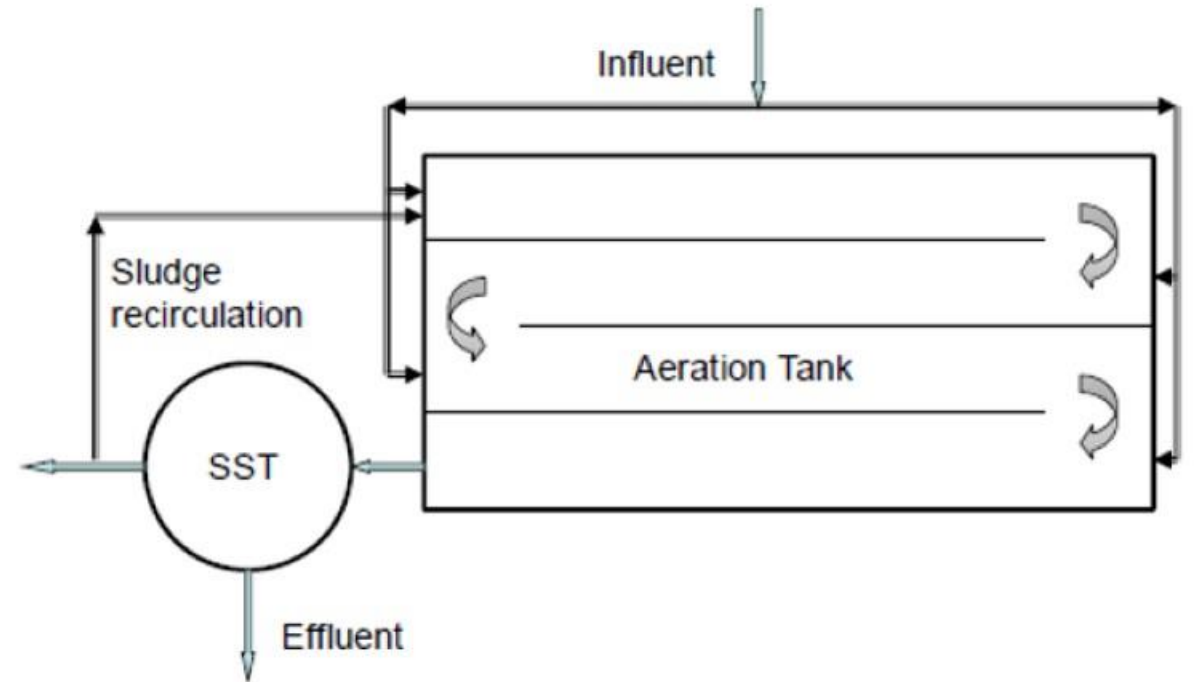


SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

2. ACTIVATED SLUDGE PROCESS (SUSPENDED GROWTH SYSTEM)

3. Step Aeration

- If the sewage is added at more than one point along the aeration channel, the process is called as step aeration.
- This will reduce the load on returned sludge. The aeration is uniform throughout the tank.

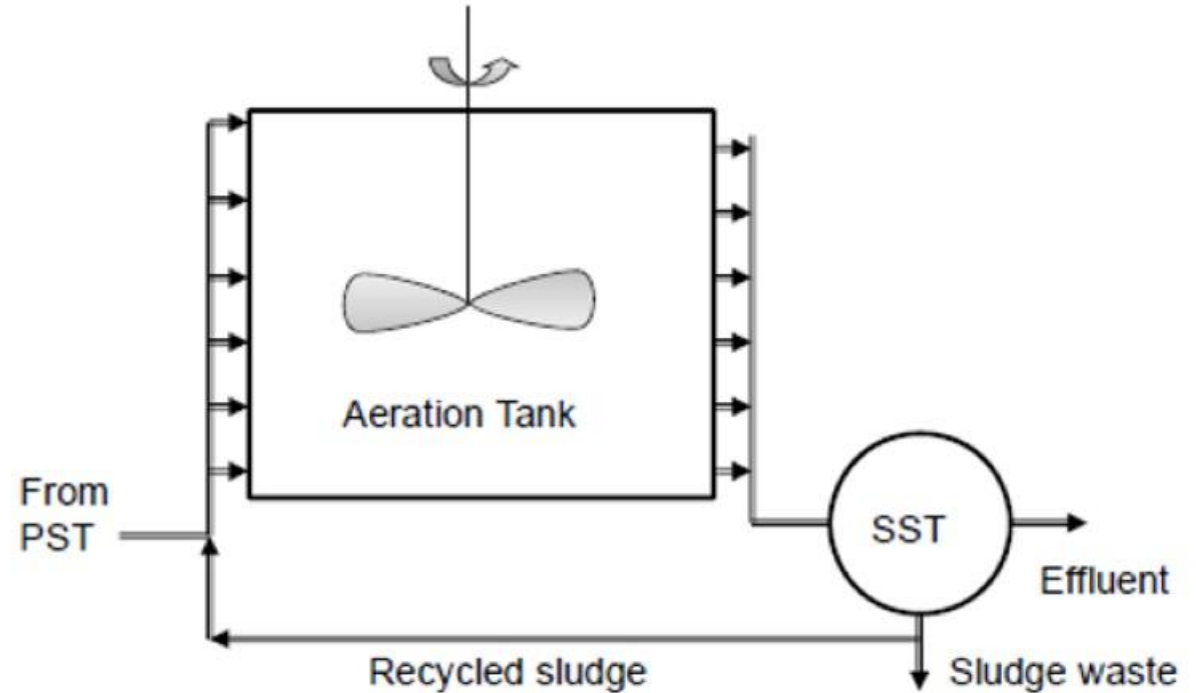


SECONDARY TREATMENT (BIOLOGICAL TREATMENT)

