* Characteristics and examination of sewage

(a) Physical Characteristics

(i) Colour

* Fresh domestic sewage – grey, somewhat resembling a weak solution of soap.
* With the passage of time, as putrefaction starts, it begins to get black.

→ Color of septic sewage - more or less black or dark in color

→ Color of industrial wastewater – depends upon the chemical process used in the industries.

(ii) Odour

→ Normal fresh sewage has a musty odour; not offensive.

→ Stale sewer – offensive odour as within 3 or 4 hrs. all the oxygen present in the sewage gets exhausted and it starts emitting offensive odour of hydrogen sulphide gas and other sulphur compounds produced by anaerobic micro-organisms.

(iii) Temperature

→ Normal temperature of sewage is slightly higher than that of natural water.

→ An increase of temp. also increases microbial activity.

→ Aerobic digestion ceases at a temp. greater than 50°c.

→ At less than 15°c, anaerobic digestion is affected.

→ The solubility of gases in waste water decreases with increase in temp. and vice – versa.

(iv) Turbidity.

→ depends on the quantity of solid matters present in the suspension state.

→ measure of light-emitting properties of wastewater, and turbidity test is used to indicate the quality of waste discharges w.r.t colloidal matter.

→ depends upon the strength of sewage or waste water. The stronger or more concentrated the sewage, the higher is its turbidity.

→ determined either by Turbidity rod or Jackson's turbidimeter.

(v) Total Solids

→ Sewage normally contains 99.9 percent of water and 0.1 percent of solids.

→ Analytically, the total solids content (S_T) of a wastewater is defined as all the matter that remains as residue upon evaporation to 103 to 105°c.

- Total Solids
  - Filterable (passing from filter paper)
    - Dissolved
    - Colloidal
  - Non-Filterable (retain on filter paper) (suspended)
    - Settlable
    - Non-settlable

- Total Solids
  - Fixed Solid (In-organic solid) eg. sand, gravel, debris etc
  - Volatile Solid (organic solid)
    - Nitrogenous (urea, proteins, amines & amino acids)
    - Non-nitrogenous (carbohydrates, Soaps)

* Objectives of examination of sewage.

(1) To identify the strength, characteristics, and constituents of wastewater.

(2) To control and regulate the sewage treatment plant

(3) To find the behavior of water bodies after dilution.

(4) To prescribe the degree of treatment and treatment process.

(5) To know the physical, chemical, and biological characteristics of waste water.

(b) Chemical Characteristics

(i) pH Value

→ fresh sewage - generally alkaline in nature (7·3 to 7·5)

→ As time passes, pH value tends to fall due to production of acids by bacterial action, & sewage tends to be acidic.

→ However, after oxidation, when it is relatively stable, it becomes alkaline again

→ High concentration of either an acid ($pH \ll 7$) or alkali ($pH \gg 7$) in wastewater is indicative of industrial wastes.

(ii) Chlorides Content

→ mineral salts.

→ measured by tiltrating the sample of wastewater with standard silver nitrate solution, using potassium chromate as indicator.

(iii) Nitrogen Content

→ Presence of nitrogen in wastewater indicates the presence of organic matter in it.

→ Appears in five different forms in wastewater

(1) Ammonia Nitrogen or free ammonia

(2) Organic Nitrogen

(3) Albuminoid nitrogen

(4) Nitrites nitrogen and

(5) Nitrates nitrogen

(iv) Fats, grease and Oils.

→ fats & oil are mainly contributed by kitchen waste.

→ oil & grease - from garages & workshops

→ float on the top of the sedimentation tanks, often choke pipes in winter, & clog the filter.

(v) Surfactants

→ Come primarily from synthetic detergents · discharged from kitchens, bathrooms, washing machines etc.

→ Cause foaming in wastewater treatment.

(vi) Phenols, Pesticides and agricultural chemicals

(vii) Toxic Compounds

↳ Copper, lead, Silver, Chromium, arsenic & boron - toxic to micro-organisms

↳ results from industrial wastewater.

(viii) Oxygen

→ reported in following three ways:

(1) Oxygen Consumed

→ Oxygen required for the oxidation of carbonaceous matter.

(2) Dissolved Oxygen (DO)

→ amount of oxygen in the dissolved state in the wastewater.

→ Presence of DO in untreated wastewater indicates that the wastewater is fresh.

→ Presence in treated wastewater / effluent indicates that considerable Oxidation has been accomplished during the treatment stages.

→ atleast 4 ppm of DO

(3) Oxygen Demand

→ expressed in following ways

(a) Biochemical oxygen demand (BOD)

(b) Chemical oxygen demand (COD)

(c) Total oxygen demand (TOD)

(c) Biological Characteristics

(1) Aquatic Plants - eg. water weeds, Algae, Mosses, ferns etc.

(2) Aquatic Animals - eg. fish & Amphibia, Snails, insects, earthworm, hydra, Polyzoa

(3) Aquatic molds, bacteria & Viruses
(fungi)

* Decomposition of sewage

→ takes through combined biological and chemical processes.

→ The decomposition of organic matter takes place through the agency of different types of bacteria (ie. aerobic bacteria, anaerobic bacteria or facultative bacteria) and the nitrogenous and carbonaceous materials in the sewage serve as food for them.

The biological decomposition can be of two types:

(i) Aerobic decomposition (also called aerobic oxidation)

(ii) Anaerobic decomposition (also called putrefaction)

Aerobic decomposition

→ caused by aerobic bacteria as well as facultative bacteria operating aerobically, in presence of air or oxygen which is available in the wastewater in the dissolved form.

→ Organic matter is broken up & oxidized to form stable & non objectionable end products like carbon dioxide, nitrates, sulphates etc.

→ Treatment units which work on aerobic decomposition are trickling filters, aeration tanks, contact beds, oxidation ponds etc.

Anaerobic decomption

→ Caused by anaerobic bacteria, as well as facultative bacteria, operating anaerobically.

→ The anaerobic bacteria survive by extracting and consuming the bounded molecular oxygen present in compounds like nitrates (NO_3) and sulphates (SO_4).

→ The end products of putrefaction include black residue, nitrogen, hydrogen etc.

→ Treatment units which work on putrefaction are septic tanks, Imhoff tanks, and sludge digestion tanks.

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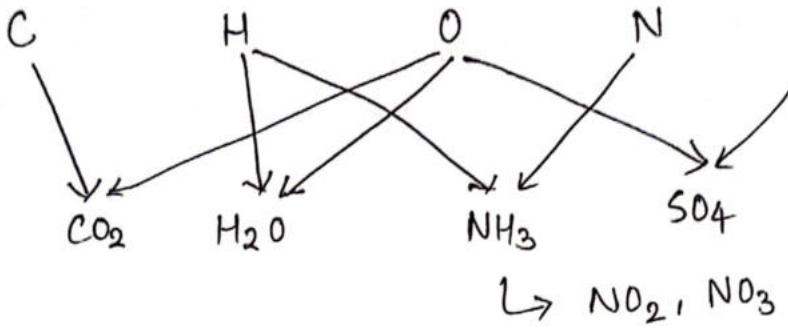
* Aerobic Decomposition

$$Protein + O_2 \xrightarrow[Bacteria]{Aerobic} CO_2 + H_2O + NH_3$$
$\hookrightarrow NO_2, NO_3$

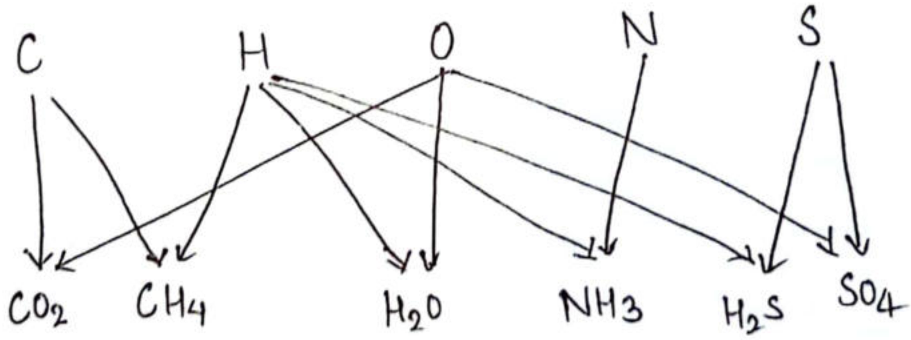
$$Carbohydrate + O_2 \xrightarrow[Bacteria]{Aerobic} CO_2 + H_2O$$

$$fats + O_2 \xrightarrow[Bacteria]{Aerobic} CO_2 + H_2O$$



$$Organic\ Matter + free\ O_2 \xrightarrow[Bacteria]{Aerobic} new\ cells + Stable\ Compounds + CO_2 + heat$$

* Anaerobic Decomposition

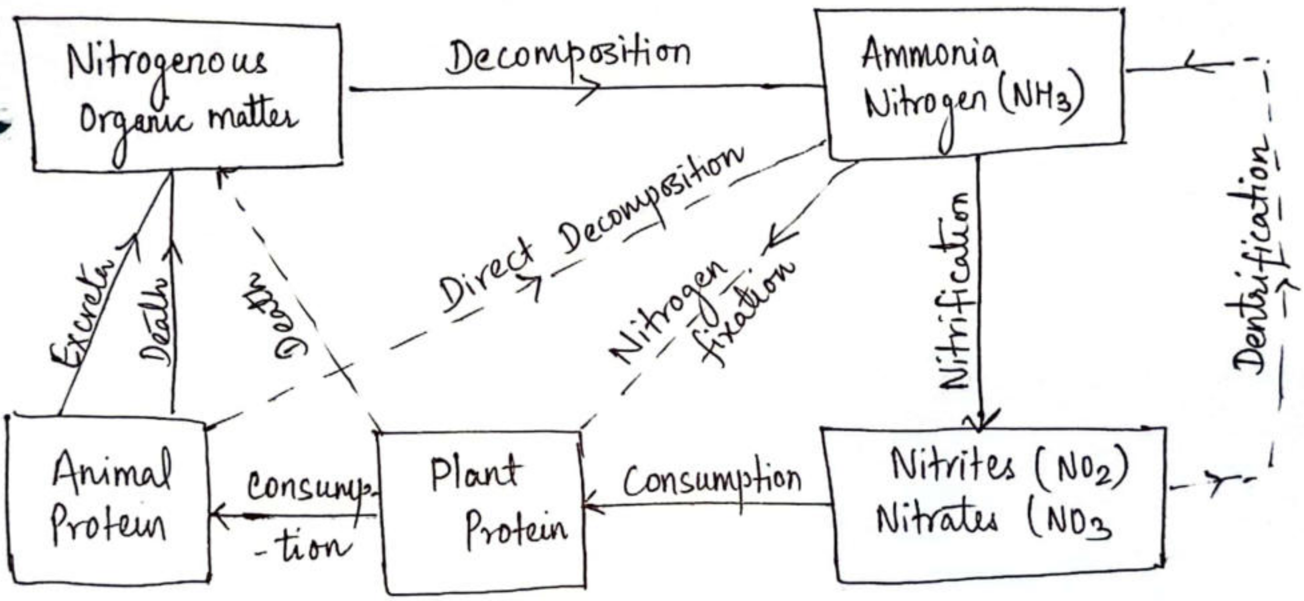


$$Organic\ Matter + Molecular\ O_2 \xrightarrow[Bacteria]{Anaerobic} New\ cells + stable\ products + NH_3 + CO_2 + H_2S + CH_4 + heat$$

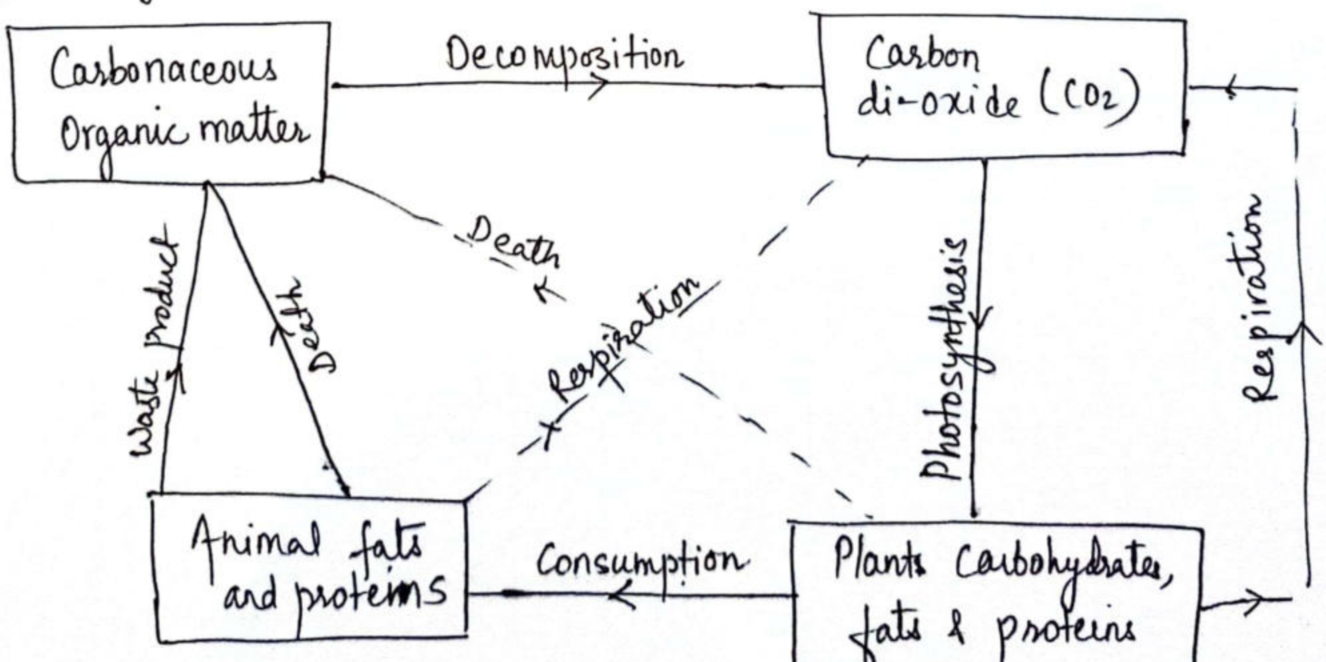
Cycles of Decomposition

(i) Nitrogen Cycle
(ii) Carbon Cycle
(iii) Sulphur Cycle
(iv) Calcium Cycle
(v) Phosphrous Cycle

