: Sanitary Engineering :

Sanitary Engineering:

↳ Branch of public health engineering in which all aspects of provision or sanitation facilities are included inside the public health category.

some important definitions:

1. sewage:

↳ All kind of liquid waste or waste water produced from community.

2. Domestic sewage:

↳ sewage obtained from residential and commercial building.

3 Industrial sewage:

↳ sewage obtained from industries.

4. Sanitary sewage:

↳ Sewage that produces during dry weather and doesnot include storm water is called sanitary sewage.

5. storm water:

↳ Run-off rainwater from locality.

6. sewer:

↳ Underground conduit or drain through which sewage is conveyed.

Types of sanitation system:

↳ Generally disposal of waste products of a community comprises two system:

(i) conservancy system.

(ii) water carriage system.

(i) conservancy system:

↳ also known as dry system.

↳ old system in which wastes are collected separately in vessels and then removed periodically in 24 hrs.

Merits:

(i) cheap system. (less initial cost).

(ii) quantity of sewage reaching at treatment plant is low.

Demerits:

(i) Unhygienic system.

(ii) foul smell due to excreta and vegetable waste.

(iii) requires large area for sewage disposal.

(ii) Water-carriage system:

↳ water is used as a carrying agent for sewage.

↳ labour force required is negligible amount.

↳ final disposal of sewage is risk free.

Merits:

(i) hygienic system. as waste is disposed after treatment.

(ii) less chances of epidemic brokedown.

(iii) labour and maintenance cost is low.

(iv) less odour producing system.

Demerits:

(i) initial cost is high.
(ii) large quantity of water required.
(iii) large quantity of sewage is to be treated during rainy season.

*! Types of sewerage system:

↳ Basically there are three types of sewerage system.

(i) separate system
(ii) combined system
(iii) partially separate system.

(i) Separate system:

↳ consists of two different sewers, one for convergence of sewage and other for rain water.

↳ only domestic and industrial sewers are treated but storm sewage are diverted directly into rivers.

Merits:

(i) load on treatment plants is reduced.
(ii) has uniform process for purification.
(iii) rainwater can be directly discharged in river.
(iv) sewer of smaller section can be easily ventilated than larger ones.

Demerits:

(i) costly as requires two set of sewers.
(ii) chocking problem may occurs.
(iii) occupies more space due to two sewers.
(iv) possibility of wrong connection due to confusion.

(ii) combined system:

↳ consists of only one sewer to carry both rainwater and sanitary sewage.

↳ sewage must be treated before discharge to river.

Merits:

(i) reduced cost due to only one sewer.

(ii) reduced maintenance cost.

(iii) self cleansing velocity can be easily maintained.

(iv) strength of sewage is reduced by dilution.

Demerits:

(i) rainwater remains prone to pollution.

(ii) ventilation problem may occurs due to large size.

(iii) load in treatment plant increases.

(iv) handling and transportation of large size of sewer is difficult.

(iii) Partially separate system:

↳ Sewerage system in which water from roof top, courtyard, garden etc are combined in sanitary sewer is called partially separate system.

Merits:

(i) has combined advantages of both separate and combined system.

(ii) sewers dimension is of reasonable size and easy to clean.

(iii) self cleansing is done by rainwater itself..

Demerits:

(i) self cleansing velocity may not be achieved in dry weather

(ii) loads on treatment plants may increase

(iii) only suitable for area with proper rainfall.

Differences between separate system and combined system.

S.N.	Separate system	S.N.	combined system.
(i)	It consists of two set of sewers.	(i)	It consists of one set of sewer.
(ii)	low quantity of sewage is to be treated.	(ii)	treatment of storm water is to be done.
(iii)	low treatment cost.	(iii)	high treatment cost.
(iv)	rain water is separately discharged into river.	(iv)	rain water becomes polluted.
(v)	choking problem may occurs.	(v)	choking problem doesnot occurs.
(vi)	suitable for area having more intensity of rainfall.	(vi)	suitable for area having less intensity of rainfall.
(vii)	Less degree of sanitation is achieved.	(vii)	High degree of sanitation is achieved.
(viii)	Degree of treatment is high.	(viii)	Degree of treatment is low.

: Quantity of wastewater:

*: Sources and nature of waste water:

↳ Sources of waste water are:

1. Public water supply.
2. Private water supply.
3. Ground water seepage.
4. Unauthorized connection.

*: Dry weather flow and wet weather flow:

Importance of estimating waste water:

1. For sanitation
2. For maintaining self cleansing velocity.

*: Dry-weather flow:

↳ quantity of water that flows in dry season when no storm water flows.

↳ minimum amount of flows available throughout the year.

↳ includes waste water through residance and industries.

*: Wet weather flow:

↳ additional amount of flow contributed by rain water.

↳ includes street water, rain water, domestic and industries waters.

*: Factors affecting quantity of sanitary sewage:

1. Population growth.
2. Rate of water supply
3. Ground water infiltration.
4. Unauthorized connection.
5. Types of area served.

I. Population growth:
- ↳ popl^n ↑, quantity of waste sewage ↑.
- ↳ quantity of sewage $\propto$ popl^n growth.

II. Rate of water supply:
- ↳ more quantity of water supplied creates more waste water.
- ↳ quantity of sewage $\propto$ rate of water supply.

III. Ground water infiltration.
- ↳ Ground water may infiltrate into sewers from broken pipes, leak joints and contribute to waste water.
- ↳ infiltration ↑, quantity of sewage ↑.

IV. Unauthorized connection:
- ↳ includes connections that are not registered in municipal system.
- ↳ also includes storm water
- ↳ unauthorized connection ↑, quantity of sewage ↑.

V. Types of area served:
- ↳ quantity of sanitary sewage also depends on type of area such as residential, industrial or commercial.

*: Factors affecting quantity of storm sewage:

1. Shape and size of the catchment area.
2. Topography
3. Character of catchment area.
4. Direction of prevailing storm.
5. Types of precipitation.
6. Rainfall distribution.
7. Intensity and duration of rainfall.
8. Soil moisture deficiency.

*: Quantity of sanitary sewage:

↳ Sanitary sewage production rate = 70 to 80 % of water supply rate.

↳ generally expressed in litres per capita per day (lpcd).

*: Peak factor:

↳ Ratio of maximum to average rate of flow.

↳ Depends upon contributing population, variation in sewage flow as per wsr, system of design etc.

*: Quantity of storm sewage:

↳ Storm sewage is determined by:

1. Rational methods
2. Empirical methods.

1. Rational methods:

↳ storm water flow is given by:

$$Q_s = \frac{CIA}{360}$$

; where I = intensity of rainfall (mm/hr)

A = catchment area (ha)

C = runoff coefficient.

*: Intensity of rainfall:

↳ Rainfall intensity (I) is given by:

$$I = \frac{a}{t+b}$$ → general formula,

Cases:

case (i):

$$I = \frac{760}{t+10}$$ for storm duration 5 to 20 minutes.

case (ii):

$$I = \frac{1020}{t+20}$$ for storm duration 20 to 100 minutes.

; where t = duration of rainfall.

*: Time of concentration:

↳ Time of concentration is the time required for rainwater to flow over ground from extreme point of catchment area to point under consideration.

Limitation of rational methods:

(i) Applicable for area < 50 km^2

(ii) Intensity of rainfall may not be uniform throughout the catchment.

(iii) storm duration may be < time of concentration.

(iv) catchment slope is not considered.

(v) Basin storage is neglected.

(vi) Runoff coefficient may vary in different seasons.

II. Empirical methods:

a. Ryvees formula.

↳ developed for south indian catchment.

$$Q = C_R \times A^{2/3}$$

; C_R = Ryvees constant

A = catchment area in km^2.

b. Dicken's formula:

↳ developed for north indian catchments.

$$Q = C_D \times A^{3/4}$$

; C_D = dicken's constant

A = catchment area in km^2.

c. Inglis's formula:

↳ developed for Maharastha

$$Q = \frac{124A}{\sqrt{10.4+A}}$$; A = catchment area in km^2.

Numerical:

Determine the design discharge for separate and combined system of a small town with projected population of 45000 residing over an area of 20 hectares.

Also calculate the diameter of sewer to carry the combined discharge.

Rate of water supply = 150 lpcd, Runoff coefficient = 0.45

time of concentration = 30 minutes, sewer slope = 1 in 500.

Mannings, n = 0.013

solution:

Given

population (N) = 45000

Area (A) = 20 ha.

WSR = 150 lpcd

Runoff coefficient (C) = 0.45

Time of concentration (t) = 30 mins

slope of sewer (S) = 1 in 500

Manning's (n) = 0.013

Dry weather flow:

$$Q_{DWF} = \frac{45000 \times 150 \times 0.80 \times 2.75}{24 \times 60 \times 60 \times 10^3} \; m^3$$

$= 0.17 \; m^3$

; P.F = 2.75 (assumed)

; 0.80 is for 80% of WSR.

