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Branch:- CIVIL

Environmental Engineering-II

CONTENT

Environmental Engineering-II

Unit 1 Sewage and Sewarage, definitions and some common terms, object of sewage disposal. System of sanitation: Conservancy systems, Water system, sewage system-combined, separate and partially separate, patterns of collection system. Amount of sewage-Estimation of domestic and storm sewage, variations in the quantity of sewage, Design of sewers (Only circular sewer) Manholes, Pumping stations, Wet well capacity.

Unit 2 Characteristics of sewage-physical, chemical and biological characteristics, fundamentals of aerobic & anaerobic process. Sewage treatment-preliminary treatment systems, Racks and screens, comminuters, Grit chambers. Primary treatment systems-Plain sedimentation, detention time and over-flow rates, types of inlets and outlets, onsite wastewater treatement- septic tank, Imhoff tank, oxidation pond .

Unit 3 Secondary treatment systems-(i) Attached growth process-Trickling filters, standard and high rates, efficiency (NRC) formula, operational problems of trickling filters (ii) Suspended growth process, principle of suspended growth process, Activated sludge process, Oxidation ditch aeration and mixing techniques, Operational problems of activated sludge systems, stablisation tools aerobic, anaerobic and facultative lagoon.

Unit 4 Sewage sludge treatment-Importance, amount and characteristics of sludge, sludge digestion, Anaerobic digestion, aerobic digestion, sludge drying beds. Sewage disposal: disposal by dilution, self purification of polluted streams, factors affecting self purification, Sag curve, disposal on land surfaces. Stream standards, Effluent standards, theories of waste treatment (Volume reduction, strength reduction, new Equalization and proportioning) Summery of Industrial waste, its origin, character and treatment.

Unit 5 Solid waste management, source and characteristics, environmental and health implications, refuse characteristics, collection methods, disposal of solid waste by land filling, composting and incineration methods. Collection and disposal of refuse, Composting of refuse.

UNIT-I Sewage and Sewarage

Sewage and Sewarage, definitions and some common terms, object of sewage disposal. System of sanitation: Conservancy systems, Water system, sewage system-combined, separate and partially separate, patterns of collection system. Amount of sewage-Estimation of domestic and storm sewage, variations in the quantity of sewage, Design of sewers (Only circular sewer) Manholes, Pumping stations, Wet well capacity.

Q.1. Define the following terms.

(I) Sewerage: - It is the branch of engineering which deals with the collection and carrying of sewage through underground sewers by water carriage system away from the towns and dispose it if in such an order, that it may not cause any danger to the human health.

(II) Refuse: - It includes all types of dry wastes of the community. It is divided into following categories.

(i) Garage (ii) Rubbish (iii) Ashes (iv) Sewage (v) Silage.

(i) **Garage:** - It includes all types of semi solids and solid waste food and products as vegetables, peelings of fruits, waste meats etc.

(ii) **Rubbish:** - It means all sundry solid wastes as paper, broken furniture, Pottery, waste building materials etc.

(iii) **Ashes:** - These are the residues which remain after the combustion of coal, coke, timber un the hearts and furnaces of houses and industries.

(iv) **Sewage:** - It includes the liquid waste from the community, discharge from latrines, urinals, industrial waste and storm water. It is further classified into two categories:-

(a) **Strom sewage:** - It includes surface runoff developed during and immediately after rainfall over the concerned area.

(b) **Sanitary sewage:** - It includes liquid wastes of domestic and industrial places. This sewage is extremely foul in nature and required to be disposed off very carefully.

(c) **Silage:** - The water collector from kitchen, baths, sinks and similar appliances from building which does not contain human or any animal excreta is known as Silage.

(III) Drainage: - The removal of any liquid by a system constructed for the purpose.

(IV) Drain: - A line of pipes including all fittings and equipments such as manhole, traps, gullies and floor traps used for the drainage of a particular area. It also include open channels used for conveying surface water.

(V) Sewer: - The underground conduits or drains through which sewage is conveyed are known as the sewers.

Following terms are used in practice in connection with different types of sewers.

(i) **Combined sewer:** - The sewer which carries domestic sewage and storm water is known as a combined sewer.
(ii) **Common sewer:** - The sewer on which all the inhabitants have equal legal rights is known as a common sewer.
(iii) **Depressed sewer:** - When an obstruction or obstacle is met with the sewer is constructed lower than the adjacent sections to overcome the obstruction or obstacle. Such a section of sewer is known as a depressed sewer.
(iv) **Intercepting sewer:** - This term is used to indicate the sewer which intercepts the discharge from a number of main or outfall sewers and it carries the flow to the point of treatment and disposal.
(v) **Lateral sewer:** - The sewer obtaining its discharge directly from buildings is known as a lateral sewer.
(vi) **Brach or Submain sewer:** - This term is used to indicate the sewer which obtains its discharge from a few laterals and delivers it to the main sewer.
(vii) **Main sewer:**- This term is used to indicate the sewer which obtains its discharge from a few branch or submain sewers.

Q.2 Explain the methods of collection of the refuse.

Ans. There are two method which are employed for the collection and disposal of refuse.

(i) Conservancy system and (ii) Water carriage system.

(i) Conservancy system: - In this system, the different types of refuses are collected separately and then each type is carried and suitably disposed off. Sometimes this system is also called as dry system.

In this system, the garbage or dry refuse is collected from roads and streets in pans or baskets. It is then conveyed by carts, trucks etc., to some suitable place. The garbage is separated into two categories, flammable and inflammable matters. The flammable matter is burnt into

incinerators and the inflammable matter is buried into low-lying areas for the reclamation of soil.

The night soil is collected in pans from lavatories and the sewage is carried by labors in cars, trucks etc. It is then buried into the ground and is thus converted into manure.

The storm water and silage are collected and conveyed separately by closed or open channels. They are discharged in natural rivers or streams.

(ii) Water carriage system:- In this system, the water is used as medium to convey the sewage to the point of its treatment or final disposal. The quantity of water to be mixed with solid matter is quite sufficient and the dilution ratio of solid matter with water is so great that the mixture behaves more or less like water.

In this system, the garbage is collected and conveyed as in case of conservancy system. The storm water may be carried separately or may be allowed to flow with the sewage.

Q.3 (a) Compare the "Conservancy system" and "Water carriage system".

Conservancy system	Water carriage system
1) It does not permit compact design of structures.	1) It permits compact design of structures.
2) It is laid above ground hence it is visible but non-hygienic.	2) It is necessarily laid below ground, hence it is not visible but hygienic
3) It requires small quantity of water to the extent of about 30 to 40 liter per capital per day	3) It requires large quantity of water to the extent about 100 to 120 liter per capita per day.
4) There exists putrefaction.	4) There are no chances for putrefaction.
5) It has been normally considered as system for rural conditions.	5) It has come up basically as an urban system
6) The labour force required is much more.	6) Only few labors are required.
7) It is cheap in initial cost but expensive in maintenances work.	7) It is expensive in initial cost but maintenance costs are low.
8) There are chances for out-break of epidemic.	8) It requires the help of skilled or technical personals for laying maintenance and running

	of treatment units.
9) It does not require the help of skilled or technical personals	9) It requires the help of skilled or technical personals for laying maintenance and running of treatment units.
10) The city remains dirty and foul smelling	10) The city appears neat and clean.
11) It is likely that underground sources of water may be polluted due to soaking of liquid wastes from the latrines.	11) There is practically no risk of pollution of underground sources of water as sewage is carried in closed sewer and above the water pipes.

Q.4 (a) What is the classification is of sewerage system? Explain suitability of each system and state the advantages and disadvantages of each.

Ans. Following are the three systems of sewerage:

(1) Separate system,
(2) Combined system and
(3) Partially separate system.

(1) Separate system: - In this system, the two sets of sewers are laid, one for carrying sewages and the other for carrying storm water. The sewages are carried to the treatment plant and the storm water is directly discharged into the natural outlet in the form of river or stream.

Advantages:-

(i) The load on treatment units becomes less.
(ii) The natural water is not unnecessarily polluted.
(iii) The sewers are small in size.
(iv) The storm water can be discharged into natural streams without any treatment.
(v) The system proves to be economical when pumping is required for the lifting of sewage.

(2) Combined system: - In this system, only one set of sewers is laid and it carries both, sewage and storm water. The sewage and storm water are carried to the sewage treatment plant.

Advantages:-

(i) It is easy to clean a combined sewer as it is of large size.
(ii) The maintenance costs are reasonable.
(iii) The strength of sewage by dilution.
(iv) This system requires only one set of sewers and it may thus prove to be economical.

Disadvantages:-

(i) During extraordinary heavy storms, the combined sewer may overflow and it may thus put public health in danger.
(ii) The combined sewer, if not properly designed gets easily silted and it may even become foul in dry weather.
(iii) The load on treatment plant increases.
(iv) The sewers are large in diameter.
(v) The store water is unnecessarily polluted.
(vi) The system proves to be uneconomical when pumping is required for the lifting of sewages.

(3) Partially separate system: - In this system, the arrangement is made to permit early washings by rain into sewers carrying sewages. But when the quantity of storm water exceeds a particular limit, it is collected and conveyed in open drains to the natural river or stream.

Advantages:-

(i) It combines the advantages of both above systems.
(ii) The entry of storm water avoids silting in sewers.
(iii) The problem of disposing storm water from houses is simplified.
(iv) The sewers are of reasonable size.

Disadvantages:-

(i) The quantity of storm water admitted in sewer may increase the load on pumping an treatment units.
(ii) The velocity of flow is low in dry weather.

Q.5 (a) Compare the Separate and Combined system.

Ans.

Separate system	Combined system
1) In this system the quantity of sewage which is to be treated is very less, because there is no need to treat the storm water.	1) In this system the treatment of sewages and storm water are to be done, so it is very costly method.
2) This system is suitable at the places where more intensity of rainfall place.	2) In the city having less intensity of rainfall, this system very suitable
3) Sewage pumping can be done by this system. Only sewages have to be pumped, so it is less costly.	3) Pumping of sewage is costly because sewages are having storm water.
4) Two sets of sewer liras are laid by one line which is under ground. Sewer flows	4) Total cost of construction in this system is more than the separate

and storm water open drains on ground surface.	system
5) It is difficult to use this system in narrow streets.	5) It is suitable for narrow streets.
6) If intensity of rainfall is less throughout the year then this system is not suitable	6) For less intensity of rainfall this method is totally suitable.

Q.6 (a) Give the various patterns of collection systems.

Ans. There are various patterns of collection systems but important and common system are as follows.

(i) Perpendicular pattern.
(ii) Interceptor pattern.
(iii) Radial pattern.
(iv) Fan pattern.
(v) Zonal pattern.

(i) **Perpendicular pattern:** - In this pattern, the main trunk sewers are land perpendicular to the natural water course and thus they are of the shortest length. This pattern proves useful for separate or partially separate system, in which case, storm water can be disposed off directly without any treatment. This pattern will be impracticable for combined system, as it will require a treatment unit at every point of outlet.

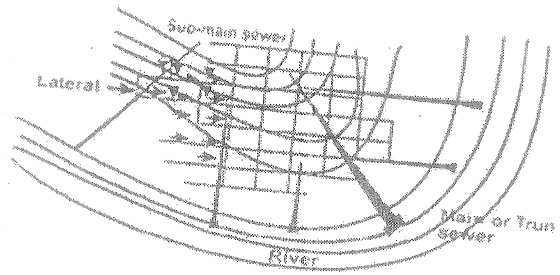


Fig. Perpendicular pattern

(ii) **Interceptor pattern:-**

This pattern is an improvement over the perpendicular pattern. In this pattern, the sewers are intercepted by large size sewers which are laid along the water course. The sewage is carried to the treatment plant and depending upon the facilities provided, it is disposed off either with or without treatment. If the quantity of storm water is more, the storm regulators may be provided at suitable points.

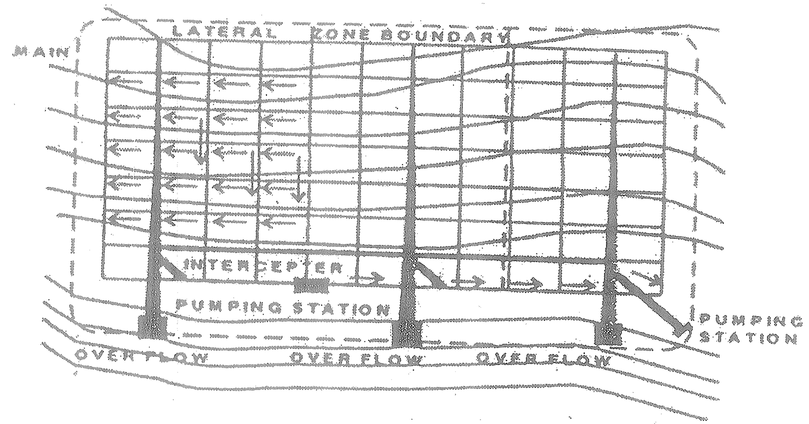


Fig. Intercepter pattern

(iii) **Radial pattern:-**

In this pattern, the sewers are radially outwards from the centre of the city. This pattern is useful for cities, where the faculties of sewage disposal by land treatment are available. This pattern will require large number of disposal works.

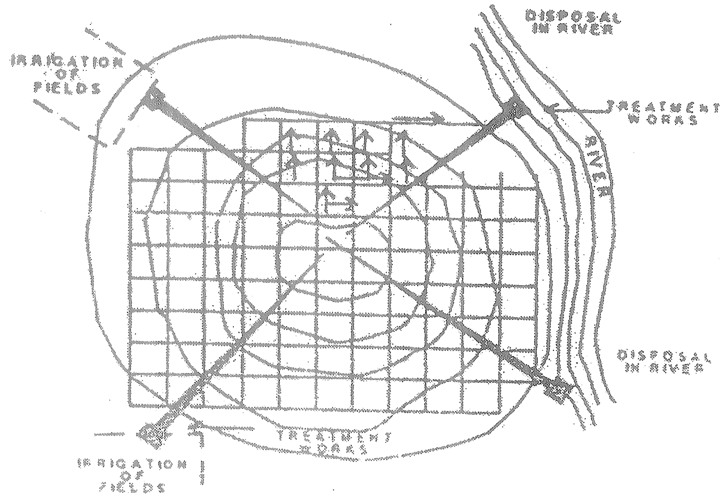


Fig. Radial Pattern

(iv) **Fan pattern:** - In this system of layout, the treatment plant is located at a certain point and the entire sewage flow is directed towards this point. Thus, a fanlike network of conveying main sewers is laid in this pattern. The advantage of this pattern is that only one unit of treatment plant will be required. But it has the following two disadvantages:

(i) The diameter of main trunk sewers will be more and it may result in increase of cost of laying such sewers.

(ii) The development of the surrounding area will increase the load on the treatment plant and hence restriction will have to be imposed on such development.

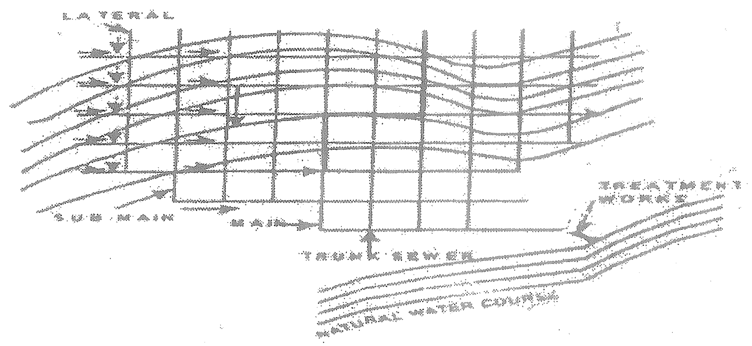


Fig. Fan Pattern

(v) **Zonal pattern:-** In this pattenr, the city is divided into suitable zones and a separate intercepter is provided for each zone. This pattern proves to be economical for cities which are situated on sloping hills.

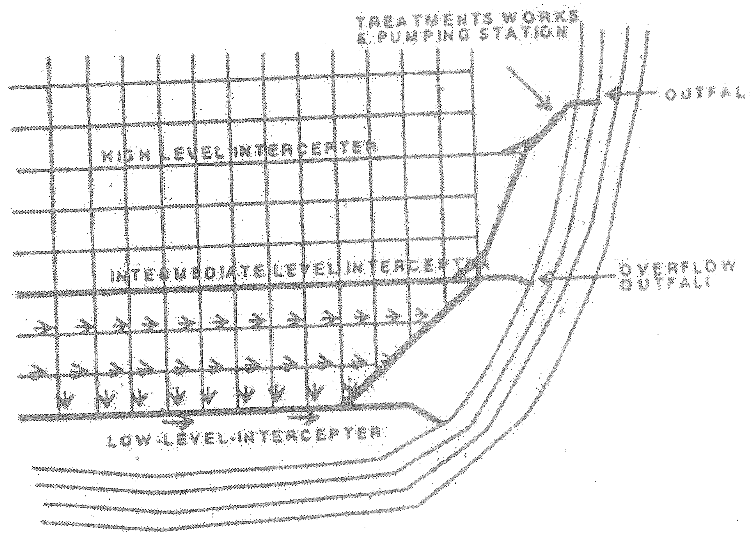


Fig. Zone Pattern

Q.7 List out and explain the factors to be considered in the determination of the quantity of sanitary sewage.

Ans. The quantity of storm water from an area depends upon a number of factors enumerated below.

(i) Intensity and duration of rainfall: - As intensity and duration of rainfall increases, the quantity of storm water also increases.

(ii) Topography of the watershed: - This include such factor as:

(a) Extent of the catchment area: - Bigger the catchment area, greater would be the quantity of storm water.

(b) Shape of be area: - Fan shaped areas drain away discharge more quickly than the oblong-shaped areas.

(c) Slope of the area: - On a steeper slope, the rate of storm water flow would be greater.

(d) Nature of soil: - On a steeper slope, the rate of storm water flow would be greater.

(e) Number of available ditches in the area: - If the number is large and the ditches are also large sized, part of the storm water may be retained or removed. Thus decreasing quantity available for providing storm water drainage.

(iii) Atmospheric temperature, wind and humidity: - Warm temperature, high winds and greater humidity tends to reduce the storm water flow.

Q.8 (a) How the storm water quantity is estimated?

Ans. The quantity of storm water may be calculated by using the following two methods.

(i) The rational method and
(ii) Empirical formulae method.

In both the above methods, the quantity of storm water is a function of the area, the intensity of rainfall and the co-efficient of run-off. The co-efficient of run-off the maximum rate of runoff mainly depends on the surface slope and the estimated condition of the drainages area with reference to the proportion of the rainfall that will run.

(i) The rational method: - The storm water quantity is determined by the following rational formulae.

$$Q = \frac{CiA}{360},$$

Where Q = Quantity of storm water in m^3/s.

C = Coefficinet of run-off.

I = Intensity of rainfall in mm/hr.

A = Catchment area in hectares.