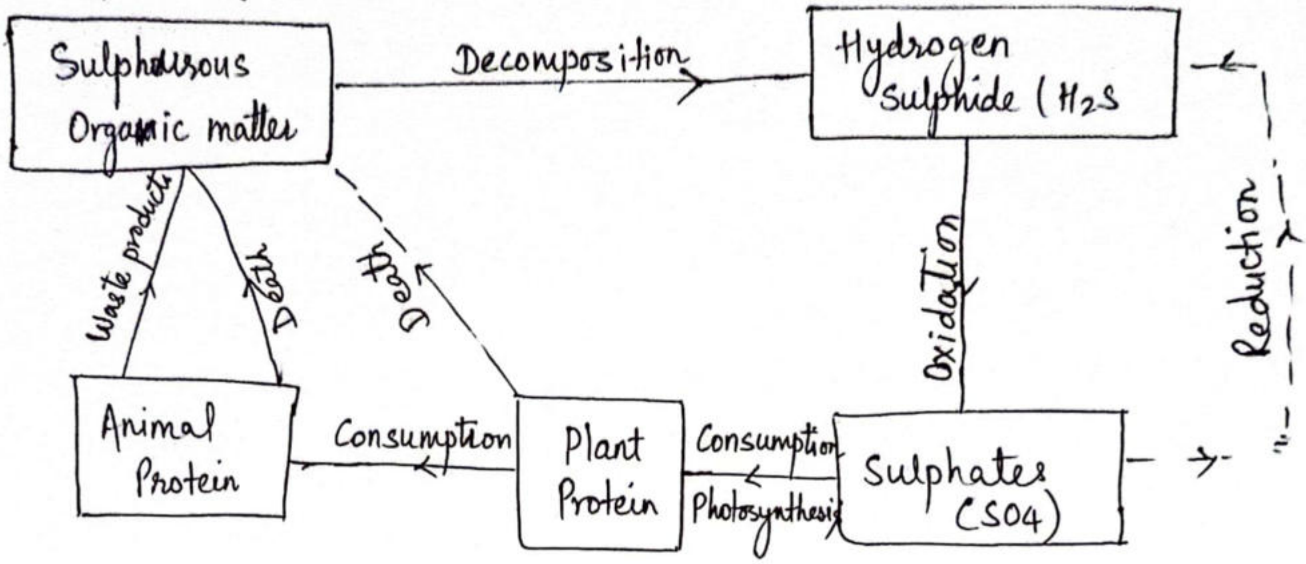
* Nitrogen Cycle



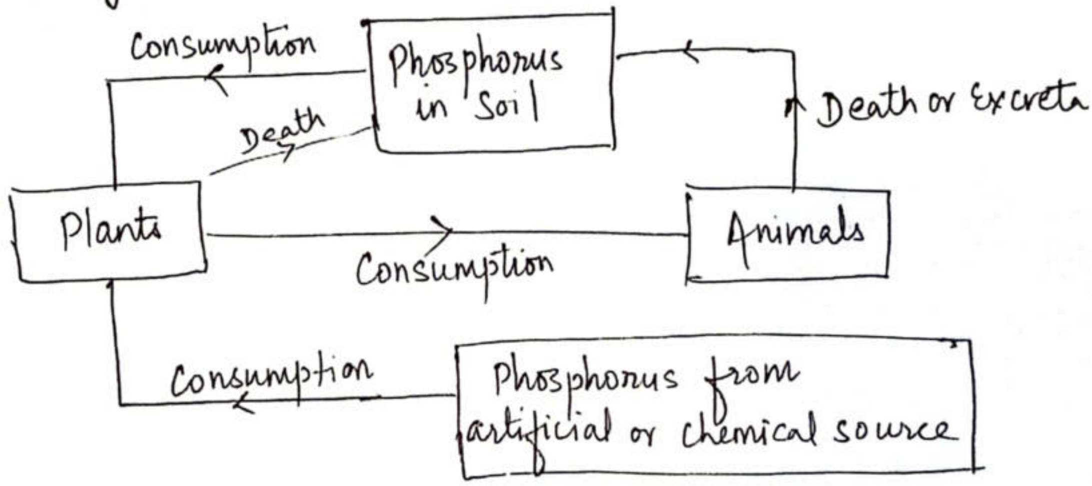
* Carbon Cycle



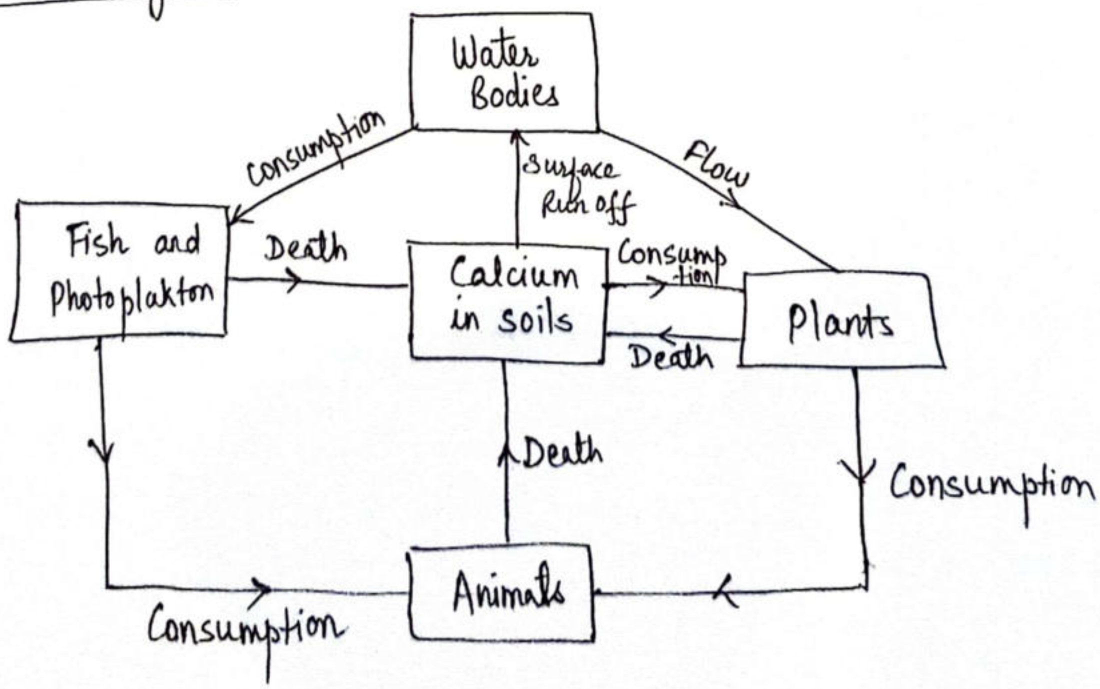
Sulphur Cycle



Phosphorous Cycle.



Calcium Cycle



Biochemical Oxygen Demand (BOD)

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

The BOD test results are used for the following purposes:

(i) Determination of approximate quantity of oxygen required for the biological stabilization of organic matter present in the wastewater.

(ii) Determination of size of wastewater treatment facilities.

(iii) Measurement of efficiency of treatment processes.

(iv) Determination of strength of sewage

(v) Determination of amount of clear water required for the efficient disposal of wastewater by dilution.

Organic matter present in wastewater may belong to two groups:
(i) Carbonaceous matter and (ii) Nitrogenous matter

→ The ultimate carbonaceous BOD of a liquid waste is the amount of oxygen necessary for the micro-organisms in the sample to decompose the carbonaceous materials that are subject of microbial decomposition. This is the first stage of oxidation & the corresponding BOD is called first stage demand.

→ The nitrogenous oxygen demand caused by the autotrophic bacteria is called the second stage BOD.

Generally, a 5 day period is chosen for standard BOD test, during which oxidation is about 60 to 70 percent complete, while within 20 days period, the oxidation is about 95 to 99 percent complete.

A constant temperature of 20°c is maintained during the incubation

The BOD value of 5-day incubation period is generally written as BOD_5 or 5-day BOD.

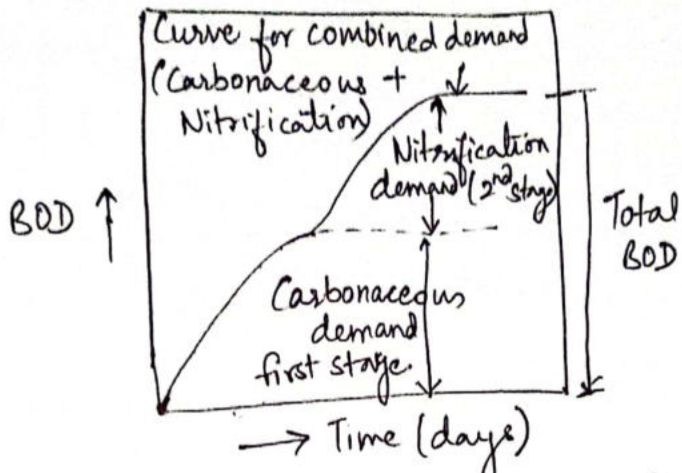


fig: Combined Carbonaceous & Nitrification demand.

* BOD Test

→ performed by two methods

(i) Direct method (ii) Dilution method

Direct Method

→ Consists of keeping the sample of wastewater in contact with a definite air or oxygen, in a specially prepared vessel.

→ The BOD is then measured menometrically.

Dilution Method

→ Commonly used method.

→ In this method, the sample is suitably diluted with a specially prepared dilution water (include a mixture of salts providing all trace nutrients necessary for biological activity, along with phosphate buffer to maintain a neutral pH)

→ The water is aerated to saturate it with oxygen before mixing it with the sewage sample.

→ The initial DO of this diluted ~~water~~ ~~is~~ sample is measured.

→ The diluted sample is then incubated for 5 days at 20°C in an air tight glass vessel.

→ DO of the sample is then again measured.

$$\text{Oxygen consumed} = \text{Initial DO} - \text{final DO}$$

$$BOD_5 = [\text{Oxygen consumed}] * \text{Dilution ratio}$$

where,

$$\text{Dilution ratio} = \frac{\text{Volume of diluted sample}}{\text{Volume of undiluted sewage sample}}$$

Limitations of BOD test

(i) BOD test measures only biodegradable organic matter.

(ii) Pretreatment is needed if the sample contains toxic wastes.

(iii) The effects of nitrifying bacteria should be reduced or eliminated by pretreatment or by use of inhabitory agents before the test is applied.

(iv) It is essential to have high concentration of active bacteria present in the sample waste water. If relatively clean industrial wastes are to be analysed, a high concentration of active, acclimated seed bacteria is required to be applied.

(v) The test looses its stoichiometric validity after the soluble organic matter present in the solution has been used or exhausted

(vi) The test uses an arbitrary long period of time, to obtain results.

(vii) for the BOD_5 test, the 5-day period may or may not correspond to the point where soluble organice matter present has been used.

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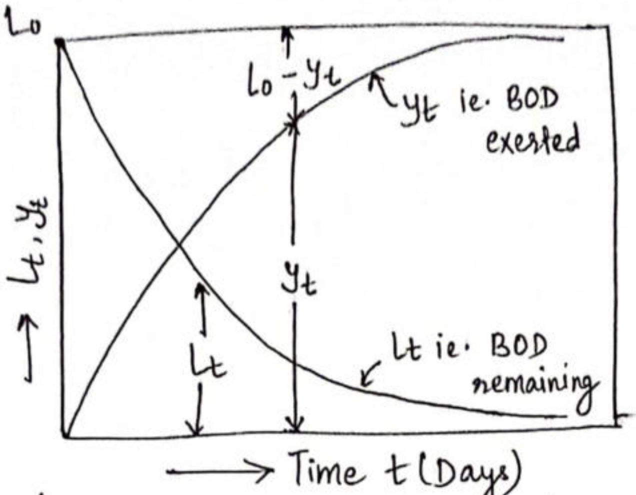
Expression for BOD

The BOD exerted and BOD remaining expressed below are represented by the curves shown in figure below :



At a given temperature, the rate at which BOD is satisfied at any time (ie. rate of deoxygenation) may be assumed to be directly proportional to the amount of organic matter present in the sewage.
In other words, the exertion of BOD is considered to be first order reaction defined by.

$$\frac{dL_t}{dt} = -K' \cdot L_t \qquad \text{(i)}$$

Where,

L_t = amount of first stage BOD remaining in the sample at any time t (or oxygen equivalent of carbonaceous oxidizable organic matter present at any time t), expressed as mg/l.

K' = rate constant signifying the rate of oxidation of organic matter, having a unit $(day)^{-1}$.
Its value depends upon the nature of organic matter present & the temperature during the reaction

t = time in days

Integrating eqⁿ (i) between time $t = 0$ (as which $L_t = L_0$, say) to $t = t$, we get,

$$\int_{L_0}^{L_t} \frac{dL_t}{L_t} = -K' \int_0^t dt$$

or, $\log_e \frac{L_t}{L_0} = -k't$

or, $\frac{L_t}{L_0} = e^{-k't} = 10^{-kt}$

where the rate constant $k = \frac{k'}{2.303}$

L_0 = oxygen equivalent of organic matter present in sewage at the beginning.

The amount of BOD remaining at any time t is

$$L_t = L_0(10^{-kt})$$

Hence, y_t, the amount of BOD ~~exerted~~ that has been exerted at any time t is given by :

$$y_t = L_0 - L_t$$
$$= L_0(1-10^{-kt}) \quad \text{——— (ii)}$$

y_t is the BOD of t days (ie. $y_t = BOD_t$)

The ultimate first stage BOD (ie y_u) will be obtained by substituting $t=\infty$ in eq^n(ii)

ie. $y_t = L_0(1-10^{-K \cdot \infty})$

$$y_t = L_0$$

Thus, we conclude that the ultimate first stage BOD of a given wastewater is equal to the initial oxygen equivalent of the organic matter present in the sample of waste water.

y_u is thus a fixed quantity for a given specimen, and does not depend on the temperature during the reaction.

* Though the BOD test is usually conducted at 20°C, the reaction constant K_T at any other temp. T°C, is related to the reaction constant K_{20} (at 20°C), by following approximate relationship :

$$K_T = K_{20}\,\theta^{(T-20^\circ)} \quad (\theta = 1.056^\circ) \;/\; \theta = 1.047^\circ \text{ — usually}$$

* Dissolved Oxygen (DO)

→ DO is the amount of oxygen in the dissolved state in the wastewater.

→ Though waste water generally does not have DO, its presence in untreated wastewater indicates that the wastewater is fresh.

→ Presence of DO in treated wastewater/effluent indicates that considerable oxidation has been accomplished during the treatment stages.

→ While discharging the treated wastewater into receiving waters, it is essential to ensure that atleast 4 p.p.m of DO is present in it. If DO is less, the aquatic animals like fish etc. are likely to be killed near the vicinity of disposal.

→ Presence of DO in wastewater is desirable because it prevents the formation of noxious smell.

→ DO of the wastewater decreases as the temperature increases.

The actual quantity of DO is governed by

(i) solubility of oxygen (ii) partial pressure of oxygen in atmosphere

(iii) the temperature (iv) purity (salinity, suspended solids etc).

* Chemical Oxygen Demand (COD)

→ COD is the amount of oxygen required to oxidize/stabilize organic and inorganic matters.

→ It is used to measure the content of oxidizable organic as well as inorganic matter.

→ The quantity of oxygen required for the chemical oxidation of organic matter, readily oxidizable carbonaceous matter & other reducing agents present in the sewage with the help of the strong chemical $K_2Cr_2O_7$ (potassium dichromate) in the presence of H_2SO_4 is called COD.

→ COD can be determined only in 3 hrs.

→ suitable to measure organic matter present in industrial wastes having compounds that are toxic to biological life.

5.2.5 Hydraulic Design of Sewers

→ general approach for the design of sewers is similar to the design of water mains as the sewage, to be transported through sewers, is mostly liquid (ie. water) containing hardly 0.1 to 0.2 percent of solid matter in the form of organic matter, sediments and minerals.

→ However, there are two differences in the design of the sewers and of the water mains:

(i) Presence of solid matter

→ Water flowing through the water mains is practically free from solid matter, while the sewage flowing through ~~sewage~~ sewers contain particles of solid matter (both organic as well as inorganic).

→ These solid particles settle at the bottom and have to be dragged during the sewage transport. In order that the sewers are not clogged, they are to be laid at such a gradient that self cleansing velocity is attained/achieved, at all value of discharges.

→ Also, the inner surface of the sewers must be resistant to the abrasive action of these solid particles.