Wet weather flow:

$$Q_{WWF} = \frac{CIA}{360}$$

$$= \frac{0.45 \times I \times 20}{360}$$

for intensity,

$$I = \frac{1020}{50+20} = 20.4 \text{ mm/hr.}$$

$$Q = \frac{0.45 \times 20.4 \times 20}{360} = 0.51 \text{ m}^3.$$

Total (combined) discharge $= Q_{DWF} + Q_{WWF}$

$= 0.17 + 0.51$

$= 0.68 \text{ m}^3$

Now,

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

$$0.68 = \frac{\pi d^2}{4} \times \frac{1}{0.013} \times R^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$

for ~~circular sewer~~

$$R = \frac{A}{P} = \frac{\frac{\pi d^2}{4}}{\pi d} = \frac{d}{4}$$

$$0.68 = \frac{\pi d^2}{4} \times \frac{1}{0.013} \times \left(\frac{d}{4}\right)^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$

on solving, we get

$d = 0.89 \text{ m}$

check for velocity:

$$V = \frac{1}{n} R^{2/3} S^{1/2} = \frac{1}{0.013} \times \left(\frac{0.89}{4}\right)^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$

$\therefore V = 1.26 \text{ m/s} > 0.60 \text{ m/s (ok)}$

Design and construction of sewers:

↳ Factors to be considered for design of sewer are:

1. Resistance to corrosion
2. Resistance to abrasion.
3. strength and durability
4. light weight
5. Economy and cost.
6. Imperviousness
7. Hydraulically efficient.

Design criteria of sewers are:

1. Design period = 25 to 30 years
2. Velocity of flow ≥ self cleansing velocity
3. sewer size should not be less than 15cm. But recommended size is 20 cm.

   ↳ commercially available sizes are: 15, 20, 25, 30, 35, ---

   ↳ max^m size of sewer = 3m (available)
4. sewers are designed to flow $\frac{1}{2}$ to $\frac{2}{3}$ full at peak cond^n.
5. sewer are designed to ensure self cleansing and limitting velocity.

Self cleansing velocity:

- Minimum velocity of flow to be maintained so that solid particles will be in suspension without setting at bottom of sewer.
- For combined sewer, self cleansing velocity = 0.75 m/s.
- Depends upon the diameter of pipe:

Diameter (cm)	self-cleansing velocity
15 to 25 cm	1.0 m/s.
30 to 60 cm	0.75 m/s.
> 60 cm	0.60 m/s.

Non-scouring velocity:

- Maximum velocity of flow at which interior of sewer is not damaged.
- non-scouring velocity depends on inner material of sewer.

sewer material	Non-scouring velocity
earthen channel	0.6 to 1.2 m/s.
cement concrete	3 to 4.5 m/s.
cast iron pipe	2.5 to 3 m/s.

Hydraulic formula for design of sewer:

1. Discharge (Q)

$Q = A \times V$; A = area

v = velocity

1. Velocity:

↳ several formulas are available:

a. Manning's formula.

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

; n = manning's roughness coefficient.

R = A/p = hydraulic mean depth.

S = bed slope of sewer.

b. Chezy's formula:

$V = C\sqrt{RS}$; C = chezy's constant.

R = A/p = hydraulic mean depth.

S = bed slope of sewer.

c. Hazen William's formula:

$$V = 0.84\,C R^{0.63} S^{0.54}$$

; C = Hazen's william's constant.

R = A/p = Hydraulic mean depth.

S = bed slope of sewer.

d. Kutter's formula:

$V = C\sqrt{RS}$

; C = Kutter's constant.

$$C = \frac{\frac{1}{n} + \left(23 + \frac{0.00155}{S}\right)}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{n}{\sqrt{R}}}$$

Hydraulic elements of circular sewer for partial flow condition:

↳ Mostly circular sewer are choosen for sewer because:

① simple and economic manufacturing.

② less sediment deposition

③ utilization of materials.

↳ But sewage flowing inside sewer mostly flow partial full as open channel flow:

*: For circular sewer running full:

flow area $(A) = \frac{\pi D^2}{4}$

wetted perimeter $(P) = \pi D$

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

*: For circular sewer running half full:

flow area $(a) = \frac{\pi D^4}{8}$

wetted perimeter $(p) = \frac{\pi D}{2}$

Hydraulic mean depth $(R) = \frac{\frac{\pi D^2}{8}}{\frac{\pi D}{2}} = \frac{D}{4}$

*: Partial flow in circular sewer:

- depth $(d) = \frac{D}{2}(1 - \cos\theta/2)$

- area $(a) = A \times \frac{\theta}{360^\circ}\left(1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right)$

- Hydraulic mean depth $(r) = R \times \left(1 - \frac{360 \sin\theta}{2\pi\theta}\right)$

- Perimeter $(p) = P \times \frac{\theta}{360}$

- velocity $(v) = V \times \left(1 - \frac{360 \sin\theta}{2\pi\theta}\right)^{2/3}$

- discharge $(q) = Q \times \frac{\theta}{360} \left(1 - \frac{360 \sin\theta}{2\pi\theta}\right)^{5/3}$

Shape of sewer:

↳ Mostly used shape of sewer are...

ⓐ Circular sewer

ⓑ Non-circular sewer.

i. Egg shaped.
ii. Rectangular
iii. Horse shoe shaped
iv. semi-elliptical.
v. Parabolic sewer
vi. V-shaped sewer etc

*: Sewer materials:

↳ Materials used for sewer are bricks, cement concrete, cast iron, steel and stone-ware etc

Requirements of sewer are:

① Must be able to resist corrosion.

(ii) Resistance to abrasion.

(iii) should be able to bear external load.

(iv) Light weight

(v) Impervious

(vi) least cost..

(vii) Durable.

Types of sewer materials:

↳ Different types of sewer materials are:

(i) salt glazed stoneware.

(ii) cement concrete sewer

(iii) cast iron sewer.

Construction of sewer:

↳ Various process involved in construction of sewer are:

(i) setting out centerline of sewer.

(i) Alignment and gradient selection.

(iii) Excavation of trenches

(iv) Timbering and Dewatering

(v) laying and jointing

(vi) Testing of sewer

(vii) Backfilling of sewer.

*: Testing of sewer:

↳ Generally three tests are carried out for testing of sewer.

(i) straightness test and obstruction test.

(ii) water test

(iii) Air test.

(i) straightness test and obstruction test:

procedure:

(i) A smooth ball of diameter 13 mm less than diameter of pipe is released at high end.

(ii) If no obstruction, ball will roll down and emerge out.

(iii) For straightness, a mirror is placed at one end and lamp at other end.

(iv) For straight sewer, full circle light will appear.

(ii) Water test:

↳ used to find out water tightness of the joints.

↳ water is passed through lower end and air is released at upper end.

↳ The lower end is closed & level of water is noted for 30 minutes.

↳ water loss should not be greater than 2 litres per cm diameter per km length.

(iii) Air test:

↳ This is necessary in pipes of large diameter to check water tightness when large quantity of water is not available for testing.

↳ Pipe is subjected to pressure of 100 mm of water.

↳ If pressure is maintained at 75 mm of water, the joint is assumed to be watertight.

Q. The population of a town is 80000 with a water supply rate of 145 lpcd. Assuming 80% of water supply contribute sewage flow, taking manning's 'n' as 0.013, average slope as 1:400 and peak factor = 3, determine the minimum diameter of sewage required to carry maximum discharge if it runs at 0.75 times depth?

Solution:

population = 80,000

Water supply rate = 145 lpcd

% contribution in sewage flow = 80%

slope = 1:400

manning's n = 0.013

$\frac{d}{D} = 0.75$

peak factor = 3

Here,

Dry weather flow (Q) = $\frac{80000 \times 145 \times 3 \times 0.80}{1000 \times (24 \times 60 \times 60)}$

$= 0.322\ m^3/s.$

for angle, θ,

$\frac{d}{D} = \frac{1}{2}(1 - \cos\theta/2)$

or, $1 - \cos\theta/2 = 2 \times 0.75$

or, $\cos\theta/2 = 1 - 2 \times 0.75$

or, $\frac{\theta}{2} = \cos^{-1}(1 - \frac{3}{2})$

$\therefore \theta = 240°$

And $\sin\theta = -0.866$

$$\frac{a}{A} = \frac{\theta}{360}\left(1 - \frac{360\sin\theta}{2\pi\theta}\right)$$

$$\frac{a}{A} = \left(1 - \frac{360\sin 240^\circ}{2\pi \times 240^\circ}\right)$$

$$\frac{a}{A} = 0.804$$

$$\Rightarrow a = 0.804 \times \frac{\pi D^2}{4}$$

$$\Rightarrow a = 0.631\, D^2 \quad --- \text{(i)}$$

$$\frac{r}{R} = \left(1 - \frac{360\sin\theta}{2\pi\theta}\right)$$

$$r = R \times \left(1 - \frac{360(-0.866)}{2\pi \times 240}\right)$$

$$r = \frac{D}{4} \times 1.206$$

$$\therefore r = 0.301\, D \quad --- \text{(ii)}$$

Now,

$$q = \frac{a}{n} \times (r)^{2/3} \times S^{1/2}$$

$$0.322 = \frac{1}{0.013} \times (0.301 D)^{2/3} \times \left(\frac{1}{400}\right)^{1/2} \times 0.631 D^2$$

solving, we get

$$D = 0.633 \text{ m} \simeq 0.64 \text{ m}.$$

$\therefore$ The minimum diameter of sewer $= 0.64$ m

Characteristics and Examination of sewage:

↳ sewage is made up of large amount of water (about 99.9%) and 0.1 % solid matter.

characteristics of sewage:

↳ sewage characteristics can be classified into:

(I) Physical characteristics.
(II) chemical characteristics.
(III) Biological characteristics.

(I) Physical characteristics:

a. Colour:

↳ fresh sewage: Grey (PPSC-Bagmati)
↳ septic sewage: Blue
↳ stale sewage: Black.

b. Odour:

↳ fresh sewage: odourless
↳ Decomposed sewage: rotten egg odour.

c. Temperature:

↳ increase in tempr increases biological activity

d. Turbidity:

↳ due to suspended, colloidal and dissolved solids.