(ii) Empirical formulae method:- All the empirical formulae are applicable only under certain specific conditions, such as slope of land, imperviousness, rate of rainfall etc. These have been developed suiting a particular region after long practical experience and collection of field data.

(a) Burkli- Ziegler formula:-

$$Q = \frac{CiA}{141.58}\sqrt[4]{\frac{S}{A}}$$

(b) Mc Math's formula:-

$$Q = \frac{CiA}{148.35}\sqrt[5]{\frac{S}{A}}$$

(c) Fuller's formula:-

$$Q = \frac{CM^{0.8}}{13.23}$$

(d) Fanning's formula:-

$$Q = 12.8M^{5/8}$$

(e) Talbot's formula:-

$$Q = 22.4M^{1/4}$$

Where Q = Run-off in M^3/sec.
C = Run-off coefficient.
I = Intensity of rainfall in cm/hr.
S = Slope of the area in m per 1000m length of sewer.
A = Drainage area in hectare.
M = Drainage area in km^2.

Q. 9 What is time of concentration? Explain.

Ans. Time of concentration: This is defined as the longest time without unreasonable delay that would be required for a drop of water to flow from the upper limit of the drainage area to the point where concentration or the of concentration to any point in a storm sewer is a combination of two things.

(a) Inlet time and (b) Time of flow in the sewer.

(a) **Inlet time:** - Also called time of entry, is the time required for first drops of rain water to flow from the distant points of watershed to the head of the sewer or drain. This is found

(i) To decrease with any increase either in the slope or imperviousness of the ground surface.

(ii) To increase either with an increase in the distance over which water has to travel or with greater watershed-storage. In practices, it is generally assumed to lie between 3 minutes for a steep and impervious area an 20 minutes for a flat and agricultural area.

(b) Time of flow in the sewer: - Is the ratio of the length of the sewer to the velocity of flow when running full. The velocity of flow is calculated by means of the hydraulic formulae.

Q.13 What are self-cleansing, scouring and limiting velocities? Explain.

Ans. Self-cleansing velocity :- The minimum velocity at which the sewer will kept itself clean over a wide variation in discharge is known as self-cleansing velocity.

Self-cleansing velocity depends upon the size of the particles present in sewages and also on their specific gravity.

Scouring velocity: - The minimum velocity to cause the scouring of the suspension of solids heavier than sewage or liquid is known as scouring velocity.

The self-cleansing velocity of the sewage depends upon the scouring action of the flowing sewage.

Limiting velocity: - The maximum permissible velocity which does not cause any wear of contact surface and not make the surface rough is known as limiting velocity.

Above this limiting velocity, scouring take place.

Shield's expression for self-cleansing velocity. Self cleansing velocity, which is necessary to cause scouring and suspension of solid particles (heavier than water), can be determined as follows:

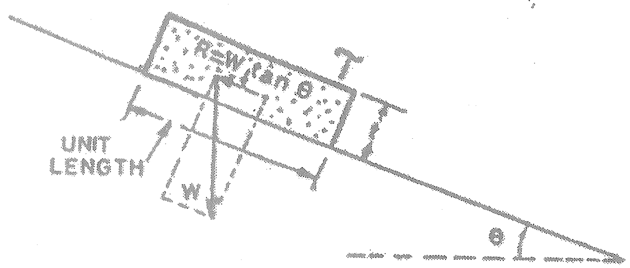


Fig.

Consider a layer of sediment of unit width and unit length and of thickness t deposited at the invert of a sewer of gradient θ. Let Υ_{sub} is the submerged unit weight of the sediment.

Then, the weight of the sediment considered

$$W = \Upsilon_{sub}(1)(1)t$$

But $\Upsilon_{sub} = \Upsilon_\omega \left(\frac{S_s - 1}{1+e}\right)$

Where Υ_ω = Unit weight of the water

S_s = Specific gravity of the sediment.

E = Void ratio of sediment.

But the porosity of sediment

$n = \left(\frac{e}{1+e}\right)^*$, where n = porosity of sediment

$\therefore \quad 1 - n = \frac{1}{1+e}$

$\therefore \quad \Upsilon_{sub} = \Upsilon_\omega (S_s - 1)(1 - n)$

$\therefore \quad W = \Upsilon_\omega (S_s - 1)(1 - n)t$

Now, in order to scour the deposited sediment, and for just causing it to slide down the inclined plane, it is necessary that the drag force (τ) exerted by the flowing water on the surface of the channel equals the frictional resistance R, i.e. $\tau = R$;

But $R = W \tan\theta$

And for smaller values of θ, $\tan\theta = \sin\theta$

$\therefore \quad R = W \sin\theta$

Or $\tau = R = W \sin\theta$ ...(ii)

or $\tau = \Upsilon_\omega (G - 1)(1 - n)t \sin\theta$ ...(a)

But we know that the drag force or the intensity of reactive force (τ) which is exerted by the flowing water on a channel of hydraulic mean depth r is given by

$\tau = \Upsilon_\omega r. s^*$ (a')

Where τ = drag force

R = hudraulic mean depth of the channel

S = bed slope of the channel.

Equating Eq. (a) and (a'), we have

$\Upsilon_\omega (G - 1)(1 - n)t \sin\theta = \Upsilon_\omega r. s$.

Using $(1 - n)t \sin\theta, = k'$ (a constant), we get

$(G - 1)k'.t. = r.s.$

Or $s = \frac{k'}{r}(G - 1)t,$

For single grains, the volume per unit area (i.e.t) becomes a function of the diameter of the grain d' as an inverse measure of the surface area of the individual grains exposed to drag or friction.

$\therefore \quad s \propto \frac{k'}{r}(G - 1)d'$ (for self cleansing)

Or $s = \frac{k}{r}(G - 1)d'$

Hence, the self cleansing invert slope (s) is given as:

$$\boxed{s = \frac{k}{r}(G - 1)d'} \quad \text{... (b)}$$

Where k is a dimensional constant, indicating an important characteristic of sediment (solids) present in sewage. Its value usually varies from 0.04 (minimum) - applicable to start of scouring of clean grit, to about 0.8- applicable for full removal of sticky grit. For relatively clean inorganic and organic matters present in sewage, its values are taken at 0.04 and 0.06, respectively. The actual value of k, should, however be determined only by experiments for different materials.

Hence, the invert slope at which the sewer will be self-cleansing is given by the Eq. (b).

Now, from Chezy's formula, the velocity

$V = c\sqrt{rs}$

$\therefore$ Self- cleansing velocity (V_s) is, hence, given as:

$$V_s = c.\sqrt{r}\sqrt{\frac{k}{r}(G - 1)d'}$$

Or $V_s = c.\sqrt{kd'(G - 1)}$ .... (c)

The Chezy's constant (c) in the above equation can be equated to $\sqrt{\frac{8g}{f'}}$ by comparing Chezy's formula and Darcy-Weisbach formula *. Therefore, Eq. (c) becomes, *From Darcy-Weisbach formula,

$H_L = \frac{f'LV^2}{2gD}$ (where D is the pipe dia)

Or $H_L = s = \frac{f'V^2}{2gD}$

Or $V = \sqrt{\frac{2gD.s}{f'}}$ ... (i)

By Chezy's formula,

$V = c\sqrt{rs}$ ... (ii)

Comparing (i) and (ii), we get

Or $c\sqrt{rs\sqrt{\frac{2gD}{f'}}}$

But $r = \frac{D}{4}$ (for circular pipes running full)

$\therefore \quad c.\sqrt{\frac{D}{4}} = \sqrt{\frac{2gD}{f'}}$ or $c = \sqrt{\frac{8g}{f'}}$

Self cleansing velocity

$V_s = \sqrt{\frac{8g}{f'}kd'(G-1)}$ ... (d)

The usual value of f' for sewer pipes is 0.03.Similarly, by equating Chezy's formula with Manning's formula $(i.e. V = 1n.r2/3s$, we can get $c=1n.r1/6$. The Eq. (c) then becomes

$V_s = \frac{1}{n}.r^{1/6}\sqrt{k.d'(G-1)}$

(The usual value of n for sewer pipes is 0.013.)

Q.5 Write a short note on the followings:

(a) Manholes.
(b) Drop manholes.
(c) Flushing tanks.
(d) Lampholes.
(e) Street inlets.
(f) Catch basins or Catch pits.

(g) Ventilating shafts.
(h) Grease and oil traps.
(i) Inverted siphons.
(j) Storm water regulators.

(a) Manholes: - A manhole is defined as the construction made to connect the ground level with the hole or opening made in the sewer line so that a man can easily. Conveniently and safely enter through it and carry out the usual maintenance operations.

A manhole consists of

(i) A working chamber,
(ii) An access shaft.
(iii) A strong cover on the top flush with the road level.

The lower portion of a deep manhole is known as a working chamber and it provides a working space to carry out cleaning and an inspection of sewer line.
The access shaft provides an access to the working chamer.

At the top of manhole, the manhole cover of cast-iron or RCC is provided to cover the opening.

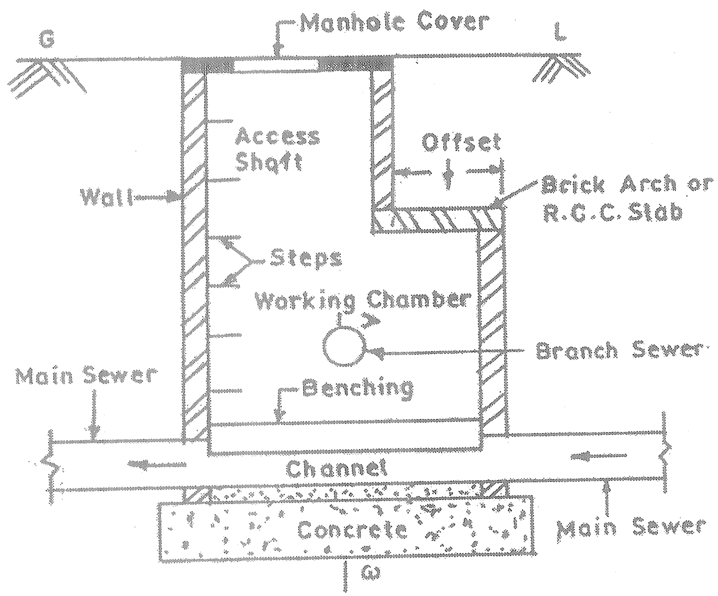
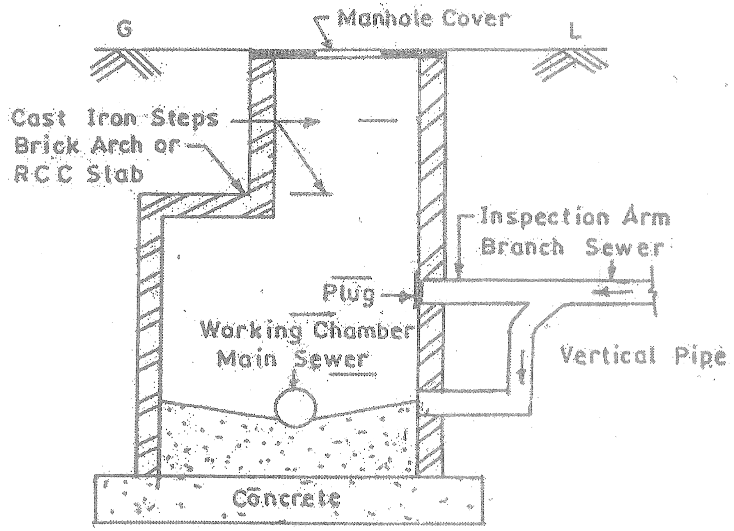


Fig. Manhole

(b) Drop manholes: - When it is uneconomical or impracticable to arrange the connection with 60cm of the invert of the sewer and manhole, then a vertical shaft is constructed outside the manhole chamber through which the sewage of branch sewer is allowed to enter the manhole as shown in figure. Such manholes which drop the level of invert of the incoming sewer by providing a vertical shaft are called drop manhole. The main purpose of drop manhole is to avoid the splashing of sewage on the man working and on the masonry work.



Drop manholes

(c) Flushing tanks: - A flushing tank is a device or an arrangement, which is made to hold and then to throw water into the sewer for the purpose of flushing it. When the gradients of the sewers are flat and the velocity of sewage is very low, the suspended matter of sewage starts settling in the bed of the sewer and causes clogging of sewer lines. At such places where self-cleaning velocity is not available, flushing tanks are provided to flush the sewers. Two types of flushing tanks are used.

(i) Hand operated flushing tank and

(ii) Automatic flushing tank

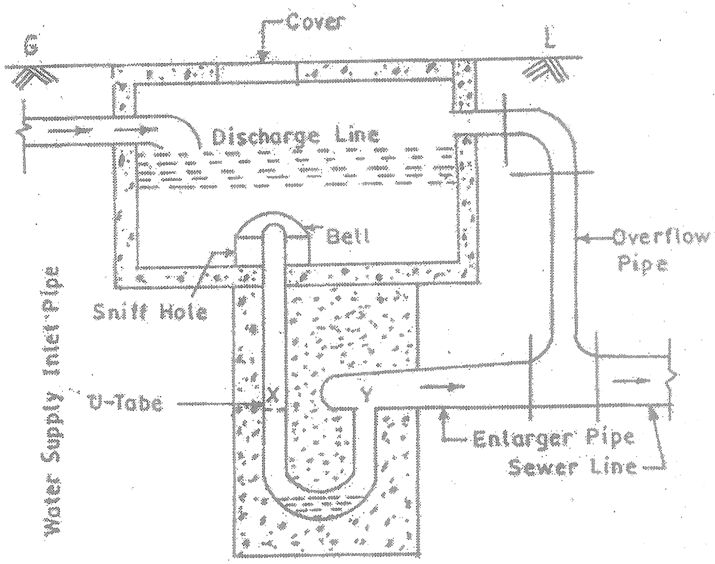


Fig. Automatic flushing tank

(d) Lampholes: - A lamphole is an opening or hole constructed in a sewer for the purpose of lowering a lamp inside it. It consists of vertical stoneware or concrete pipes which are connected to the sewer line through a tee-junction. The pipes are surrounded by concrete to make them stable. At the ground level, the manhole cover with frame is provided to take up the load of traffic.

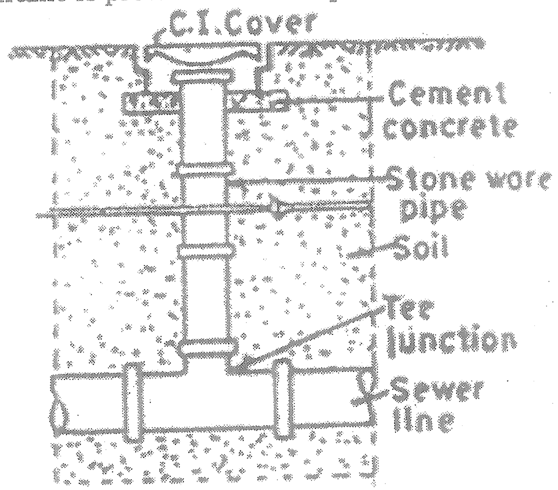


Fig. Lamp-hole

(e) Street inlets: - A street inlet is an opening through which storm water and surface wash flowing along the streets are admitted and conveyed to the storm water sewer or combined sewer by means of pipes. These are placed at the roads, gutters, generally at street junctions. At the street junction, inlets should be placed in such a way that the storm water may not flow across any of the streets or flood, the cross walks causing interference with the traffic.

The inlets are of the three types.

(i) Curb inlet: - An opening is provided in the road curb for the entrance of storm water.

(ii) Gutter inlet: - These are placed directly below the road gutter and storm water directly enters from the top.

(iii) Combined gutter and curb inlet: - In this type of inlet, storm water enters from both the gutter and curb.

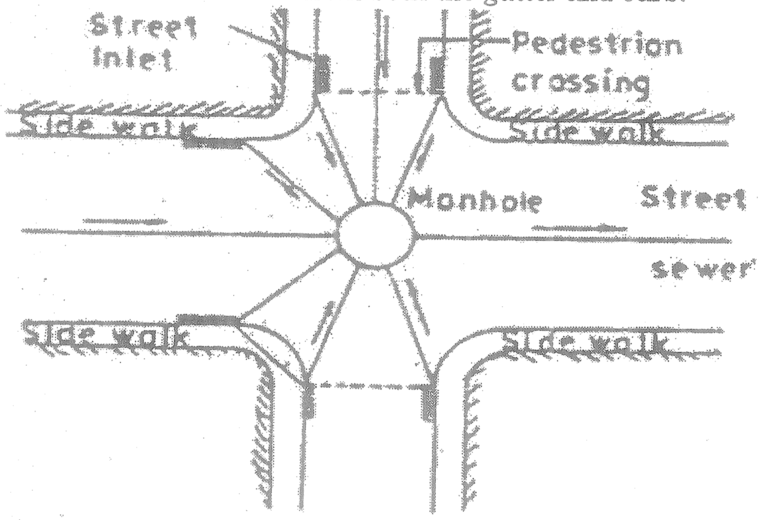
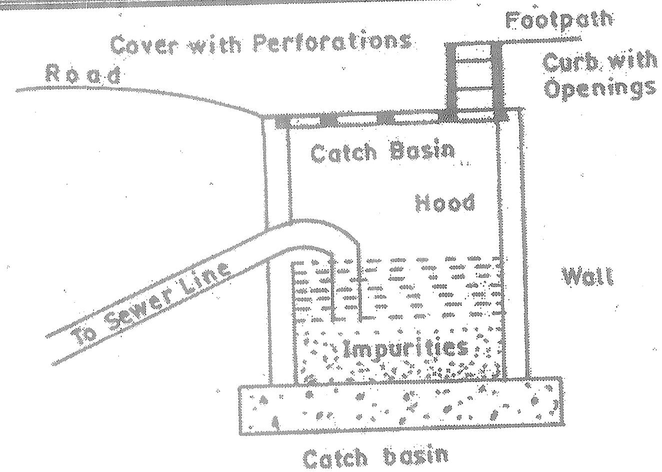


Fig. Street Inlets

(f) Catch basins of Catch pits: - A catch basin or catch pit is a structure in the form of a chamber which is provided along the sewer line to admit clear rain water free from silt, grit debris etc. into the combined sewer.

The catch basins are adopted for the combined sewerage system. But at present, the trend is to lay sewers with such a gradient self-cleaning velocity is achieved and to construct paved streets which contribute little debris or grit. Hence it is not necessary to provide the catch basins in the modern separate sewerage systems.



(g) Ventilating shafts: - It is a vertical shaft provided in the sewer line to remove foul gases from it and to provide fresh air to the workers, working in the manholes.

It may be of RCC or cast-iron 15-25 cm in diameter with a cowl provided at the top. The height of the ventilating shafts should be more than the roof of the tallest building in its neighborhood.