(ii) Pressure

→ Water in the water mains flow under pressure. Hence, the water mains can be carried, with certain limits, up and down the hill or gradient. The hydraulic gradient line lies very much above the pipe surface.

→ In most cases, sewers may be considered as open channels, wherein the sewage runs under gravity. The sewers seldom run full, and the H.G line falls under the sewer. Hence, the sewers must be laid at continous downward gradient. Sewers run under pressure only when they are designed as force mains and as inverted siphons.

Hydraulic Formulae

→ Design of sewers is done on the basis of following empirical hydraulic formulae.

(i) Chezy's Formula

$$V = C\sqrt{RS}$$

where,

V = Velocity of flow (m/s)
S = hydraulic gradient or slope of the sewer
R = hydraulic mean radius = A/P
A = area of cross-section (m^2)
P = wetted perimeter
C = Chezy's constant

C → very complex in nature, & it depends upon several factors, such as roughness of inner surface of sewer, hydraulic mean radius, size and shape of sewer, slope etc.

→ value of C is either found by Kutter's formula or by Bazin's formula.

Kutter's Formula

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

Where,

R = hydraulic mean radius
S = slope
N = rugosity coefficient ; depends upon the nature of inside surface of the sewer.

→ As reported, with increase in dia. of conduit, reduction in the value of N.

Bazin's formula

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{R}}}$$

K = Bazin's Constant.

(ii) Manning's Formula.

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

(iii) Crimp and Bruge's formula

$$V = 83.47 R^{2/3} S^{1/2}$$

for N = 0.012,

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

(iv) Hazen's and William's Formula.

$$V = 0.85\, C R^{0.63} S^{0.54}$$

where,

C = Hazen and William's constant.

* Knowing the velocity of flow V from above formulae, the channel section is designed by the general formula.

$$Q = AV$$

where,

Q = discharge in m^3/s.

* Factors that influence the flow of sewage in sewers.
    (i) Slope of sewer
    (ii) Geometry of sewer
    (iii) Roughness of interiors surface of sewer
    (iv) Bends, transitions, obstructions, etc.
    (v) Flow conditions
    (vi) Characteristics of sewage.

Flow Velocity

(i) Minimum Velocity of Flow | Self-Cleansing Velocity

→ A self cleansing velocity may be defined as that velocity at which the solid particles will remain in suspension, without settling at the bottom of the sewer.

$$V_s = \sqrt{\frac{8\beta}{f}(G_s - 1)g d_s}$$

where,

V_s = self cleansing velocity

β = Characteristics of solids flowing in the sewage, in suspension

f = Darcy-Weishbatch friction factor ; 0.03

G_s = specific gravity

g = gravitational acceleration constant

d_s = diameter of solid particles, to be carried by the liqui

→ Heavier particles & sticky particles require higher velocity for their transport than lighter and cleaner particles.

Self-Cleansing velocities for various types of particles.

S.N.	Nature of material	Self cleansing velocity (cm/s)
1.	fine clay and silt	7.5
2.	fine Sand and clay	15
3.	Coarse Sand	20
4.	fine gravel	30
5.	Round pebbles (12 mm - 25 mm dia)	50 - 60
6.	Angular stones	100

Self cleansing Velocities for various diameters

S.N.	Diameter of sewer (cm)	Self-cleansing Velocity (cm/s)
1.	15 to 25	100
2.	30 to 60	75
3.	Above 60	60

(ii) Maximum Velocity of flow / Non-Scouring Velocity

→ The maximum velocity at which no scouring action or abrasion takes place (as the flow becomes turbulent at higher velocity) is known as non-scouring velocity.

→ depends upon the material used for the construction of sewer.

Non-Scouring Velocities

S.N.	Material of sewer	Non-scouring velocity (cm/s)
1.	Earth Channels	60 to 120
2.	Ordinary brick-lined sewers	150 to 250
3.	Cement Concrete sewers	250 - 300
4.	Stone ware sewers	300 - 450
5.	Cast Iron Sewer Pipes	350 - 450
6.	Vitrified tile & glazed bricks	450 - 500

* Effect of variations of discharge on velocity in sewers

→ Discharge in a sewer does not remain constant at all times.
As Q varies → R varies — V is a function of $R^{2/3}$, the velocity of flow also varies as the sewage discharge varies.
(more prominent in case of combined sewer or partially combined sewer)

→ Q ↓es → V ↓es ; when sewer becomes less than half-full. (1/3 of avg. flow).

→ Velocity of flow - atleast 40 cm/sec.

→ Max^m discharge / flow — Velocity 90 cm/s is developed.

While designing the sewers, following points should be observed in connection with the self-cleansing velocity & non-scouring velocity.

(i) Before sewer design, discharge is known. Hence, the vel. of flow & gradient of the sewer are to be appropriately determined & correlated, to achieve the desired results.

(ii) for sewers in flat country — design should be done in a way that
- Self-cleansing velocity is obtained at max^m discharge.
- Even at Qmin, V atleast equal to 40 cm/sec.

(iii) for sewers in rough country —
- Self-cleansing vel. at min^m discharge.
- Non-scouring vel. at max^m discharge.
(drop manholes provided to reduce vel.)

(iv) Combined sewers - Egg shaped sewers should be adopted to obtain Vmin during DWF.

* Hydraulic Elements of Circular Sewer

→ Sewers of circular cross-section are more commonly used.

Advantages

(i) Easily manufactured.

(ii) A circular section gives the maximum area for a given perimeter, and thus gives the greatest hydraulic mean depth when running full or half full. It is therefore the most efficient section at these flow conditions.

(iii) Most economical section since it utilises minimum quantities of the materials.

(iv) uniform curvature all around, & hence it offers less opportunitie for deposits.

(a) Circular Section running full

Let D be the internal diameter of circular sewer.

Area of cross-section, $A = \frac{\pi}{4} D^2$

Wetted perimeter, $P = \pi D$

Hydraulic mean depth, $R = A/P$

$$= \frac{\frac{\pi}{4} D^2}{\pi D}$$

$$= \frac{D}{4}$$

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(b) Circular Sewer running partially full

⇒ fig shows a circular sewer running partially full.

→ Let 'd' be the depth at partial flow and let θ be the central angle subtended.

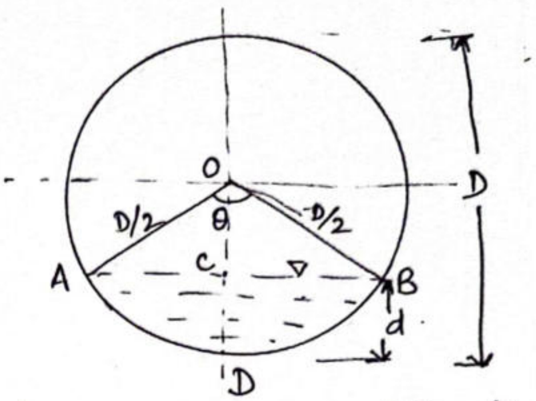


fig: sewer running partially full

Let.

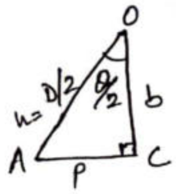
a = area of cross-section

p = wetted perimeter

r = hydraulic mean depth

v = velocity of flow

1. Depth of flow (d)



* $\sin \theta/2 = \frac{AC}{OA}$

$\Rightarrow AC = D/2 \sin \theta/2$

* $\cos \theta/2 = \frac{OC}{OA}$

$\Rightarrow OC = \frac{D}{2} * \cos\frac{\theta}{2}$

$$d = OD - OC$$
$$= D/2 - D/2 * \cos \theta/2$$
$$= D/2 \left(1 - \cos \theta/2\right)$$

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

2. Area of flow (a)

Area of flow (a) = Area of ACBD

= Area of sector OADB − Area of ΔOAB

$$= \frac{\pi D^2}{4} * \frac{\theta}{360} - \frac{\pi D^2}{4} * \frac{\sin\theta}{2\pi}$$
$$= \frac{\pi D^2}{4}\left(\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right)$$
$$= A\left(\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right)$$

$\therefore$ Proportional area $= \frac{a}{A} = \frac{\theta}{360} - \frac{\sin\theta}{2\pi}$

* If $\theta = 360°$,

$(A)_{OADB} = \frac{\pi D^2}{4}$.

For $\theta = \theta$

$(A)_{OADB} = \frac{\pi D^2}{4} * \frac{\theta}{360}$

* $(Area)_{OAB} = \frac{1}{2} * AB * OC$

$= \frac{1}{2} * 2AC * OC$

$= \frac{D}{2}\sin\theta/2 \cdot \frac{D}{2} \cdot \cos\frac{\theta}{2}$

$= \frac{D^2}{4} \cdot \sin\theta/2 \cdot \cos\frac{\theta}{2}$

$= \frac{D^2}{8} \cdot \sin\theta$

$= \frac{\pi D^2}{4} * \frac{\sin\theta}{2\pi}$

3. Wetted perimeter of flow (p)

$$p = \text{length of } ADB$$
$$= \pi D * \frac{\theta}{360}$$
$$= P * \frac{\theta}{360}$$

If $\theta = 360^\circ$, $p = \pi D$

If $\theta = \theta^\circ$, $p = \pi D * \frac{\theta}{360}$

$$\text{Proportional perimeter} = \frac{p}{P} = \frac{\theta}{360^\circ}$$

4. Hydraulic Mean Depth of flow (r)

$$r = a/p \quad , \quad R = A/P$$

$$\text{Proportional H.M.D} = \frac{r}{R} = \frac{a/p}{A/P}$$
$$= \left(\frac{a}{A}\right) / \left(\frac{p}{P}\right)$$
$$= \left(\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right) / \frac{\theta}{360}$$
$$= 1 - \frac{360^\circ \sin\theta}{2\pi\theta}$$

5. Velocity of flow (v)

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

$$\text{Proportional velocity} = \frac{v}{V} = \left(\frac{r}{R}\right)^{2/3}$$
$$= \left(1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right)^{2/3}$$

6. Discharge (q)

$$q = a.v$$

$$\text{Proportional discharge} = \frac{q}{Q} = \frac{av}{AV} = \frac{a}{A} \times \frac{v}{V}$$
$$= \left(\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right) * \left(1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right)^{2/3}$$
$$= \frac{\theta}{360^\circ} * \left(1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right)^{5/3}$$

5.2.10 Sewage Treatment

→ Sewage treatment is a broad term that applies to any process/operation or combinations of processes and operations that can reduce the objectionable properties of water carried waste and render it less dangerous with the following:

(i) Removal of suspended and floatable material
(ii) Treatment of biodegradable organics
(iii) Elimination of pathogenic organisms
(iv) Removal of nitrogen, phosphorous and toxic organic compounds

Treatment Methods

(a) Conventional treatment methods

1. Preliminary Processes/treatment
2. Primary treatment
3. Secondary (or biological) treatment

(b) Advanced waste.water treatment

1. Tertiary treatment

1. Preliminary processes

→ Consist of pumping, screening & grit removal.
→ purpose is to remove floating materials (like dead bodies of animals, pieces of wood, papers, rags, metal containers, plastic or rubber containers, grease etc). and also heavy settleable inorganic solids, including flow measuring devices.
→ reduces the BOD load of the wastewater by about 5 to 10 percent.

Various units involved in preliminary treatment are:

(i) Screens - for removal of floating matter
(ii) Grit chambers or Detritus tank → for removal of sand & grit.
(iii) Comminutors → for grinding or chopping large size suspended solids.
(iv) Floatation units, Skimming tanks → for removal of oils & grease
(v) Flow measuring devices
(vi) Pumping (vii) Pre-aeration.

2. Primary treatment

→ includes those physical unit operations and chemical unit processes through which larger suspended solids are removed from the wastewater.

→ Suspended solids – organic if the wastewater has been subjected to preliminary treatment prior to primary treatment,
– if no preliminary treatment is given, the suspended solids are both organic as well as inorganic.

Process or units employed:

(i) Plain sedimentation tanks

(ii) Sedimentation with coagulation

(iii) Septic and Imhoff tanks.

→ **Design of sedimentation tank**

factors influencing the design and performance of sedimentation tanks.

→ Flow variations
→ solids concentration
→ Area
→ Overflow rate
→ density currents
→ solids loading
→ detention time

* Design Considerations.

- Generally sedimentation tank is designed for peak flow and may be designed for average flow.

Surface Overflow rate (SOR) = 40 to 50 $m^3/m^2/day$ (PST for Q_{peak})
= 25 to 30 $m^3/m^2/day$ (PST for Q_{avg})
= 40 to 50 $m^3/m^2/day$ (SST for Q_{peak})
= 15 to 35 $m^3/m^2/day$ (SST for Q_{av})

Detention time, t = 1 to 4 hours
Flow Velocity, V_h = 30 to 60 cm/min
Height or depth, d = 2.5 m to 3.5 m
Width, b = 6 to 12 m
Length, L = 12 to 100 m
L/B ratio = 3 to 5
Free Board = 0.3 to 0.5 m
Sludge zone = 0.3 to 0.5 m (≈ 1m sometimes)
Bottom slope (towards inlet) = 1 %
Side slope = ~~1:2:1~~ 1.2 : 1 to 2 : 1 (V : H)
For circular tank diameter, ϕ = 12 to 30 m (Sometimes 3 to 60 m)
Effective volume, $V = (0.011\phi + 0.785d)\phi^2$
tank slope = 7.5 to 10%.

Weir loading (flow per unit length) = 125 to 500 $m^3/d/m$.

3. Secondary Treatment / Biological Treatment

→ removal of contaminants are brought by biological activity.
→ Objective is to coagulate and remove the non-settleable colloidal solids and to stabilise the organic matter.
→ Biological / secondary treatment systems are living systems which rely on mixed biological cultures to break down waste organics and remove organic matter from the solution.
→ A treatment unit provides a controlled environment for the desired biological process and are designed to maintain a large active mass of bacteria within the system confines.

Types

1. Process according to operational conditions.

(a) Aerobic Process
→ those which occur in presence of dissolved oxygen.
→ includes (i) Trickling filters
(ii) Activated sludge processes
(iii) Aerobic stabilization ponds
(iv) Aerated lagoons.

(b) Anaerobic Process
→ involves the decomposition of organic and/or inorganic matter in absence of molecular oxygen.
→ includes. (i) Anaerobic sludge digestion
(ii) Anaerobic contact process
(iii) Anaerobic filters
(iv) Anaerobic lagoons & ponds.

(c) Aerobic - Anaerobic Process
→ Combination of aerobic, anaerobic & facultative bacteria.

→ Most of the biological treatment processes are preferred to work on aerobic bacterial decomposition because such decomposition does not produce bad smells and gases as produced by anaerobic decomposition, & also aerobic bacteria are about three times more active than anaerobic bacteria at 30°c.

2. Process according to microbial maintenance in the system

(a) Attached growth processes (or fixed film processes)

→ These are the biological treatment processes in which the micro-organisms responsible for the conversion of the organic matter or other constituents in the wastewater to gases and cell tissue are attached to some inert medium, such as rock, slag or specially designed ceramic or plastic materials.

→ Such processes includes the following:

(i) Intermittent Sand filters
(ii) Trickling filters
(iii) Rotating biological contactors
(iv) Packed bed reactors
(v) Anaerobic lagoons (ponds)
(vi) fixed film denitrification

(b) Suspended growth processes

→ These are the biological treatment processes in which the micro-organisms responsible for the conversion of the organic matter or other constituents in the wastewater to gases and cell tissue are maintained in suspension within the liquid in the reactor by employing either natural or mechanical mixing.