(II) chemical characteristics:

a. pH:

↳ fresh sewage alkaline : 7.3 to 7.5 pH
↳ decomposed sewage: acidic.

b. organic and inorganic solids:
↳ organic solid: by product of plants and animal.
↳ inorganic solid: nitrogen, chlorine, ammonia, nitrate etc.

c. Nitrogen content:
↳ NH_3, NH_4, N_2 gas, NO_2^-, NO_3^- etc

(iii) Biological characteristics:
↳ Microorganism such as bacteria, virus, algae, fungi etc

*! Sampling of waste water:
↳ sampling is the process of collection of representative sample from waste water/sewage:

Types of sample:
(i) Grab sample:
(ii) composite sample:

(i) Grab sample:
↳ sample collected over a specific place a short period of time.
↳ collected when a source is constant in composition.

(ii) composite sample:
↳ sample collected by combining multiple grab samples.
↳ collected when source varies its proportion.

Decomposition of waste water:

- Most of the organic matter present in sewage is unstable and decomposes readily through chemical as well as the biological process.
- Biological decomposition of waste water is done by....
  - a. Anaerobic decomposition.
  - b. Aerobic decomposition.

a. Aerobic decomposition:

- Decomposition of sewage by both aerobic and facultative bacteria in presence of air is called aerobic decomposition.
- Bacteria oxidizes organic matter by utilizing free oxygen
- stable end products like CO_2, SO_4, NO_2, H_2O etc are produced
- Aerobic treatments yields better effluent quality

Eg: oxidation pond, aeration tank, trickling filter.etc

complex organic matter

↓ hydrolysis.

simpler organic compound.

↓ oxidation

End products: CO_2, NO_2, SO_4, H_2O etc.

6. Anaerobic decomposition:

- Decomposition of sewage by anaerobic bacteria in absence of air is called anaerobic decomposition.
- Bacteria oxidizes organic matter by extracting molecular oxygen.
- End products like H_2S, NH_3, CH_4 etc are produced.
- Anaerobic treatments yields low effluent quality.

Eg: septic tank, sludge digestion tank, etc.

complex organic matter

$\downarrow$ hydrolysis

simple organic compound

$\downarrow$ acidogenesis

volatile fatty acid

$\downarrow$ oxidation

End products

H_2S, NH_3, CH_4 etc.

S.N.	Aerobic decomposition	S.N.	Anaerobic decomposition.
(i)	Takes place in absence of oxygen	(i)	Take place in presence of oxygen.
(ii)	End product of decomposition are: CO_2, SO_4, NO_2, H_2O etc	(ii)	End product of decomposition are: NH_3, H_2S, CH_4 etc
(iii)	Example: oxidation pond, aeration tank, trickling filter	(iii)	Example: septic tank, sludge digestion tank.
(iv)	Better effluent quality.	(iv)	lower effluent quality than aerobic process.
(v)	Aerobic and facultative bacteria are responsible.	(v)	Anaerobic and facultative bacteria are responsible.

*: Biochemical Oxygen Demand (BOD):

- Biochemical oxygen demand is defined as the amount of oxygen required for micro-organism to carryout the biological decomposition of organic matter in sewage under aerobic condition at standard temperature.
- The amount of oxygen consumed in the process of decomposition depends upon amount of organic matter in sewage.
- BOD is used as an index in sewage or wastewater treatment plant.

*: Significance of BOD results:

1. It determines quantity of oxygen required to stabilize organic matter present in sewage.
2. It determines the size of treatment unit required.
3. It measures the efficiency of some treatment plant.
4. It determines the strength of sewage.
5. It determines the amount of clear water required for disposal of sewage by dilution.

Stages of BOD:

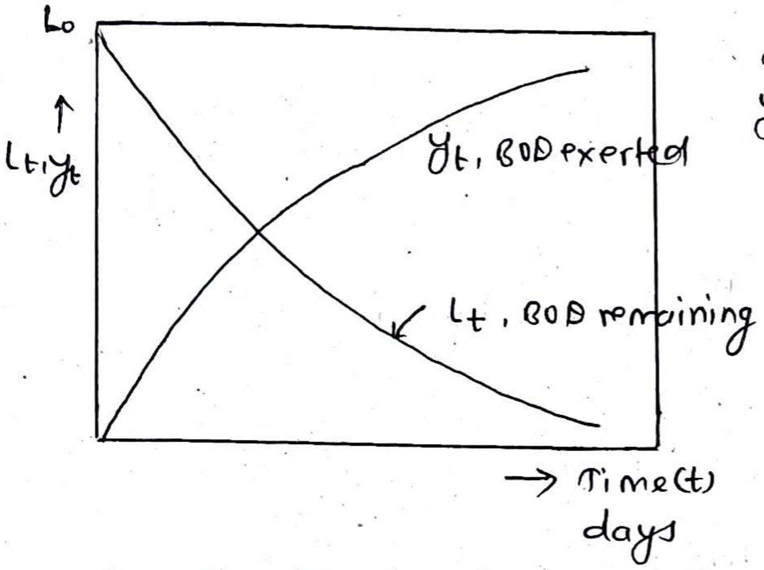
- According to biochemical decomposition, oxidation proceeds in two stages:

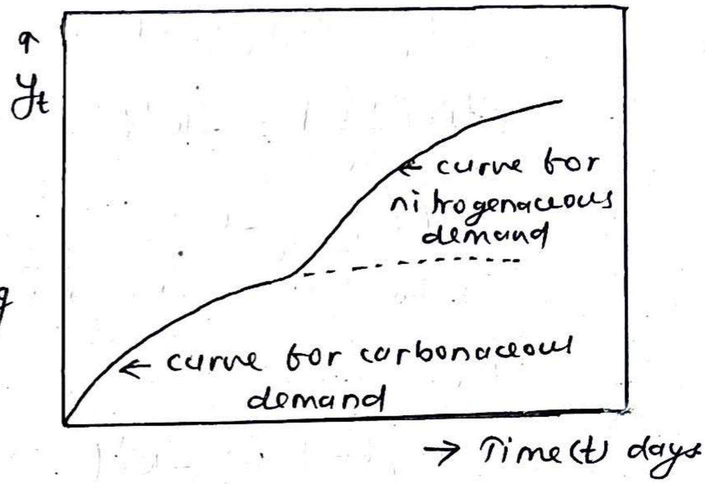
1. First stage BOD:

- It consists of breaking down of carbonaceous matter with production of carbondioxide and water with simple amine compounds.
- First stage decomposition lasts for 7 to 10 days.

d. Second stage BOD:

- It consists of breaking down of nitrogenous matter into nitrites and nitrates.
- second stage decomposition lasts for longer period until stabilization.





d: Expression for first stage BOD:

- The rate at which BOD is satisfied at a given temperature is directly proportional to the amount of organic matter present in sewage at that time.

$$\frac{dL_t}{dt} = -k' \quad \text{—— (I)}$$

; where L_t = first stage BOD remaining at any time 't'.

t = time in days

k' = rate of de-oxygenation.

Integrating (I) both sides,

$$\int \frac{dL_t}{L_t} = -\int k\, dt$$

$$\ln L_t = -k't + c \quad \text{—— (II)}$$

At $t = 0$, $L_t = L_0$

substituting in equ^n (II)

$$\ln L_0 = 0 + C$$

$$C = \ln L_0$$

thus,

$$\ln L_t = -k't + \ln L_0$$

$$\ln L_t - \ln L_0 = -k't$$

$$\ln\left(\frac{L_t}{L_0}\right) = -k't$$

$$\frac{L_t}{L_0} = e^{-k't} \quad \text{—— (III)}$$

Also,

$$2.303 \log_{10}\left(\frac{L_t}{L_0}\right) = -k't$$

$$\log_{10}\left(\frac{L_t}{L_0}\right) = \frac{-k'}{2.303} \times t$$

$$\frac{L_t}{L_0} = 10^{-kt} \quad ; \text{ where } k = \frac{K'}{2.303}$$

$$L_t = L_0 \times 10^{-kt} \quad \text{----- (IV)}$$

; where L_0 = initial first stage BOD.

If y_t represents the amount of BOD exerted or satisfied after 't' days,

$$BOD, y_t = L_0 - L_0 10^{-kt}$$

$$BOD, y_t = L_0 (1 - 10^{-kt}) \quad \text{—— (V)}$$

Note: The ultimate first stage BOD is obtained by substituting $t = \infty$ in the equation (V)

$$y_u = L_0 (1 - 10^{-K \times \infty})$$

$$y_u = L_0 (1 - 0)$$

$$y_u = L_0$$

Relation of de-oxygenated rate constant with temperature

$$K_T = K_{20} \times (1.047)^{T-20}$$

*! Chemical Oxygen Demand (COD):

- Chemical oxygen demand is defined as the amount of oxygen required to oxidize organic matter by strong oxidising agent.
- BOD analysis takes minimum 5 days that cannot be useful for treatment process, so COD results are used.
- COD analysis takes only 3 hours time.
- COD value is relatively higher than BOD value

Note:

- COD value is used during plant operation whereas BOD value is used for monitoring sewage as per environmental regulations and standards.

Examination of Waste water:

> Examination of waste water involves various tests to be carried out for determining characteristics of waste water:

Necessity of sewage examination:

1. For determing strength of sewage.
2. For determining various substance present in sewage
3. For determining degree of treatment required.
4. For determining physical, chemical and biological characteristics.