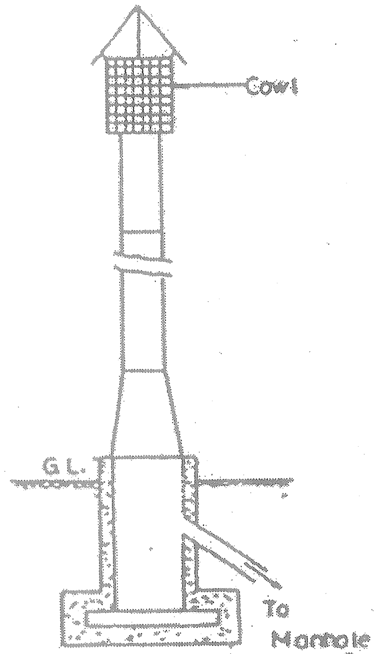


Fig. Ventilating shaft

(h) Grease and oil traps: -

These are the traps or chamber which are provided on the sewer line to exclude grease and oil from sewage before it enters the sewer line.

The grease and oil beign light in weight and can float on the surface of sewage. Hence , if outlet draws the sewage from lower level, the grease and oil are excluded. Thus, the outlet level is near the bottom of chamber and inlet level is near the top of chamber. If sand is desired to be excluded from sewage, the space should be kept at bottom of chamber for sand to be deposited.

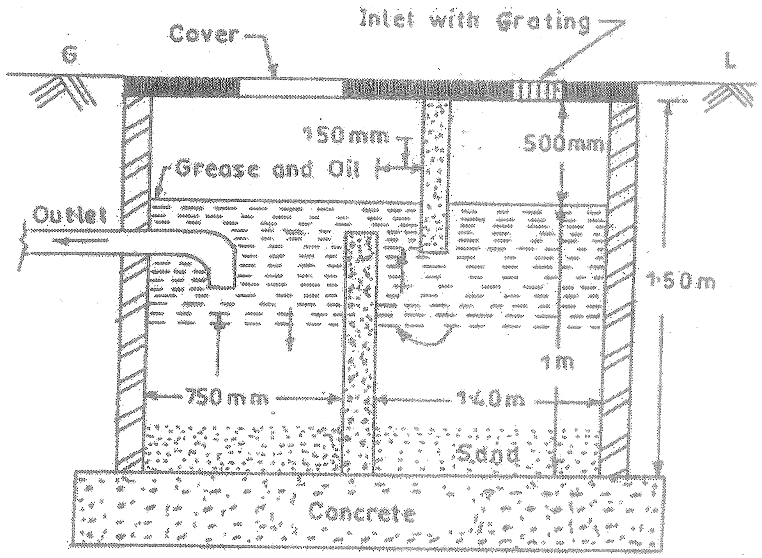
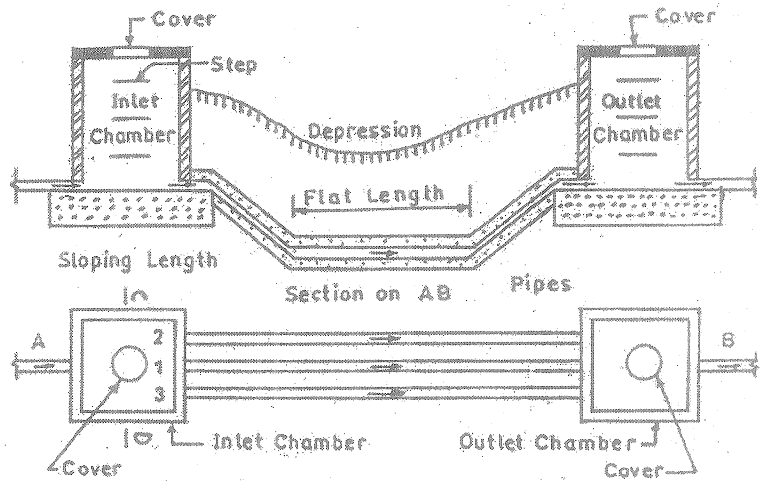


Fig. Combined sand grease and oil trap

(i) Inverted siphon: - An inverted siphon is a sewer section which is constructed lower than the adjacent sewer sections and which runs full under gravity with pressure greater than the atmosphere. The main purpose of installation of inverted siphon to carry the sewer line below obstructions such as ground depressions, streams, rivers, railways etc. In an inverted siphon, then HGL is above the flown, whereas in true siphon, the HGL is below the flow line. It is also known as depressed sewers.

Figure shows the plain and sectional elevation of an inverted siphon. The pipe of inverted siohon must be able to withstand the internal pressure. The pipe diameter should be such that sewage may flow with great velocity to avoid silting.

In a very large single pipe, it is difficult to obtain high velocity for very small quantity of sewage. Therefore, in the inverted siphon, two or more pipes are laid in parallel as shown in figure which come into action or combined in proportion to the amount of flow.



Storm water regulators: - The structures constructed to the divert part of sewage in case of combined sewers are known as the storm water regulators and they come into operation. When the discharge exceeds a certain value. The excess sewage will be composed of storm water and it will, therefore be not foul in nature. It will further result in the decrease in load on the treatment units or pumping stations.

Storm water regulators are of the following three types:

(1) Leaping wait or jumping weir.
(2) Overflow weir and
(3) Section spillway.

Q.14 How to locate manholes?

Ans. Location of manholes: - Manholes are provided at every bend, junction, change of gradient or change of diameter. On straight reaches, manholes are provided at convenient spacings which depend upon the size of sewers. The larger the diameter of the sewer, the grater may be the spacing between two manholes. The spacing between the manholes will also depend upon the nature of sewer cleaning device in use. Table 6.1 gives the spacing of manholes as recommended by the Indian Standard IS: 1742-1960.

TABLE 6.1 RECOMMENDED SPACING OF MANHOLES

Size of sewer	Recommended spacing on straight reaches
Dia. up to 0.3 m	45m
Dia. up to 0.6 m	75m
Dia. up to 0.9 m	90m
Dia. up to 1.2 m	120m
Dia. up to 1.5 m	250m
Dia. up to 1.5 m	300m

Pumping Station

Q.15 What points should be kept in mind while locating the site of pumping stations?

Ans. The following points should be considered while locating the site of pumping stations.

(1) The topographical condition of the city should be thoroughly studied to locate the best site of pumping stations.

(2) If the quantity of sewage is very large, the site should be near the point of disposal or at such places where during emergencies, the sewage can be directly disposed off.

(3) The site should be such that during flood, it should not be flooded with river water of seepage from the ground.

NUMERICAL:-

Example 1 A combined sewer of a circular section is to be laid to serve a particular area. Calculate the size of this sewer from the following data:

Area to be served =120 hectares.

Population = 1, 00,000

Maximum permissible flow velocity = 3m/sec.

Time of entry for storm water = 10 minutes

Per capital water supply liters/day/person. = 250

Coefficient of run-off for the area = 0.45.

Hourly, Maximum rainfall for the area

At the design frequency = 5cm

Assume any other data not given, and if needed.

Solution. Sewage Discharge (i.e. D.W.F.) Computations.

Average water supplied $= 250 \times 1{,}00{,}000$ litres/day

$= \frac{250\times1{,}00{,}000}{1000\times24\times60\times60}$ cumecs

Assumes that 80% of the water supplied appears as sewage, we have

Average sewage discharge $= 0.8 \times 0.289 = 0.23$ cumecs

A ssuming the maximum sewage discharge to be 3 time the average discharge, we have

Maximum sewage discharge $= 3 \times 0.23 = 0.69$ cumecs.

Storm water discharge computations

Time of concentrations

T_c = Time of entry + Time of flow

$= (10 + 20)$ minutes $= 30$ minutes.

Now, maximum hourly rainfall for the area

$= P_o = 5$cm/hr.

∴ Using Eq. (3,3), we have

$= P_c = P_o\left(\frac{2}{1+T_c}\right)$

Where T_c is the concentration time in hours

$= \frac{30}{60} = 0.5$ hour

∴ $P_c = 5\left(\frac{2}{1+0.5}\right)$

$= \frac{10}{0.5} = 6.67$cm/hr.

Now, using rational formula Eq. (3.1), we have

Maximum storm run off $= Q_p = \frac{1}{36}K.P_cA$

$= \frac{1}{36} \times 0.45 \times 6.67 \times 120$comecs.

$= 10$comecs

∴ The combined maximum discharge

= Storm run-off + Sewage discharge

$= 10 + 0.69 = 10.69$cumecs.

Now assuming the sewer to be running full at the maximum velocity of 3m/sec at the time of maximum flow, we have

Area required $= \frac{Q}{V}$

$= \frac{10.69}{3} m^2 = 3.56m^2$

$\therefore$ Dia. of sewer pipe required

$= \sqrt{\frac{4}{\pi}.3.56} = \sqrt{4.53} = 2.13m.$

Hence, use a sewer pipe of 2.13m dia.

Example2. A population of 50,000 is residing in a town having an area of 60 hectares. If the average coefficient of run-off for this area is 0.06, and the time of concentration of the design rain is 30minutes, calculate the discharge for which the sewers of a proposed combined system will be designed for the town. Make suitable assumptions where needed.

Solutions. Given data.

Population =50,000

Area =60 hectares

Coefficient of run – off = 0.6

Time of concentration (t) =30 minutes

Dry weather flow: Assuming rate of water supply = 270*lpcd*.

Average discharge per second $= \frac{5000 \times 270 \times 10^{-3}}{24 \times 60 \times 60}$

$= 0.156m^3/sec$

Assuming a multiplying factor of 2,

Maximum discharge $= 2 \times 0.156 = 0.3125m^3/sec$

Storm water:-

Intensity of rainfall (R)$= \frac{25.4a}{t+b}$

Where a= 40 and b= 20 for storms of durations 20 to 100 minutes.

$\therefore \quad R = \frac{25.4 \times 40}{30+20} = 20.32mm/hr$

Then $Q = \frac{AIR}{360} = \frac{60 \times 0.6 \times 20.32}{360} = 2.032m^2/sec$

Combind discharge = Dry weather flow + Storm water flow

$= 0.3125 + 2.032 = 2.344m^3/sec.$

Now Q = AV

Assuming $V = 2.5m/s$ running full at the time of maximum flow.

$\therefore A = \frac{Q}{V} = \frac{2.344}{2.5}$

$\therefore A = 0.938m^2$

Diameter of pipe $d = \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4 \times 0.938}{\pi}}$

$= 1.093m \simeq 1.1m$

Q.3 Design a suitable sewer section for the following data when it is running half full:

No.	Area type	%	Runoff coefficient
(1)	Pavements	30	0.85
(2)	Gardens	30	0.15
(3)	Ground surface	40	0.30

For a total drainage area of 25ha. And rainfall intensity governed by general formula ($a = 40, b = 20$) in which the time of concentration is 35min.

Assume the population of town as 80000 and rate of water supply as 150lpcd and design the section as a combined section.

Ans. From given data, calculate Average Runoff Coefficient.

$a_1 i_1 = \frac{300}{100} \times 25 \times 0.85 = 6.375$

$a_2.i_2 = \frac{30}{100} \times 25 \times 0.15 = 1.125$

$a_3.i_3 = \frac{40}{100} \times 25 \times 0.30 = 3.0$

$\overline{\sum a_1 i_1} \qquad \overline{= 10.5}$

$\sum a = a_1 + a_2 + a_3 = A = 25ha$

$Avg I = \frac{\sum a_{1} i_1}{\sum a} = \frac{10.5}{25} = 0.42$

Intensity of rainfall

$R = \frac{a}{b+t} = \frac{40}{20+35} = 0.72\text{cm/hr}$

Or $= 25.4 \times 0.72 = 18.3\text{mm/hr}$

Storm water flow, $Q = \frac{AIR}{360} = \frac{25 \times 0.42 \times 18.3}{360}$

$= 0.532\text{m}^3/\text{sec.}$ ... (1)

Now,

Town population = 80,000

Rate of water supply = $150lpcd$

Average rate of water supply = $80{,}000 \times 150$

$= 12 \times 10^6 \text{lit/day}$

$= \frac{12 \times 10^6}{1000 \times 24 \times 60 \times 60} 1.4\text{m}^3/\text{sec.}$

Assuming multiplying factor = 2

Maximum discharge = $1.4\text{m}^3/\text{sec} \times 2 = 2.8\text{m}^3/\text{sec.}$

Total or combined discharge = $0.534 + 2.8 = 3.334\text{m}^3/\text{sec.}$

For sewer diameter running half full. Let d be the diameter.

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

$m = \frac{d}{2}$ For half full

Proportionate discharge for running half full

$= \frac{q}{Q} = 0.5 \quad or \ \frac{d}{D} = 0.5$

∴ Assuming minimum self cleansing velocity $V = 1.2m/s$

$Q = A \times V$

$= \frac{1}{2}\left(\frac{\pi d^2}{4}\right) \times 1.2$ ..... for running half full

$3.334 = \frac{1}{2} \times \frac{\pi d^2}{4} \times 1.2$

$d = 2.66m$

For slope, using Manning's formula

$Q = A \times V \Rightarrow V = \frac{Q}{A}$

$3.334 \frac{\pi}{4}(2.66)^2 \times \frac{1}{0.015} \times \left(\frac{2.66}{4}\right)^{2/3} \times S^{1/2}$ Where n= 0.015

$= 5.55 \times 50.8 \times S^{1/2}$

$S^{1/2} = 0.0118 = 0.1087$

Example 4. A town has a population of 100,000 persons with a per capita water supply of 200 litres/day. Design a sewer rulings 0.7 times full at maximum discharge. Take a constant value of $N = 0.013$ at all depths of flow. The sewer is to be laid at a slope of 1 in 500. Take a peaking factor of 3.

Solution. Water supplied = $100{,}000 \times 200 = 20 \times 10^6$ litres/day

$= \frac{20 \times 10^6}{10^3 \times 24 \times 3600} = 0.2315$ cumecs.

Assuming that 80% of the water supplied to the town appease as swage, we have average discharge in the sewer

$= 0.8 \times 0.2315 = 0.1852$cumecs.

At a packing factor of 3,

Maximum discharge = $3 \times 0.1852 = 0.5556$ cumecs.

Since the sewer is to be designed as running 0.7 times the full depth $d/D = 0.7$ and $q = 0.5556$ cumecs.

For a sewer running partially full (Fig. 4.7)

$\cos\frac{\theta}{2} = 1 - 2\frac{d}{D} = 1 - 2 \times 0.7 = -0.4$

∴ $\frac{\theta}{2} = 113.58°; \theta = 227.16°; \sin\theta = -0.7332$

From Eq. 4.12(a)

$a = \frac{\pi}{4} D^2 \left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right] = \frac{\pi}{4} D^2 \left[\frac{227.16}{360} + \frac{0.7332}{2\pi}\right]$

$= 0.5872D^2$

$p = \pi D \frac{\theta}{360} = D\frac{227.16}{360} = 1.9823D$

Now, $q = \frac{1}{N} a r^{2/3} S^{1/2}$

∴ $0.556 = \frac{1}{0.013} \times 0.5872D^2 (0.2962D)^{2/3} \left(\frac{1}{500}\right)^{1/2}$

Or $D^{8/3} = 0.6190$

From which $D = 0.835m$

Check for self cleansing velocity at maximum discharge

$r = 0.2962D = 0.2962 \times 0.835 = 0.2474\text{m}$

$\therefore \quad v = \frac{1}{V} r^{2/3} S^{1/2} = \frac{1}{0.013}(0.2474)^{2/3}\left(\frac{1}{500}\right)^{1/2}$

$= 1.356 m/sec.$

This is much more than the self cleansing velocity of 60cm/sec.

Check for self clearing velocity at minimum discharge. Let us assume minimum flow equal to $\frac{1}{3}$ times the average flow.

$\therefore q_{min} = (1/3) \times 0.1852$

Also, maximum flow $Q = 3 \times 0.1852$

$\therefore \frac{q_{min}}{Q} = \frac{1}{9} \approx 0.11$

From Fig. 4.8 for $\frac{q}{Q} = 0.11$, we get $\frac{d}{D} = 0.22$, assuming $n = N$. Alternatively, we may get these values from Table 4.8 by interpolations.

$\therefore \frac{d_{min}}{D} = 0.22$

Corresponding to this depth ratio, $\frac{v_{min}}{V} \approx 0.647$

$\therefore v_{min} = 0.647 \times 1.356 = 0.88m/sec$

This is more than the required value of 40cm/sec.

Example 5. A 60 cm diameter sewer is to discharge 0.07cumecs at a velocity as self-cleansing as a sewer flowing full at 0.85m/sec. Find the depth and velocity of flow and the required slope. Take uniform value of $N = 0.015$.

Solutions.

(a) For sewer running full

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

Hence $N = 0.015; V = 0.85\text{cm/sec.}$

$R = D/4 = 0.6/4 = 0.15m$

$\therefore \quad 0.85 = \frac{1}{0.015}(0.15)^{2/3} S^{1/2}$

From which $S = 0.00204 = \frac{1}{490.2}$

And, $\quad Q = \frac{\pi}{4}(0.6)^2 0.85 = 0.2403$ cumecs.

(b) For partial depth self cleansing flow

$q_s = 0.07$ cumecs (given)

$\therefore \frac{q_s}{Q} = \frac{0.07}{0.2403} = 0.2913$

But $\frac{q_s}{Q} = \frac{N}{n}\left(\frac{a}{N}\right)\left(\frac{r}{R}\right)^{1/6}$

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

And $\frac{r}{R} = \left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]$

$\therefore \quad \frac{q_s}{Q} = \frac{N}{n} \times \frac{\theta}{360}\left(1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right)\left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]$

Or $0.2913 = \frac{1 \times \theta}{360}\left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]^{7/6}$

Solving this by trial and error, by assuming several values of θ, we get $\theta \approx 143.5^\circ$

$\therefore \quad \frac{d}{D} = \frac{1}{2}\left(1 - \cos\frac{\theta}{2}\right) = 0.3434$

Also, $\frac{r}{R} = \left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right] = \left[1 - \frac{360^\circ \times \sin 143.5}{2\pi(143.5)}\right]$

$= 0.7624$

Now $\frac{v_s}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{1/6}$

$\therefore \quad \frac{v_s}{V} = 1(0.7624)^{1/6} = 0.9558m/sec.$

$\therefore \quad V_s = 0.9558 \times 0.85 = 0.812m/sec$

And $\frac{S_s}{S} = \left(\frac{R}{r}\right) = \frac{1}{0.7624} = 1.3116$

$\therefore \quad = \frac{1}{373.7}$

(Alternatively, the values of d/D, V_s/V and S_s/S can be obtained for q_s/Q= 0.2913 if Fig. 4.9 is available)

Example 6. A 40 cm dia. sewer is to flow at 0.3 depth on a grade ensuring a degree of self-cleansing equivalent to that obtained at full depth at a velocity of 80 cm/sec. Find.

(i) The required grade
(ii) Associated velocity
(iii) The rate of discharge at this depth.