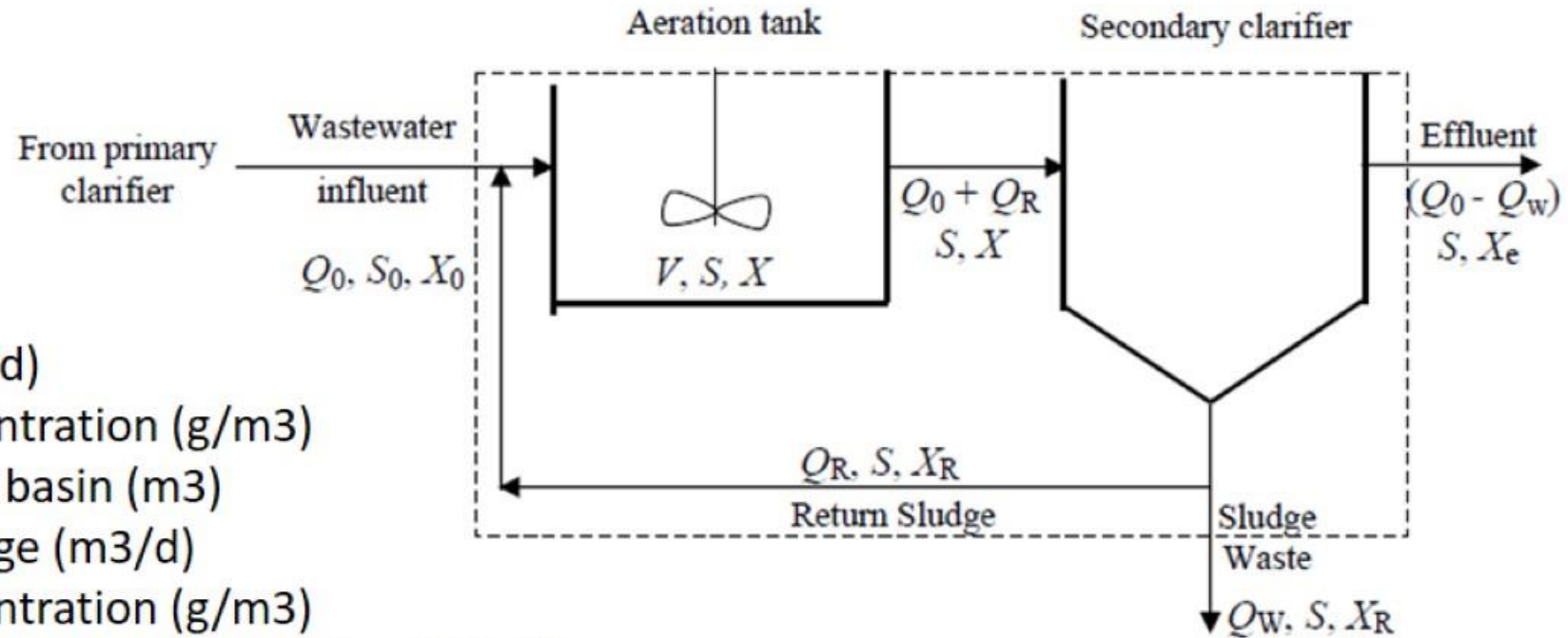
2. ACTIVATED SLUDGE PROCESS (SUSPENDED GROWTH SYSTEM)

4. Completely Mixed Type

In this type of aeration tank completely mixed flow regime is used. The wastewater is distributed along with return sludge uniformly from one side of the tank and effluent is collected at other end of the tank. This type of ASP has better capability to handle fluctuations in organic matter concentration



Process Analysis of Completely Mixed Reactor with Sludge Recycle



- Q_0 = Influent flow rate (m³/d)
- X_0 = Influent biomass concentration (g/m³)
- V = Volume of the aeration basin (m³)
- Q_w = Flow rate of waste sludge (m³/d)
- X_e = Effluent biomass concentration (g/m³)
- X_r = Biomass concentration in the return sludge (g/m³)
- S = Soluble food applied

Process Analysis of Completely Mixed Reactor with Sludge Recycle

1. Hydraulic retention time (HRT)

$$T = \frac{V}{Q_0}$$

Q_0 = Influent flow rate (m³/d)
 V = Volume of the aeration basin (m³)

- Usually kept between 5 to 8 hours while treating sewage.

Process Analysis of Completely Mixed Reactor with Sludge Recycle

2. Mean Cell residence time (MCRT) or Sludge age (θ_c)

- The mean cell residence time (MCRT) of microorganisms in the system is the length of time the microorganisms stay in the process.
- This is also called the solids retention time (SRT) or the sludge age. This is expressed as

$$\theta_c = \frac{\textit{Total Biomass in the aeration basin}}{\textit{Biomass wasted per unit time}}$$

$$\theta_c = \frac{VX}{Q_w X_R + (Q_0 - Q_w) X_e}$$

- If effluent biomass concentration is very low, i.e. $X_e = 0$

$$\theta_c = \frac{VX}{Q_w X_R}$$

Process Analysis of Completely Mixed Reactor with Sludge Recycle

3. Food To Microorganism Ratio

- A balance between substrate consumption and biomass generation helps in achieving system equilibrium.

$$F/M = \frac{[\text{BOD of wastewater (g/m}^3\text{)}] [\text{Influent flow rate (m}^3\text{/d)}]}{[\text{Reactor volume (m}^3\text{)}] [\text{Reactor biomass (g/m}^3\text{)}]} \quad F/M = \frac{S_0 Q_0}{VX}$$

- The *F/M ratio is responsible for the decomposition of organic matter.*
- The type of activated sludge system can be defined by its *F/M ratio* as below:
 1. Extended aeration, $0.05 < F/M < 0.15$
 2. Conventional activated sludge system, $0.2 < F/M < 0.4$
 3. Completely mixed, $0.2 < F/M < 0.6$
 4. High rate, $0.4 < F/M < 1.5$

Process Analysis of Completely Mixed Reactor with Sludge Recycle

4. Sludge Recycling

- The MLSS concentration in the aeration tank is controlled by the sludge recirculation rate and the sludge settle ability and thickening in the secondary clarifier.
- The recirculation ratio is estimated as stated below considering the mass of microorganisms entering aeration tank and leaving the aeration tank:

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

MLSS (mixed liquor suspended solids) represents both living and dead bacteria.

Que. A completely mixed activated sludge process is used to treat a waste water flow of 1 MLD having BOD_5 of 200 mg/L. The biomass concentration in the aeration tank is 2000 mg/L and the concentration of net biomass leaving the system is 50 mg/L. Volume of aeration tank is $200 m^3$. Flow rate of waste sludge $Q_w = 0$. Find

- a) HRT (Hydraulic Retention Time)**
- b) What is average time for which biomass stays in the system?**

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a) HRT (Hydraulic Retention Time)

b) What is average time for which biomass stays in the system?

$$\begin{aligned} \text{HRT} &= \frac{V}{Q_0} = \frac{200 m^3}{1 \times 10^6 \times 10^{-3} m^3} \text{ day} \\ &= \frac{200}{1000} \text{ days} \approx 0.2 \text{ days} \approx 4.8 \text{ hours} \end{aligned}$$