Examination of waste water is carried out by:

i. physical test
ii. Chemical test.
iii. Biological test

I. physical tests:

a. colour : tintometer.

b. Odour: threshold odour number.

c. Temperature: thermometer.

d. Turbidity: Turbidity rod or Jackson turbidity unit.

II. chemical tests:

a. pH: pH meter.

b. solids:

> in terms of total solids, volatile and fixed solid suspended and dissolved solids etc.

c. Nitrogen:

III. Biological test:

a. BOD test:

- BOD test is carried out by two methods:
  1. Direct methods.
  2. Dilution methods.

1. Direct method:

- This test consists of keeping sample of wastewater in contact with a definite air or oxygen in a specially prepared vessel.

2. Dilution method:

- This method is based on determinatio of DO in undiluted sample and DO in diluted sample after incubation.

I. Dissolved oxygen (DO) present in undiluted sample is determined.

II. The sewage is diluted with specially prepared dilution water so that adequate "nutrients" will be available during incubation period.

III. DO present in diluted sample before incubation is determined.

IV. Diluted sample is then incubated at constant temperature of 20°C for 5 days.

V. DO present in incubated sample after 5 days is determined.

VI. Oxygen consumed = Initial DO - final DO

BOD_5 = oxygen consumed × dilution ratio

= (Initial DO − final DO) × Dilution ratio

; where Dilution ratio = $\frac{\text{vol. of diluted sample}}{\text{vol. of undiluted sample.}}$

for % mixtures

$$\text{Dilution ratio} = \frac{100}{\%\ \text{mixture}}$$

b. COD test:

steps:

I. Sewage sample is diluted with distilled water.

II. Known quantities of standard potassium dichromate solution ($K_2Cr_2O_7$) & conc. sulphuric acid (H_2SO_4) are added to known volume of sewage sample.

III. Mixture is then boiled with silver sulphate (Ag_2SO_4) as catalyst for 2 hours and then cooled.

IV. The amount of dichromate remaining is measured by titration with standard ferrous ammonium sulphate solution $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$

V. COD is determined by calculating oxygen used in oxidising the sewage from dichromate.

Q. Differentiate between BOD and COD: [5 marks]

S.N.	BOD	S.N.	COD
(i)	BOD is biological oxidation process.	(i)	COD is chemical oxidation process.
(ii)	BOD is performed by aerobic bacteria.	(ii)	COD is performed by chemical reagents.
(iii)	BOD value is determined in 5 days.	(iii)	COD value is determined within few hours (3-5) hrs
(iv)	BOD value is lower than COD value.	(iv)	COD value is higher than BOD value.
(v)	BOD value is determined by keeping sealed water sample under specific temperature for 5 days.	(v)	COD value is determined by placing water sample with strong oxidizing agent under specified temperature for few hrs.
(vi)	Used for monitoring sewage	(vi)	Used for plant operation.

Numerical:

Q1. The BOD_5 of a sewage incubated at 30°C is found to be 170 mg/l. What will be the 5 day BOD at 20°C? Assume K = 0.12 (base 10) per day at 20°C.

Solution:

At 30°C

$BOD_5 = 170$ mg/l

$K_{30} = ?$

At 20°C

$K_{20} = 0.12$ per day

$BOD_5 = ?$

$\therefore K_{30} = (1.047)^{30-20} \times 0.12 = 0.189$ per day

$BOD_5 = L_0(1 - 10^{-KT})$

$170 = L_0(1 - 10^{-0.189 \times 5}) \Rightarrow L_0 = 191.705$ mg/l

Now,

BOD_5 at 20°C $= L_0(1-10^{-KT})$

$= 191.765\,(1-10^{-0.12\times5})$

$= 143.596$ mg/l. Ans.

Q2. 2.5 ml of raw sewage is diluted to 250 ml. DO concentration of diluted sample at the beginning was 7.8 mg/l and 5.1 mg/l after the 5 day incubation at 20°C, find the 5-day BOD of raw sewage and kg of BOD contained in 3.2 million litres of sewage.

<u>Solution:</u>

Vol. of sewage before dilution = 2.5 ml

" " " after " = 250 ml

Initial DO = 7.8 mg/l

Final DO = 5.1 mg/l

Now,

Dilution factor $= \frac{250}{2.5} = 100$

(i) BOD_5 = (initial DO − final DO) × D.F.

$= (7.8-5.1)\times100$

$= 2.7\times100$

$= 270$ mg/l

(ii) kg of BOD contained $= \frac{270}{1000\times1000}\times3.2\times10^6$

$= 864$ kg. Ans.

Q3. The following observation were made on 5% dilution of a sewage sample. The DO of blank is 5 mg/l and DO of sample after 5-day incubation at 20°C is 1 mg/ltr. calculate BOD_5 and ultimate BOD of sample. Assume DO of original sample as 0.5 mg/l.

solution:

DO of blank = 5 mg/ltr.

DO of original sample = 0.5 mg/ltr.

DO of test specimen before incubation = DO of blank × its % concn + DO of original sample × its % concn.

$$= 5 \times 0.95 + 0.5 \times 0.05$$

$$= 4.775 \text{ mg/l}$$

DO of sample after incubation = 1 mg/l.

DO consumed = initial DO − final DO

$$= 4.775 - 1$$

$$= 3.775 \text{ mg/l}$$

BOD_5 = DO consumed × D.F.

$$= 3.775 \times \left(\frac{100}{\% \text{ mixture}}\right)$$

$$= 3.775 \times \frac{100}{5}$$

$$= 75.50 \text{ mg/l.}$$

for ultimate BOD:

$$BOD_5 = L_0(1 - 10^{-kt})$$

$$75.50 = L_0(1 - 10^{-0.12 \times 5})$$ (Assume k = 0.12 perday at 20°C)

on solving, we get

$$L_0 = 100.12 \text{ mg/l}$$

: Sewage Treatment:

↳ Waste water treatment process is defined as the process in which impurities present in waste water is removed partially and changed into stable organic solids.

↳ waste water treatment compose of 3-units:

a. Physical units:

↳ screen
↳ skimming tank
↳ Grit chamber
↳ sedimentation tank.

b. chemical units:

↳ chemical precipitation unit
↳ Aeration tank
↳ Disinfection tank
↳ De-chlorination tank.

c. Biological units:

↳ Activated sludge unit
↳ Oxidation pond
↳ Filtration units

Classification of waste water treatment process:

↳ waste water treatment process is classified into 4 types

1. Preliminary process:
    a. screening
    b. skimming
    c. Grit removal.

2. Primary process:
    a. sedimentation
    b. chemical precipitation.

3. Secondary treatment process.
    a. Aeration
    b. filtration
    c. activated sludge process
    d. oxidation pond and ditches.

↳ suspended growth process
↳ attached growth process
↳ combined growth process

4. Tertiary treatment process.
    a. Disinfection.
    b. chlorination.
    c. Nitrogen removal.
    d. Demineralization.
    e. membrane technique.
    f. reverse osmosis process.

g: flowsheet of treatment process of waste water:

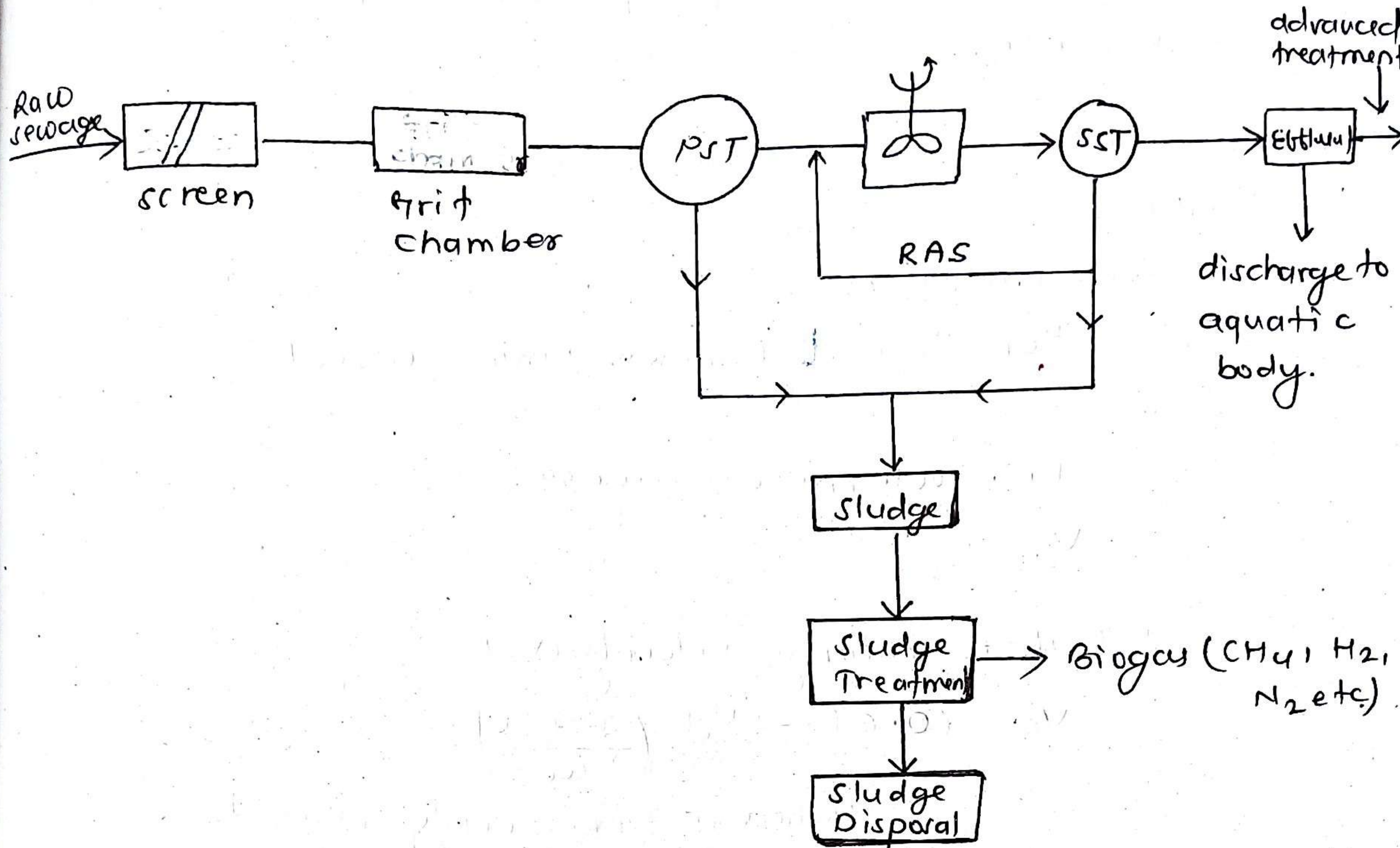


fig: layout process of waste water treatment plant.