Given

(i) Manning's rigidity coefficient = 0.014
(ii) Proportionate area = 0.252
(iii) Proportionate HMD $(r/R) = 0.684$

Solution.

(a) For sewer running full

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

Hence $V = 0.8\text{cm/sec.}$; $R = D/4 = 0.4/4 = 0.1m$

$\therefore \quad 0.85 = \frac{1}{0.0145}(0.1)^{2/3} S^{1/2}$

From which $S = 0.0027 \approx \frac{1}{370}$

Also, $\quad Q = \frac{\pi}{4}(0.4)^2 \times 0.8 = 0.1005$ cumecs.

(b) For partial depth self cleansing flow

At 0.4 depth, $\frac{d}{D} = 0.4$

Also $\frac{a}{A} = 0.252$ and $\frac{r}{R} = 0.684$

$\frac{S_s}{S} = \frac{R}{r} = \frac{1}{0.684} = 1.462$

$\therefore \quad S_s = 1.462 \times 0.0027 = 0.00395 = \frac{1}{253.3}$

Also $\frac{v_s}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{1/6} = 1(0.684)^{1/6} = 0.9387$

$\therefore \quad v_s = 0.9387 \times 0.8 = 0.751 m/sec$

And $\frac{q_s}{Q} = \left(\frac{N}{n}\right)\left(\frac{a}{A}\right)\left(\frac{r}{R}\right)^{1/6} = 0.252 \times 0.9387$

$\therefore \quad q_s = 0.252 \times 0.9387 \times 0.1005 = 0.0238$ cumes

Alternatively, $q_s = a.v_s = \frac{a}{A}.A\, v_s$

$= 0.252 \times \frac{\pi}{4}(0.4)^2 \times 0.751 = 0.0238$

Example 7. Determine the size of a circular sewer for a discharge of 500 liters per second running half full. Assume $S = 0.0001$ and $N = 0.015$.

Solution. Given $d = 0.5D$

$\therefore \quad \cos\frac{\theta}{2} = 1 - 2\frac{d}{D} = 0$

Form which $\frac{\theta}{2} = 90°, \theta = 180°$ and $\sin\theta = 0$

From Eq. 4.12 (a)

$a = \frac{\pi}{4}D^2\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right] = \frac{\pi}{4}D^2\left[\frac{1}{2} - 0\right] = \frac{\pi}{8}D^2$

$p = \pi D\frac{\theta}{360} = \pi D\frac{180}{360} = \frac{\pi D}{2}$

$\therefore \quad r = \frac{\pi}{8}D^2 \times \frac{2}{\pi D} = \frac{D}{4}$

Now, $q = \frac{1}{N}a.r^{2/3}S^{1/2}$

Hence $q = 500$ litres/sec= 0.5 cumecs

$\therefore \quad 0.5 = \frac{1}{0.015} \times \frac{\pi}{8}D^2\left(\frac{D}{4}\right)^{2/3} \times (0.0001)^{1/2}$

Or $D^{8/3} = 4.8128$

From which $D \approx 1.80m$

Q.8 The following data is available regarding various types of area and corresponding impermeability factors of a town.

Type	% of Area	Impermeability coefficient
Roof	15%	0.9
Pavements	20%	0.8
Lawns, Gardens	40%	0.15
Unpaved	15%	0.2
Wooded	10%	0.05

Determine the average coefficient of run off. If the total area of the district is 20 hectares, determine the maximum storm water flow for a rainfall intensity of 50mm/hr having a frequency of once in five years. Use Rational formula.

Ans. Impervious factor or overall runoff coefficient

$$C = \frac{A_1C_1 + A_2C_2 + \cdots \ldots\ldots\ldots A_nC_n}{A_1 + A_2 + \ldots\ldots\ldots\ldots A_n}$$

$$= \frac{20(0.15 \times 0.9 + 0.2 \times 0.8 + 0.4 \times 0.15 + 0.15 \times 0.2 + 0.1 \times 0.05)}{20(0.15 + 0.2 + 0.4 + 0.15 + 0.1)}$$

$= 0.39$

Quantity of storm water

$Q = \frac{CiA}{360} = \frac{0.39 \times 50 \times 20}{360} = 1.083 m^3/sec.$

Example 9. Find the relation between the side of a square section of one sewer and the diameter of a circular section of another sewer when both are hydraulically equivalent.

Solution. Let D be the diameter of the circular while running full at a gradient of 1 in S

$= \frac{1}{N}\left(\frac{\pi}{4}D^2\right)\left(\frac{D}{4}\right)^{2/3}\sqrt{S} \qquad \ldots$ **(i)**

The discharging capacity of the rectangular section while running full* at a gradient of 1 in S

$= \frac{1}{N} . b^2 \left(\frac{b^2}{4b}\right)^{2/3} \sqrt{S}$

$\therefore \quad \frac{1}{N} \left(\frac{\pi}{4} D^2\right) \left(\frac{D}{4}\right)^{2/3} \sqrt{S} = \frac{1}{N} b^2 \left(\frac{b^2}{4b}\right)^{2/3} \sqrt{S}$

Or $\frac{\pi}{4} . \frac{D^{8/3}}{2.52} = \frac{b^{8/3}}{2.52}$

Or $D^{8/3} = 1.272 b^{8/3}$

Or $D = 1.094b$.

This is the required relation, where b is the side of a square and D is the dia. of the circular section.

Example 10. A rectangular sewer with width 1.5 times its depth is hydraulically equivalent to a circular to a circular one. Find the relations between the width of the rectangular sewer and the diameter of the circular sewer.

Solution. Let B and D_1 represent the width and depth of the rectangular sewer, respectively.

$\therefore \quad B = 1.5D_1$

Now, where this rectangular sewer is running completely full, the area of cross-section $A = BD_1$

$= 1.5{D^2}_1$

The wetted perimeter P (assuming the roof as part of the wetted perimeter)

$= 2(B + D_1)$

$5D_1$.

$R = \frac{A}{P} = \frac{1.5{D^2}_1}{5D_1} = 0.3D_1$

$\therefore$ Discharging capacity of rectangular sewer

$= \frac{1}{N} (1.5{D^2}_1)(0.3D_1)^{2/3} \sqrt{S}$ ... (i)

If D is the dia. of the circular sewer, then its capacity at full depth

$\frac{1}{N} \left(\frac{\pi D^2}{4}\right) \left(\frac{D}{4}\right)^{2/3} \sqrt{S}$ ...(ii)

for hydraulically equivalent sections, equating (i) and (ii), we get

$\frac{1}{N} (1.5{D^2}_1)(0.3D_1)^{2/3} \sqrt{S} = \frac{1}{N} \left(\frac{\pi D^2}{4}\right) \left(\frac{D}{4}\right)^{2/3} \sqrt{S}$

Or $2.25{D^{8/3}}_1 (0.448) = \frac{\pi}{4} . \frac{1}{2.52} D^{8/3}$

Or ${D^{8/3}}_1 = \frac{\pi}{4 \times 2.52 \times 2.25 \times 0.445} D^{8/3}$

Or $D^{8/3} = 3.24{D^{8/3}}_1$

Or $D = (3.24)^{\frac{3}{8}=0.375} D_1$

Or $D = 1.565D_1$

But $B = 1.5D_1$

Or $D_1 = \frac{B}{1.5}$

$\therefore \quad D = 1.565 \frac{B}{1.5}$

$D = 1.043B$.

This is the required relation, where D is the dia. of the circular sewer and B is the width of the rectangular sewer

Example 11. A population of 30,000 is residing in a town having on over of 60ha. If the average co. efficient of run off for this area is 0.60 and time of concentration of the design rain is 30min, calculate the discharge for which the sewers of 0 proposed combined system will be designed for town in question. Make suitable assumption where needed.

Sol.:- Given data

Pop/n = 30,000

Area = $60ha$.

Coefficient of run off = 0.6

Time of concentration (t) = 30min.

Dry weather flow – Assuming rate of water supply = 270lpcd.

Average discharge per second = $\frac{30000 \times 270 \times 10^{-3}}{24 \times 60 \times 60}$

$= 0.093 m^3/sec$

Assuming a multiplying factor of 2

Maximum discharge = $2 \times 0.093 = 0.1875 m^3/sec$

Storm water:-

Intensity of rainfall $(R) = \frac{25.4a}{++b}$

Where $a = 40$ and $b = 20$ for stores of durations 20 to 100 min

$\therefore \quad R = \frac{25.4 \times 40}{30+20} = 20.32 mm/hr$

Then $Q = \frac{AIR}{360} = \frac{60 \times 0.6 \times 20.32}{360} = 2.032 m^2/sec$

Combined discharge = Dry weather flow + storm water flow

$= 0.1875 + 2.032$

$= 2.2195 m^3/sec$

Now Q = AV

Assuming $V = 2.5m/s$ running full at the time of maximum flow.

$\therefore \quad A = Q/V = \frac{2.219}{2.5}$

$= A = 0.8878m^2$

Diameter of pipe $d = \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4\times0.8878}{\pi}}$

$= 1.063$m

Example 12. A 30cm dia. sewer having an inverted slope 1 in 150 was flowing full. What would to the velocity of flow and discharge? ($n = 0.013$). Is the velocity self cleansing? What would be the velocity and the discharge when some is flowing 0.2, 0.6m depth?

Solution. According to manning's formula

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

$R = \frac{A}{P} = {}^{d}/_{4}$ (for circular sewer running full)

$= \frac{0.3}{4} = 0.075m$

$\therefore V = \frac{1}{0.013} \times (0.075)^{2/3} \times \left(\frac{1}{150}\right)^{1/2}$

$V = 76.92 \times 0.1778 \times 0.08$

$V = 1.116m/sec$

If $R = 0.2$ (R- hydraulic mean depth)

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

$= \frac{1}{0.013} \times 0.2 \times 0.08$

$V = 76.92 \times 0.34 \times 0.08$

$V = 2.10$m/sec

If $R = 0.6m$

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

$= 76.92 \times (0.6)^{2/3} \times 0.08$

$V = 4.3775$m/sec

Example 13. A main sewer is to be designed to carry the sewage of a township spread over on area of 44. Sq. km. with on average population of 200 persons per nectar. The average rate of wastewater flow can be taken as 250lpcd and the maximum flow is 50% in excess of the average. Calculate the discharge for which the sewer is to be designed and find the diameter of the sewer with sewer running half-full Take n= 0.013 and available slope as 1in 1000

Solution. Total population $= 44 \times 10^2 \times 200$

$= 880000$

Average flow $= 880000 \times 250$

$= 22 \times 10^7$

$= \frac{22\times10^7}{24\times60\times60} \times \frac{1}{1000}$

$= 2.546$

Now Q = AV

When the sewer runs half full

d = 0.5D and $\theta = 180^\circ$

$a = {}^{1}/_{2} \times {}^{\pi}/_{4} D^2 = {}^{\pi}/_{8} D^2$

$P = \pi D \frac{\theta}{360}$

$= \pi D \frac{180}{360}$

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

$R = {}^{\pi}/_{8} D^2 \times \frac{2}{\pi D} = D/4$

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

$V = \frac{1}{0.013} \times (D/4)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$

$\therefore \quad Q = AV$

$\therefore \quad 2.546 = \frac{\pi D^2}{4} \times \frac{1}{0.013} \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$

$2.546 = 0.787 \times 0.0316 \times 0.3968 \times D^{4/3} \times 76.92$

$D^{4/3} = 3.361$

$D = 2.?8$m

CSVTU April-May 2012

UNIT-I Part - A

Q.1 (a) Term used to indicate the wash basin waste water: 2

(i) Sullage
(ii) Sewage
(iii) Night Soil
(iv) Garbage

Ans.: (i) Sullage

Part – B

(b) Describe the conditions for satisfactory disposal of sewage. 7

Ans: Refer Q-22 unit 3

(c) Give various empirical formulae for determining storm water flow in sewers, explaining their applicability. 7

Ans.: Refer Q-7

(d) A 40cm die sewer is to flow at 0.3 depth on a grade ensuring a degree of self cleansing equivalent to that obtained at full depth at a velocity of 80 cm/sec. Find: 7
(i) The required velocity
(ii) Associated grade
(iii) Rate of discharge at this depth

Ans.: Refer Example-6

CSVTU Nov.- Dec 2011

UNIT-I Part- A

Q.1 (a) (i) List 6 sewer appurtenances.
(ii). Zero specific gravity of sewage is :
(1). Zero (2). Equal to 1 (3). >1 (4). <1 2

Part- B

(b) A 30 cm dia sewer having an invert slope of 1 in 150 was flowing full. what would be the velocity of flow and discharge ? (n = 0.013) Is the velocity self cleansing ? What would be the velocity and the discharge when the same is flowing 0.2, 0.6 and 0.8 of full depth? 7

Ans.: Refer Example-12

(c) Derive the expression for shields self cleansing velocity? Also derive expression for proportionate area, Velocity and HMD . 7

Ans.: Refer Q-9

(d) A 60 cm diameter sewer is to discharge 0.07 cumec at a velocity as self cleansing as a sewer flowing full at 0.85 m/sec.

Find the depth and velocity of flow and the required slope ? 7
N= 0.015

Ans.: Refer Example-5

CSVTU April-May 2011

Unit-I

Q.1 (a) Define the term sullage. 2

Ans.: Refer Q-1

(b) Discuss the relative merits of separate and combined system of sewage and give the conditions favourable for the adoption of each one of them. 7

Ans.: Refer Q-4

(c) The following data is available regarding various types of area and corresponding impermeability factors of a town: 7

Type	% Area	Impermeability coefficient
Roofs	15%	0.9
Pavements.	20%	0.8
Lawns,Gardens vegetation	40%	0.15
Unpaved	15%	0.20
Wooded	10%	0.05

Determine the average coefficient of runoff. If the total area of the district is 20 hectares, determine the maximum storm water flow for a rainfall intensity of 50 mm/hour having a frequency of once in five years. Use rational formula.

Ans.: Refer Example-8

(d) For a circular sewer and a rectangular sewer to be hydraulically equivalent, find the relation between the depth of rectangular sewer and diameter of circular sewer. Take the width of rectangular sewer as 1.5 times the depth and assume that only three sides of the rectangular sewer are wetted. 7

Ans.: Refer Example-10

CSVTU Nov - Dec 2010

Q.1 (a) What is importance of quantity of sewage? 2

Ans.: Refer Q-6

(b) Describe briefly the various commonly adopted sewerage systems? What type of sewerage system will you recommend for cities of Chhattisgarh? Explain your choice giving suitable reasons. 7

Ans.: Refer Q-5

(c) What is the importance of providing man holes in sewerage line? Explain the construction and working of drop man hole with sketch. 7

Ans.: Refer Q-10

(d) Determine the size of a circular sewer for a discharge of 1:2 cumecs running half full. Assume a grade of 1 in 2000 and rugosity coefficient as 0.013.

Ans.: Refer Example-7

CSVTU April-May 2010

Q.1 (a) How the amount of sewage is estimated? 2

Ans.: Refer Q-6

(b) Describe the various systems of sanitation giving their advantages and disadvantages. Considering the water shortage in townships and cites. What are the modifications you would suggest for better functioning of the system? 7

Ans.: Refer Q-2&3

(c) Why are the manholes required and where are these provided? Explain the constructions of one with sketch. 7

Ans.: Refer Q-10

(d) A main sewer is to be designed to carry the converge of a township spread over an area of 80sqKm with an average population of 200 persons per hectare. The average rate of wastewater flow can be taken as 300 ipcd and the maximum flow is 50% in access of the average. Calculate the discharge for which the sewer is to be designed and find the diameter of the sewer with sewer running half-full. Take n = 0.012 and available slope is 1 in 1000. 7

Ans.: Refer Example-13

CSVTU Nov.- Dec 2009

Q.1 (a) What do you mean by hygienic conditions? 2

Ans. The condition which is free from all atmospheric pollution.

(b) Describe the various systems of sanitation giving their advantages and disadvantages. Considering the water shortage

in townships and cities, what are the modifications you would suggest for better functioning of the system. 7

Ans.: Refer Q-2&3

(c) Why are the manholes required and where are these provided? Explain the construction of one with sketch. 7

Ans.: Refer Q-10

(d) A main sewer is to be designed to carry the sewage of a township spread over an area of 44.sq.Km. With an average population of 200 persons per hectare. The average rate of wastewater flow can be taken as 250 ibcd and the maximum flow is 50% in excess of the average. Calculate the discharge for which the sewer is to be designed and find the diameter of the sewer with sewer running half-full. Take n=0.013 and available slope as 1 in 100.. 7

Ans.: Refer Example-13

CSVTU April-May 2009

UNIT – I

Q.1 (a) What do you understand by self cleansing velocity? 2

Ans.: Refer Q-9

(b) Describe in brief the patterns of collection of stream and waste water 7

Ans.: Refer Q-5

(c) What point should be kept in mind while locating the site of pumping station? What are requirement of sewage pump: describe in brief ? 7

Ans.: Refer Q-11

(d) Design the section of circular sewer from following data: 7

(i) Area to be served =150 hectares
(ii) Population of locality = 50,000
(iii) Maximum permissible velocity =3.2 m/s
(iv) Time of entry =5 minutes
(v) Time of flow =20 minutes
(vi) Rate of water supply =270 litre/day/capils
(vii) Impermeability factor = 0.45. 7

Ans.: Refer Example-1

CSVTU Nov.- Dec 2008

UNIT – I

Q.1 (a) Define Sewage. 2

Ans.: Refer Q-1

(b) Differentiate between water carriage system and conservancy system. 7

Ans.: Refer Q-3

(c) A population of 30,000 is residing in a town having an area of 60 hectares. If the average co-efficient of run off for this area is 0.06 and time of concentration of the design rain is 30 minutes. Calculate the discharge for which the sewer of a proposed combined system will be designed for town in question. Make suitable assumption where needed. 7

Ans.: Refer Example-11

(d) Calculate the diameter and discharge of circular sewer laid as a stop of din 400 when it is running half fully and which a velocity of 1.9m/sec. (n is Manning formula 0.012). 7

Ans.: Refer Example-7

UNIT-II Characteristics of sewage & Primary Treatments Systems

Characteristics of sewage-physical, chemical and biological characteristics, fundamentals of aerobic & anaerobic process. Sewage treatment-preliminary treatment systems, Racks and screens, comminuters, Grit chambers. Primary treatment systems-Plain sedimentation, detention time and over-flow rates, types of inlets and outlets, onsite wastewater treatement- septic tank, Imhoff tank, oxidation pond .

Q.1. Write a note on characteristics of sewage.

Ans. Sewage is a dilute mixture of the various types of wastes from the residential, pubic and industrial places. The characteristics and composition of sewage mainly depends on the source. Sewage contains organic and inorganic matters which may be in dissolved, suspension and colloidal state. The characteristics of sewage can be classified as.

(i) Physical characteristics,
(ii) Chemical characteristics and
(iii) Biological characteristics.