Que. A completely mixed activated sludge process is used to treat a waste water flow of 1 MLD having BOD_5 of 200 mg/L. The biomass concentration in the aeration tank is 2000 mg/L and the concentration of net biomass leaving the system is 50 mg/L. Volume of aeration tank is $200 m^3$. Flow rate of waste sludge $Q_w = 0$. Find

a) HRT (Hydraulic Retention Time)

b) What is average time for which biomass stays in the system?

$$Q_c = \frac{VX}{Q_w X_r + (Q_0 - Q_w) X_e}$$

$$= \frac{VX}{Q_0 X_e} \Rightarrow \frac{200 \times 2000 \times 10^{-3} \times 10^{-3}}{10^6 \times 10^{-3} \times 50 \times 10^{-6}} = \underline{\underline{8 \text{ days}}}$$

Secondary Sedimentation Tank

- The Secondary Sedimentation Tank is also called as Secondary Clarifier or Secondary Settling Tank
- Objectives of SST are :
 1. To produce a sufficiently clear effluent
 2. It must concentrate the biological solids to minimise the quantity of sludge that must be handled

It is designed on the basis of

- a) Solids loading rate
- b) Overflow Rate

Secondary Sedimentation Tank

- In SST, hindered or Zone Settling occurs and velocity fields overlap in the upper portion of the tank
- In the lower portion of the tank where the solids get deposited, compression settling occurs

SLUDGE THICKNER:

To reduce the volume to be handled in sludge digester, sludge thickener is provided

Sludge thickening is done by

- a) Gravity
- b) Centrifugation
- c) Seeding

Secondary Sedimentation Tank

SLUDGE BULKING:

- Sludge with poor Settling characteristics is termed as BULKING OF SLUDGE
- It results in poor effluent due to the presence of excess decomposed organic matter
- It occurs due to
 - Inadequate air supply
 - Low pH which results in killing of bacteria
- It can be reduced by
 - Chlorination of returned activated sludge
 - Addition of Nutrients

SLUDGE DIGESTION

- **AEROBIC DIGESTION –**

- It is adopted for sludge of secondary sedimentation tank only.
- In aerobic digestion, endogenous respiration starts because of the availability of oxygen and scarcity of food.
- It requires external energy since oxygen is supplied externally.
- It has more operational cost and lesser **capital** cost as compared to anaerobic digestion.

SLUDGE DIGESTION

- **ANAEROBIC DIGESTION**

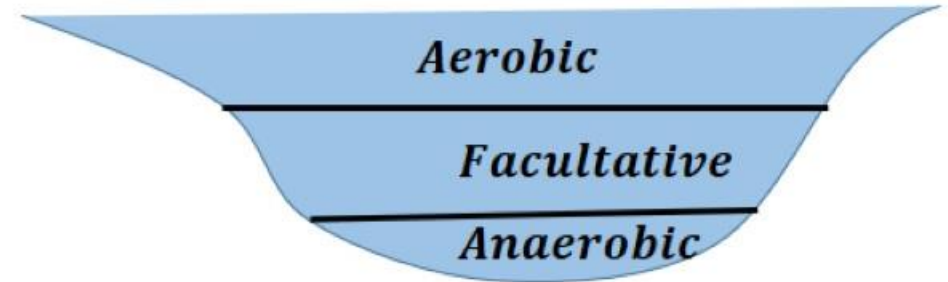
- It is carried out for primary sludge (from PST) only.
- It produces lesser biomass and its primary function is to convert as much as sludge as possible to liquid and gases so that the energy by using the liquid and gases can be obtained efficiently.
- In anaerobic process, there are two stages of decomposition –
 - Acid formation
 - Methane formation

COMPARISON OF AEROBIC AND ANAEROBIC PROCESS

- Anaerobic digestion recovers the energy in the form of methane mostly.
- In anaerobic digestion pathogens completely die out because of lack of oxygen.
- Anaerobic has lower operational cost as compared to aerobic digestion.
- Only demerit of anaerobic digestion is that it requires closed process control to prevent aerobic condition.

OXIDATION POND/WATER STABILISATION POND

- They are open flow through earthen basins.
- They have long detention period during which the waste gets stabilized by the action of natural process.
- In the oxidation pond, a symbiotic relationship exists, in which algae in the presence of sunlight produce oxygen and this oxygen is utilized by bacteria for oxidizing the organic matter.
- The end products are carbon dioxide and water.
- The organic matter decomposed in the top aerobic layer settles down and works as a catalyst to facilitate decomposition in the anaerobic layer.
- The anaerobic layer, in turn, produces nutrients for the survival of bacteria in other layers.
- Moreover, aerobic layer at the top prevents foul gases to come out.



DESIGN PARAMETERS OF OXIDATION POND

- Depth = 1 to 1.5m
- Detention time = 15 to 30days
- BOD removal = 80 to 90%
- Sludge accumulation is 2 to 5 cm per year
- Minimum depth of water to be kept in pond = 0.3m
- L/B ratio is 2.5 to 3, where L should not be greater than 750m
- Organic loading rate = $150 - 325 \text{ kgBOD}_5/\text{hec/day}$

NOTE –

1. The effluent of oxidation pond is not discharged into river because it contains algae.
2. The effluent of oxidation pond is majorly used for irrigation.

Que.

The detention period for oxidation ponds is usually kept as:

- a) 4-8 hrs**
- b) 24 hrs**
- c) 10 to 15 days**
- d) 3 months**

Que.

The detention period for oxidation ponds is usually kept as:

- a) 4-8 hrs**
- b) 24 hrs**
- c) 10 to 15 days**
- d) 3 months**

Que. Calculate the dimension of an oxidation pond and determine the detention time for treating sewage from a residential colony with a population of 8000 persons.

Assume that sewage is produced at the rate of 125lpcd and **BOD**₅ of sewage is 325 kg/day.

Given –

Population = 8000 @ 125lpcd

BOD (kg/day) = 325 kg/day

Que. Calculate the dimension of an oxidation pond and determine the detention time for treating sewage from a residential colony with a population of 8000 persons.

Assume that sewage is produced at the rate of 125lpcd and **BOD**₅ of sewage is 325 kg/day.

Assume organic loading rate = $300 \text{ kgBOD}_5/\text{hec}/\text{day}$

$$\text{Surface area} = \frac{325 \text{ kg/day}}{300 \text{ kg/hec/day}} = 1.08 \text{ ha} = 1.08 \times 10^4 \text{ m}^2$$

Let $L/B = 3$

$$L \times \frac{L}{3} = 1.08 \times 10^4 \text{ m}^2$$

Hence

$$L = 180 \text{ m} \nabla 750 \text{ m}$$

$$B = 60 \text{ m}$$

Que. Calculate the dimension of an oxidation pond and determine the detention time for treating sewage from a residential colony with a population of 8000 persons.