A. Pre-liminary treatment:

1. Screening:

↳ process of removing large floating and suspended matters such as dead animals, plastics, leaves etc.

Types of screen:

a. coarse screen.

b. medium screen.

c. fine screen.

2. skimming:

↳ Process of removing oily substances such as grease, fat, wax etc.

3. Grit chamber:

↳ process of removing grit particles such as sand, gravel clinker etc.

Grit chamber design steps:

Known:

discharge = q m^3/s.

detention time = t (approx. 1 min = 60 sec)

steps:

1. calculate volume of sewages

$$V_s = q_s \times t$$

2. Calculate settling velocity (V_s)

$$V_s = 60.6 (S_g - 1) d_g \left(\frac{3T + 70}{100}\right)$$

; where S_g = sp. gravity of grit.

d_g = diameter of grit particles

T = temperature.

3. Calculate depth of tank:

$$\text{Depth } (D) = V_s \times t$$

; V_s = settling velocity.

t = detention time.

4. Calculate area of grit chamber

$$\text{Area } (A) = \frac{\text{volume}}{\text{depth}}$$

5. Assume the width of grit chamber:

width (B) = 1 to 2 m

6. calculate length of tank:

$$A = L \times B$$

$$\Rightarrow L = \frac{A}{B} = ---$$

7. Provide free board of 0.25m (approx).

8. check for velocity,

- calculate setling velocity of organic matter & grit.

$$V_{sc\,organic} = \sqrt{\frac{8K(S_g - 1) g d_g}{f_s}}$$

f = darcy frictional factor (0.03) ; K = 0.06

$S_g = 2.65$ for grit

$S_g = 1.2$ for organic matter.

- calculate flow velocity

$$V_h = K\sqrt{(S-1) g d_g} \text{ or } \frac{Q}{B \times D}$$

; K = 4 (V_h = 0.15 m/s to 0.30 m/s)

$\therefore$ $V_{sc\,grit} > V_h > V_{sc\,organic}$ (ok).

Numerical:

Q1. Design a grit chamber for maximum flow of sewage 4×10^6 l/day. having sp. gravity of grit = 2. size of the grit particle to be removed is 0.25mm. Assume temperature 20°C. Assume other necessary data suitably.

solution

sewage flow, $Q_s = 4 \times 10^6$ l/day

Assume detention time, t = 1 min = 60 sec.

$$Q_s = \frac{4 \times 10^6 \times 10^{-3}\ m^3}{24 \times 60 \times 60\ s}$$

$$Q_s = 0.0463\ m^3/s.$$

sewage volume (V) = $q \times t$

$= 0.0463 \times 60$

$= 2.78\ m^3$

settling velocity of sewage, $V_s = 60.6\,(S_g - 1)\left(\frac{3T+70}{100}\right) d$

$= 60.6 \times (2-1) \times \frac{0.25}{1000} \times \left(\frac{3 \times 20 + 70}{100}\right)$

$= 0.019\ m/s.$

Depth of grit chamber = $V_s \times t$

$= 0.019 \times 60$

$= 1.14\ m$

Area of grit chamber $= \frac{V}{D}$

$= \frac{2.78}{1.14} = 2.438\ m^2$

Assuming width of grit chamber (B) = 0.5 m.

length $L = \frac{A}{B} = \frac{2.438}{0.5} = 4.87\ m.$

taking 0.25 m for grit storage and 0.25 m for free board,

total depth = 1.14 + 0.5 = 1.64 m. R.

Check for velocity:

$V_{sc_{organic}} = \sqrt{\frac{8 \times 0.06 \times (1.2-1)\ 9.81 \times \frac{0.25}{1000}}{0.03}} = 0.088$

$V_{sc_{grit}} = \sqrt{\frac{8 \times 0.06 \times (2-1)\ 9.81 \times \frac{0.25}{1000}}{0.03}} = 0.198\ m/s.$

Horizontal flow velocity, $V_h = \frac{Q}{B \times D}$

$$= \frac{0.0463}{0.5 \times 1.14} = 0.08 \text{ m/s.}$$

Since $V_h <$ 0.15 m/s to 0.30 m/s (range)

Redesign the tank.

Assume width = 0.25 m

$$L = \frac{2.438}{0.25} = 9.75 \text{ m.}$$

Now,

$$V_h = \frac{0.0463}{0.2 \times 1.14} = 0.16 \text{ m/s.} \quad (0.15 \text{ m/s} - 0.30 \text{ m/s}) \text{ (ok).}$$

$$V_{sc_{grit}} > V_h > V_{sc_{organic}} \text{ (ok).}$$

B. Primary treatment:

4. Sedimentation:

- process of removal of fine suspended impurities under the action of gravity. is called sedimentation.

- primary settling tank and secondary settling tank are used in wastewater treatment process.

Design of sedimentation tank:

- same as watersupply part:

5. Chemical precipitation:

- process of removing suspended and colloidal impurities from waste water by adding coagulants.

Process involved:

(i) Feeding of coagulants.
(ii) Mixing of coagulants.
(iii) Flocculation.
(iv) sedimentation.

C. secondary treatment / Biological treatment:

- Removal of colloidal and dissolved organic matter from sewage by biological action.

Principle of biological treatment process:

- The basic principle of biological treatment process is to create favourable environment condition required for micro-organism (bacteria).

Types of bacteria:

a. Aerobic bacteria.
b. Anaerobic bacteria.
c. Facultative bacteria.

↳ Biological decomposition of organic matter occurs by two types:

① Aerobic decomposition.

⑪ Anaerobic decomposition.

↳ Further biological decomposition process occurs by following three process:

a. suspended growth process.

b. attached growth process.

c. combined growth process.

a. suspended growth process:

↳ cells tissues / mo are maintained in suspension.

↳ eg: activated sludge process, aeration lagoons, sludge digestion tank etc.

b. Attached growth process:

↳ cells tissues / mo are attached to some inert medium.

↳ eg: trickling filter, sand filter etc.

c. combined growth process:

↳ cells tissues / mo are maintained in suspension with liquid as well as attached to some inert medium.

↳ eg: trickling filter activated sludge process, facultative lagoons.

6. Filtration:

- process of passing sewage from filter bed
- biological treatment process.

Types of filter used in wastewater treatment plants:

1. Intermittent sand filter.
2. Contact bed filter.
3. Trickling filter.

(i) Intermittent sand filter:

- Rectangular tank with specially prepared sand bed.
- Tank is 1 to 1.25 m deep, 1000 to 4000 m^2 plan area, $\frac{L}{B}$ = 3 to 4.
- Filtering media consists of sand of size 0.2 to 0.5 mm with uniformity coefficient 2 to 5.
- In order to facilitate drainage, gravel of depth 0.15 to 0.30 m depth is provided.

(ii) Contact bed filter:

- Rectangular tank with gravel, ballast, broken stones of size 15 to 40 mm as filter media.
- Depth of filter bed = 1.2 m and area of filter = 2000 m
- Four cycles of working,
  - i. Filling
  - ii. Contact
  - iii. Emptying.
  - iv. Resting for oxidation.

(iii) Trickling filter:

- circular shaped reinforced cement concrete tank with stone or broken bricks as filter media.
- sewage is applied by sprinkling.
- Filter media consists of stones, gravels and coal of effective size 25 to 75 mm.
- Depth of filter material: 1.2 to 1.8 m.
- Preferred for treatment of strong or moderate sewage.

Types of trickling filter:

(i) convectional/standard trickling filter.
(ii) High rate trickling filter.

7. Activated sludge Process:

↳ An activated sludge process is an aerobic suspended growth biological decomposition process. used for treatment of waste water.

- Aerobic biological decomposition process:

$$\text{Bio. degradable OM} \xrightarrow[\text{aerobic MO}]{O_2} \text{decomposed. OM.}$$

- suspended growth process.

MO is maintained in suspension in waste water.

↳ In this process raw water is aerated for some hours (4-8) hrs.