(i) Physical characteristics :- The sewage has the following physical characteristics

(a) **Colour :-** The colour of fresh sewage is earthy or grey and it has soapy or ily smell. It starts decomposition and begins to get black after few hours of its production. The colour of industrial sewage depends on the chemical process used in the industries.

(b) **Odour :-** Fresh domestic sewage has slightly soapy or oily odour, but the stale sewage has offensive odour of hydrogen sulphide and other sulphur compounds.

(c) **Temperature :-** Generally, the temperature of the sewage is slightly higher than the water supply. When the sewage flows in closed conduits its temperature further rises resulting in the increase of viscosity and bacterial activity.

(d) **Turbidity :-** The normal sewage is usually turbid and it contains some matter which can be easily identified when the sewage is fresh. Such matter includes, fecal matter or night soil, pieces of paper, cigarette ends, grease, and fruit, soap, match sticks, vegetable debris etc.

(e) **Solids:-** The sewage contains a very small amount of solid in relation to huge amount of water. The liquid content of normal sewage is about 99.9% and the total amount of solid matter present either in suspension state or dissolved state is only about 0.1%

(ii) Chemical characteristics :- The nature of fresh sewage and treated or purified sewage is alkaline. The nature of stale sewage is acidic. In addition to solids and liquids, the sewage also contains various gases such as hydrogen sulphide, methane, ammonia and carbon dioxide. Industrial sewage may possess unusual chemical properties.

(iii) Biological characteristics:- The sewage contains bacteria and other living micro-organisms such as algae, fungi protozoa etc. The bacteria are present in sewage in large number and depending upon their nature, they may be classified as pathogenic bacteria or non-pathogenic for causing diseases. The sewage obtains such bacteria from the discharge of persons and animals suffering from various diseases. The non-pathogenic bacteria are harmless. Depending upon their action, the bacteria are divided into three categories, namely aerobic bacteria, anaerobic bacteria and facultative bacteria.

Q.2. Define the following term.

(i) Anaerobic processes

(ii) Aerobic processes

Ans. (i) Anaerobic processes:- The work done by anaerobic bacteria, i.e. decomposition of organic matter is called putrefaction and the result is called liquefaction, as the solid organic matter is dissolved by enzymes. Aerobic bacteria oxidize organic matter utilizing electron acceptors other than oxygen. In carrying out their metabolic processes, they produce. CO_2, H_2S, CH_2, NH_3, N_2 reduced organics and more bacteria. Treatment units which work on putrefaction alone are septic tanks, Imhoff tanks, and sludge digestion tanks. The

end products of an anaerobic fermentation are likely to be odorous.

(ii) Aerobic processes : The work of the acrobic bacteria, i.e. combination with oxygen is called oxidation. Aerobic bacteria utilize free oxygen as an electron acceptor. The end products of aerobic activity are Co_2, H_2o, So_4, No_3, NH_3 and more bacteria. The bulk of the available energy finds its way into cell mass or heat, yielding a stable effluent which will not undergo further decomposition.

Q.3. Explain the procedure of determination of total solids, suspended solids. And settle able solids for a waste water sample. (Nov.-Dec.,2009)

Ans. Following procedure are adopted for determination of

(a) The total amount of solids:- Present in a given sewage can be determined by evaporating a known volume of sewage sample, and weighing the dry residue left. The mass of the residue divided by the volume of the sample evaporated, will represent the total solids in mgll.

(b) The suspended solids:- Are those solids which are retained by a filter of 1μm pores ; and they are, therefore, also called as non-filterable solids. Their quantity can be determined by passing a known volume of sewage sample through a glass-fiber filter apparatus, and weighing the dry residue left. The mass of the residue divided by the volume of sample filtered, will represent the suspended solids, in mgll.

(c) Settle able solids :- Can be determined easily with the help of a specially designed conical glass vessel called Imhoff cone (Refer Fig. 7.2). The capacity of the cone is 1 litre, and it is graduated up to about 50 ml.

Sewage is allowed to stand in this Imhoff cone for a period of two hours. And the quantity of solids settled in the bottom of the cone then be directly read out. However, in order to obtain precise amount of settle able solids collected at the bottom of the cone should be dried and weighed.

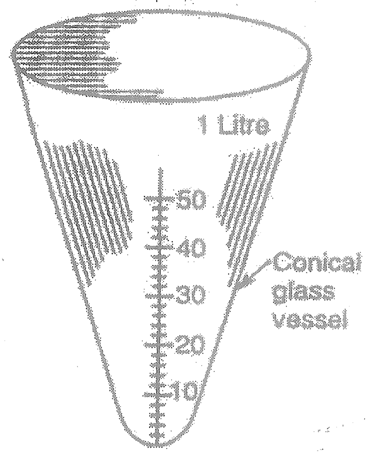


Fig. Imhoff cone.

Q.4. Define BOD. Explain its meaning.

Ans. The amount of oxygen required for micro-organisms to carry out the biological decomposition of dissolved solids or organic matter in sewage under aerobic conditions at standard temperature and within the specified time.

The standard time and temperature for this test in USA is 5 days and 20°C respectively. But in Indian condition, this test is done at 37°C. The organic matter in sewage can be classified in the two groups (a) Carbonaceous matter and (b) Nitrogenous matter. In the first stage, the carbonaceous matter is oxidized and in the second stage the nitrogenous matter is oxidized.

The amount of oxidation is nearly 70% after 5 days and nearly 90% after 10 days and nearly 98% or total after 20 days.

Q.5. What do you understand by the significance of BOD? How it is determined?

Ans. The presence of oxygen is necessary for the life of organisms. The aerobic action continues till the oxygen is present in sewage. As the oxygen exhausts, the aerobic action begins due to which foul smell starts coming. Therefore, indirectly the decomposable matters require oxygen, which is used by the organisms. The length of aerobic action can be increased if the percentage of oxygen is increased in the beginning and the BOD is satisfied.

For performing this test, the sample of sewage free from preservative is diluted in water in 1:100 ratio. The water used for dilution has excess of oxygen, which is determined before dilution. The diluted sample is kept in incubator at average temperature 20°C for 5 days. The quantity of dissolved oxygen in sample is determined after incubation. The difference between the quantity of oxygen present in water in the beginning and the end of incubation is the amount of oxygen consumed by the sewage.

Q.6. What are the limitations of BOD test.

Ans. Following are the limitation of BOD test:-

(i) If the sample of sewage contains toxic wastes, it should be given pretreatment before applying the BOD test.

(ii) It is essential to have a high concentration of active bacteria present in the sample of sewage.

(iii) The effects of nitrifying organisms should be reduced before applying the test.

(iv) The test losses its stoichiometric validity after the soluble organic matter present in the sample of sewage has been exhausted or utilized

(v) The test measures only the biodegradable organic.

(vi) The time required for the test is arbitrary and long.

Q.7 Define BOD, deduce expression for first stage BOD.

(April-May,2011)

Ans. First stage BOD : At a given temperature the rate at which BOD is satisfied at any time. (i.e. rate of deoxygenating) may be assumed to be directly proportional to the amount of organic matter present in sewage. In other works, the exertion of BOD is considered to be first order reaction defined by

$$\frac{dL_t}{dt} = -K'.L_t \qquad \text{......(1)}$$

Where L_t= amount of first stage BOD remaining in the sample at any time t (or oxygen equivalent of carbonaceous oxidisable 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 and the temperature during the reaction.

t = time in days.

Integrating Eq. 1between time t=0 (as which as 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 $\text{Log}_e \left(\frac{L_t}{L_0}\right) = -K't$ ....(a)

Or $\frac{L_t}{L_0} = e^{-K't} = 10^{-kt}$ ....(b)

Where the rate constant $K = \frac{K'}{2.303}$ ....(c)

In the above equation, L_0 is the oxygen equivalent of organic matter present in sewage at the beginning. Also K is known as base 10 rate constant (or deoxygenating constant) while K' is known base e rate constant.

The amount of BOD remaining at any time t is

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

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

$y_t = (L_0 - L_t) = L_0(1 - 10^{-kt})$ ....(d)

In the above equation y_t, is the BOD of t days (i.e. $y_t = BOD_t$).

From Eq. d, 5-day BOD is evidently given by

$BOD_5 = y_5 = L_0 - L_5 = (1 - 10^{-5k})$ ....(e)

The relationships expressed by Eqs. (c) and (d) are represented by the corresponding curves shown in Fig. 1

The ultimate first stage BOD(i.e. yu) will be obtained by submitting t=∞ in Eq.(e) Thus,

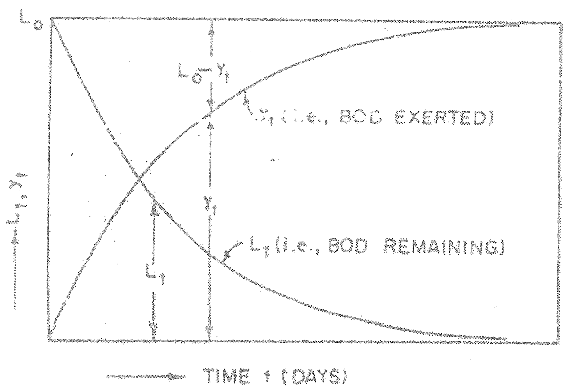


Fig. FIRST STAGE BOD CURVE

Q.8. What do you understand by " chemical Oxygen demand"? (April-May,2009-2012)

Ans. CHEMICAL OXYGEN DEMAND (COD): COD test, which can be used to measure content of organic matter of both wastewater as well as natural waters. COD can be determined only is 3 hours in contrast to 5 days of BOD test. In COD test, a strong chemical oxidizing agent is used in an acidic medium to measure the oxygen equivalent of organic matter that can be oxidised.

The COD test is specifically more suitable to measure organic matter present in industrial wastes having compounds that are toxic to biological life. For typical untreated domestic wastes, the ratio COD/BOD_5 is found to vary from 1.25 to 2.5. A higher value of the ratio indicates that the wastewater is difficult to biodegrade. For non-biodegradable wastewater, generally specified by the authorities is 250 mg/I

Significance of COD

The ratio of COD are generally higher than the ratio of BOD

Q.9 Derive the stricter Phelps Equation. (April-May,2012)

Ans. 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 gives below.

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

$$\frac{dD_t}{dt} = K'L_t - R'D_t \qquad \text{...... (9)}$$

or

where D_t =DO deficit at any time t.

L_t = amount of first stage BOD remaining in the sample at any time t.

k' = BOD reaction rat constant or deoxygenation con-stant to the base e.

R' = reoxygenation constant to the base e

t = time (in days)

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

But $L_t = L_o . e^{-k't}$

Where L_o =BOD remaining at time $t = 0$

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

Or $\frac{dD_t}{dt} + R'^{D_t} = K'L_o . e^{-k't}$ ..... (b)

This is the first order first degree differential equation. Using the standard procedure for the solution of the above differential equation, one can obtain.

$D_t = \frac{K'L_o}{R'-K'}[e^{-k't} - e^{-R't}] + D_o . e^{-R't}$ ..... (c)

Changing it to the base 10, we get

$D_t = \frac{K'L_o}{R-K}[10^{-k't} - 10^{-R't}] + D_o . 10^{-R't}$ ..... (d)

Where K = BOD reaction constant to the base 10.

R = Reoxygenation constant to the base 10.

D_o = Initail oxygen deficit at the point of wasle discharge at time $t = 0$

Eq. (d) is the classic Streeter-Phelps oxygen sag equation which is most commonly used in river analysis. The graphical representation of Eq. (d) in shown in Fig. (c).

Q.10 Define preliminary Treatment.

Ans. Preliminary Treatment: The preliminary treatment consists of the processes which remove those constituents of the wastewater the presence of which would otherwise interfere with subsequent treatment processes or mechanical equipment. Wastewater contains varying quantities of floating and suspended solids, some of considerable size. Preliminary treatment processes remove floating materials (like dead bodies of animals, pieces of wood, papers rags, metal containers, plastic or rubber containers, grease etc.) and also heavy settle able inorganic solids like grit, and fragments of masonry etc. The process units also include pumping as well as flow measurement systems.

Various units involved in preliminary treatment are:

(i) Screening, for removal of floating matter.
(ii) Grit chamber or detritus tank, for removal of sand and grit
(iii) Comminutes for grinding or chopping large size suspended solids.
(iv) Floatation units and skimming tanks for the removal of soils and grease.
(v) Flow measuring units, such Parshall flume etc.
(vi) Pumping
(vii) Pre-aeration

Q.11 Define the following term.

Ans. 1. RACKS AND SCREENS

Screening is the first unit operation (Physical unit operation) in wastewater treatment plants. A screen is device with openings generally of uniform size. The screening elements may consist of parallel bars. Rods, gratings or wire mesh or perforated plates, and the screens may be of any shape although generally they are circular or rectangular. The usual procedure is to pass the influent water through racks or coarse screens. Bar racks are used to protect pumps, valves, pipe lines and other appurtenances from damage or clogging by rags and large objects.

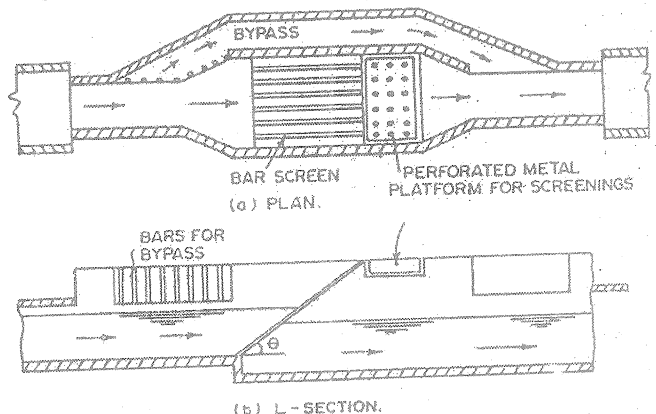


Fig. HAND-CLEANED BAR SCREEN WITH OVERFLOW BYPASS.

A bar rack having clear openings greater than 40 mm should precede mechanically cleaned grit-removal facilities. The bars run vertically or at a slope varying from 30° to 80° with horizontal. Small plants often utilize hand-cleaned racks while mechanically cleaned racks may be used on large plants. The cleaning devices are rakes which periodically sweep the entire screen, removing the solids for further processing or disposal.

2. COMMINUTORS AND BARMINUTORS (Shredders)

Book

Pg 290

A comminuting device is a mechanically cleaned screen which incorporates a cutting mechanism that cuts the retained material enabling it to pass along the sewage. Frequently, they are installed in the wet well of pumping stations to protect the pumps against clogging by rags and large objects. However, provision must be made to bypass comminutes in case flows exceed the capacity of the commenter or in case there is a power or mechanical failure. The use of comminutes tends to reduce odours, flies and unsightliness.

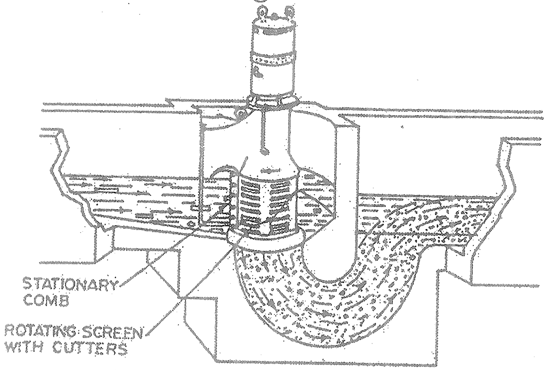


Fig. COMMINUTOR WITH ROTATING SCREEN CUTTER.

A comminutors consists of a vertical revolving drum-screen with 6 mm to 10 mm slots. The head loss across comminutors depends upon screen details and flow, the normal values being on the order of 50 to 100 mm.

Q.12 Draw neat diagram and explain working of,

(i) Screen chamber. (ii) Grit chamber

Ans. (i) Screen chamber:- A screen is a device with openings generally of uniform size for removing bigger suspended of floating matter in sewage. The main purpose of the installation of screens is to remove the floating. Matter of comparatively large size. If such materials are not removed they will choke up the small pipes or affect seriously the working of sewage pumps.

The screening element may consists of parallel bars rods, grating or wire meshes or perforated plates and the opening may be of any shape although generally they are circular or rectangular.

The racks or screens are constructed of flat iron bars set on edge across the channel through which sewage flows with a

velocity of at least 0.45 m/sec. It is usually placed in an inclined position. Will an angle of about 30° to 60° with the direction of flow. The screens are sometimes accommodated in the body of great chambers.

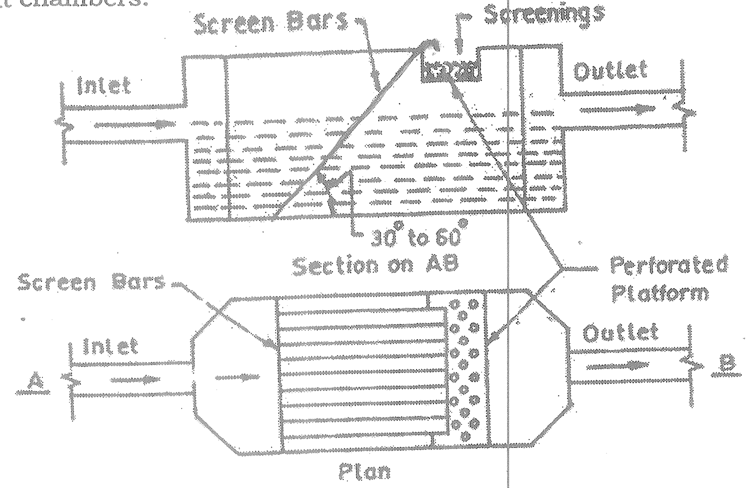


Fig. Fixed screen

(ii) Grit Chambers:- The purpose of providing grit chamber in the sewage treatment process is to remove grit sand and such other inorganic matter from sewage. To achieve this purpose, the velocity of flow in grit chamber is decreased to such an extent that the heavier inorganic materials settle down at bottom of chamber and the lighter organic materials are carried for further treatment.

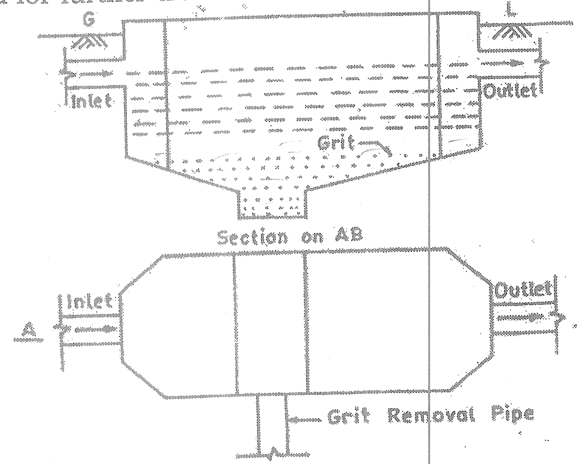


Fig. Grit chamber with direct flow

Q.13. Define the Term.