Assume that sewage is produced at the rate of 125lpcd and **BOD₅** of sewage is 325 kg/day.

Assume depth = 1.5m

Organic loading rate = 150 – 325 kgBOD₅/hec/day

Hence dimensions = (180 × 60 × 1.5)

$$D_t = \frac{V}{Q}$$

$$D_t = \frac{(180 \times 60 \times 1.5) m^3}{(8000 \times 125 \times 10^{-3}) m^3/day}$$

Hence **detention time = 16.2days**

Since detention time is between 15 to 30 days hence design is OK.

Que. Calculate the dimension of an oxidation pond and determine the detention time for treating sewage from a residential colony with a population of 8000 persons.

Assume that sewage is produced at the rate of 125lpcd and **BOD**₅ of sewage is 325 kg/day.

detention time = 16.2days

And final dimensions

$$L = 180\text{m}$$

$$B = 60\text{m}$$

$$H = 1.5 + 0.3(\text{free board}) = 1.8\text{m}$$

SEPTIC TANK

- It is designed as an ordinary settling tank except that detention time is 12 to 36 hours with extra provision for digestion of sludge by anaerobic bacteria.
- Directly raw sewage is entered in the septic tank and the sludge settles at the bottom.
- The settled sewage is allowed to remain in the tank for 6 to 12 months during which it is digested anaerobically.

DESIGN PARAMETERS FOR SEPTIC TANK

- Flow of sewage is taken as 50 – 70 litre per capita per day
 - Rate of accumulation of sludge is 30L/cap/year
 - Detention time = 12 – 36 hours
 - L/B ratio = 2 – 3
 - Minimum capacity = 1000L
 - Depth = 1.2 – 1.8m
 - Cleaning interval = 6months to 1 year
 - Adopt free board of 0.3m
- $$V = QD_t + \text{sludge accumulation rate} \times \text{cleaning interval}$$

Que. Design a septic tank for 200 persons with a water supply of 125lpcd. Assume other data as required.

Given –

$$\begin{aligned}\text{Quantity of sewage water} &= 200 \times 125 \times 0.8 \\ &= 25 \text{ m}^3/\text{day} \times 0.8 \\ &= 20 \text{ m}^3/\text{day}\end{aligned}$$

Let detention time $D_t = 1 \text{ day}$

Cleaning interval = 1 year

Que. Design a septic tank for 200 persons with a water supply of 125lpcd. Assume other data as required.

$$V = QD_t + \text{sludge accumulation rate} \times \text{cleaning interval}$$

$$V = 20 \times 1 + 6 \times 1$$

$$V = 26m^3 > 1m^3$$

Hence check OK

Que. Design a septic tank for 200 persons with a water supply of 125lpcd. Assume other data as required.