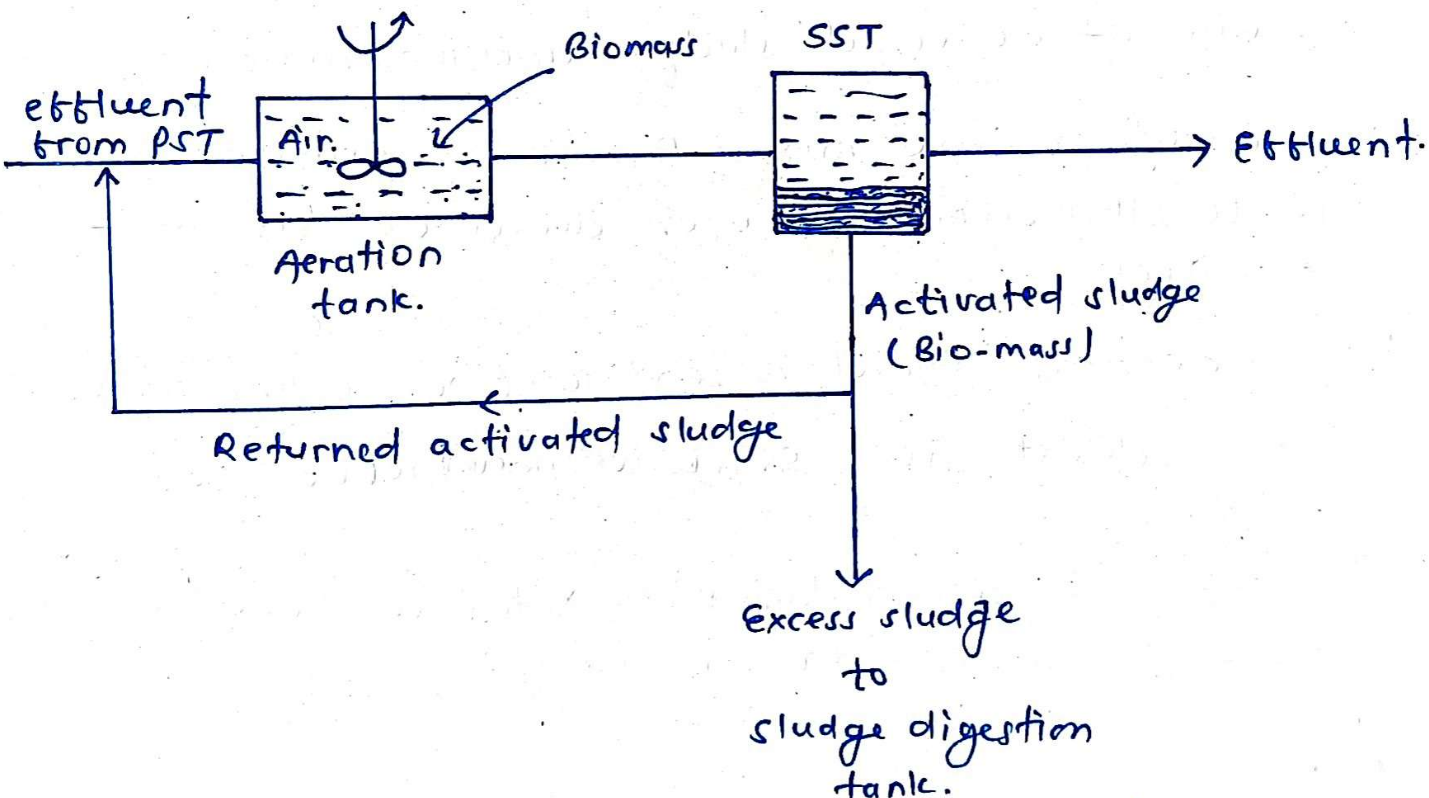


fig: activated sludge process layout

Principle of ASP:

↳ ASP has two principle action:

a. Physical action.

b. Biochemical action.

a. Physical action:

↳ aeration helps to combine small suspended particles to form bigger flocs.

b. Biochemical action:

↳ Bacteria use organic matter and decompose into stable products.

Operating mechanism:

I. The effluent from PST is mixed up with required amount of activated sludge and sent in aeration tank

II. In aeration tank, mixed liquoir is aerated and agitated for (4-8)hrs depending upon degree of treatment required.

III. The aerated liquid is sent to final settling tank.

IV. The effluent from SST which is clear is disposed off.

V. A part of settled sludge is returned back in aeration unit for seeding the raw sewage

Advantages:

(I) less initial cost

(II) clear effluent and no fly nuisance.

(III) small operational head

(IV) degree of purity can be varied as per desire.

(V) No need of pumping and effluent is free from offensive odour.

Disadvantages:

(i) high operational cost.
(ii) large quantity of wet sludge produced.
(iii) skilled attendance is necessary.
(iv) troublesome when it gets out of odour.
(v) process is sensitive to certain types of industrial waste.

8. Oxidation pond:

↳ An oxidation pond is a low cost, large and shallow depth pond which stabilize the sewage in presence of algae and micro-organism.

↳ The pond is usually 2 to 4 feet deep (also 10 to 20 ft. deep has been used)

↳ Rate of oxidation is slower as a result (30-50) days retention time is common.

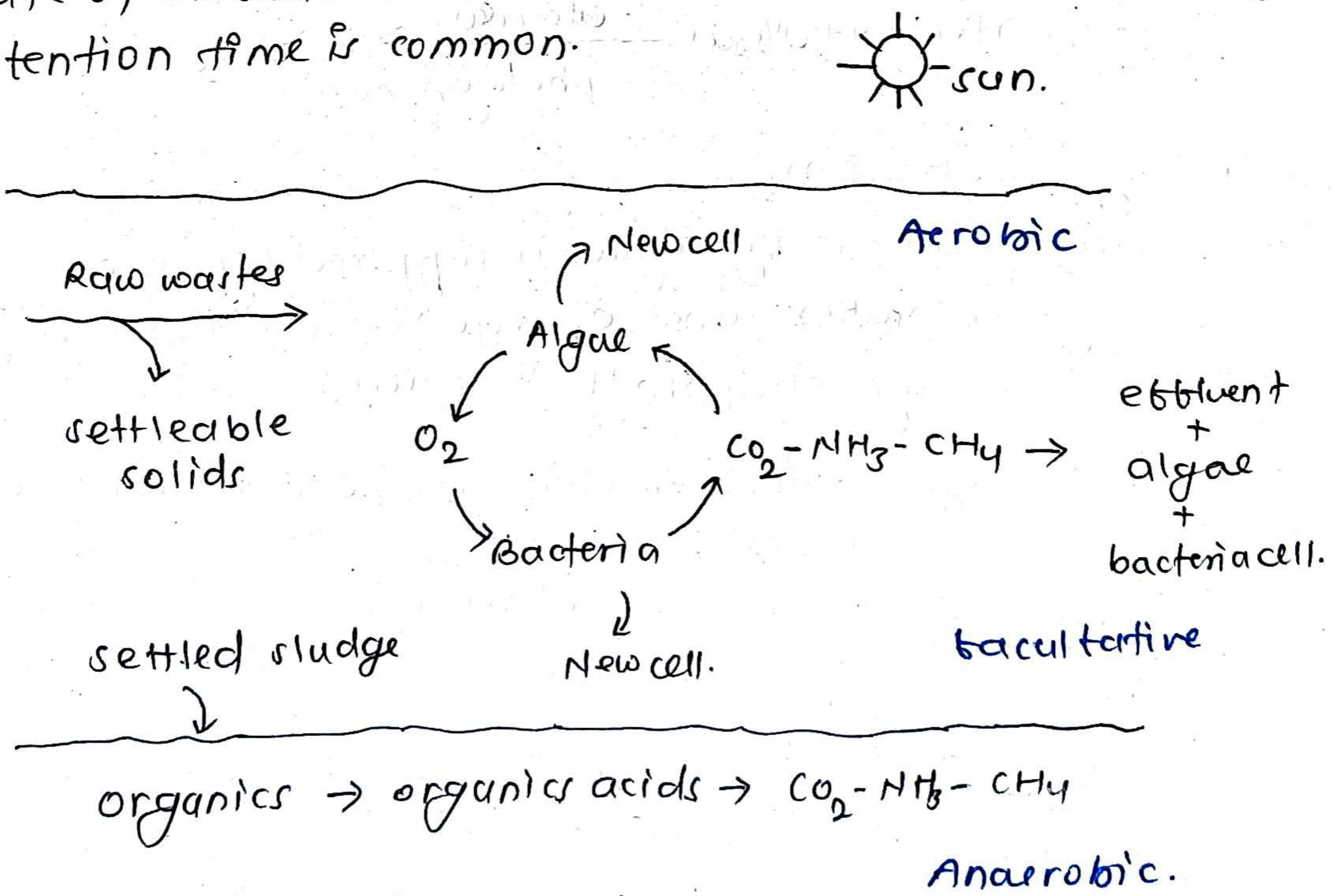


fig: oxidation pond.

Principle of oxidation pond:

- Oxidation pond is based on principle of bacteria-algae symbiosis.

  i.e. bacteria decompose organic matter aerobically and produce CO_2 gas by consuming oxygen produced by algae during photosynthesis and,

  algae consume the CO_2 produced by bacteria for photosynthesis in presence of sunlight.

  This interdependency of algae and bacteria upon each other is called symbiosis.

- Illustration:

  - Organic matter + bacteria $\xrightarrow{O_2}$ $CO_2 - NH_3 - CH_4 + H_2O$

  - Nutrients + algae $\xrightarrow[\text{photosynthesis}]{CO_2}$ O_2

Operating mechanism:

i. The CO_2 required by algae is supplied by decomposition of organic matter and O_2 required by bacteria is supplied by photosynthesis process.

ii. The sewage solids entering in pond is converted into new microbial cells.

iii. CO_2 evolved is taken by algae and multiply their number.

iv. Decomposition of sewage is carried out by aerobic, anaerobic and facultative process.