→ Such processes includes the following:

(i) Activated sludge processes
(ii) Aerated lagoons
(iii) Sludge digestion systems
(iv) Suspended growth nitrification
(v) Suspended growth denitrification

(c) Combined processes

→ These consist of both attached growth processes as well as suspended growth processes.

→ include the following in sequence:

(i) Trickling filter, activated sludge
(ii) Activated sludge, trickling filter
(iii) Facultative lagoons

→ Biological processes only help in changing the unstable organic matter into stable forms which are then removed in the secondary settling tanks. Thus, in the biological treatment processes, secondary settling tanks are essential.

CamScanner

4. Tertiary treatment

→ includes all operations and processes used to remove the pollutants not removed in preliminary, primary and secondary treatment.

→ These pollutants may include soluble inorganic compounds such as phosphorus or nitrogen which may support algal growth in receiving water; organic materials contributing BOD, COD, color, taste & odour; bacteria; Viruses; Colloidal solids contributing turbidity; or soluble minerals which may interfere with subsequent re-use of the wastewater.

→ aimed at the re-use of the wastewater.

The common processes that are used in tertiary treatment are as follows:

(i) Chemical clarification
(ii) Recarbonation
(iii) Filtration
(iv) Activated carbon adsorption
(v) Disinfection
(vi) Nitrogen removal
(vii) Phosphorus removal
(viii) Demineralisation.

* Sewage Filtration

→ Sewage filtration is the process of sewage treatment in the presence of air with the help of aerobic bacteria.

→ The action involved in the sewage filtration consists of building new compounds, which are stable, by combining with oxygen.

→ Filtration satisfies the BOD of organic waste with the help of aerobic bacteria.

→ The filter units used for biological treatment consists of open beds of coarse aggregates over which effluent from the primary clarifier is applied or sprinkled intermittently.

→ When the sewage is passed through the beds, where aerobic action takes place, following actions are done by aerobic bacteria:

i) The colloidal and dissolved putrescible organic matters present in the sewage are absorbed by bacterial film.

ii) The bacteria ~~absor~~ consumes the organic matters so absorbed, which are necessary for their life.

iii) The bacteria convert the organic matters into stable inorganic film.

iv) finally, nitrates, CO_2 & sulphates etc. remain in sewages. The gases escape in the atmosphere.

Sewage filters

i) Intermittent sand filters

ii) Contact beds

iii) Trickling filters.

* Intermittent Sand filters

→ biological sewage treatment, consists of a layer of sand with an effective size of 0.2 to 0.5 mm, uniformity coefficient of 2 to 5 and of depth 75 to 100 cm.

→ a layer of about 15 cm to 30 cm depth of gravel is provided at the bottom of sand layer to facilitate the drainage of filtered effluent.

→ filters are generally rectangular in plan, with length to width ratio between 3 to 4, and area of each unit varying from 0.2 to 0.4 ha.

→ Usually. 3 to 4 beds are provided adjacent to each other, so that they can work in rotation.

Operation

- On each bed, sewage effluent from primary settling tank is applied intermittently, through a dosing tank containing a siphon.

→ The flooding is done from 5 to 10 cm in depth after an interval of 24 hours.

→ the sewage effluent then percolates through the sand bed, and in this process, the suspended organic matter gets trapped in the voids of top portion of sand, through straining action.

→ During the rest period, the trapped organic matter is acted upon by aerobic bacteria present in the filter layer. These aerobic bacteria flourish well in the presence of free oxygen available from atmosphere during the rest period when the sewage dose has percolated down.

Effluent from the intermittent filter.

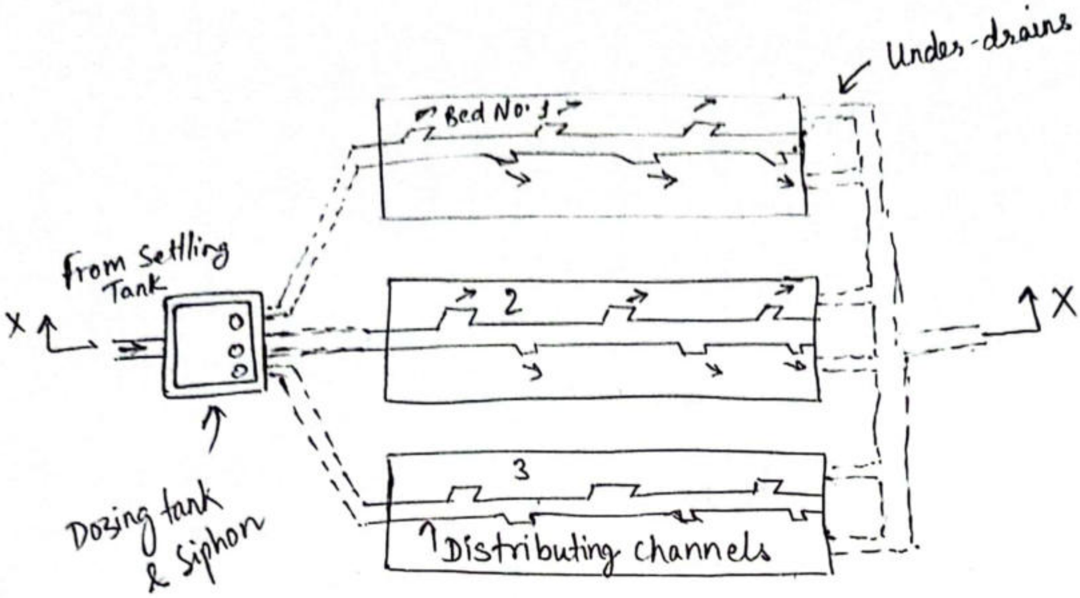
→ Effluent is quite clear, well nitrified (Conversion of ~~ammonia~~ nitrogen in the form of ammonia to nitrate) and stable.

→ Suspended solids < 10 ppm, BOD < 5 ppm

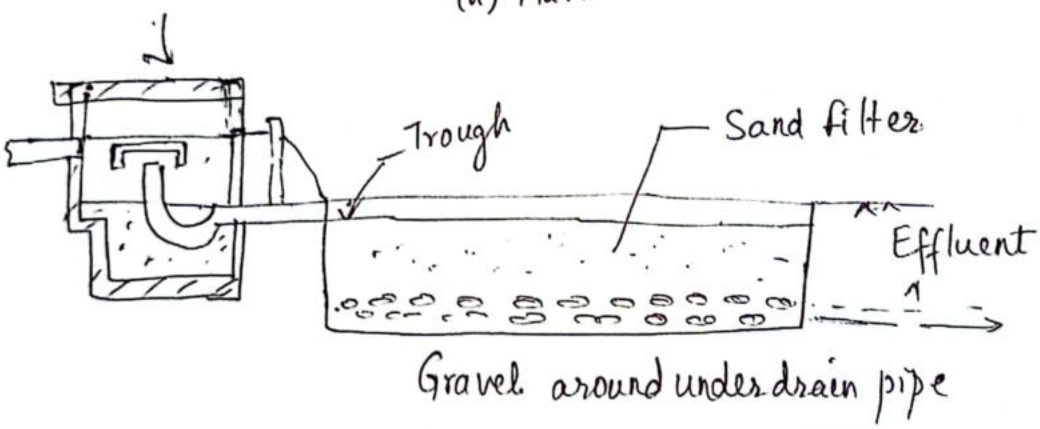
Maintenance

→ The topmost layer of depth of about 25 mm should be raked at regular intervals to breakup the materials caught up in the top part of the filter.

→ The sand of the filter should also be renewed from time to time.



(a) Plan



(b) Section x-x

fig: Intermittent Sand filter.

Advantages

(i) The effluent from intermittent sand filter is of better quality. It is more clean and more stable, hence does not need further treatment before disposal.

(ii) The filter works under aerobic conditions, and hence there is no trouble of odour, flies and insects.

(iii) The operation is very simple, requiring no mechanical equipment except for dosing.

(iv) Smaller head is required for applying the sewage on the surface of the filter.

(v) There is no secondary sludge which is to be disposed of, except for the occasional sand scraping.

Disadvantages

(i) The rate of filtration, & hence that of loading is very small, per unit surface area of the filter. Hence, they cannot be employed for medium size or bigger plants.

(ii) They requires large area and large quantity of sand, due to which their construction is very costly.

* Contact Beds

- A contact bed is a water tight tank of masonry walls and of rectangular shape.
- The filter media is very coarse, consists of broken stone, called ballast of 20 to 50 mm gauge.
- Depth of filtering media is kept between 1 to 1.8m (common depth being 1.2 m)
- the effluent from primary settling tank is first received by the dosing tank and then distributed over one contact bed at a time.
- The effluent, after passing over the coarse filtering media is collected at the ~~medi~~ bottom and conveyed through the under drainage system to the effluent pipe which may be taken to secondary sedimentation tank for settling out the oxidised organic matter.
- The sewage is uniformly applied over the whole surface of contact bed by means of distributing troughs having perforations/outlets at regular interval.
- Rate of loading is slow and may vary from 4000 to 6000 m^3/ha/day
- The area of one bed generally does not exceed 0.2 hectares.

Operation of Contact beds

- The complete cycle of operation of a contact bed consists of four operations which requires 8 to 12 hour.

(i) Filling.

- The outlet valve of the under-drain is closed and the tank is slowly filled with sewage effluent through the dosing tank.
- The depth of sewage effluent may be 5 to 10 cm over the top of bed.
- The filling may take about 1 to 2 hours.

(ii) Contact

- The dosing tank outlet is then closed, and the sewage admitted over the contact bed is allowed to stand for about 2 hours. During this period, the colloidal and dissolved matter gets transferred to the filter media, and comes in contact with the bacterial film covering the filter media.

iii) Emptying

→ The outlet valve of the underdrain is then opened and the sewage present in the contact bed is withdrawn slowly, without disturbing the organic film.

→ This operation may take about 1 to 2 hours.

iv) Oxidation

→ The contact bed is then allowed to stand empty for about 4 to 6 hours. During this period of rest, atmospheric air enters the void space of the contact media, thus supplying oxygen to the aerobic bacteria, resulting in the oxidation of the organic matter present in the film.

Effluent from Contact bed.

→ usually non-putresible, but is turbid and high in bacterial content.

→ In general, 85 to 90% of suspended ~~sol~~ matter, 60 to 80% of organic matter and 50 to 75% of bacteria are removed by contact filters.

Hence, the effluent from contact bed is passed through final (or secondary) settling tank.

Advantages

(i) can work under small heads.

(ii) can be operated without exposing the sewage effluent to view.

(iii) no nuisance of filter flies.

(iv) problem of odour is much less as compared to trickling filters.

Disadvantages

(i) Rate of loading is much less in comparison to trickling filters.

(ii) Large area of land is required for installation.

(iii) requires continuous attendance.

(iv) Cost of contact beds is much more as compared to trickling filters.

* Trickling filters

- Trickling filters, also known as percolating filters or sprinkling filters are the sewage filters in which sewage is allowed to sprinkle or trickle over a bed of coarse, rough, hard filter media and it is then collected through the under-drainage system.
- The operation of trickling filter is continuous & allow constant aeration.
- The biological purification is brought about mainly by aerobic bacteria which form a bacterial film, known as bio film, around the particles of filtering media.
- For the existence of this film, sufficient oxygen is supplied by providing suitable ventilation facilities in the body of the filter & also to some extent by intermittent functioning of the filter.
- The trickling filter is always preceded by primary sedimentation along with skimming devices to remove the scum. This will prevent the clogging of the filter by settleable solids.
- The effluent from the filter is then taken to secondary sedimentation tanks for settling out organic solids oxidised while passing through the filter.
- The trickling filter serves both to oxidise and biofloccculate the organic matter in sewage and their efficiency is assessed on the total reduction in BOD effected through the filter and the subsquent sedimentation tank, since the effluent quality is reckoned after the settlement of the bioflocculated solids.

Biological process in a trickling filter

- The microbial film (or the biofilm) or the slime layer formed on the filter medium is aerobic to a depth of only 0.1 mm to 0.2 mm, and the remaining part of the film is anaerobic.
- As the wastewater flows over the microbial film, the soluble organic material in the sewage is rapidly metabolised while the colloidal organics are adsorbed onto the surface.
- In the outer portions of the biological film (or slim layer), the organic matter is degraded by the aerobic micro-organisms. Since food concentration is higher at the outer layer, ~~the micro-organisms~~ the micro-organisms near the outer surface are in a rapid growth ~~rate~~ phase. As the micro-organisms at the outer surface grow, the thickness of the slime layer increases and the diffused oxygen is

consumed before it can penetrate the full depth of the slime layer. Hence, the lower zone of the film is in a state of starvation, due to which anaerobic environment is established near the surface of the media.

→ As a result of having no external organic source available for cell carbon, the micro-organisms near the media surface enters into an endogenous phase of growth and lose their ability to cling to the media surface. Eventually there is scouring of the slime layer due to flowing liquid and a fresh slime layer begins to grow on the media. This phenomenon of scouring of the slime is called sloughing or unloading of the filter.