Let

$$L/B = 3$$

$$h = 1.5m$$

Therefore

$$L \times B \times H = 26$$

$$L \times \frac{L}{3} \times 1.5 = 26$$

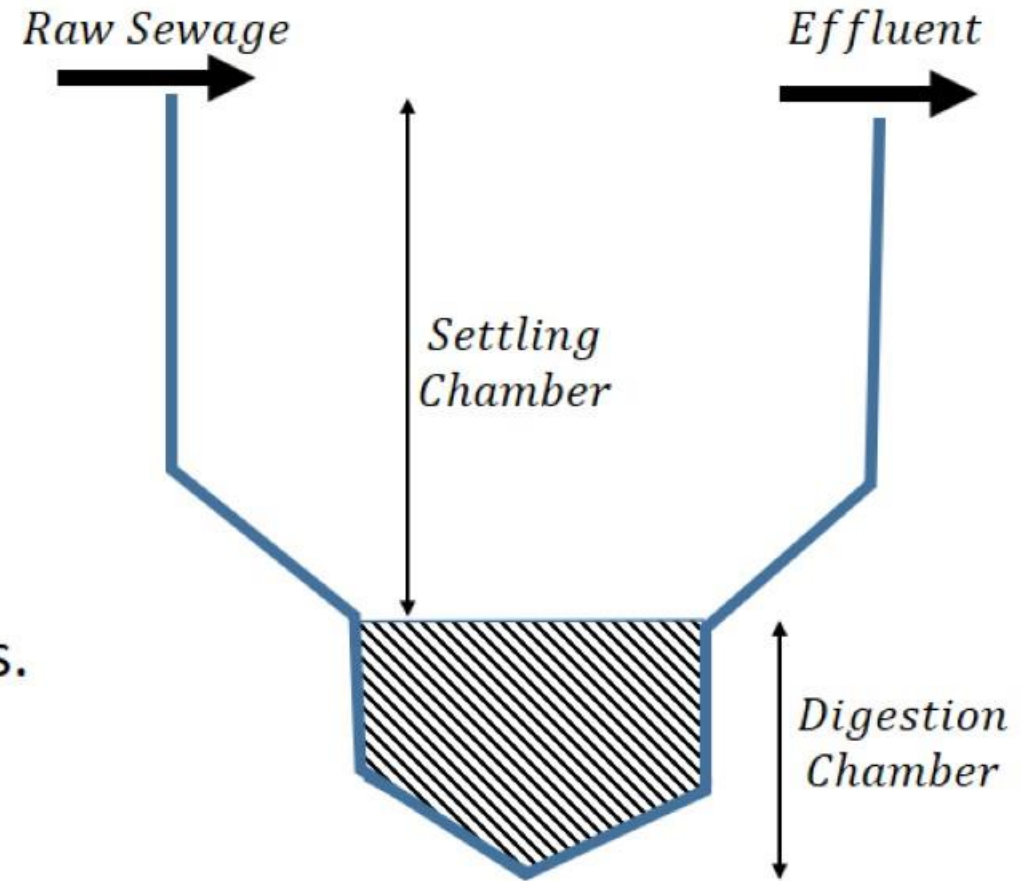
$$L = 7.2m$$

$$B = 2.4m$$

$$h = 1.5 + 0.3(\text{free board}) = 1.8m$$

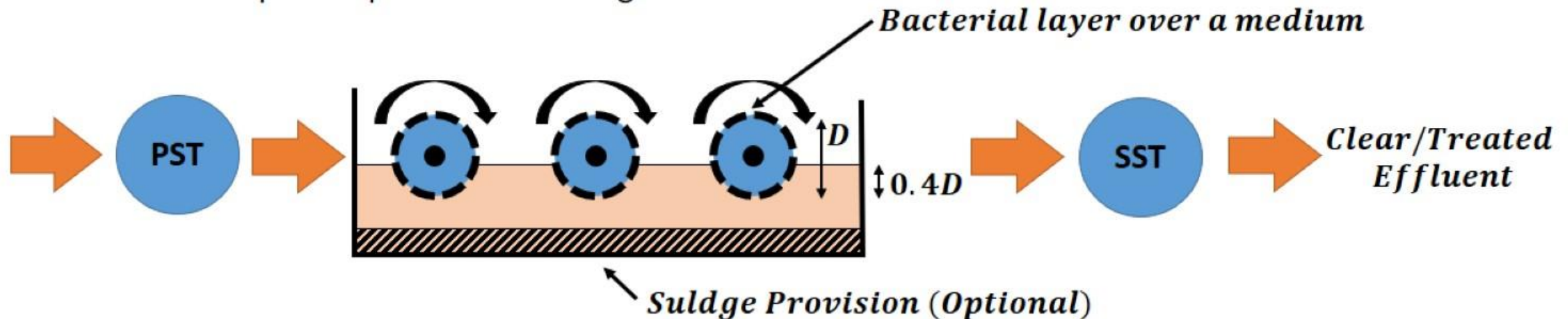
IMHOFF TANK

- An Imhoff Tank is an improvement over septic tank in which incoming sewage is not allowed to get mixed up with the sludge produced.
- The outgoing effluent is not allowed to carry large amount of organic load.
- It is also called DOUBLE STOREY DIGESTION TANK.
- It is used in case of small treatment plants. Requiring only primary treatment.
- They are economical and do not require skilled supervision.



ROTATING BIOLOGICAL CONTRACTOR

- RBCs is aerobic attached growth system.
- In this case, it is the film that is moving at the rate of 3 to 6rpm and the water is still.
- RBC discs are kept immersed upto 40% of diameter.
- The bio film attached to the surface gets a chance to interact with dissolved organics when immersed.
- It takes oxygen from the atmosphere when exposed.
- As the growth of bacterial film increases, and becomes excessive, it gets sheared off.
- Sheared off mass is kept in suspension by the turbulence created due to movement of discs.
- There is an optional provision for sludge accumulation in RBC itself.



Chapter: DISPOSAL OF SEWAGE EFFLUENTS

After treatment, the sewage effluents generally is disposed off by two methods.

1. Dilution, (disposal in water).
2. Effluent irrigation or Broad irrigation or sewage farming, (disposal on land)

Dilution is more common among the two methods

DISPOSAL OF SEWAGE EFFLUENTS

1. Dilution:

- Disposal by dilution is the process in which the treated sewage or the effluent from the sewage treatment plant is discharged into a river stream, or a large body of water, such as a lake or sea.
- The discharged sewage, in due course of time, is purified by what is known as self *purification process of natural waters*

DISPOSAL OF SEWAGE EFFLUENTS

1. Dilution:

**Standards of Dilution
for discharging of
waste water into
rivers**

$$\text{Dilution factor } DF = \frac{\text{volume of diluted sample}}{\text{volume of undiluted sample taken}}$$

Dilution factor	Standards of Purification required
Above 500	No treatment such as sewage can be directly discharged into the volume of dilution water.
Between 300 to 500	Primary treatment such as plain sedimentation should be given to sewage, and the effluents should not contain suspended solids more than 150 ppm.
Between 150 to 300	Treatment such as sedimentation, screening and essentially chemical precipitation are required. The sewage effluent should not contain suspended solids more than 60 ppm.
Less than 150	Complete through treatment should be given to sewage. The sewage effluent should not contain suspended solids more than 30 ppm. And its BOD ₅ at 18.3° should not exceed 20 ppm.

DISPOSAL OF SEWAGE EFFLUENTS

1. Dilution

Tolerance limit for sewage effluent discharged into surface water sources as per IS: 4764–1973 is

BOD₅ – 20 mg/L

TSS – 30. mg/L

Dilution in Rivers and self-purification of Natural streams

- When sewage is discharged into a natural body of water, the receiving water gets polluted due to waste products, present in sewage effluents
- But the conditions do not remain so forever, because the natural forces of purification, such as dilution, sedimentation, oxidation reduction in sunlight, etc; go on acting upon the pollution 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*.

Natural forces of purification which affect self-purification process

1. Physical forces.

- a) Dilution and dispersion: When sewage of concentration C_S flows at the rate Q_S into a river stream with concentration C_R flowing at the rate Q_R , the concentration C of the resulting mixture is given by

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

- b) Sedimentation
- c) Sun-Light: the sun light has a bleaching and stablishing effect of bacteria. It acts through the biochemical reactions.

Natural forces of purification which affect self-purification process

2. Chemical forces aided by biological forces:.

a) Oxidation:

- The oxidation of the organic matter present in sewage effluents, will start as soon as the sewage outfalls into the river water containing dissolved oxygen.
- The deficiency of oxygen so created will be filled up by the atmospheric oxygen.
- This is the most important action responsible of effecting self purification of rivers

Natural forces of purification depends on

- 1. Temperature**
- 2. Turbulence**
- 3. Hydrography**
- 4. Available dissolved oxygen and the amount and type of organic matter present**
- 5. Rate of re-aeration, etc.**

Natural forces of purification depends on

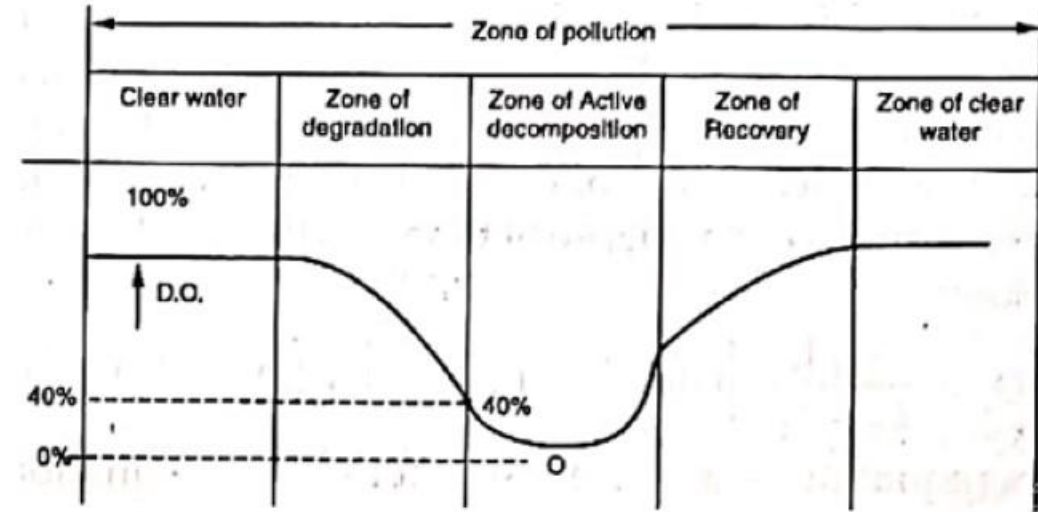
- At higher temperature, the capacity to maintain the D.O. concentration is low; while the rate of biological and chemical activities are high, causing thereby rapid depletion of D.O.
- The larger amount of D.O. present in water, the better and earlier the self-purification will occur.
- Algae which absorbs CO_2 and gives oxygen, is thus, very helpful in the self-purification process