Advantages:

(i) lower initial cost than mechanical plant.

(ii) lower operating cost.

(iii) control of pollution during critical time as regulation of effluent discharge is possible.

(iv) Treatment is not influenced by leaky sewage system.

Disadvantages:

(i) Requires extensive land area.

(ii) potential odour problems

(iii) industrial wastes decomposition is less effective

: Sewage Disposal :

The treated sewage need to be disposed off. This can be done by two process:

(i) sewage disposal by dilution.
(ii) sewage disposal by land treatment.

1. Sewage disposal by dilution:

- Disposal of sewage by discharging into water bodies like rivers, streams, lakes, sea etc is called sewage disposal by dilution.
- The discharged sewage, in due course of time gets purified by self purification of river.

Essential condition for disposal by dilution:

(i) sewage should be fresh (5-6) hrs of production.
(ii) diluting water should have high DO content.
(iii) Natural water body should be available nearby
(iv) Water body should have large quantity of water.
(v) sewage should be free from toxic industrial wastes.

Self purification of river:

- When waste water is discharged into the river or stream, the BOD of mix increases initially and DO level starts falling
- As the river travels further, BOD gradually decreases and DO increases and reaches its saturation level.
- Thus the river gets purified by its own.
- This phenomena is called self purification of stream.

factors affecting self purification of stream:

- Various factors affecting self purification of stream are:

(i) Dilution
(ii) oxidation
(iii) Reduction
(iv) sedimentation
(v) Action of sunlight
(vi) current of water.
(vii) Temperature

Oxygen-sag curve:

- The curve representing the deficit of oxygen at any point of time during self purification process is called oxygen sag curve.
- The oxygen sag curve initially declines and then rises after critical DO deficit point.

Deoxygenation curve:

- curve representing oxygen deficit during the decomposition of organic matter is deoxygenation curve

Reoxygenation curve:

- curve representing oxygen deficit met up by stream is reoxygenation curve.

Note:

The combined effect of both this curve is called oxygen sag curve.

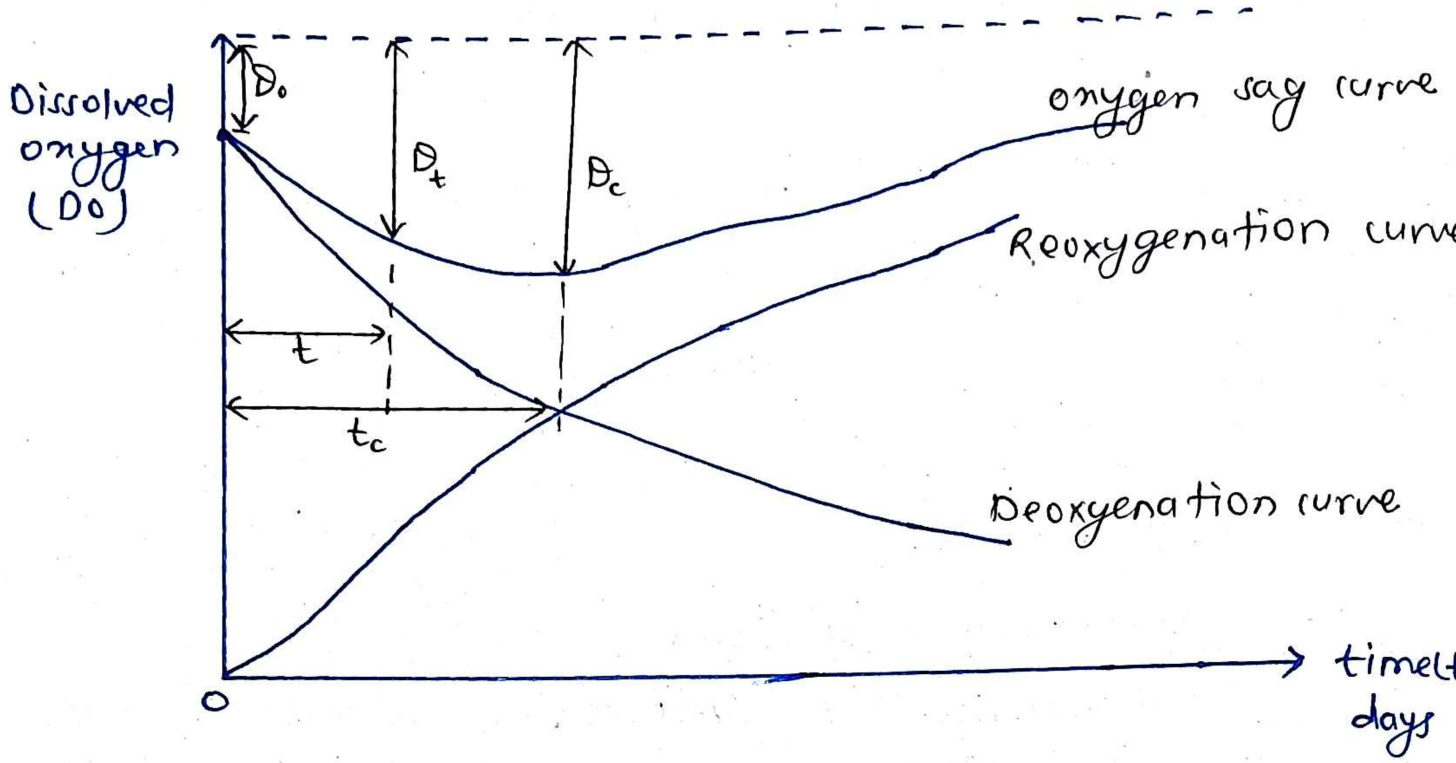


Fig: Oxygen sag curve

Streeter phelp's equation:

$$\left[\frac{L_o}{f_s D_c}\right]^{f_s-1} = \left[f_s\left(1-(f_s-1)\frac{D_o}{L_o}\right)\right]$$

; where L_o = ultimate first stage BOD.

D_c = critical DO deficit

$f_s = \frac{R}{K}$ = ratio of reoxygenation and deoxygenation constants.

D_o = initial DO deficit.

Numerical

Q1. A sewage effluent of 800 lit/sec with a BOD = 70 mg/l DO content = 3 mg/lit and temperature = 20°c enters a river where the flow is 30 m^3/s. and BOD = [illegible] mg/l, DO content = 8.8 mg/l and temperature = 18°c. Determine the following for the mixture of sewage and river.
(i) combined discharge (ii) BOD (iii) DO (iv) temperature.

Solution:

Q2. The treated domestic discharge of a town is to be discharged into a stream. Determine the maximum permissible effluent BOD and percentage of purification required in the treatment plant with following particulars.

population = 40,000

Min^m flow of stream = 0.15 m^3/s.

BOD of stream = 2 mg/l

DWF of sewage = 150 lpcd

BOD contribution per capita = 0.075 kg per day

Maximum BOD of stream downstream : 5 mg/l

solution.

DWF of sewage = 150 × 40000 l/day

$$Q_s = \frac{150 \times 40000 \times 10^{-3} \, m^3}{24 \times 60 \times 60 \, s}$$

$$= 0.069 \, m^3/s.$$

stream discharge (Q_R) = 0.15 m^3/s.

BOD of stream (BOD_R) = 2 mg/l

BOD at d/s (BOD_{mix}) = 5 mg/l.

we know,

$$BOD_{mix} = \frac{BOD_s \times Q_s + BOD_R \times Q_R}{Q_s + Q_R}$$

$$5 = \frac{BOD_s \times 0.069 + 2 \times 0.15}{0.069 + 0.15}$$

$\therefore BOD_s = 11.52$ mg/l

Thus maximum effluent BOD is 11.52 mg/l.

BOD contribution per capita = 0.075 kg per day = 75000 mg/day

$\therefore$ Actual BOD effluent $= \frac{75000}{150} = 500$ mg/l.

$\therefore$ percentage purification required $= \frac{500 - 11.52}{500} \times 100\%$

$= 97.7\%$.

Q. Differentiate between sewage disposal methods:

Ans:

S.N.	Dilution method	S.N.	Land treatment method:
(i)	Large volume of water is required.	(i)	large area of land is required
(ii)	Doesnot require frequent management.	(ii)	Requires frequent management of land.
(iii)	In urban area, disposal by dilution is cheap.	(iii)	In urban area, disposal on land is expensive.
(iv)	Efficient pre-treatment to meet the effluent quality requirement is must.	(iv)	Sewage can be applied either raw or after primary treatment.
(v)	In hot climate DO content of water is low resulting in pollution hazard.	(v)	Such complication doesnot occurs in land treatment.
(vi)	Pumping is not required.	(vi)	Pumping may be required.
(vii)	Recreational use of natural water body may vanish.	(vii)	Ground may be polluted.
(viii)	Income cannot be generated	(viii)	Income can be generated from sewage farming.

2. Sewage Disposal by land treatment:

↳ Disposal of sewage by spreading on the surface of land is called sewage disposal by land treatment.

↳ In this process organic matter and suspended solids remains on surface of soil but water percolates into the ground.

Advantages:

Disadvantages:

Essential conditions for disposal by land treatment:

a. Nature of soil: sandy, alluvium deposit.

b. climatic condition: dry

c. water table level: low water level.

d. Demand of each crop: prefermed.

e. scarcity of water: high.