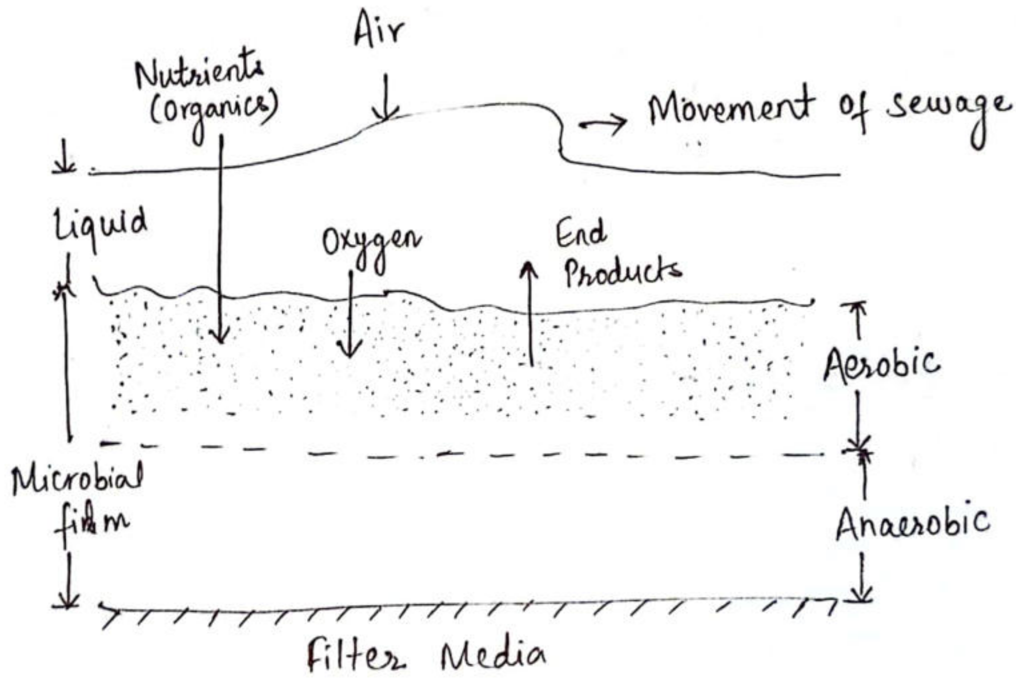
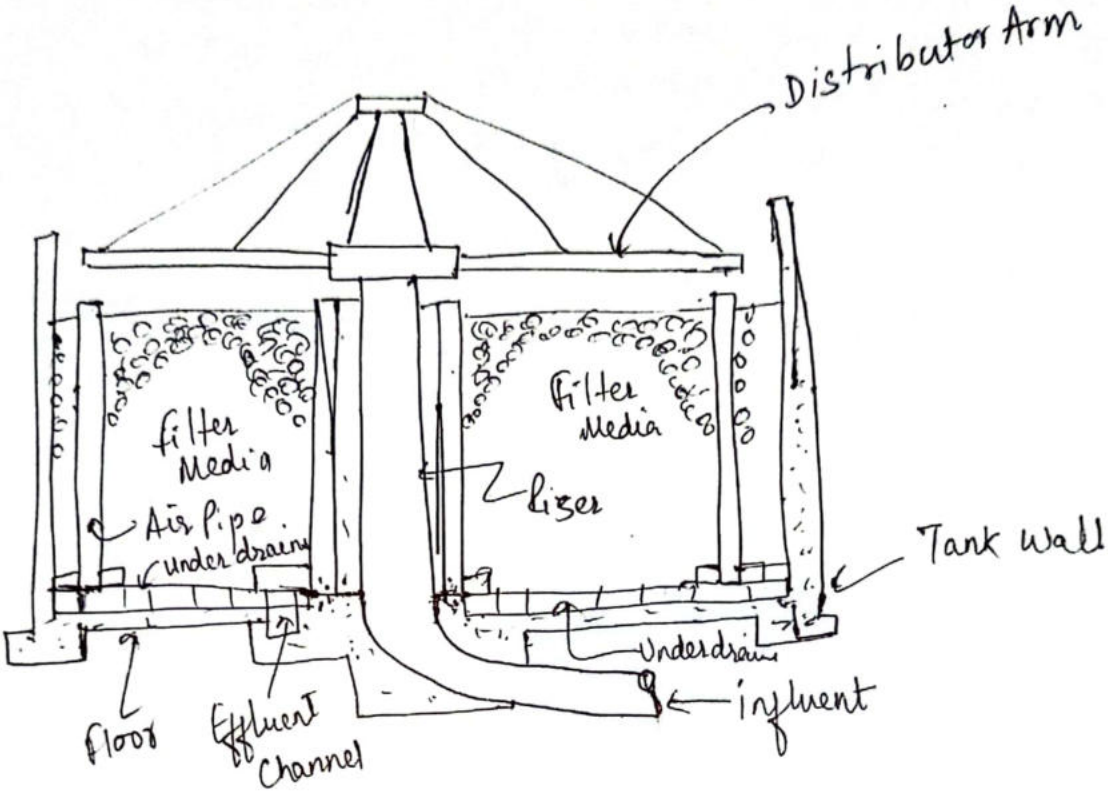


fig: Attached growth process in trickling filter.

Use of trickling filter

→ Used for biological treatment of domestic sewage and industrial wastes which are amenable (co-operative) to aerobic biological processes.
→ for complete treatment of moderately strong wastes and as roughing filter for very strong wastes prior to activated sludge units.
→ to handle shock loads; particularly suited for plants of capacities less than 5 mLd.
→ to treat industrial wastewaters & with synthetic media, these can handle higher organic and hydraulic loadings and can use deeper beds (upto 12m) which reduces the required land area.



Typical Cross-section

* **Classification of trickling filters**

→ On the basis of hydraulic & organic loading rates,

(i) low rate filters / Conventional filter

(ii) High rate filters.

* **Comparison between conventional and high-rate trickling filters**

Characteristics	Conventional or low rate filter	High rate filter
1. Depth of media	1.8 to 2.4 m	1.2 to 1.8 m
2. Hydraulic loading ($m^3/d/m^2$)	1 to 4	10 to 30 (including recirculation)
3. Organic loading as 5-day BOD in $g/d/m^3$	80 to 320	500 to 1000 (excluding recirculation)
4. Recirculation System	Usually not provided, but can be provided if the hydraulic load does not exceed the limit	Always provided. Recirculation ratio 1 : 1 to 4 : 1
5. Volume of bed	5 times	1
6. Interval of dosing	≯ 5 minutes. The sewage is applied at intervals.	≯ 15 seconds. Sewage is thus applied continuously.
7. Sloughing	Intermittent	Continuous.
8. Cost of operation	More	less
9. Land required	More	Less
10. Characteristics of final effluent	Contains BOD ≤ 20 mg/l; it is highly nitrified into nitrate stage.	Contains BOD ≥ 30 mg/l; it is not fully nitrified.
11. Secondary sludge	Highly oxidized, Black colour, having light fine particles.	Not fully oxidized; brownish black colour containing fine particles

* Recirculation and trickling filter flow sheets

→ Recirculation is the return of a portion of treated or partly treated sewage to the treatment process.
Usually, the return is from the secondary settling tank to the primary settling tank or to the dosing tank of the filter.

→ Recirculation of sewage is an important feature of high rate filter. It is expressed in terms of recirculation ratio (R).

Recirculation ratio

→ The ratio of recirculated flow to the flow of raw sewage is called recirculation ratio.

→ R determines the required capacity of recirculating pumps and the hydraulic load placed upon the filters.

Capacity of recirculating pump = R * (influent sewage flow)

Hydraulic load of filter = (1+R) * (influent sewage flow)

Recirculation factor

→ The number of effective passes through the filter is known as recirculation factor (F) & is given by the equation:

$$F = \frac{1+R}{[1+(1-f)R]^2} = \frac{1+R}{(1+0.1R)^2}$$

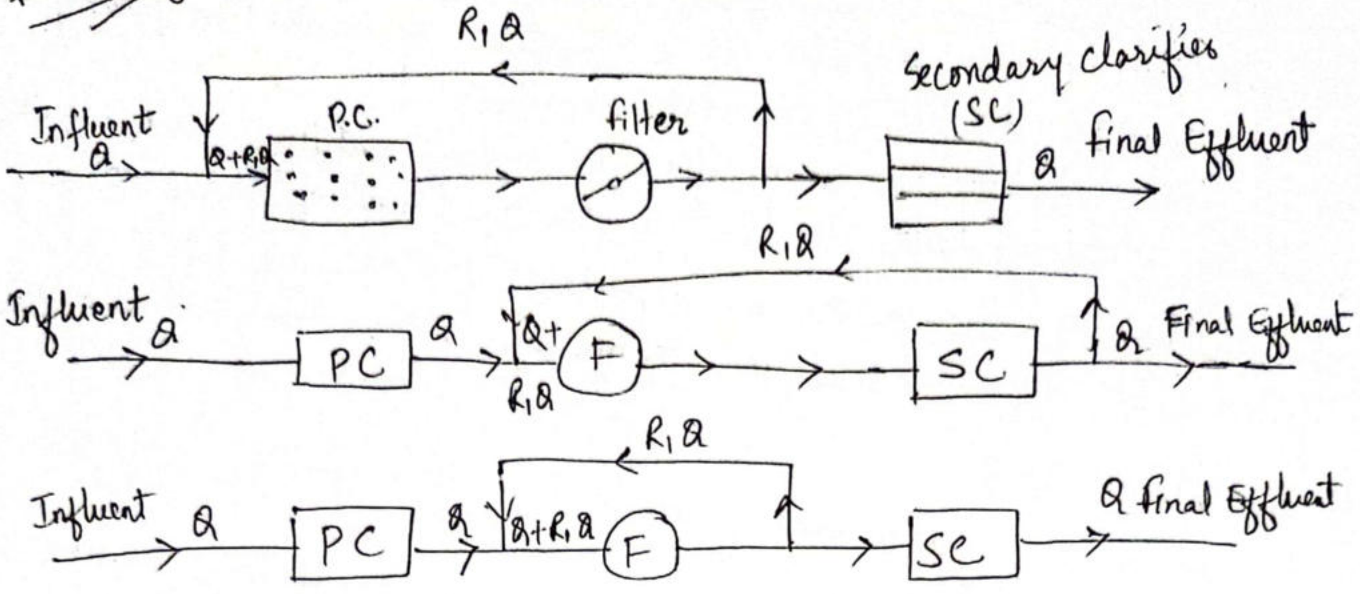
f = treatability factor = 0.9 for sewage

Hydraulic recirculation factor:

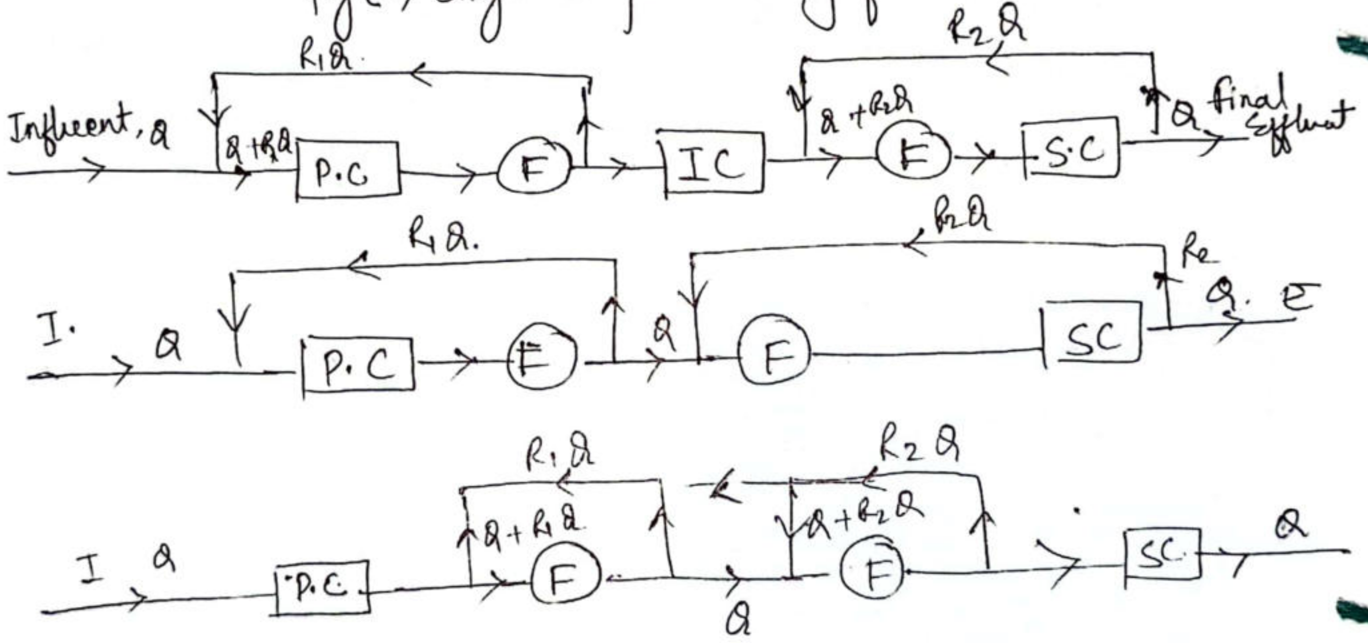
The number of hydraulic passes of recirculated sewage through the filter is called hydraulic recirculation factor (F_h) & is given by.

$$F_h = \frac{\text{Inflow} + \text{Recirculation}}{\text{Inflow}} = 1 + R.$$

Flow diagrams



fig(a) Single stage trickling filter



fig(b) Two stage Trickling filters

Advantages of recirculation

- provide uniform hydraulic loading as well as dilute the high strength wastewaters.
- keeps the self propelled distributors running at the time of reduced flows (ie. during night hours)
- the filter influent is freshened due to which foul odour is prevented.
- the filter influent is diluted and weakened so that filter works at a constant efficiency and the quality of filter effluent is improved.
- Recirculation loads deeper portions of the filters more effectively.

Flow diagrams of high rate trickling filter

(a) Single Stage filter

(b) Double stage filter.

* Trickling filters problems & remedies

(a) Fly nuisance

→ in slow rate trickling filters

Remedial measures

(i) Flooding the filter for about 24 hrs, at weekly or biweekly intervals

(ii) Jetting down the inside walls of the filter.

(iii) Chlorinating the filter influent (0.5 to 1.0 mg/l)

(iv) Application of larvicides such as DDT, Chordane etc.

(v) Continuous hydraulic loading to hamper the flies & larvae.

(vi) Sprinkling lime

(b) Odour nuisance

→ due to undesirable growth, sludging & anaerobic decomposition.

→ indication that the filter is not operating efficiently.

Remedies

(i) Maintaining a well ventilated filter, either by natural ventilation or forced ventilation

(ii) Recirculation of filter effluent or secondary clarifier effluent.

(iii) Aeration or chlorination of sewage before primary settling of sewage.

(c) Ponding nuisance

→ caused when all the voids of the trickling filters are filled up due to choking by heavy fungus or other suspended matters.

→ Ponding decreases filter ventilation, reduces the effective volume of filter & reduces efficiency.

→ due to excessive organic loading, inadequate hydraulic loading and inadequate size of media.

Remedies

(i) Opening the clogged section by flushing the with a fire hose & and simultaneously loosening the aggregates by a steel bar.

(ii) Reducing the strength of filter influent by re-circulation.

(iii) Flooding the filter once in day and allowing it to stand for 24 hours)

(iv) Chlorinating the influent

(v) Stopping the distributor over the ponded area

Oxidation Ponds

- It is an open, flow-through earthen basin of controlled shape, specifically designed and constructed to treat sewage and biodegradable industrial wastes.
- In an oxidation pond, a wide variety of microscopic plants find the environment a suitable habitat. In addition to the algal population, waste organics are metabolized by bacteria and saprobic protozoans as primary feeders and by protozoans, rotifers, crustaceans etc as secondary feeders.
- The daily flow of sewage containing organic material provides necessary food to the microbial population which stabilize the putrescible matter by oxidising it to form nitrates and CO_2. The nutrients released by microbial population are used by the algal population which in turn release oxygen through the process of photosynthesis. Such a combined symbiotic action of bacteria and algae is called 'Bacterial-algal-symbiosis' which results in complete stabilization of organic wastes.
- When the pond bottom is anaerobic (due to provision of greater depth or due to lack of proper mixing & aeration), biological activity results in digestion of settled solids.
- provide comparatively long detention periods extending from few to several days when the putrescible organic matter in the waste gets stabilized by the action of natural forces.