Ans: Plain sedimentation : When the impurities are separated from suspending fluid by action of natural forces alone, i.e. by gravitation and natural aggregation of setting particles. The operation is called plain sedimentation.

Sedimentation with coagulation(Clarification): When chemicals or other substances are added to induce or hasten aggregation and settling of finely divided suspended matter, colloidal substances, and large molecules, the operation is called sedimentation with coagulation or simply clarification.

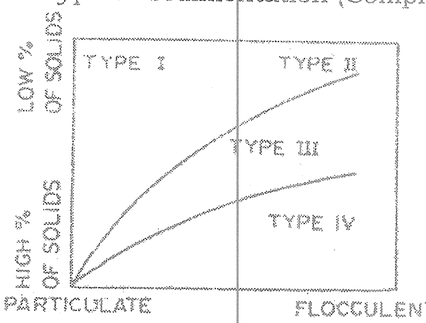
Chemical precipitation : When chemicals are added to throw dissolved impurities out of solution, the operation is called chemical precipitation.

Discrete particles : A particle that does not alter its shape, size and weight while settling or rising in water, is known as discrete particle.

Q.14 Explain various types of settlings.

Ans : TYPES OF SETTLINGS : Particles may settle out of a suspension in the following four ways, depending upon the concentration of the suspension and the flocculating properties of the particles

1. Types I sedimentation (Discrete settling)
2. Type II sedimentation (Flocculant settling)
3. Type III sedimentation (Hindered or zone settling)
4. Type IV sedimentation (Compression settling)



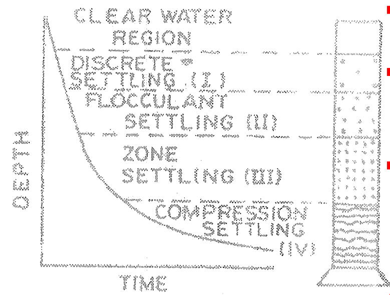


Fig. TYPES OF SETTLINGS

Types I Discrete settling : This corresponds to the sedimentation of discrete particles in a suspension of low solids concentration. This is also known as free settling since the particles have little tendency to flocculate or coalesce upon contact with each other.

Type II Flocculant settling: This type of settling refers to rather dilute suspension of particles that coalesce or flocculate during sedimentation process. Due to flocculation, particles increase in mass and settle at a faster rate.

Type III Hindered or zone settling : This type of setting refers to flocculent suspension of intermediate concentration. Inter particle forces hold the particles together and hence the mass of the particles subside as a whole.

Type IV Compression settling: This refers to flocculent suspension of so high concentration that particles actually come in contact with each other, resulting in the formation of a structure. Further setting can occur only by compression of structure brought about due to weight of particles which are constantly being added to the structure .

The discrete settling removes pit and sand particles from the

Q.15 What do you mean by overflow rate of a setting tank ? (Nov.-Dec.,2010)

Ans : Overflow rate or surface loading rate : The overflow rate represents the hydraulic loading per unit surface area of tank in unit time, usually expressed as $\frac{m^3}{d}/d/m^2$. Overflow. Rates must be checked both at average plant flows and peak flow. Table 12.1 gives the values of overflow rates for different types of primary settling tanks, as recommended by the Manual on sewerage and sewage treatment prepared by the Ministry of Urban Development (MUD). New Delhi.

TABLE 12.1 DESIGN PARAMETERS FOR SETTLING TANKS.

Type	Overflow rate ($m^3/d/m^2$)		Depth (m)
	Average	Peak	
1. Primary setting only	25–30	50–60	3.0–3.5
2. Primary setting followed by secondary treatment	35–50	80–125	3.0–3.5
3. Primary setting with	25–35	50–60	3.5–4.5

activated sludge return			
4. Secondary settling for tricking filter	10–25	40–50	3.0–3.5
5. Secondary settling for activated sludge (excluding extended aeration)	15–35	40–50	3.5–4.5
6. Secondary settling for extended aeration	8–15	35	3.5–4.5

Q.16 What are the object of plain sedimentation ?

Ans : Following are the objects of plain sedimentation tanks:-

1) The process of sedimentation reduces the strength of sewage to the extent of about 30–35%
2) The quantity of solids in the sewage is reduced to the extent of about 80–90%
3) There is reduction in BOD to the extent of about 30–35%
4) The sewage after being treated in the sedimentation tanks becomes fit for further treatment processes.

Q.17 Explain about Inlet and outlet device ?

Ans : Inlet and outlet device : Performance of sedimentation tanks is very much influenced by inlet devices which are intended to distribute and draw the flow evenly across the basin. All intents must be designed to keep down the entrance velocity to prevent formation of eddy or inertial currents in the tank to avoid short circuiting.

(a) **Rectangular Tanks :** In horizontal flow rectangular tanks, inlet and outlets are placed opposite each other separated by the length of the tank with inlet perpendicular to the direction of flow. Following methods are used to distribute the flow uniformly across the tank Outlet is generally an overflow weir located near the effluent end, preferably adjustable for maintaining the weir at a constant level. V-notches are provided on the weir to provide for uniform distribution of flow at low heads of discharge over the weir. Weir lengths could be increased by placing outlet channel inside the tank with weirs on both sides. Scum baffles are provided ahead of outlet devices to prevent the escape of scum with the effluent. Of outlet devices to prevent the escape of scum with the effluent.

Chandrakant Dewangan (9589676161)

Chandrakant Dewangan

(b) **Circular tanks :** In radial flow circular tanks, the usual practice is to provide a central inlet and a peripheral outlet. The central inlet pipe may be either a submerged horizontal pipe from wall to centre or an inverted siphon laid beneath the tank floor. An inlet baffle is placed concentric to the pipe mouth generally will a diameter of 10–20% of the tank diameter and extending 1 to 2 m below water surface. Where the inlet pipe discharges into central hollow pillar, the top of the pillar is flared to provide adequate number of inlet diffusion ports through which sewage enters the tank with an entry velocity of 0.1 to 0.25 m/s through the ports.

Outlet is generally a peripheral weir discharging freely into a peripheral channel. The crest of the weir is provided with V-noteches for uniform draw off at low flows. In all primary settling tanks, a peripheral scum baffle extending 0.2 to 0.3 m below water surface is provided ahead of the effluent weir. If the length of the peripheral weir is not adequate, a weir trough mounted on wall brackets near the periphery with adjustable over flow weir on both sides is provided to increase the length of weir

Q.18 Explain with neat sketch "stabilization Ponds" ?

Ans : STABILIZATION PONDS (OXIDATION PONDS) : A stabilization pond (or lagoon) is an open, flow-through earthen basin of controlled shape, specifically designed and constructed to treat sewage and biodegradable industrial wastes. It is a relatively low-Cost treatment system which has been widely used. Particularly in rural areas. These ponds may be considered to be completely. Mixed biological reactors without solids return. The mixing is usually provided by natural processes (such as wind, heat, fermentation), but may be augmented by mechanical or diffused aeration. Stabilization ponds provide comparatively long detention periods extending from a few to several days when the putrescible organic matter in the waste gets stabilized by the action of natural forces fee . The degree of treatment that can be achieved is as good as that of the of the conventional system, if these low cost system are adopted.

Classification of stabilization ponds. Stabilization ponds are usually classified according to the nature of biological activity that is taking place as:

(i) Aerobic (ii) anaerobic (iii) facultative (aerobic-anaerobic).

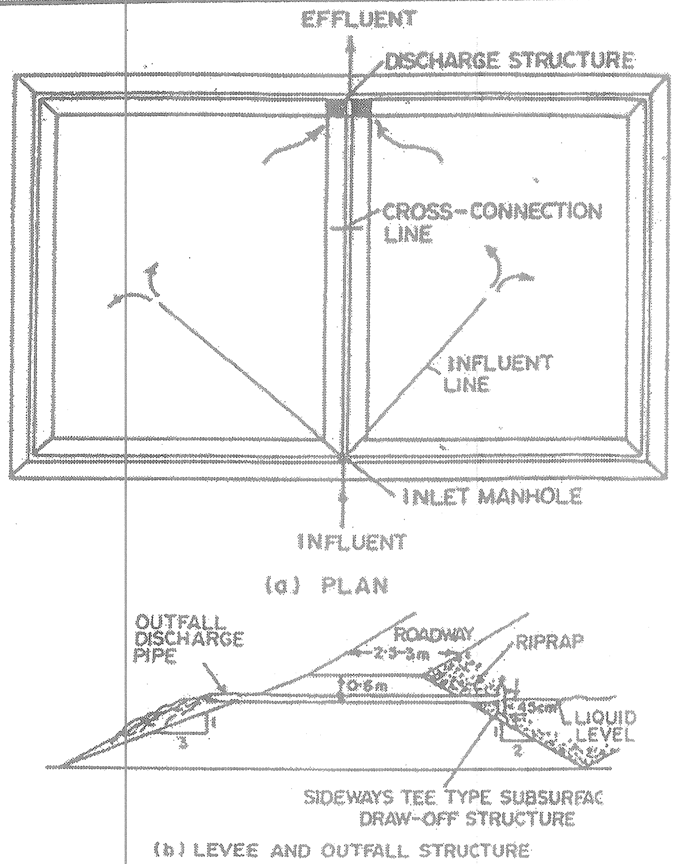


Fig. STABILIZATION POND

Advantages of stabilization ponds of lagoons

(i) Lower initial cost than required for a mechanical plant.
(ii) Lower operating costs.
(iii) Regulation of effluent discharge possible, thus provides control of pollution during critical time of the year.
(iv) Treatment system is not significantly influence by a leaky sewage system bringing storm water along with sewage.

Disadvantages

(i) Required extensive land area. Hence the method can be used only in rural areas where land costs are less.
(ii) Assimilative capacity of certain industrial wastes is poor.
(iii) There are potential odour problems.
(iv) If used in urban areas, expansion of town and new developments may encroach on the lagoon site.

(v) Effluent quantity standards of 30 mg/l for suspended solids are not met.

Q.19 Explain the function of septic tank & Imhoff tank.

Ans : SEPTICTANKS : A septic tank is a special form of primary sedimentation tank with a longer detention time, in which digestion of settled sludge also takes place. In other words, a septic tank is a combined sedimentation cum digestion tank. This tank has, therefore, larger capacity than ordinary primary sedimentation tank, so as to accommodate and hold the settled sludge for its subsequent digestion. The digestion of settled sludge is carried out by anaerobic decomposition process, giving rise to simplicity or septic condition; that's why this unit is known as septic tank. Since the foul gases (such as hydrogen supplied methane, carbon dioxide) are evolved during the digestion process, the tank is kept completely covered on the top, with a provision of a high vertical vent shaft for the escape of these gases. Septic tanks are recommended only for individual homes and small communities and institution (such as school, hospitals etc.) whose contributory population does not exceed 300 or where suitable wastewater carriage system is not available. For septic tanks to function satisfactorily, a fairly adequate water supply is a prerequisite.

IMHOFF TANKS : An Imhoff tank, designed and developed by Karl Imhoff (Germany), is an improvement over the septic tank. The tank, which is basically a sedimentation-cum-digestion tank, has two chambers. The upper chamber is called the sedimentation chamber or flowing-through chamber, through which sewage flows at a very low velocity so that sedimentation may take place. The lower chamber is called the digestion chamber in which anaerobic or septic decomposition occurs. The solids of the sewage setting to the bottom of the sedimentation chamber are made to fall in the digestion chamber through sloping bottom walls (slope about 60°) and an entrance slot at the lowest point. The slot is trapped or overlapped in such a way that gases generated in the digestion chamber do not enter the sedimentation chamber. The gas vent, also called scum area is provided with the digestion chamber for the escape of gases. Gas vent and scum area should be 20 percent of the total surface area.

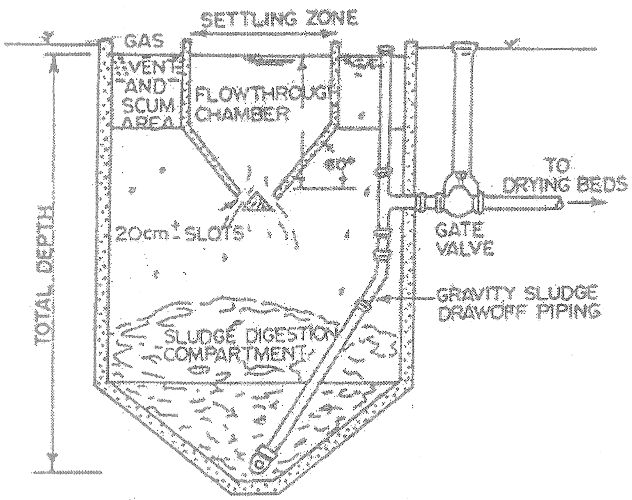


Fig. IMHOFF TANK CONFIGURATION

Q.20 Write short notes with neat skethes? (Nov.-Dec.,2011)

Ans : FACULTATIVE PONDS (OXIDATION PONDS) : A facultative pond combines the features of the aerobic and anaerobic ponds. Constructed of intermediate depth (1.0 to 1.5 m), a facultative pond consists of three zones: (i) aerobic zone at the top (ii) anaerobic zone at the bottom, and (iii) facultative zone situated between the aerobic and anaerobic zones (Fig. 15.6) where decomposition of incoming organic wastes and products of anaerobic decomposition are done by facultative bacteria. The top aerobic layer act as a good check against odour evolution from the pond. The remain on the bottom and will be subjected to anerobic decomposition. The action in the aerobic zone is similar to the one found in the aerobic ponds, giving rise to bacterial-algal-symbiosis. The facultative ponds is best suited and most commonly used for treatment of sewage.

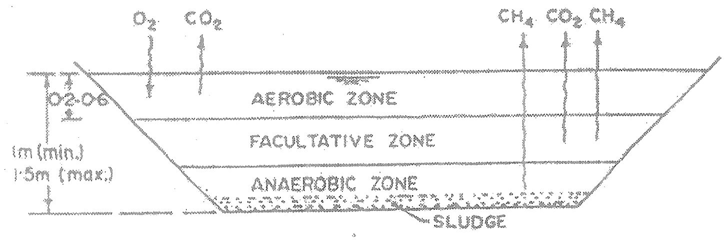


Fig. ELEVATION DIAGRAM OF FACULTATIVE POND STRATA AND OPERATION

Mechanism of purification: In a facultative pond, the influent organic matter is stabilized by methane fermentation in the bottom layers and partly by the bacterial oxidation in the top layers. In the liquid above the bottom sludge layer, there is a zone (known as facultative zone), in which facultative bacteria oxidize the incoming

organics as well as the products of anaerobic decomposition of the bottom anaerobic zone. When the sewage enters the ponds, the suspended organic matter in the influent as well as the bioflocculated colloidal organic matter settle to the bottom of the pond. In the absence of dissolved oxygen at the pond bottom, the settled sludge undergoes anaerobic fermentation with the liberation of methane which represents a BOD removal from m the system-0.25 g of methane being literate for every grimmer of ultimate BOD utilized. In the liquid layer of the pond, algae begins to grow under favorable conditions which maintains aerobic conditions in the upper layer of the pond. The aerobic conditions promote the oxidation of organic waste matter by aerobic bacteria. Thus it is seen that there is an interdependence between algae and bacteria with the algae supplying oxygen required by the bacteria and bacteria making available the carbon dioxide required by the algae.

(2) **Oxidation ditches:** Oxidation ditches may be constructed either in earthwork with earthen embankments or in brick or stone masonry with vertical walls. Brick or masonry walls are preferred, because they occupy lessees land area, and don't get eroded. Whether they are constructed in earthwork or masonry, water-tightness is essential, to ensure the desired immersion of the rotor.

Each ditch channel is usually equipped with a special type of horizontal axis rotor, which serves the purpose of agitating and circulating the sewage, and thereby oxygenating the same. The rotor, not only give oxygen supply to the sewage, but also helps in keeping the sewage-solids in suspension (which act as carriers of aerobic bacteria), by imparting sewage a velocity of more than 0.3 m/sec. The Thoroughly aerated sewage is then settled in a settling tank by, stopping the rotors for about 2 hours, and then taking out the clear supernatant liquor at the time of on flow (i.e. during night hours in case of small communities). A part of the settled sludge is used for recirculation, and the excess settled sludge, which is well stabilized due to long detention periods (characterized by low BOD), can be easily dried on sand beds, and disposed off suitably. A typical arrangement of an oxidation ditch is shown in Fig.

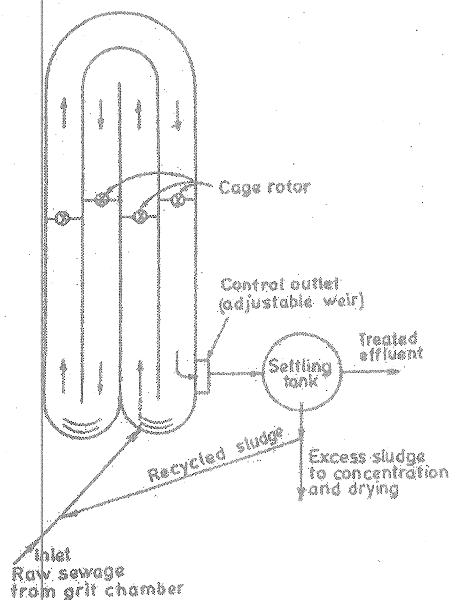


Fig. Plan view of a typical Oxidation ditch.

Q.21 What do you mean by (1) Population Equivalent (2) Relative stability. **(April-May,2011)**

Ans : (1) Population Equivalent: Industrial wastewaters are generally compared with per capita normal domestic wastewaters. So as to rationally charge the industries for the pollution caused by them. The strength of the industrial sewage is, thus, worked out as below:

$$\begin{bmatrix}\text{Standard (5 days)}\\ \text{of industial sewage}\end{bmatrix} = \begin{bmatrix}\text{Standard BOD(5 days)}\\ \text{of domestic sewage per}\\ \text{person per day}\\ \times\ [\text{population equivalent}]\end{bmatrix}$$

The average BOD_5 of domestic sewage is worked out to be about 0.08 kg/day/person. Hence, if the BOD_5 of sewage coming from an industries out as 300 kg/day, then

The population equirvalent

$$= \frac{\text{Total } BOD_5 \text{ of the industry in kg/day}}{0.08 \text{ kg/day/person}}$$

$$= \frac{300}{0.08} = 3750.$$

The population equivalent, thus indicates the strength of the dustrial wastewaters for estimating the treatment required at the municipal sewage treatment plant, and also helps in assessing

realistic charges for this treatment to be charged from the industries instead of charging them simply by the volume of sewage.

(2) Relative stability : The term relative stability of a sewage effluent may be defined as the ratio of oxygen available in the effluent (as D.O., nitrite or nitrate) to the total oxygen required to satisfy its first stage B.O.D. demand. It is expressed as percentage of the total oxygen required, and can be expressed by the equation:

$$\text{Relative stability} = S = 100[1-(0.794)^{t_{20}}]$$

$$S = 100[1-(0.630)^{t_{(37)}}]$$

Where S = The relative stability, $t_{(20)}$ and $t_{(37)}$ represent the time in days for a sewage sample to decolourise a standard volume of methylene blue solution, when incubated at 20°C or 37° C* respectively.