Zones of pollution in a River-system

A polluted stream undergoing self-purification can be divided into the following four zones

1. Zone of degradation:

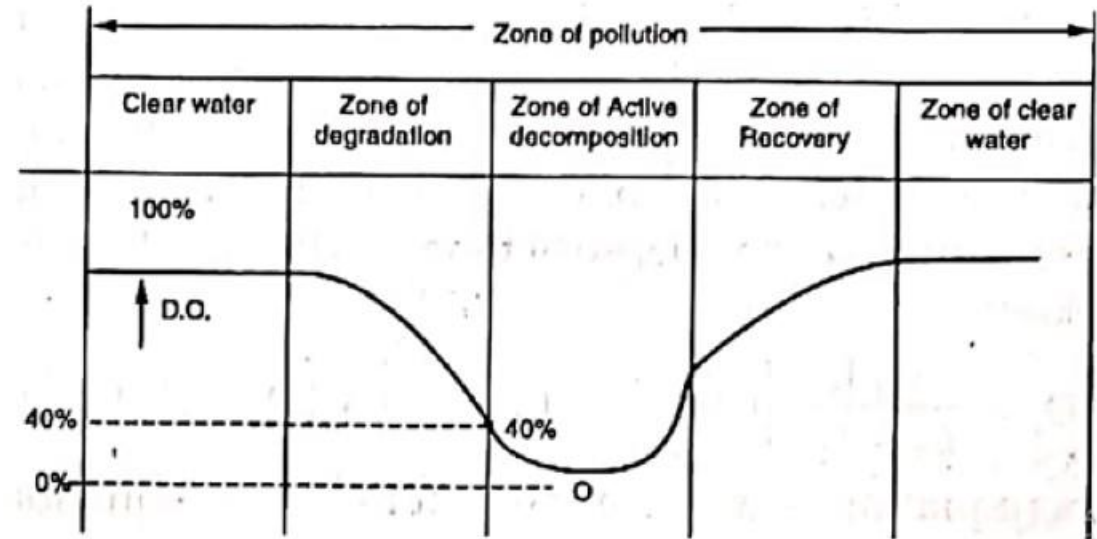
- D.O. is reduced to about 40% of the saturation value. Reoxygenation (i.e. re-aeration) occurs but is slower than de-oxygenation.



Zones of pollution in a River-system

2. Zone of active decomposition:

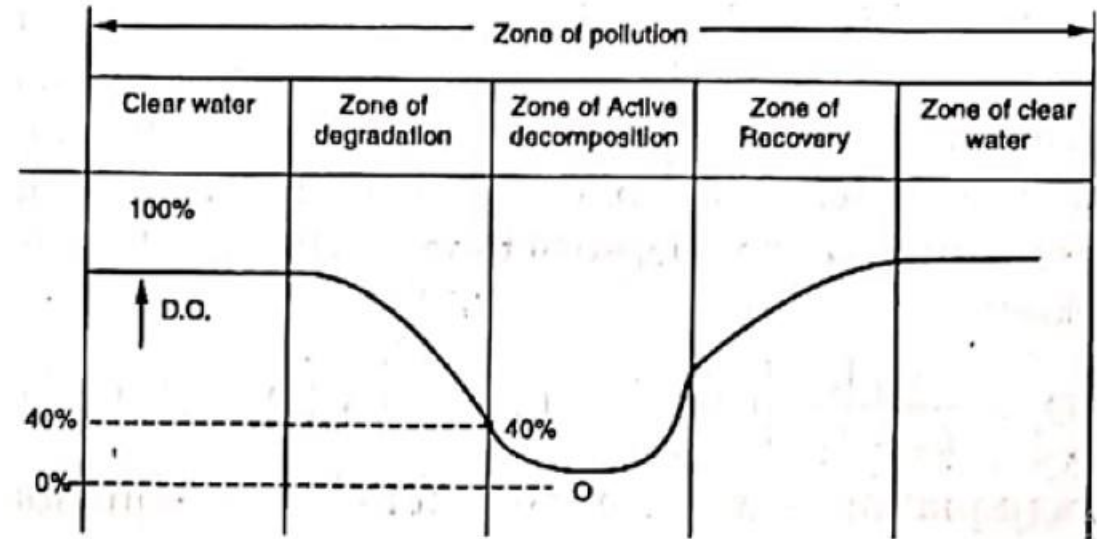
- This zone is marked by heavy pollution. It is characterized by water becoming greyish and darker than in the previous zone. D.O. concentration falls down to zero, and anaerobic conditions may set in with the evolution of gases like CH_4 , CO_2 , H_2S etc.



Zones of pollution in a River-system

3. Zone of recovery:

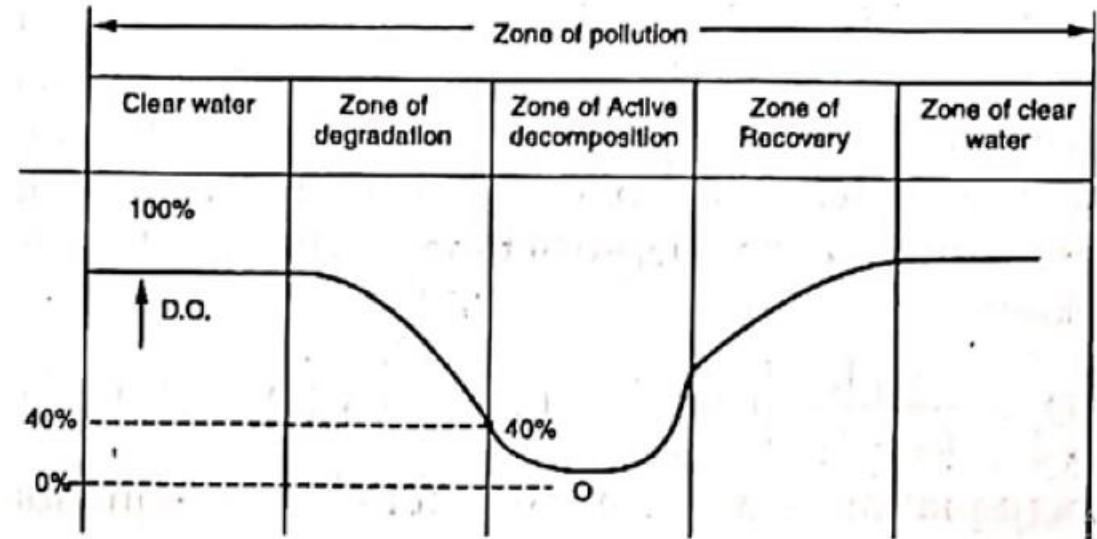
- In this zone B.O.D. falls down and D.O. content rises above 40% of the saturation value. The organic material will be mineralized to form nitrates, sulphates, phosphates, carbonates etc.