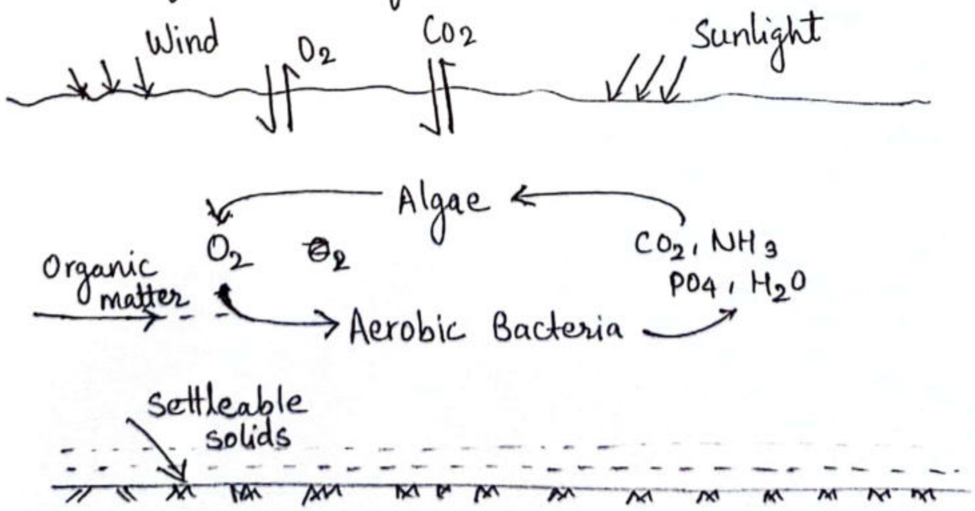


fig: Symbiotic relationships and functioning of oxidation pond

* Design Criteria of Oxidation Pond

1. Detention time (t) = 10 to 45 days (depend upon temperature) $t \propto \frac{1}{t}$

$$L_t = L_a(10^{-kt}) \Rightarrow t = \frac{1}{K}\log_{10}\left(\frac{L_a}{L_t}\right)$$

L_a = influent BOD
L_t = effluent BOD
K = deoxygenation constan

2. Surface area (As) = 0.2 to 0.4 ha/1000 persons

3. Organic Loading (U) $= \frac{W}{A_s}$ = 40 to 330 kg/ha/day

4. Effective depth = 0.8 to 1.5 m

5. Free Board = 0.5 to 1m

6. Shape = rectangular, L/B = 2 to 3

7. Side Slope = 1:1.5 to 1:3

- ✓ underground water pollution
- ✓ flooding
- ✓ breeding of mosquito
- ✓ nuisance

* Activated Sludge Process

→ ASP is a suspended growth process of biological treatment which involves the production of an activated mass of micro-organisms capable of aerobically stabilizing a waste.

→ The activated sludge process of sewage treatment is based on providing ~~init~~ intimate contact between the sewage and biological active sludge. Such sludge is developed initially by prolonged aeration under conditions which favours the growth of micro-organisms with special ability to oxidise organic matter.

Mechanism

→ The effluent from the primary settling tank is mixed with a dose of activated sludge and is aerated in an aeration tank for a period of some hours.

→ During the aeration, the micro-organisms in the sewage multiply by assimilating part of the influent organic matter. In this process, part of organic matter is synthesised into new cells and part is oxidised to derive energy.

→ The synthesis reaction, followed by subsequent separation of the resulting biological mass and the oxidation reaction are the main mechanisms of BOD removal in the activated sludge process.

→ The biomass is generally flocculant and quick settling and is separated from the aerated sewage in a secondary settling tank and is recycled continuously to the aeration tank as an essential feature of the process.

→ The mixture of recycled sludge & sewage in the aeration tank is referred to as mixed liquor.

Fig below shows the generalised biological process reactions in ASP.

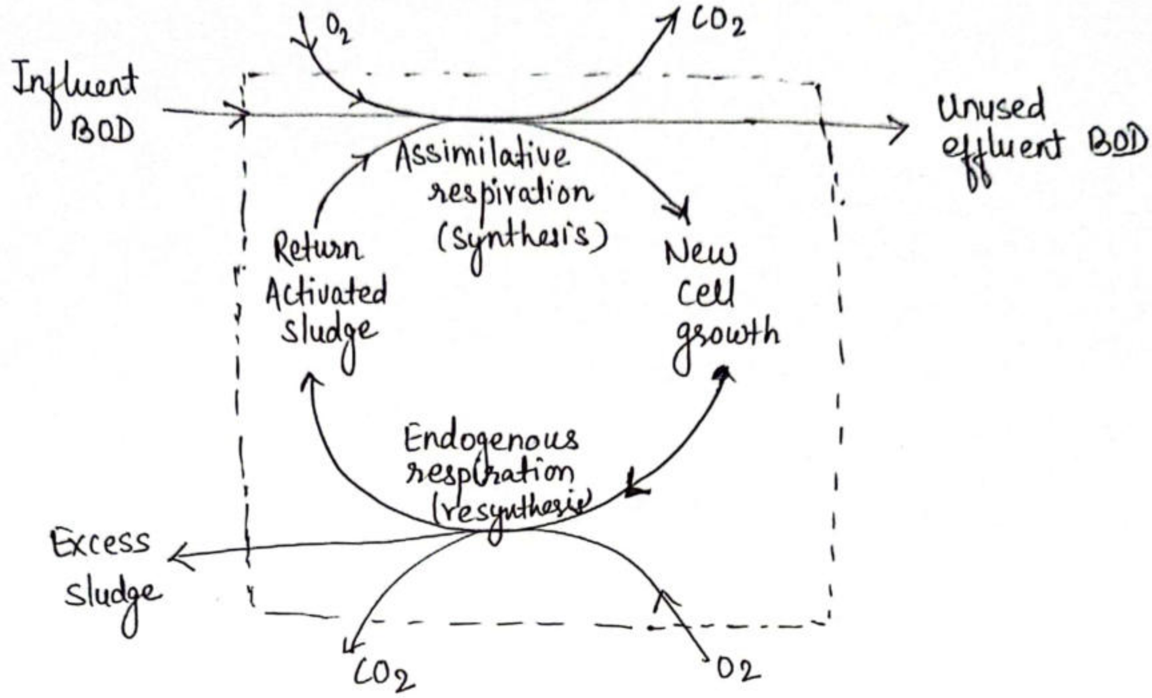


fig: generalised biological process reaction in ASP

Eqⁿ

Organic material $+ O_2 +$ Nutrients $\xrightarrow{\text{Micro-organisms}}$ $CO_2 + H_2O +$ Energy $+$ Micro organisms

→ The total oxidation of organics in the sewage by micro-organisms takes place in two phases.

→ The first phase involves the conversion of organic matter to CO_2, water or new-microorganisms.

→ The second phase involves endogenous respiration during which the micro-organisms consume their own cell material for energy. The rate is relatively slow, and at the end of this phase, non-biodegradable residue remains.

Flow diagram of activated sludge process

→ The three basic operations involved in the ASP are:

(i) mixing of activated sludge

(ii) aeration of mixed liquor

(iii) settling in secondary clarifier

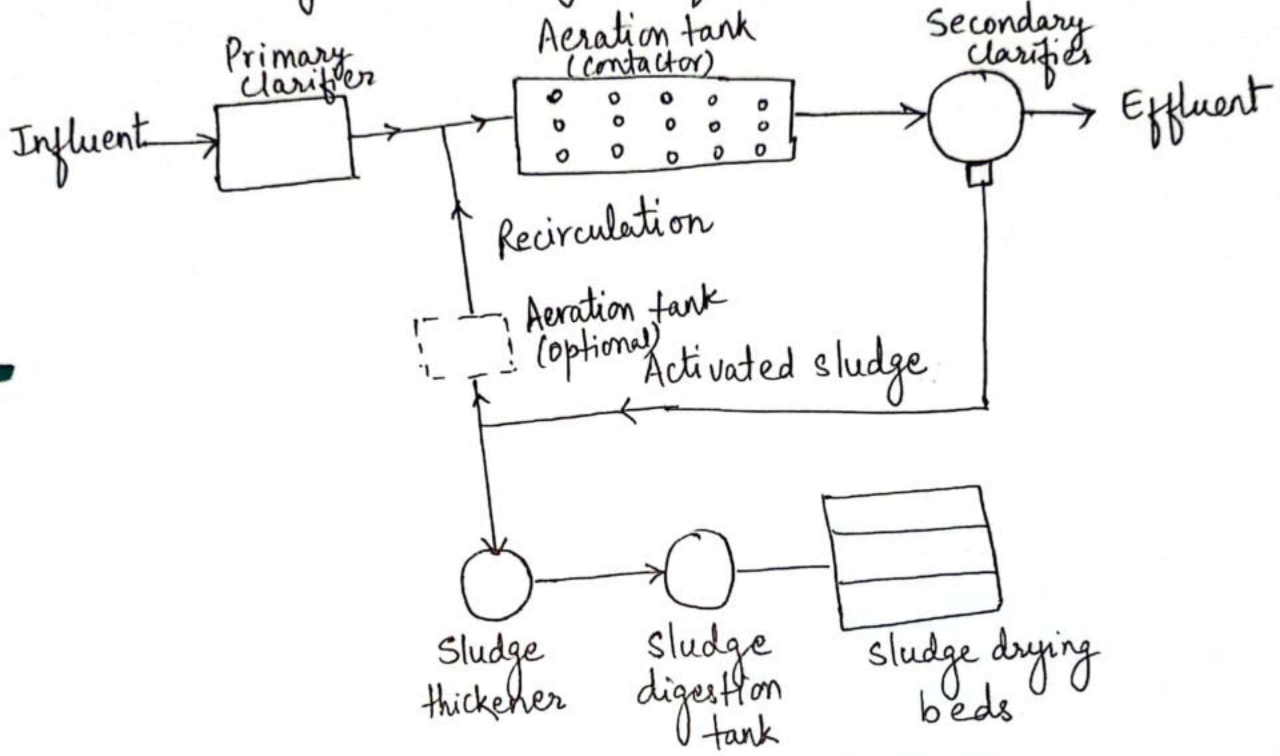


fig: flow diagram of ASP

Operational Difficulties

(i) Rising Sludge or Floating Sludge

→ due to denitrification in the settling tank releasing nitrogen bubbles which buoys up the sludge caused by (a) high sludge age (b) long retention time in the clarifier.

Remedies

(a) increasing the return sludge age

(b) increasing the speed of the sludge scraper mechanism, where possible

(c) decreasing the mean cell residence time by increasing the sludge washing rate

(ii) Sludge bulking – Sludge with poor settling characteristics:

→ occurs due to (a) inadequate air supply

(b) low pH

(c) prolonged detention of sludge in the settling tanks

(d) sludge accumulation on the bottom of aeration tank

(e) presence of certain industrial waste containing carbohydrates which favours the growth of filamentous fungi.

Remedies

(a) reducing the flow of sewage to the aeration tanks for a short period.

(b) reducing the suspended solids in the mixed liquor.

(c) prolonged aeration and reaeration of return sludge.

(d) application of chlorine either to the sewage or to the return sludge, so as to control filamentous growth.

(e) application of hydrogen peroxide.

(f) application of hydrated lime to raise pH to 8 or more.

Advantages of Activated Sludge Process

(i) Clear, sparkling and non-putrescible effluent possible
(ii) No odour during the process as compared to other biological processes
(iii) No fly nuisance
(iv) Highly efficient. Removal of SS, BOD & bacteria are around 90% each
(v) Degree of stabilisation or nitrification is controllable between limits, so as to match with the quantity & character of receiving water.
(vi) Relatively low cost of installion as compared to trickling filter. installations, cost of land, cost of huge filtering material, cost of distribution mechanisme.
(vii) smaller area required, as compared to trickling filters.
(viii) The excess sludge has higher fertilizing values as compared to sludge obtained from other treatment methods.
(ix) Amount of hydraulic head consumed by the process is less.

Disadvantages

(i) Very sensitive to variations in the quality of sewage, particularly in respect of industrial wastes which may cause sludge bulking. Trickling filters are best in this respect.
(ii) High cost of operation
(iii) Necessity of constant skilled attendance.
(iv) Uncertanity of expected results under all conditions.
(v) Large quantity of sludge is produced which is difficult to dewater, digest and dispose of.

Sewage Disposal

After conveying the wastewater through sewers, the next step is its disposal, either after treatment or even before treatment.
The methods of disposal of wastewater may be classified under the following categories.

(i) Natural methods	(a) By dilution, and (b) By land treatment
(ii) Artificial methods	(a) Primary treatment, and (b) Secondary treatment.
(iii) Combined methods	(a) Primary treatment, and (b) Effluent disposal by natural methods.

* Sewage disposal by Dilution

→ Disposal by dilution is the process whereby the treated wastewater or effluent from treatment plants is discharged either in large static water bodies (such as lake or sea) or in moving water bodies such as river or streams.

→ The discharged waste water or effluent is purified in due course of time, by the so called self purification process of natural waters.

→ The limit of effluent discharge and the degree of treatment of waste water depend upon the self purification capacity of natural waters as well as the intended use of water body at the downstream side.

Essential Conditions for dilution

(i) The wastewater is quite fresh ie. it is discharged within 2 to 3 hours of its collection.

(ii) The floating matter and settleable solids have been removed from wastewater

(iii) Water body has large volume in comparison to the volume of waste water.

(iv) The diluting water has high content of DO, so that not only BOD is satisfied but sufficient DO remains available for aquatic life.

(v) It is possible to throughly mix or diffuse the wastewater through the water body

(vi) Swift forward currents are available, so that there is no deposition of sewage at the site.

(vii) The wastewater does not contain industrial wastewater having toxic substances.

(viii) The receiving water is not a source of drinking water collection immediately to the downstream side.

* Self-purification of streams

→ When the wastewater or the effluent is discharged into a natural stream, the organic matter is broken down by bacteria to Ammonia, nitrates, sulphates, Carbon-dioxide etc. In this process of oxidation, the DO content of natural water is utilised. Due to this, deficiency of dissolved oxygen is created. As the excess organic matter is stabilized, the normal cycle will be re-established in a process known as self-purification wherein the oxygen is replenished by its re-aeration by wind. Also, the stable byproducts of oxidation mentioned above are utilized by plants & algae to produce carbohydrates and oxygen.

~~Thus, the abi~~ Water quality standards are often based upon maintenance of some minimum dissolved oxygen concentration which will protect the natural cycle in the stream while taking advantage of its natural assimilative capacity.

Thus, Self purification of streams is the ability of streams to purify itself naturally and to bring back the polluted water into its original purified condition.

Factors affecting self-purification

(i) Dilution

→ When wastewater is discharged into the receiving water, dilution takes place due to which the concentration of organic matter is reduced and the potential nuisance of sewage is also reduced.

→ When the dilution ratio is high, large quantities of DO are always available which will reduce the chances of putrefaction and pollutional effects.

→ Aerobic conditions will always exist because of dilution. This will however not be there if dilution ratio is small, ie. when large quantities of effluent is discharged into a small stream.

The dilution capacity of a stream can be calculated using the principles of mass balance.

$$C_S Q_S + C_R Q_R = C(Q_S + Q_R)$$

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

where,

C = resulting mixture concentration (mass/volume)

C_S, C_R = sewage concentration & Concentration in river/stream resp.

Q_S, Q_R = flow rate of sewage & river resp.

(ii) Dispersion due to currents

→ self purification of stream largely depends upon currents which will readily disperse the wastewater in the stream, preventing locally high concentration of pollutants.

→ High velocity improves reaeration which reduces the concentration of pollutants and time of recovery, though the length of stream affected by the wastewater is increased.

→ low velocity → causes formation of sludge bank

(iii) Sedimentation

→ If the stream velocity is lesser than the scour velocity of particles, sedimentation will take place, which will have two effects:

(a) the suspended solids, which contribute largely to oxygen demand will be removed by settling & hence water quality to the downstream will be increased.

(b) due to settled solids, anaerobic decomposition may take place.

(iv) Oxidation

→ The organic matter, present in the wastewater is oxidised by aerobic bacteria utilising DO of the natural water and this process prevails till complete oxidation of organic matter takes place.

→ The stream which is capable of absorbing more oxygen rapidly through re-aeration can purify heavily polluted water in a short time.

(v) Reduction

→ The reduction occurs in the streams due to hydrolysis of the organic matter biologically or chemically.

→ Anaerobic bacteria will split the organic matter into liquid & gases, thus paving way for their ultimate stabilization by oxidation.

(vi) Temperature

→ At low temp, the activities of bacteria is low & hence rate of decomposition will also be slow, though DO will be more and vice-versa.