The decolourisation caused by the enzymes produced by anaerobic bacteria, infect, is an indication of the available oxygen in oxidizing the unstable organic matter.

Q.22. What do you mean by most probable Number (MPN) in a waste water example **(April-May,2010)**

Ans : Most probable number (MPN) : MPN is the number which represents the bacterial density which is most likely to be present.

It is necessary to note positive test obtained on portion of sample to know number of coliforms.

MPN of coliforms is decided using statistical tables per 100 ml from positive test.

The standard sample consists of 10 ml. If five samples are tested and all gives negative results, then MPN is zero. If one is positive, then MPN is 2.2 per 100 ml and so on.

MPN is more accurate than E-Coli index MPN index counts coliform by multiple tube fermentation technique, when five 10 ml, five 1 ml and five 0.1 ml portions are used.

No. of tubes giving positive reaction			
5 of 10 ml each	5 of 1 ml each	5 of 0.1 ml each	MPN
0	0	0	0
0	0	1	2
1	0	0	2
1	0	4	4
1	1	1	6

2	0	1	7
2	1	0	7
2	2	0	9
2	3	0	12
3	2	1	17
4	3	1	33
5	5	5	2400

Q.23. Draw a waste water treatment flow. Diagram showing various treatment units. Clearly show the preliminary treatment. Primary treatment and secondary treatment units on it /? (April-May,2010- Nov.-Dec.,20[illegible])

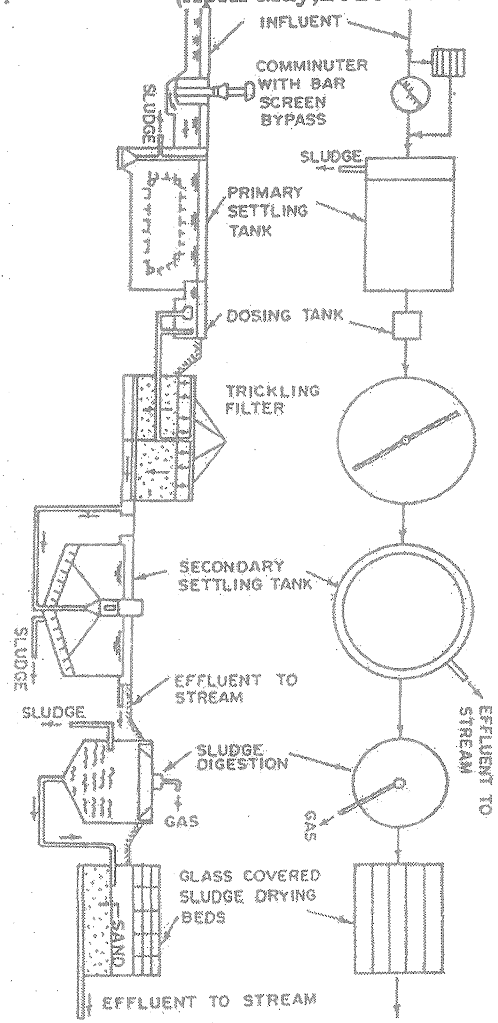


FIG. FLOW DIAGRAM OF SEWAGE TREATMENT PLANT CONFIGURATION II

Numerical

(1)Determine the ultimate BOD and 1-day BOD for a sewage having 5-day BOD at 20°C as 200 mg/lit. Assume.

$k_{20} = 0.1/\text{day}$.

Solution: $y_t = Lo(1 - 10^{-kt})$

$y_5 = Lo(1 - 10^{-5k})$

$200 = Lo(1 - 10^{-5\times0.1})$

$Lo = 292.5$ mg/lit.

∴ Ultimate BOD = 292.5 mg/lit

$y_t = Lo(1 - 10^{-kt})$

$y_5 = 292.5(1 - 10^{-1\times0.1})$

= 60.16 mg/lit.

∴ 1-day BOD = 60.16 mg/lit.

(2) The 5-day BOD of the waste water sample at 20°C is 210 mg/lit. Find out the ultimate first stage BOD. Find out the 5-day BOD of the same sample if the incubation is done at 30°C. Assume the BOD rate constant as 0.23 per day.

Solution: $k' = 0.23$ per day.

$y_5 = 210$ mg/lit. at 20°c

$y_t = Lo(1 - e^{-kt})$

$210 = Lo(1 - e^{-5\times0.23})$

$Lo = 307.3$ mg/lit.

Ultimate first stage BOD(Lo) = 307.3 mg/lit

$K'_T = K'_{20}(1.047)^{T-20}$

$K'_{30} = 0.23(1.047)^{T-20}$

$K'_{30} = 0.364$ per day

$y_5 = Lo(1 - e^{-k/t})$

$= 307.3\ (1 - e^{-0.364\times5})$

$y_5 = 257.53$ mg/lit.

5-day BOD at 30° C(y_5)= 257.53 mg/lit.

$= \dfrac{6\times0 + 294\times8.6}{300}$

= 8.428 mg/lit.

5-day BOD

$(BOD)_5 = [(DO)_0 - (DO)_5] \times$ dilution factor

$= (8.428 - 5.4) \times \frac{300}{6}$

$= 151.4\ mg/lit$

(3) A 5-day BOD of waste water sample was found to be 40mg/lit. The initial DO concentration of dilution water used is 9 mg/lit. While the DO of the mixture after 5 days incubation was 2.74 mg/lit. If the waste water sample taken is 40 ml and volume of BOD water is 300 ml. Find the initial DO concentration in the waste water.

Solution :

$(BOD)_5 = 40$ mg/lit.

$(OD)_5 = 2.74$ mg/lit.

$[BOD]_5 = [(OD)_0 - (OD)_5] \times$ dilution factor

$40 = [(OD)_0 - 2.74] = \frac{300}{40}$

$(OD)_0 = 8.073$ mg/l

$V_m \times C_m = V_s \times C_s + V_d \times C_d$

$C_s = \frac{V_m\times C_m - V_d\times C_d}{V_s}$

$= \frac{300\times8.073-260\times9}{40}S$

= 2.047 mg/l

∴ Initial DO concentration in waste water = 2.047 mg/lit.

(4) 3-day BOD of a waste water sample at 37°C is 300 mg/lit. Find out its 10 days BOD at 20°C and 5 day BOD at 30°C. Assume BOD rate constraint at 20°C is 0.23 per day.

Solution :

y_3 at 37°C = 300 mg/lit.

$k' = 0.23$ per day.

BOD rate constant at 37°C

$K'_T = K'_{20}(1.047)^{T-20}$

$K'_{37} = K'_{20}(1.047)^{37-20}$

$= 0.23\ [1.047]^{37-20}$

= 0.502 per day

Ultimate first stage BOD

$y_t = Lo(1 - e^{-k't})$

$y_3 = Lo(1 - e^{-0.502\times3})$

$300 = Lo(1 - e^{-1.502\times3})$

Lo = 385.46 mg/lit.

10-day BOD at 20°C

$y_{10} = Lo(1 - e^{-k't})$

$y_{10} = 385.46(1 - e^{-0.23\times10})$

$y_{10} = 346.81$ mg/lit.

$K'_T = K'_{20}(1.047)^{T-20}$

$K'_{30} = K'_{20}(1.047)^{30-20}$

$= 0.23(1.047)^{10}$

$K'_{30} = 0.36$ per day

$y_5 = Lo(1 - e^{-k't})$

$= 385.5\ (1 - e^{-0.36\times5})$

$y_5 = 323.04$ mg/lit.

(5) A 2.5 ml of waste water sample is diluted to 200 ml of BOD test. The initials DO for the diluted sample is 7.8 mg/lit. and final DO after 5. Days of incubation is 3.2 mg/lit. Find out the BOD of waste water.

Solution:

$DO_{inirial} = 7.8$ mg/lit.

$DO_{Final} = 3.2$ mg/lit.

$$\text{Dilution factor} = \frac{\text{Total volume of dilute sample}}{\text{volume of raw sample}}$$

$$= \frac{250}{2.5}$$

$$BOD = (DO_{inirial} - DO_{Final})\ \text{Dilution factor.}$$

$$= (7.8 - 3.2) \times \frac{250}{2.5}$$

$$= 460 \text{ mg/lit.}$$

$\therefore$ BOD of waste water = 460 mg/lit.

(6) The BOD of a sewage incubated for one day at 30°C has been found to be 110 Mg/L. what will be the 5 days BOD at 20°C ? Assume the values of reaction constants K_1 as 0.1 at 20°C (base '10').

Ans. Given: 1 day BOD at 30°D = 110 mg/L

5 day BOD at 20°C = ?

$K_1 = 0.1$ at 20°C

y_1 at 30°C $= 110\frac{mg}{L}$ & k_1 at 20°C = 0.1

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

$K_{30} = 0.1(1.047)^{30-20}$

$K' = k'_{20} = 0.1(1.047)^{10}$

$= 0.1583$ per day

Ultimate 1 st stage BOD

$y_t = L_0(1 - e^{-k'_{20}} \times t)$

$\therefore y_1 = L_0(1 - e^{-0.1583 \times 1})$

$110 = L_0(1 - e^{-0.1583})$

$\therefore L_0 = 751.34$ mg/lit

$\therefore$ 5 days BOD at 20°C

$y_5 = L_0(1 - e^{-k/ \times 5})$

$y_5 = 751.34(1 - e^{-0.1 \times 5})$

$= 295.63$mg/lit

Thus 5 days BOD = 295.63 mg/lit.

(7) The 5 day 30°C BOD of s sewage sample is 110 mg/I. Calculate its 5 days 20°C BOD. Assume the deoxygenating constant at 20°C, K_{20} as 0.1 $K_{D(20°)}$

Solution. $K_{D(20°)} = 0.1$

Now, using equation

$K_{D(T°)} = K_{D(20°)}\,[1.047]^{T-20}$, we get

$K_{D(30°)} = 0.1\,[1.047]^{30°-20} = [1.047]^{10} = 0.158$ .... (i)

Now using $Y_t = L[1 - (10)^{-k_D \cdot t}]$, w; get

$Y_t = L[1 - (10)^{-k_D \cdot t}]$, w; get

$Y_5 = L[1 - (10)^{-k_D \cdot 5}]$

$\therefore Y_{5\ at\ 30°} = L[1 - (10)^{-k_D \cdot (30°) \times 5}]$, w; get

Or $110 = L[1 - (10)^{-0.158 \times 5}] = [1 - (10)^{-0.79}]$

$$= L\left[1 - \frac{1}{(10)^{0.79}}\right] = L[1 - 0.162]$$

Or $110 = L\,(0.838)$ or $L = \frac{110}{0.838}$

Or $L = 131.3$ mg/I. ....(ii)

Now $Y_{5\ at\ 20°C} = L[1 - (10)^{-k_D(20°) \times 5}]$

$$= 131.3[1 - (10)^{-0.1 \times 5}] = 131.3\left[1 - \frac{1}{(10)^{0.5}}\right]$$

$$= 131.3 \times (1 - 0.316) = 131.3 \times 0.684$$

$= 89.8$ mg/l. Ans.

(8) Calculate 1 day 37°C BOD of sewage sample whose 5 day 20°C BOD is 100 mg/l. Assume K_D at 20°C as 0.1

Solution: 5 day 20°C BOD = 110 mg/l. (given)

Now using Eq.

The BOD at 20°C, say after t = 5 days, is given by

$Y_t = L[1 - (10)^{-k_D(20°).t}]$

Using $Y_t = 100$ mg/l. (given)

$k_D(20°) = 0.1$

$100 = L[1 - (10)^{-0.1\times5}]$

$100 = L[1 - (10)^{-0.1\times5}] = L\left[1 - \frac{1}{3.16}\right]$

$= L[1 - 0.316] = L[0.684]$

$= L\frac{100}{0.684} = 146.2$ mg/l.

Net let us work out K_D at 37°C, by using Eq. as:

$K_{D(T°)} = K_{D(20°)}\ [1.047]^{T-20}$

$K_{D(37°)} = 0.1\ [1.047]^{37°-20} = 0.1[1.047]^{17}$

$= 0.1 \times 2.4 = 0.24.$

Now, we have to work out Y_t for one day i.e. Y_1 at 37°C, using

$y_t = L(1 - (10)^{-k_D.t})$

$y_1 = L(1 - (10)^{-k_D.1})$

$y_{1(at\ 37°C)} = 146.42(1 - (10)^{-k_D(at\ 37°C)\times1})$

$= 146.42(1 - (10)^{-0.24\times1}) = 146.2\left[1 - \frac{1}{(10)^{0.24}}\right]$

$= 146.2\left[1 - \frac{1}{1.738}\right] = 146.2[1 - 0.575] = 62.07.$

Hence, Y_1 at 37°C = 62.07 mg/l. Ans.

(9) A 2% solution of a sewage is incubated for 5 days at 20°C. The depletion of oxygen was found to be 4 ppm. Determine the BOD of the sewage. (Nov-Dec., 2009-2011)

Solution: Dilution factor

$= \frac{100}{\text{Per cent of solution}} = \frac{100}{2} = 50$

Depletion of oxygen = 4ppm.

Using equation (7.11), we have

BOD = Depletion of oxygen × Dilution factor

$= 4$ ppm × 50 = 200 ppm Ans.

(10) The BOD of a sewage incubated for one day at 30°C has been found to be 110 mg/l. What will be the 5-day 20°C BOD ? Assume $K_1 = 0.1$ at 20°C

Solution : $Y_{1(at\ 30°)} = 110$ mg/l ; $Y_{5(at\ 20°)} = ?$; $K_{D(at\ 20°)} = 0.1$

First of all, let us calculate K_D at 30° C, by using Eq. (7.18) i.e.

$K_{D(T)} = K_{D(20)}[1047]^{T-20°}$

or $K_{D(20°)} = 0.1[1047]^{30-20°} = 0.1[1047]^{10}$

$= 0.1 \times 1.583 = 0.158$

Now using Eq. (7.16), We have

$Y_t = L[1 - (10)^{-K_D.t}]$

At 30°C and for one day, we have

$Y_{1(30°)} = L[1 - (10)^{-K_D.(30°)\times1}]$

Or $110 = L[1 - (10)^{-0.158\times1}] = L\left[1 - \frac{1}{1.438}\right]$

$= L[1 - 0.696] = L[0.304]$

Or $L = \frac{110}{0.304} = 361.8$ mg/l

Now again using $Y_t = L[1 - (10)^{-K_D.t}]$, we have

$Y_{5(20°)} = L[1-(10)^{-K_{D(20°)} \times 5}]$

$= L[1-(10)^{-0.1\times5}] = L\left[1-\frac{1}{(10)^{0.5}}\right]$

$= L[1-0.316]$

$= 361.8[1-0.316] = 247.4$ mg/l

(11) Change in concentration of organic matter, L, with time t, is given by $\frac{dL}{dt} = -k.L.$

Calculate the organic matter remaining after 3 days if the initial concentration was 200 mgll, and K=0.4 per day.

Solution : $\frac{dL}{dt} = -KL$ or $\frac{dL}{L} = -K.dt$

Integrating, we have

$\log_c L = -Kt + C$

Or $2.3 \log_{10} L = -Kt + C$

When t= 0 (at start), L = 200 mg/l.

$\therefore 2.3 \log_{10} 200 = 0 + C$

or $C = 2.3 \times 2.301 = 5.28$

Now, the value of L after 3 days

$2.3\log_{10} L = -0.4 \times 3 + C$

Or $2.3\log_{10} L = -1.2 + 5.28 = 4.08$

Or $\log_{10} L = \frac{4.08}{2.3} = 1.773$

L= 59.3 mg/l

Hence the organic matter left after 3 days = 59.3 mg/l. Ans.

(12) Data from an unseeded domestic waste water BOD test are : 5 ml of waste in 300 ml bottle, initial D.O. of 7.8 mgll, and 5 days DO equal to 4.3 mgll. Compute

(a) the BOD; and (b) the ultimate BOD, assuming a k-rate of 0.10 per day. (April-May,2011)

Solution. Initial D.O = 7.8 mg/l

D.O. after 5 days of incubation = 4.3 mg/l

$\therefore$ D.O consumed in 5 days = 7.8 − 4.3 = 3.5 mg/l

Now, using equation (7.10), we have

BOD_5 of wastewater

= D.O. consumed by diluted sample

$\times \left[\frac{\text{Vol.of diluted sample}}{\text{Vol.of undiluted sewage used}}\right]$

$= 3.5 \text{ mg/l} \times \left[\frac{300 \text{ ml}}{5}\right] = 210$ mg/l. Ans.

Now, using equation

Now, using equation $Y_t = L[1-(10)^{-k_D.t}]$, we have

$Y_5 = L[1-(10)^{-k_D.5}]$

Where $k_D = 0.1$ per day and $Y_5 = 210$ mg/l

$\therefore = L[1-0.316] = 0.684L$

Or $L = \frac{210}{0.684}$ mg/l = 307.1 mg/l

Hence, ultimate $BOD_{(Y_u)} = L = 307.1$ mg/l. Ans.

(13) A dairy processing about 1,33,00 kg of milk daily produced an average of 246 cubic metre per day of waste water with a BOD of 1400 mgll. The principal operations are bottling of milk, and making ice cream, with limited production of cheese. Compute the waste water flow and BOD production per 1000 kg of milk received, and the equivalent population of the daily waste discharge.

Solution : Daily milk processed = 1,33,000 kg

Daily wastewater produced = 246 m^3

BOD of wastewater = 400 mg/l

Evidently,

Wastewater produced per 1000 kg of milk

$= \frac{246}{1,33,000} \times 1000m^3 = 1.85m^3$

BOD of the wastewater = 1400 mg/l

$= 1400 \times 10^3$ mg/cum

$= \frac{1400\times10^3}{1000}$ mg/cum $= \frac{1400\times10^3}{10^3\times10^3}$ mg/cum

Hence, BOD produced per 1000 kg of milk processed

$= 1.4 \times 1.85kg = 2.59$ kg. Ans

Daily BOD produced by 246 m^3 of wastewater

$= 1.4kg/m^3 \times 246m^3 = 344.4$ kg. Ans

From equation (7.20), we have

Population equivalent

$= \frac{BOD\ of\ industry\ in\ kg/day}{0.08} = \frac{344.4}{0.08} = 4305.$ Ans

(14) The 3 days 15°C BOD of a sample of sewage is 150 mg/l. Draw a graph of 5 day BOD as a function of temperature in the range 10°C to 30°C in steps of 5°C

Solution : Assume K_D at 20°C = 0.1

Then K_D at 15°C is given as :

$K_{D(T^\circ)} = K_{D(20^\circ)}[1.047]^{T-20^\circ}$

Or $K_{D(15^\circ)} = 0.1[1.047]^{15-20^\circ}$

$= 0.1[1.047]^{-5}$

$= \frac{0.1}{(1.047)^5} = 0.079$

Now, Using

$Y_{t\ at\ T^\circ} = L[1 - (10)^{-k_D \cdot t}]$, we have

$Y_{3\ at\ 15^\circ} = 1500$

$= L[1 - (10)^{-0.079\times3}]$

$= L\left[1 - \frac{1}{(10)^{-0.0237}}\right] = 0.422$ L

Or L= 355.53 mg/I.