Methods for land treatment:

(i) sewage farming
(ii) overland flow
(iii) Rapid infiltration.

sewage farming:

- sewage is applied to irrigation field directly.
- Production increases by 35%.

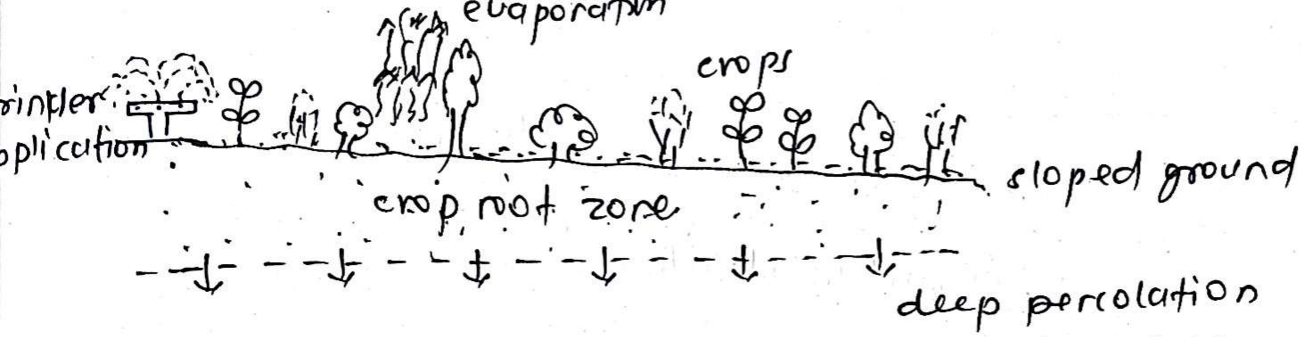


fig: sewage application on irrigation field.

Methods of application on irrigation field:

(a) flooding
(b) surface irrigation
(c) sub-surface irrigation
(d) furrow method
(e) spray irrigation.

overland flow:

- sewage is applied to irrigation field having slope 2 to 8 %.
- suitable for impermeable land

fig: overland flow.

(iii) Rapid infiltration:

- sewage is allowed to percolate to the ground
- useful for ground water recharge

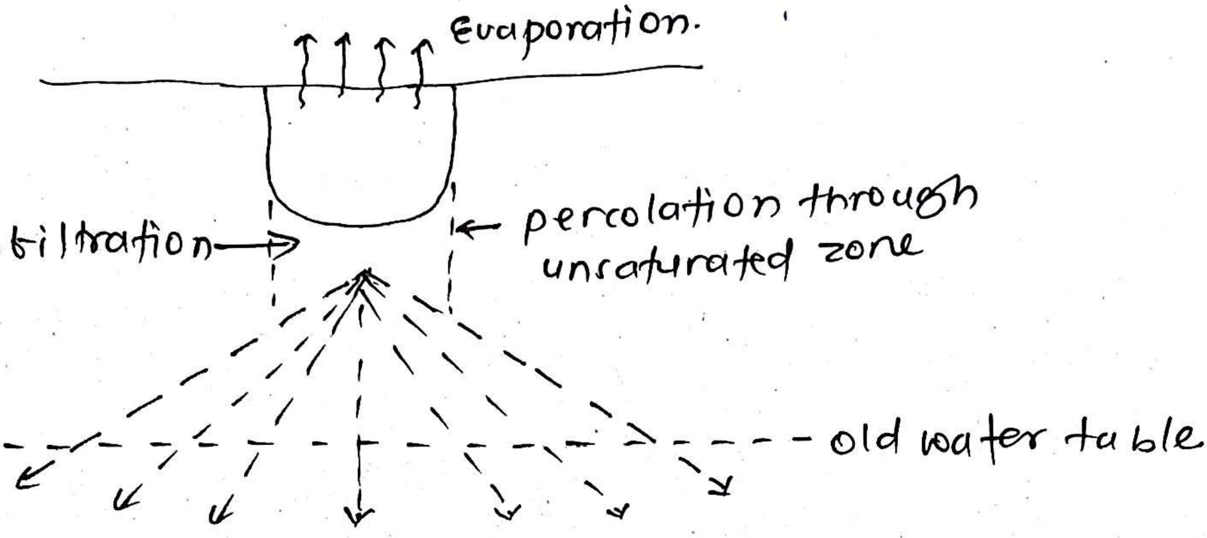


fig: rapid infiltration.

Sewage sickness:

- When sewage is applied continuously on a piece of land, pores or voids gets filled up there by free circulation of air gets prevented and anaerobic conditions develops.
- At this stage land is unable to take any further sewage load and due to anaerobic decomposition foul smells are produced by poisonous gases. This phenomena is called sewage sickness.

Prevention of sewage sickness:

- sewage sickness can be prevented by following measure

a. Pretreatment of sewage:

b. Provision of extra land.

c. construction of under drainage.

d. Proper choice of land.

e. Rotation of crops

f. shallow depth sewage application.

g. Intermittent application

h. Treatment of land (ploughing)

Sludge treatment and Disposal:

→ The residue that accumulates in sewage treatment plant is called sludge.

Sources of sludge:

(i) primary settling tank.
(ii) trickling filter
(iii) chemical coagulation plants.
(iv) secondary settling tank
(v) activated sludge process.

Necessity of sludge treatment:

(i) To reduce large volume by removing water.
(ii) To decompose organic matter to stable end products.
(iii) To make sludge suitable for reuse.

Methods of sludge treatment:

I. Grinding and blending
II. Thickening
III. Digestion or stabilization
IV. Dewatering
V. Drying
VI. composting
VII. Incineration.

I. Grinding and blending:

↳ Grinding is the process of breaking large material to produce homogenous mass.

↳ Blending is the process of mixing of sludge of different characteristics.

II. Thickening:

↳ Thickening is the process of increasing solid content of sludge. by removing portion of water.

Methods of thickening.

a. Gravity thickening.

b. Flotation thickening.

c. centrifugal thickening.

III. Digestion or stabilization:

↳ Digestion is the biological decomposition of organic matter present in sludge. into simple stable compound.

↳ Digestion involves two biological process:

a. Aerobic digestion.

b. Anaerobic digestion.

IV. Dewatering: and drying

↳ Dewatering is the removal of moisture content of sludge

↳ Methods:

a. Air drying

b. Mechanical drying.

v. Composting:

- composting is bacterial decomposition process to stabilize organic wastes and produce compost.
- compost act as excellent soil conditioners and is widely used in agriculture and horticulture.

Types of composting:

a. Windrow composting
b. Mechanical composting.

vi. Incineration:

- Burning of sludge into ashes is incineration.
- Most hygienic method for sludge treatment.

Types: of incineration:

a. Flash type furnance
b. Multiple hearth furnance.

Sludge Disposal Methods:-

- Different methods of sludge disposal are:

(i) Dumping
(ii) Land filling
(iii) Lagooning
(iv) Spreading

① Dumping:

↳ sludge is disposed by throwing into depressions or water.

↳ suitable for stabilized sludge

↳ Non-hygienic method, foul gas produced.

↳ Used for digested sludge, clean grit, incinerator residue.

⑪ Land filling:

↳ sludge is disposed by filling low lying area in proper ...

↳ suitable for both stabilized and unstabilized sludge

↳ Hygienic method.

⑪ Lagooning:

↳ sludge is disposed in lagoons or ponds.

↳ organic matters are stabilized by both aerobic and anaerobic process.

↳ suitable at place where there is no chance of ground water pollution.

↳ lagoon is of fill and draw type with (1-2) months detention period.

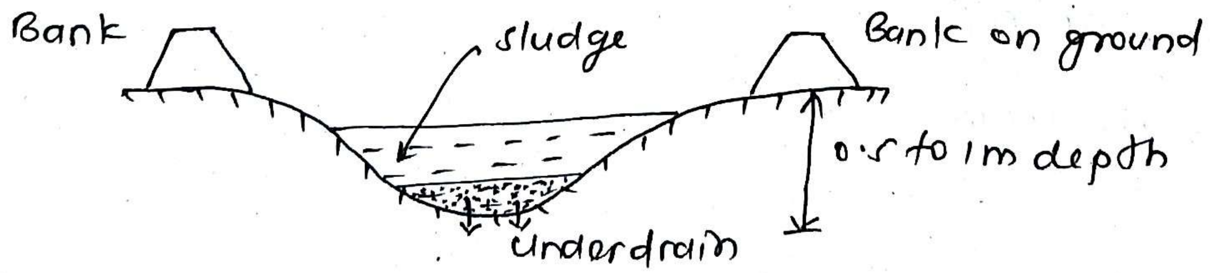


fig: lagoons

(iv) Spreading:

↳ Digested sludge is disposed off by spreading on ground as fertilizer.

↳ land should be ploughed after spreading

↳ only small amount of sludge is disposed by this process.

Extra Note: Not in syllabus:

Septic Tank and soak pit:

↳ A septic tank is an underground tank where feces, urine and other waste materials are decomposed by anaerobic digestion process.

Purpose:

(i) deposition of settling sludge

(ii) partial or complete digestion of sludge.

(iii) store sludge between successive cleaning.

General requirements of septic tank:

(i) should be water tight, constructed of brick masonary, stone masonary, concrete etc.

(ii) Rectangular in plan ($L/B = 2$ to 4)

(iii) Two compartments provided, with partition wall at $\frac{2}{3}$ rd of inlet.

(iv) Direct current is prevented using Tees at inlet and outlet.

(v) Outlet pipe is kept 15cm lower than inlet pipe.

(vi) Vent is provided for escape of gas.