(vii) Sunlight

→ Sunlight helps certain micro-organisms to absorb CO_2 & give out O_2, thus assisting in self-purification.

→ Sunlight acts as a disinfectant & stimulates the growth of algae which produce O_2 during daylight & utilize O_2 at night (anaerobic conditions exist).

* Zone of pollution in the stream

→ The self purification process of stream polluted by the wastewater or effluent discharged into it can be divided into the following four zones:

(i) Zone of degradation
(ii) Zone of active decomposition
(iii) Zone of recovery
(iv) Clear water zone.

Zone of degradation

→ This zone is situated just below the outfall sewer when discharging its content into the stream.
→ Water is dark and turbid, having the formation of sludge deposits at the bottom.
→ DO is reduced to 40% of the saturation values.
→ Increase in CO_2 content, & reaeration is much slower than deoxygenation.
→ Though conditions are unfavourable for aquatic life, fungi at higher points & bacteria at lower points breed small worms which 'work over' and stabilize the sewage sludge.
→ The decomposition of solid matter takes place in this zone and anaerobic decomposition prevails.

Zone of active decomposition

→ This zone is just after the degradation zone & is marked by heavy pollution.
→ Water in this zone becomes greyish & darker than the previous zone.
→ The DO concentration in this zone falls down to zero.
→ Active anaerobic organic decomposition takes place, with the evolution of CH_4, H_2S, CO_2 & N_2, bubbling to the surface with masses of sludge forming black scum.
→ fish life is absent in this zone but bacteria ~~floor~~ flora will flourish with the presence of anaerobic bacteria at upper end and aerobic bacteria at the lower end.
→ Protozoa and fungi will first disappear and then reappear, while algae will mostly be absent.
→ Near the end of this zone, as the decomposition slackens, reaerations sets in and DO again rises to its original level of 40%.

Zone of recovery

→ In this zone, the process of recovery starts, from its degraded condition to its former condition.

→ Stabilization of organic matter takes place in this zone. Due to this, most of the organic matter settles as sludge, BOD falls and DO content rises above the 40% value.

→ Mineralisation is active, with the resulting formation of products like nitrates (NO_4), Sulphates (SO_4), carbonates (CO_3).

→ Near the end of the zone, microscopic aquatic life reappears, fungi decrease and algae re-appears.

Clear Water Zone

→ In this zone, the natural condition of stream is restored with the result that (i) Water becomes clearer and attractive in appearance

(ii) DO rises to the saturation level, & is much higher than BOD, &

(iii) Oxygen balance is attained.

→ Recovery is said to be complete in this Zone, though some pathogenic organisms may be present in this zone.

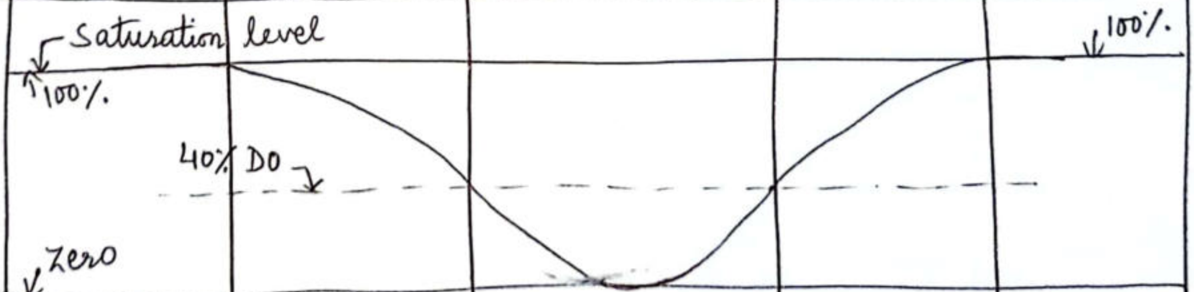
<table>
<tr><th rowspan="2">Particulars</th><th colspan="5">← Zone of Pollution →</th></tr>
<tr><th>Clear Water</th><th>Zone of Degradation</th><th>Zone of active decomposition</th><th>Zone of recovery</th><th>Clear water Zone</th></tr>
<tr><td>1. DO SAG CURVE</td><td colspan="5">
</td></tr>
<tr><td>2. PHYSICAL INDICES</td><td>- Clear Water
- No Bottom sludges</td><td>- Floating solids, Bottom sludge, Colour, Turbidity</td><td>- Greyish and darker color,
- CH_4, H_2S, CO_2, N_2 Gases evolution
- Black scum at top</td><td>- Turbid with bottom sludge</td><td>- Clearer water with no bottom sludge</td></tr>
</table>

fig: Zone of pollution along a stream

Oxygen Sag Curve

→ The oxygen sag or oxygen deficit in the stream, at any point of time during the self purification process is the difference between the saturation DO content and the actual DO content at that time.

Oxygen Deficit, D = Saturation DO − Actual DO

Deoxygenation and reoxygenation curves.

→ When pollution load / sewage is discharged into the stream, the DO content of the stream goes on depleting. This depletion of DO content is known as deoxygenation.

→ The rate of deoxygenation depends upon the amount of organic matter remaining (L_t) to be oxidised at any time t, as well as the temperature (T) of the reaction.

→ The ordinates below the deoxygenation curve indicate the oxygen remaining in the natural stream after satisfying the BOD.

→ Though the DO content of the stream is gradually consumed due to BOD load, atmosphere supplies oxygen continuously to the water through the process of re-aeration or reoxygenation.

→ The rate of reoxygenation depends upon the depth of water in the stream (more for shallow depth), velocity of flow in the stream (less for stagnant water), oxygen deficit below saturation DO & temp. of water.

→ The ordinates below the reoxygenation curve indicates the oxygen absorbed by the stream.

→ The algebraic sum of deoxygenation curve & reoxygenation curve gives a oxygen sag curve which depicts the variation of oxygen deficit (D) with the distance along the stream (& hence time of flow from the point of pollution)

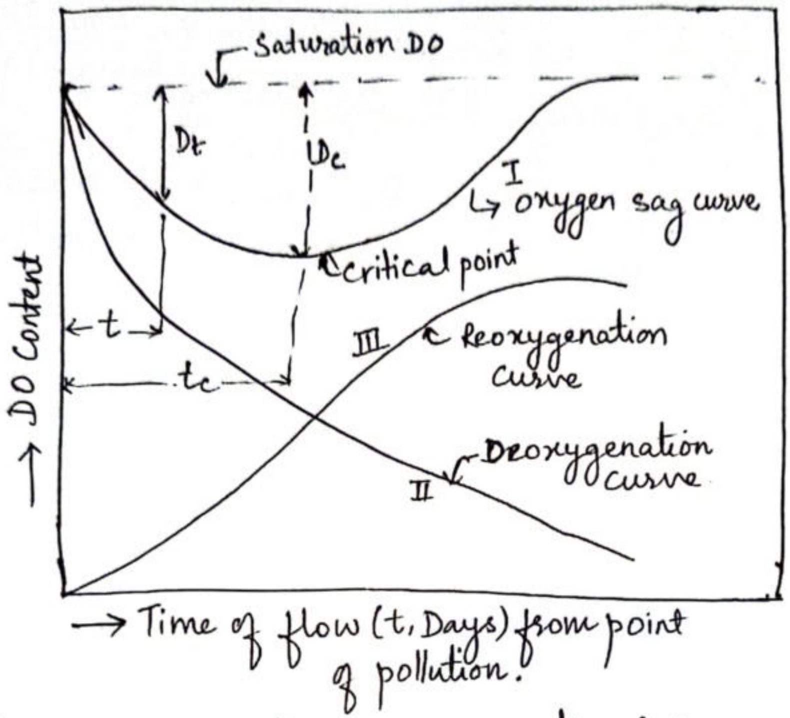


fig : Deoxygenation, Reoxygenation & Oxygen sag curve.

* Streeter - phelps equation

→ The entire analysis of oxygen sag curve can be easily done by super-imposing the rates of deoxygenation and reoxygenation, as suggested by Streeter- phelps analysis given below.

$$\frac{dD_t}{dt} = f\text{ (deoxygenation \& reoxygenation)}$$

$$\frac{dD_t}{dt} = K'L_t - R'D_t$$

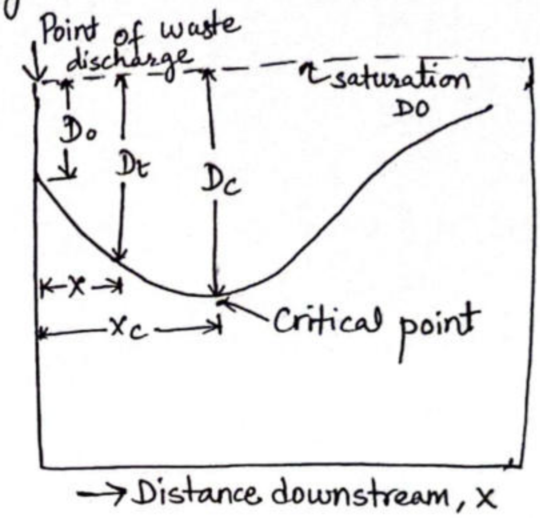


fig: Characteristic oxygen sag curve obtained using streeter-phelps eqⁿ.

where,

D_t = DO deficit at any time t

L_t = amount of 1st stage BOD remaining in the sample at any time t

K' = deoxygenation constant to the base e

R' = reoxygenation " " " " "

t = time in days

$\frac{dD_t}{dt}$ = rate of change of DO deficit

But, $L_t = L_o e^{-K't}$; L_o = BOD remaining at time t = 0

Hence, $$\frac{dD_t}{dt} = K'L_o e^{-K't} - R'D_t$$

or, $$\frac{dD_t}{dt} + R'D_t = K'L_o e^{-K't} \qquad \text{—— (i)}$$

The solution for the above 1st degree differential eqⁿ is

$$D_t = \frac{K'L_o}{R'-K'}\left[e^{-K't} - e^{-R't}\right] + D_o e^{-R't}$$

Changing it to the base 10, we get

$$D_t = \frac{KL_o}{R-K}\left[10^{-Kt} - 10^{-Rt}\right] + D_o 10^{-Rt}$$ ✓ oxygen sag eqⁿ

where,

K = Deoxygenation constant to the base 10

R = Reoxygenation constant " " " "

D_o = Initial oxygen deficit at the point of waste discharge at time t = 0.

Determination of critical DO Deficit (D_c) at the point x_c

→ At this, rate of oxygen utilised for waste decomposition is equal to the rate of atmospheric reaeration.

The value of D_c can be obtained by putting $\frac{dD_t}{dt} = 0$ in eqn (i).

Thus we obtain,

$$D_c = \frac{K'}{R'} L_0 e^{-K't_c}$$

$$D_c = \frac{K}{R} L_0 (10)^{-Kt_c}$$ where, t_c = time required to reach the critical point.

Also,

$$t_c = \frac{1}{R-K} \log_{10} \frac{R}{K} \left[1 - \frac{D_0(R-K)}{KL_0}\right]$$

Distance, $x_c = t_c \cdot V$; V = velocity of flow in the stream.

$$K_T = K_{20}\, \theta^{(T-20^\circ)} \quad ; \quad R_T = R_{20}\, \theta^{(T-20^\circ)}$$

Self purification constant ; $f = \frac{R'}{K'} = \frac{R}{K}$

$$\therefore\ t_c = \frac{1}{K(f_s-1)} \times \log_{10}\left[f_s \left\{1 - (f_s - 1)\frac{D_0}{L_0}\right\}\right]$$

Also, $D_c = \frac{L_0}{f_s} (10)^{-Kt_c}$

Taking log on both sides & solving, we get

$$\left(\frac{L_0}{f_s D_c}\right)^{f_s - 1} = f_s \left\{1 - (f_s - 1)\frac{D_0}{L_0}\right\}$$

where, L_0 is the 1st stage BOD of mixture of wastewater & stream.

* Dilution into sea.

→ Saturation concentration of DO in water decreases with increasing salt content.

→ temp. of sea water is lower than the sewage temp, whereas the specific gravity is higher.

→ Due to these reasons, when the sewage is discharged into the sea water, the lighter and warmer sewage will rise to the surface, resulting in the spreading of the sewage at the top surface of sea in a thin film or 'sleek'.

→ formation of slude banks due to chemical reaction of dissolved matter of sea & sewage.

→ However, since the sea contains large volume of water, most of these deficiences can be overcome if the sewage is discharge deep into the sea, much away from the coastline with extreme care!

CamScanner

Sewage disposal by land treatment

→ When the wastewater, either raw or partly treated, is applied or spread on the surface of land, the method is called disposal by land treatment.

→ Some part of the wastewater evaporates while other part percolates in the ground leaving behind suspended solids which are partly acted upon by the bacteria and partly oxidised by exposure to atmospheric action of air, heat and light. The sewage adds to the ~~value~~ fertilizing value of the land, and crops can be profitably raised on such land.

Conditions favourable for land treatment

(i) When natural rivers or streams are not located in the vicinity, land treatment is the only alternative.

(ii) When rivers run dry or have a very small flow during summer.

(iii) When plentiful land with sandy, loamy or alluvial soil overlying soft murram, sand or gravel is available.

(iv) When climate is arid, land treatment is favoured.

(v) When subsoil water table is low even during wet season.

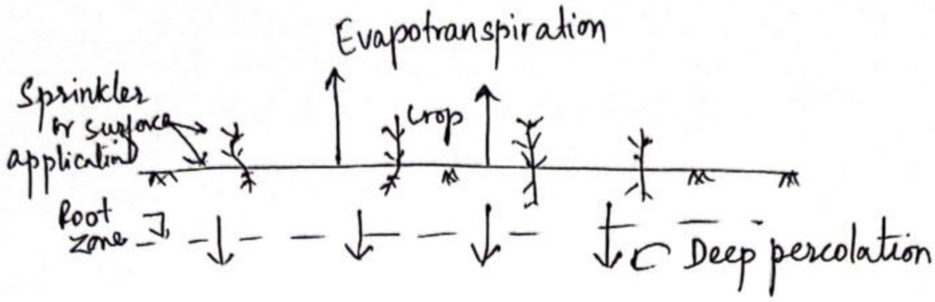
(vi) When rainfall is low & there is an acute demand for irrigation water.

(vii) When large open areas in the surround locality are available.

(viii) Cash crops can be easily grown on sewage farms.