Zones of pollution in a River-system

4. Zone of clear Water:

- In this zone, the river attains its original conditions with D.O. rising up to the saturation value.
- When once a river water has been polluted, it will not be safe to drink it, unless it is properly treated.

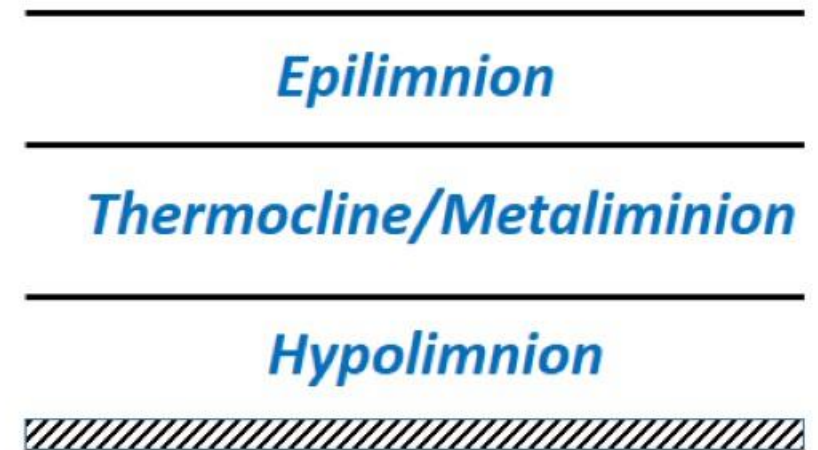


Oxygen deficit of a polluted river stream.

- **Oxygen deficit (D) = Saturated D.O. – Actual D.O.**
- **Oxygen deficit can be found out by knowing the rates of de-oxygenation and re-oxygenation**
- **If de-oxygenation is more rapid than the re-oxygenation, an oxygen deficit results.**

Disposal of waste waters in lakes and management of lake waters

- The study of lakes is called *limnology*.
- Aerobic depth of water in a lake is called *Epilimnion zone*.
- The lower depth of lakes which remains cooler, poorly mixed and anaerobic called the *Hypolimnion zone*.
- In winter season entire depth of lakes behaves aerobic.



Productivity of Lake

- Productivity is the ability to support food chain.
- It is a measure of Algal Growth
- Higher algal growth leads to decreased water quality
- Depending upon the increasing level of productivity, lakes can be classified as
 1. Oligotrophic Lake
 2. Mesotrophic Lake
 3. Eutrophic Lake
 4. Senescent Lake

Productivity of Lake

1. Oligotrophic Lake

- They have low level of productivity due to several limited supply of nutrients
- They can not support Algal growth
- Hypolimnion is very small in these lakes

2. Mesotrophic Lakes

- It has medium productivity and Hypolimnion remains almost as same as Oligotropic, but in Hypolimnion oxygen depletion occurs significantly

3. Eutrophic Lake

- It has high productivity and algal growth
- Hypolimnion is anaerobic

4. Senescent Lake

- It represents very old lake which has almost become marshy

Eutrophication of Lakes

- It is a natural process under which lakes get infested with algae and silt up gradually to become shallow and more productive through the entry and cycling of Nutrients
- The nutrients responsible are Carbon, nitrogen and phosphorous (C, N, P)
- The increase phosphate in lake water accentuate Eutrophication of lake and this is called as Eutrophication
- Once phosphorous is mixed in lake, only solution is to add lime and dredge out the sediment at the bottom of lake



Eutrophication of Lakes

- **Note: To avoid Eutrophication of lakes, lakes should not be used for disposal of even the treated waste water**
- **GOI manual dictates that there should not be any discharge of waste water or treated waste water into the lakes**

2. DISPOSAL ON LAND

Disposal of sewage effluents on land for irrigation

- In this method, the sewage effluent (treated or diluted) is generally disposed off by applying it on land.
- The percolating water may join the water table
- The degree of treatment of raw sewage depend upon the type of soil of the land

Quality standards for waste water effluents to be discharged on land for irrigation

Characteristic / Constituent of effluent waste water	Tolerance limit as per IS: 3307-1965
BOD ₅	500 mg/1
pH value	5.5 to 9.0
Total Dissolved Solid (TDS)	2100 mg/1
Oil and grease	30 mg/1
Chlorine (as CL)	600 mg/1
Boron	2 mg/1
Sulphates	1000 mg/1

Effluent irrigation and sewage farming

- In effluent irrigation (or broad irrigation), the chief consideration is the successful disposal of sewage, while in sewage farming, the chief consideration is the successful growing of the crops.

Sewage Sickness.

- When sewage is applied continuously on a piece of land, the soil pores or voids may get filled up and clogged with sewage matter retained in them
- Free circulation of air will be prevented, and anaerobic condition will develop within the pores.
- The aerobic decomposition of organic matter will stop, and anaerobic decomposition will start
- The organic matter will thus, of course, be mineralized, but with the evolution of foul gases like H_2S , CO_2 and CH_4 .
- This phenomenon of soil getting clogged is known as sewage sickness.