Methods of land treatment

(i) Broad Irrigation or Sewage farming
(ii) Rapid Infiltration
(iii) Overland runoff



(a) Irrigation

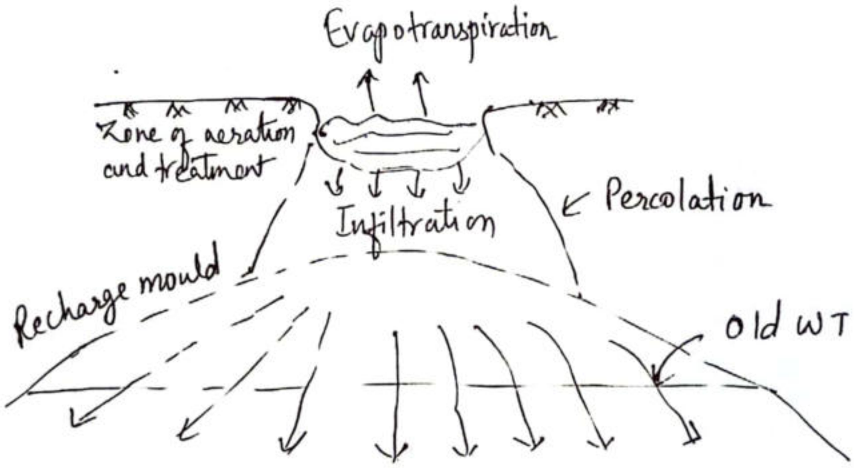
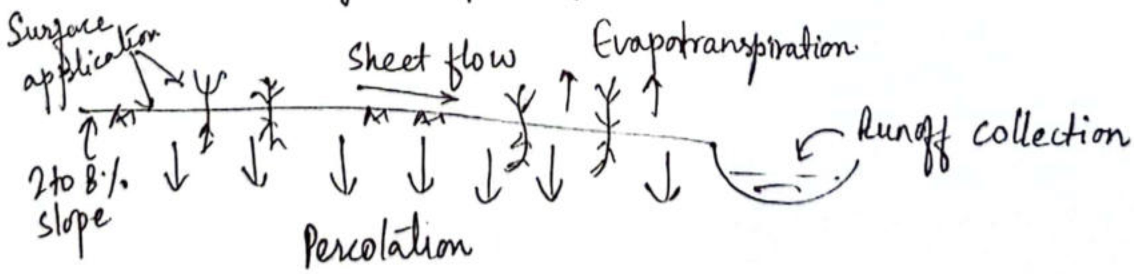


fig (b) Rapid infiltration



(c) Overland runoff

Methods of application of wastewater

(1) Sprinkler or spray irrigation
(2) Sub-surface irrigation
(3) Surface irrigation (i) Basin method (ii) Flooding method
(iii) furrow method

* Sewage Sickness

→ After continuous application of sewage on land, the pores of the soil get clogged, preventing oxidation and causing noxious smells. The land is unable to take any further load of sewage. This phenomenon of soil is known as sewage sickness of land.

Sewage sickness can be prevented by adopting the following measures.

(i) Pretreatment of sewage

(ii) Provision of extra land - acts as reserve land

(iii) Under drainage of soil - provisions of sub drains

(iv) Proper choice of land.

(v) Rotation of crops.

(vi) Shallow depth application

* Comparision of disposal methods.

(i) Disposal by dilution - large volume of natural waters are required
Disposal by land application - large area of pervious land is required

(ii) Urban areas — cost of land is high, so disposal by land application may be costly
If vicinity of natural water, disposal by dilution may be preferred.

(iii) Rural areas — cost of land is relatively less. Rate of water supply is generally less, resulting in concentrated sewage. For such cases, disposal through land application may be preferred.

(iv) Disposal by land application - either raw or treated sewage.
Disposal by dilution - efficient pretreatment to meet the effluent quality requirements, is must

(v) Disposal by land application - requires efficient land management while dilution method does not require such management.

(vi) Land application - increase yield of crops, but it should be practised with caution since it may cause serious health hazards. may also pollute ground water.

(vii) Receiving water - if source of w/s in D/S, disposal by dilution cannot be adopted unless high degree of pre-treatment is applied to the effluents.

(viii) In hot climates, DO content of natural water is low & water flow is less if high degree of pretreatment is not applied; land disposal is preferred.

* Sludge treatment and disposal

→ There are two end products obtained from various wastewater treatment plants. (i) effluent, and (ii) sludge. The treated effluent is directly discharged either in the receiving waters, or on land. However, the sludges are to be first processed before their final disposal.

→ sludge are the solids that settle when sewage is passed through a settling tank.

Sources of sludge

As the various stages or methods of treatment of wastewater yield sludges, the sources of sludge are:

(i) Primary settling tanks
(ii) Chemical precipitation
(iii) Trickling filter
(iv) Activated sludge process

Necessity of treatment

→ The sludge resulting from waste water treatment plants/processes & operation is usually in the form of a liquid or a semi-liquid which typically contains 0.25 to 12 percent solids.

→ Sludge is loaded mostly with putrescible organic substances. The high organic content of the sludge demands further treatment prior to its final disposal.

The necessity of sludge treatment are:

(i) To reduce the large bulk volume of sludge so that the disposal volume of sludge is less, thus sludge handling and treatment costs can be decreased.

(ii) To breakdown and stabilise the decomposable or putrescible organic matter present in sludge to prevent sanitary conditions.

(iii) To kill the pathogens present in the sludge.

(iv) To recover the industrial volume of the sludge.

Sludge Digestion

→ biochemical phenomenon involving organisms, enzymes, food and environment.

→ principal objective of sludge digestion is to subject the organic matter present in the settled sludge of the primary and final sedimentation tanks to aerobic or anaerobic decomposition so as to make it innocuous (not harmful) and amenable to dewatering on sand beds or mechanical filters before final disposal on land, lagoon or sea.

→ sludge digestion brings about a reduction in its volume.

Types : (i) Anaerobic digestion (ii) Aerobic digestion

Anaerobic digestion

→ biological decomposition of organic matter in absence of oxygen.

→ consists of two distinct stages which occurs simultaneously in digesting sludge.

→ The first stage, known as acid fermentation, consists of hydrolysis and liquefaction of high molecular-weight organic compounds and conversion to organic acids by acid forming bacteria.

→ The second stage, known as methane fermentation, is gassification of the organic acids to methane and carbon dioxide by acid splitting methane forming bacteria.

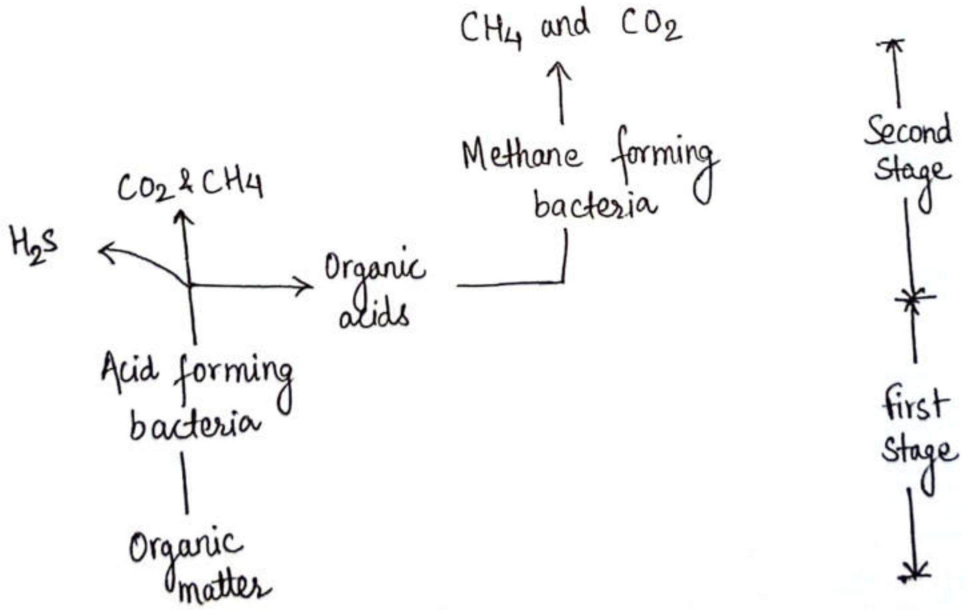


fig : Stages in anaerobic bacteria

→ Due to very low microbial growth rate, the production of biological sludge in the anaerobic processes is very low. Moreover, a major portion of organic waste is converted into gas. Hence, the effluent of an ~~aer~~ anaerobic process is much more stabilized.

Aerobic digestion

- → stabilize waste sludge by long term aeration, thereby reducing the BOD and destroying volatile solids.
- → It is a process in which micro-organisms obtain energy by endogenous or auto-oxidation of their cellular protoplasm.
- → accomplished in one or more tanks mixed by diffused aeration.
- → can be used for secondary tank humus or for a mixture of primary and secondary sludges but not for primary sludges alone.
- → factors that should be considered in designing an aerobic digester include detention time, loading criteria, oxygen requirement, mixing and process operation.
- → Biologically degradable constituents of the cellular material are slowly oxidised to carbondioxide, water and ammonia.

Advantages

(i) Lower BOD concentration in digester supernatant.
(ii) Production of odourless and easily dewaterable biologically stable digested sludge.
(iii) Recovery of more basic fertilizer value in digested sludge.
(iv) Lower capital cost
(v) few operational problems

Disadvantages

(i) Higher power costs generate higher operating costs comparable with anaerobic digestion.
(ii) generates high solids concentration in the supernatant.
(iii) Some aerobically digested sludges donot dewater easily in vacuum filtration.
(iv) No methane gas is produced for recovery as a by-product.

→ The aerobic digestion process appears to be particularly well suited for industrial sludge treatment and for small, municipal activated sludge plants.

Methods of sludge treatment

→ The object of sludge treatment is to reduce the water content of sludge and stabilize the organic content of the sludge.
sludge treatment may include all or a combination of the following unit operations and processes :
(i) grinding and blending
(ii) thickening
(iii) Stabilization
(iv) dewatering
(v) drying
(vi) composting ~~and incineration~~
(vii) incineration

(i) Grinding and blending

→ This is a preliminary operation performed to produce a uniform size of solids by cutting them into small pieces containing the sludge. It helps to prevent clogging and warping around rotating equipment.
→ Grinding is done to produce a homogenous and uniform size of sludge by grinding machine, and blending is done in a blending tank to mix sludge of different characteristics.
→ It is the only preparation of sludge for sludge treatment, though, it may be an optional operation.

(ii) Thickening

→ It is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction.
→ Three types of thickening commonly practised are
(a) gravity thickening (b) air floatation, and (c) centrifugation

the purposes of sludge thickening are :
(a) to permit increased loadings to sludge digesters.
(b) to increase feed solids concentration to vacuum filters
(c) to minimise the land requirements
(d) to save fuel (energy) required to burn the sludge.

(iii) Digestion

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

→ hydrolysis, acidogenesis, acetogenesis & Methanogenesis.

(iv) Conditioning

→ It improves the drainability of dewatering sludge.

→ It can be achieved by various methods such as elutriation, chemical conditioning, heat treatment, freezing etc.

(v) Dewatering

→ It is a physical unit operation used to reduce the moisture content of the sludge, and thus to increase the solids concentration.

→ It is accomplished either by air drying in sludge drying beds or by mechanical means such as vacuum filtration, centrifugation, pressure filtration etc.

Purpose of dewatering.

(a) Cost of trucking sludge to ultimate disposal site is reduced, because of reduced sludge volume

(b) Ease in handling dewatered sludge.

(c) Increase in calorific value of sludge by removal of moisture, prior to incineration.

(d) Rendering the sludge totally odourless and non putrescible

(e) required prior to land filling, to reduce the lechate production at landfill site.

(vi) Composting.

* Mechanical ; open window methods

→ aerobic biological decomposition of organic matter into a stable end product at an elevated temperature.

→ the finished compost has a moisture content of 40% to 50% and a volatile solid content of 40% or less.

→ to increase the amount of compost and enrich the contents, nitrogeneous matter like night soil, cowdung etc. can be added.

(vii) Heat Drying:

→ The purpose is to reduce further the moisture content and volume of dewatering sludge, so that it can be used after drying without causing offensive odours or risk to public health.

→ Drying is brought about by directing a stream of heated air or other gases at about 350°c.

(viii) Incineration

→ It involves the combustion of the sludge in a reactor under high temperature along with auxilliary fuels, if needed.

→ The purpose of incineration is to destroy the organic material and pathogens, the residual ash being generally useful as land fill.

→ Dewatered or digested sludge is subjected to temperature between 650°c to 750°c.

→ Flash type and multiple hearth type furnaces are used with proper heating arrangements with temperature control and drying mechanisms.

1. Acid fermentation - 15 days <7
2. Acid Regression - 90 days around 7
3. Alkaline fermentation - 30 days. >7

Factors affecting

1. PH - (7.2 to 7.4)
2. Temperature.
3. Seeding with digested sludge
4. Mixing raw sludge with digested sludge

Methods of sludge disposal

→ Sludge (either wet, dry or incinerated) can be disposed off by the following methods :

1. Spreading on land
2. Dumping
3. Land filling
4. Sludge lagooning
5. Disposing in water or sea

1. Spreading on land

→ Dewatered sludge may be disposed of by spreading over farm land and ploughing under after it has dried.

→ Wet dewatered sludge can be incorporated into soil directly by injection.

→ Usually a number of shallow trenches, 0.5 to 0.9m wide & 0.3 to 0.4m deep are provided about 1 to 1.5m apart, and wet sludge is discharged into it & is covered with dry earth after a sludge cake is formed due to evaporation of water. After about a month, the whole land is ploughed & used for cultivation.

→ Suitable in arid regions.

2. Dumping.

→ Dumping in an abandoned mine, quarry can be resorted to only for sludges and solids that have been stabilized so that no decomposition or nuisance conditions will result.

→ Can be safely adopted for digested sludge, clean grit & incinerator residue

3. Disposal by land filling

→ If a suitable site is convenient, a sanitary landfill can be used for disposal of sludge, grease, grit and other solids, whether stabilised or not. However, dewatering is recommended before such disposal, so that the cost of hauling the sludge is reduced.

→ In a true sanitary landfill, the wastes are deposited in a designated area, compacted in place with a tractor or roller and covered with 30 cm layer of clean soil.

→ Drainage from the site that would cause pollution of ground water supplies or surface streams must be guarded against.

4. Sludge Lagooning.

- A lagoon is a shallow earth basin into which untreated or digested sludge is deposited.
- Untreated sludge lagoons stabilize the organic solids by anaerobic and aerobic decomposition, which may give rise to objectionable odours. Hence, the lagoons should be located away from the town.
- The detention time may vary from 1 to 2 months.
- After the sludge has been stabilized & the moisture is drained/evaporated, the contents of the lagoon are dug out to about half of its volume & used as manure.
- can be used as emergency storage when digesters have to be emptied for repairs.

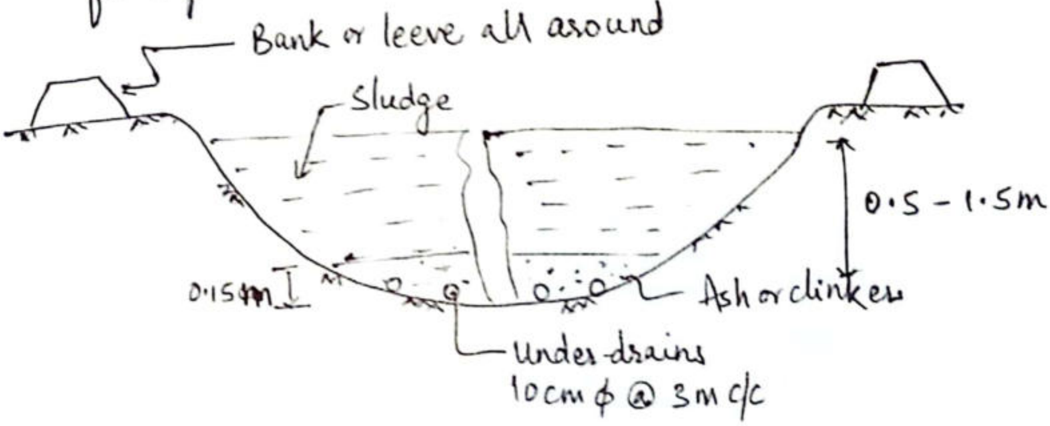


fig: Sludge lagoon

5. Disposal in water or sea

- not a common method of disposal.
- required dilutions should be maintained.
- this method requires careful consideration of all factors for proper design and siting of outfall to prevent any coastal pollution or interference with navigation.