Preventive measures for Sewage Sickness

- **Primary treatment of sewage**
- **Choice of land**
- **Under-drainage of soil**
- **Giving rest to the land**
- **Rotation of crops**
- **By sewage in shallow depths.**

Solid Waste Management

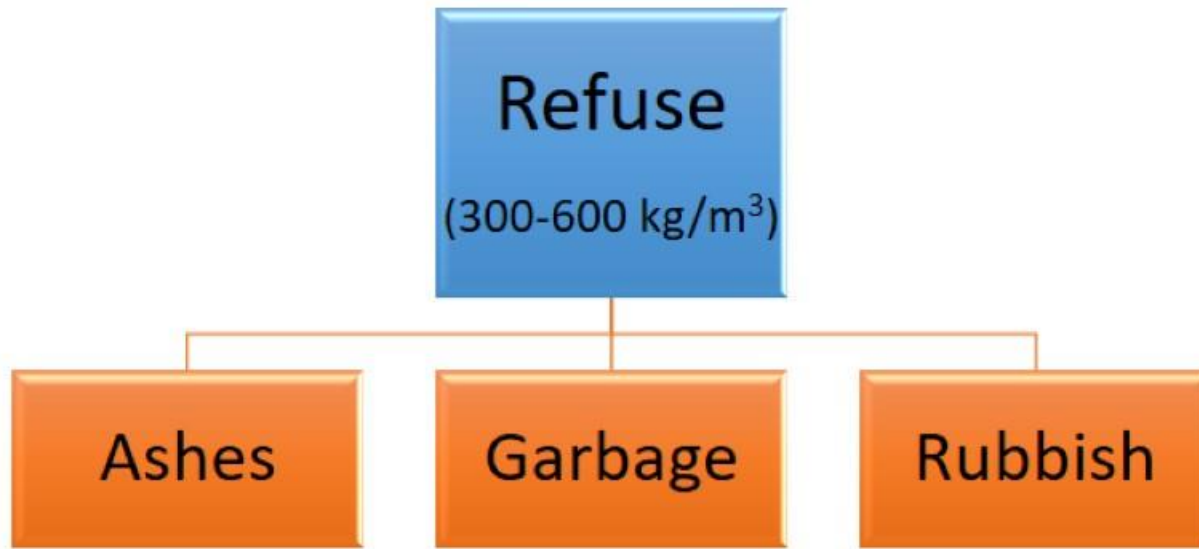
Solid wastes are total wastes arising from Human and Animal Activities that are normally solid and are useless or unwanted.

TYPES OF SOLID WASTE:

- Municipal Waste
- Industrial Waste
- Hazardous waste



1. Municipal Waste



- **Refuse** Refers to non hazardous solid waste from the community requiring collection and transporting to the treatment or disposal site
- **Refuse** consists of ashes garbage and rubbish
- **Garbage** comprises of items that are highly decomposable/putrescible food, vegetables, meat, etc
- **Rubbish** contains dry non putrescible materials such as glass, rubber, poly bags, plastics, textiles, etc
- **Ashes** are incombustible inert substances

2. Industrial Waste

- Industrial Waste can be categorised as Hazardous and Non Hazardous
- Paper and pulp industry produces maximum waste



3. Hazardous Waste

As per RCRA (Resource Conservation and Recovery Act 1976) USA, *“The Hazardous Waste is the one which causes any one of the four characteristics:*

Toxicity, Reactivity, Ignitability, Corrosivity “

Some of the common industries that generates hazardous wastes are:

- Cement
- Chemical
- Petroleum
- Fertilizers
- Ferrous Industries



Disposal of Solid Waste

1. Open Dumping
2. Sanitary land fill
3. Composting
4. Pulverisation
5. Incineration
6. Pyrolysis

Disposal of Solid Waste

1. Open Dumping

- Very Simple Method
- Solid waste is collected from city and dumped into low lying areas located outside the city
- It results in contamination of Environment
- It is unacceptable as per Government of India
- It causes obnoxious smell and is a breeding place for flies and mosquitoes



Disposal of Solid Waste

2.Sanitary Landfill

- It involves a complete disposal of Solid Waste on or in upper layers of Earth's surface
- The refuse is dumped and compacted in layers of 0.3 – 0.6 m and after the day's work when depth of filling becomes 1.5 m, it is covered by Earth layer of about 15-30cm thickness
- Before dumping the second layer, compaction is done by Bulldozers, trucks, etc
- The filled refuse gets stabilized due to the decomposition of organic matter in due course of time



Disposal of Solid Waste

2.Sanitary Landfill

- **Advantages:**
 - Simple and Economical
 - Separation of different kinds of Refuse is not done
 - No further disposal is required
 - Old Quarry pits can be easily reclaimed and put to later use
- **Disadvantage**
 - Dumping site may not be always available
 - Continuous generation of the foul gases



Disposal of Solid Waste

2.Sanitary Landfill

- **Gases in landfill**
 - The movement of landfill gases is controlled by landfill sealants.
 - For this purpose compacted clay is most commonly used

Disposal of Solid Waste

3.Composting

- Composting of refuse is a biological method of decomposing Solid Waste
- If the Organic materials excluding plastics, leather and rubber are separated from the solid wastes and are subjected to decomposition either aerobically or anaerobically, the remaining end product is called Compost/ Humus
- The Entire process involving both the separation and bacterial Conversion of organic solid waste is called as *Composting*

Disposal of Solid Waste

3.Composting

- **Carbon Nitrogen Ratio:**
 - Bacteria use Nitrogen for building their cell structures and carbon for food
 - C/N ratio should be between 30 to 50 for optimum digestion
- In India, Digestion is done by two methods
 1. Indore Method
 2. Bangalore Method

Que.

**Composting and lagooning
are the methods of**

a)Sludge digestion

b)Sludge disposal

c)Sedimentation

d)Filtration

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Aerobic method of composting practiced in India is called

- a) Bangalore Method**
- b) Nagpur Method**
- c) Delhi Method**
- d) Indore Method**

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Bangalore method and Indore method of disposing solid wastes are

- a) Identical**
- b) Different as Bangalore method is an anaerobic method**
- c) Different as Bangalore method does not contain human excreta**
- d) Different as Indore method is an incineration method**

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Disposal of Solid Waste

3. Composting

1. Indore Method

- It uses aerobic conditions for decomposition
- In this method, mixture is kept aerobic by piling it in layers and continuously turning those layers to ensure aerobic decomposition
- It is kept for 2-3 months

2. Bangalore Method

- In this method, soil is dug and the refuse is dump into that trench. The trench is then covered by a 15cm layer of soil so that anaerobic conditions prevail.
- Minimum Depth of trench = 1.5 m
- Considerable heat is evolved in the process that kills and prevents the breeding of flies and mosquitoes
- This method is widely adopted



Disposal of Solid Waste

4. Pulverisation

- Refuse is pulverised in grinding machines so as to reduce its volume
- It is then further disposed either aerobically or anaerobically

5. Incineration and Pyrolysis

- **Incineration** means burning the solid waste in well designed furnace
- It is the best method for the treatment of Solid Waste
- Oxygen and Heat is supplied so that the organic matter decompose in a limited time and then burnt
- It does not produce any odour or dust
- It is highly expensive process