$K_{D(10^\circ)} = 0.1[1.047]^{10-20} = 0.063$

$K_{D(25^\circ)} = 0.1[1.047]^{25-20} = 0.1258$

$K_{D(30^\circ)} = 0.1[1.047]^{30-20} = 0.1583$

(i) $Y_{5\ at\ 10^\circ} = 355.53[1 - (10)^{-0.063\times5}] = 183$ mg/I.

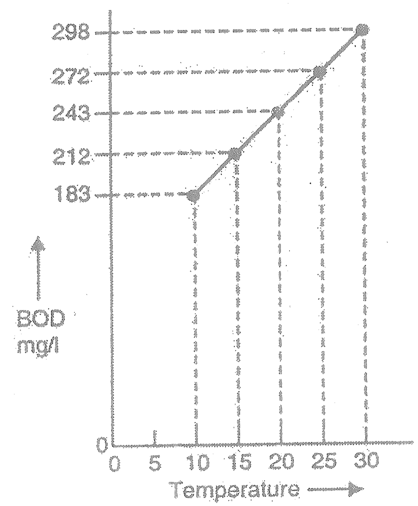
(ii) $Y_{5\ at\ 15^\circ} = 355.53[1 - (10)^{-0.079\times5}] = 212$ mg/I.

(iii) $Y_{5\ at\ 20^\circ} = 355.53[1 - (10)^{-0.01\times5}] = 243$ mg/I.

(iv) $Y_{5\ at\ 25^\circ} = 355.53[1 - (10)^{-0.01558\times5}] = 272$ mg/I.

(v) $Y_{5\ at\ 30^\circ} = 355.53[1 - (10)^{-0.01583\times5}] = 298$ mg/I.

These calculated five number BOD values w.r.t. temperature are plotted in Fig. so as to obtain the requisite graph, which is almost a straight line.



(15) The 5 day 30°C BOD of s sewage sample is 110 mg/l. Calculate its 5 days 20°C BOD. Assume the deoxgenation constant at 20°C, K_{20} as 0.1

Solution : $K_{D(at\ 20^\circ)} = 0.1$

Now, using equation(7.18)

$K_{D(T^\circ)} = K_{D(20^\circ)}[1.047]^{T-20^\circ}$, We get

$K_{D(30^\circ)} = 0.1[1047]^{30^\circ-20^\circ} = 0.1[1.047]^{10} = 0.158$ .... (1)

Now using $Y_t = L[1-(10)^{-K_D.t}]$, w; get

$Y_5 = L[1-(10)^{-K_D..5}]$

$\therefore Y_{5at30^\circ} = L\left[1-10^{-K_D(30^\circ)\times5}\right]$

$110 = L[1-(10)^{-0.158\times5.}] = L[1-(10)^{-0.79}]$

$= L\left[1-\frac{1}{(10)^{-0.79}}\right] = L[1-0.162]$

Or $110 = L\,(0.838)$ or $L = \frac{110}{0.838}$

Or $L = 131.3\, mg/l.$ ------------------ (ii)

Now $Y_{5at\,20^\circ C} = L\left[1-(10)^{-K_D(20^\circ)\times5}\right]$

$= 131.3[1-(10)^{-0.1\times5}] = 131.3\left[1-\frac{1}{(10)^{-0.5}}\right]$

$= 131.3\times(1-0.316) = 131.3\times0.684$

$= 89.8\, mg/l.$

(16) Design a grit chamber for a maximum wastewater flow of 8000 m³/day, to remove particles upto of 0.2 mm dia. Having specific gravity of 2.65. The setting velocities of these particles is found to range from 0.018 to 0.022 misec. Maintain a constant flow through the provision of a proportional flow weir.

Solution. Since the velocity control device is in the form of a proportional flow weir, let us provide a rectangular section for the grit chamber.

Now v_h= 0.3 m/sec and $Q = \frac{8000}{24\times60\times60} = 0.0926\ m^3/sec$

$\therefore A = \frac{Q}{V_h} = \frac{0.0926}{0.3} = 0.3086m^2$

Providing a depth of 1 m, the width of grit chamber is

$B = \frac{0.3086}{1} = 0.3086$ m

Provide a width of 0.35 m.

The setting velocity of the particles to be removed in the grit chamber varies from 0.018 to 0.022 m/sec. Hence let us assume a setting velocity v_s = 0.02 m/sec.

$\therefore$ Detention time $= \frac{\text{Depth of chamber}}{\text{settling velocity}} = \frac{1}{0.02} = 50$ sec.

Also, length of tank = $v_h \times$ detention time

$= 0.3\times50 = 15$m

Hence provide a grit chamber of length 15 m, width 0.35 m and depth 1 m.

(17) Design a detritus tank for a D.W.F. of 350 ips in a separate sewage system. Make suitable assumptions wherever required.

Solution. Let us assume the following:

Detention time : 3 m ; Flow velocity : 0.2 m/sec.

Max flow : 3 times DWF.

Hence Q_{max} = 3 × 350 litres/Second.

Let us provide 3 tanks attached and running parallel to each other. Hence design discharge for each tank is.

$Q = 350\ l/s = 0.35m^3/s.$

$\therefore$ Cross – section area required $= \frac{Q}{v} = \frac{0.35}{0.2} = 1.75m^2$

Let us provide a water depth of 1.2 m, in the rectangular portion.

$\therefore$ Width of tank $= \frac{\text{Area}}{\text{depth}} = \frac{1.75}{1.2} = 1.458$ m.

Provide a width of 1.5 m.

Also, length of tank =velocity× detention time

$= 0.2(3\times60) = 36\ m.$

Making a provision of 6 meters for inlet and outlet arrangement, the total length of tank = 42 m. Thus, each unit of the detritus tank will be of 1.5 m width and 42 m length. Provide a free board of 0.3 m. Also, provide a bottom depth of 0.5 m for the accumulation of detritus and this depth be tapered at an angle of 45°.

(18) Calculate the size of rectangular grit chamber by using following data: (April-May,2011)

Flow of sewage = 50 million lit/day

Sp. Gravity of grit = 2.70

Size of particles = 0.21mm

Kinematic viscosity of water = 1.0×10^2 cm^2/sec.

Assume other data required.

Solution. Quantity of sewage = 50×10^6 lit/day

$$= \frac{50\times10^6\times10^{-3}}{24}$$

$$= 2.08 \times 10^3 \ m^3/hour$$

From the stroke-law formula, settling velocity of the particle

$$= \frac{1}{18}\frac{g}{\mu}(P_s - P)d^2$$

$$= \frac{1}{18} \times \frac{981}{1\times10^{-2}}(2.7-1)(P_s - P)d^2$$

$$= 4.09 \text{ cm/sec.}$$

keeping the depth of the grit chamber 2.4 m, the detention period $= \frac{2.4\times100}{4.09} = 58.7$ say 1.0 minute.

∴ Quantity of sewage passing through in one minute is

$$= \frac{2.08\times10^3}{60} \ m^3/min$$

$$= 34.72 \ m^3/min$$

= Capacity of the grit chamber.

Surface area $= \frac{\text{Capacity}}{\text{Depth}} = \frac{34.72}{2.4} = 14.47m^2$ say $15m^2$

Provide three parallel grit chambers of size 1m×7.5 m, one will act as standby and two will work at a time.

The depth will be kept as 2.7 with 30 cm as free board and 2.4 m as effective depth.

Check for horizontal velocity,

Horizontal velocity $= \frac{Q}{BD} = \frac{34.72}{2\times2.4}$ m/min

$$= \frac{7.23m}{min} = 12.06 \text{ cm/sec.}$$

∴ Critical horizontal velocity,

$v_c = 40\sqrt{(P_s - P)d}$, where, 'd' in mm.

$$= 40\sqrt{(2.7-1)0.21}$$

$= 23.9 \frac{cm}{sec}$. is within safe limits and design ok.

(19). Design a grit chamber to handle a sewage flow from the population of 50,000 and per capita daily consumption of water is 140 liters. Assume velocity of 20 cm/sec and Detention Time one minute.

Solution: D.W.F. = 140 × 50,000

$$= 7 \times 10^6 \text{ lit/day}$$

D.W.F. = 7 M/d

∴ Design flow = 3 × D.W.F.

Design flow = 21 M/d

With detention period of 1 minute,

Volume of flow in chamber $= \frac{21\times10^6\times1}{24\times60\times10^3} = 14.58m^3$

Let Effective depth = 1.4 m

Surface area $= \frac{14.58}{1.4} = 10.41m^2$

With $\frac{L}{B} = \frac{8}{1}$ and a free board of 0.3 m.

The dimension of grit chamber are

L = 11m, B = 1.4m D = 1.7m

Provide 2 number grit chambers, one to take care of maximum flow and the other as D.W.F.

Check:

Design flow = $\frac{21\times10^6}{24\times60\times60\times10^3} = 0.243\ m^3/sec.$

Velocity of flow = $\frac{0.243}{1.4\times1.7} = 0.102\ m/sec. < 0.20 m/sec$

(20) Design a grit chamber of rectangular C/S if the maximum waste water flow rate is 8000 m³/day to remove particles upto 0.2 mm dia. With specific gravity of 2.65.

Solution: Maximum flow rate = $8000\ m^3/day$

$= \frac{8000}{24\times60\times60}$

$= 0.0926\ m^3/s$

Assuming horizontal flow velocity (V_H) = 0.25 m/s

And detention time (t) = 60 sec.

Length of grit chamber (L)= $V_H \times t$

$= 0.25 \times 60$

$= 15\ m$

C/s area of flow (A) = $\frac{Q}{V_H} = \frac{0.0926}{0.25} = 0.37 m^2$

Setting velocity(V_S) = d[3T + 70]

Where d-dia. Of particle = 0.2 mm

Normal room = 2×10^{-4} m

T-temperature Assuming, T = 20°C

$V_S = 2 \times 10^{-4}[3 \times 20 + 70]$

$= 0.026\ m/s$

Depth of chamber (H)= $V_s \times t$

$= 0.026 \times 60$

$= 1.56\ m$

Breadth of chamber = $\frac{\text{Area of chamber}}{\text{Depth of chamber}}$

$= \frac{0.37}{1.56}$

Assuming free board(FB) = 0.3 m

Overall depth = *Flow depth + FB*

$= 1.56 + 0.3$

$= 1.86\ m$

Hence, provide a grit chamber of size 15 m×0.24m×1.86 m having depth of flow = 1.56 m

(21) Design an oxidation pond for treating sewage from a hot climatic residential colony with 5000 persons, contributing sewage@ 120 liters per capita per day. The 5-day BOD of sewage is 300 mg/Il.

Solution. The quantity of sewage to be treated per day

$= 5000 \times 120 = 6{,}00{,}000$ litres

$= 0.6$ M. litres = 600 cu. m.

The BOD content per day

$= 0.6\ Ml \times 300 \frac{mg}{l} = 180\ kg$

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

The surface area required

$= \frac{180\ kg/d}{300\ kg/ha.d} = \frac{180}{300}$ ha

$= \frac{180}{300} \times 10^4 m^2 = 6{,}000\ m^2$

Assuming the length of the tank (L), as twice of its width (B), we have

$2\ B^2 = 6000$

Or $B = \sqrt{3000}$

$= 54.7$ m; say 55 m.

Use $L = \frac{6000}{55} = 11$ m

Using a tank with effective depth as 1.2 m ; we have

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

Now, Capacity = Sewage flow per day × Detention time in days.

∴ Detention time in days

$$= \frac{\text{Capacity in cu.m.}}{\text{Sewage flow per day in cu.m/day}}$$

$$= \frac{7260}{600} = 12.1 \text{ days; say 12 day.}$$

Hence, use an oxidation pond with length = 100 m; and overall depth= (1.2 + 1.) = 2.2m; and a detention period of 12 days.

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

$$\text{Discharge} = \frac{600}{8\times60\times60} \text{ cumecs.}$$

∴ Area of inlet pipe required

$$= \frac{Discharge}{Velocity} = \left(\frac{600}{8\times60\times60}\right)\frac{1}{0.9}\ m^3$$

$$= \frac{1}{7.2\times6} m^2 = \frac{1}{43.2}\ m^2 = 232 cm^2$$

∴ Dia of inlet pipe $= \sqrt{\frac{4\times232}{\pi}} = 17.2$ cm; say 18 cm. Dia of outlet pipe may be taken as 1.5 times that of the inlet; say 27 cm.

(22) Stabilization ponds for a town of 3000 population are provided to operate in series. The larger cell has an area of 60,000 π^2, and the smaller one 30,000 m^2. The average daily waste flow is 900 m^3/day containing 200 kg of BOD (222 mg/I).

(i) For series operation, calculate the BOD loadings based on both the total pond area and the large cell only.

(ii) Estimate the number days of winter storage available between 0.6 m and 1.5 m water levels, assuming an evaporation and seepage loss of 2.5 mm of water per day.

Solution: (i) (a) BOD loading based on total pond area

Total pond area of both cells joined in series

$= 60,000m^2 + 30,000m^2$

$= 90,000m^2 = 9\ hectares.$

Total BOD per day = 200 kg/day

BOD loading in kg/ha/day

$= \frac{200}{9}$ kg/day/ha = 22.2 $kg/ha/day$

(ii)To calculate the number days of storage between WL 0.6 m and 1.5 m, we have

Depth available for storage $= 1.5 - 0.6 = 0.9\ m.$

Total area $= 90,000\ m^2$

∴ Volume of storage available $= 90,000 \times 0.9 = 81,000\ m^3.$

Daily inflow of sewage = 900 cu. m/day

The sewage volume, which percolates and evaporates daily

= 2.5 mm depth

$= \frac{2.5}{10} \times \frac{1}{100}$ m × surface area of tanks

$= \frac{2.5}{1000} m \times 90,000m^2 = 225\ m^3$

∴ Net effective daily inflow of sewage

$= (900 - 225)m^3 = 675\ m^3/day$

∴ Winter storage available as days

$$= \frac{\text{Vol. of storage in } m^3}{\text{Daily net sewage inflow in } m^3/\text{day}}$$

$= \frac{81,000}{675}$ days 120 days.

(23) Design the dimensions of a septic tank for a small colony of 150 persons provided with an assured water supply from the municipal head-works at a rate of 120 liters per person per day. Assume only data. You may need.

Solution: The quantity of water supplied

$= \text{Per capita rate} \times \text{Population}$

$= 120 \times 150 \frac{\text{litres}}{\text{day}} = 18{,}000\ l/day$

Assuming that 80% of water supplied becomes sewage, we have The quantity of sewage produced

$= 18{,}0000 \times 0.8 = 14{,}400\ l/day$

Assuming the detention time to be 24 hours. We have

The quantity of sewage produced during the detention period i.e, the capacity of the tank)

$= 14{,}400 \times \frac{24}{24} = 14{,}400\ litres$

Now, Assuming the rate of deposited sluydge as 30 litres/capita/year; and also assuming the period of cleaning as 1 year, We have

The volume of sludge deposited

$= 30 \times 150 \times 1 = 4{,}500\ litre$

$\therefore$ *Total required capacity of the tank*

= Capacity for sewage +Capacity for sludge

= 14,400+4,500 = 18,900 litres = 18.9 cu.m.

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

The Surface area of the tank

$= \frac{18.9}{1.5} m^2 = 12.6 m^2$

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

$3.B^2 = 12.6$

$B = \sqrt{\frac{12.6}{3}} = \sqrt{4.2} = 2.05$; say 2.1 m.

$\therefore$ Provide width = 2.1 *m; and*

$\therefore$ Area of cross-section provieed

$= 6m \times 2.1m \times (1.5 + 0.3)$ m overall depth

[0.3 m used as free – board]

Hence use a tank of size 6 m×2.1 m× 1.8 m .

CSVTU April-May 2012

UNIT -II Part -A

Q.2 (a) Write the formulae for determination of : 2
(i) Total Solids (ii) Total Volatile Solids

Ans.: Refer Q-3

Part– B

(b) Explain COD and its significance in waste water treatment. 7

Ans.: Refer Q-8

(c) What is meant by "Population Equivalent"? How is it determined? 7

Ans.: Refer Q-21

(d) Derive the street Phelps Equation. 7

Ans.: Refer Q-9

CSVTU Nov.- Dec 2011

UNIT-II Part- A

Q.2 (a) (i). Standard BOD_5 20°c when compared to ultimate BOD is about :
(1). 58% (2). 68% (3). 78% (4). 90 % 2

(ii). Average BOD_5 of domestic sewage is
(1). 80 kg/d/p (2). 8 kg/d/p (3) 0.08 kg/d/p (4). 0.8 kg/d/p 2

Part- B

(b) The 4 days 15°c BOD a sewage sample is 200 mg/I. Draw a graph (in answer sheet only . No graph paper required) of 5 day BOD as a function of temperature in the range of 10°c to 30°c in steps of 5°c 7

Ans.: Refer Example-14

(c) Explain various types of settlings. Differentiate unit processes and operations with proper examples. 7

Ans.: Refer Q-14

(d) Write short notes with neat sketches : 7
(i). Facultative Ponds & Mechanism of Purification.
(ii). Oxidation Ditch.

Ans.: Refer Q-20

CSVTU April-May 2011

Unit-II

Q.2 (a) Define Relative Stability. 2

Ans.: Refer Q-21

(b) Define BOD, deduce expression for first stage BOD. 7

Ans.: Refer Q-4&7

(c) Data from unseeded domestic wastewater BOD test are : 5 ml of waste in 300 ml bottle, initial D.O. of 7.8 mg/I, and 5 days D.O. equal to 4.3 mg/I. Compute: 7

(i) The BOD; and

(ii) The ultimate BOD, assuming a k-rate of 0.10 per day.

Ans.: Refer Example-12

(d) Design a rectangular grit-chamber from following data: 7

Flow of sewage = 55 x 10^6 liters/day

Specific gravity of the grit = 2.70

Size of the grit practical to be removed = 0.21 mm.

Viscosity of water = 1.0×10^{-2} cm^2/sec.

Ans.: Refer Example-18

CSVTU Nov.- Dec 2010

Q.2 (a) What do you mean by overflow rate of a setting tank? 2

Ans.: Refer Q-15

(b) An analysis for solids is made on a wastewater sample. Two hundred milliliters of the sample is filtered through a fiber glass filter that has been pre- weighed at 0.138 g. The filter and residue is oven carried until a constant mass of 0.229 g is reached 100 mL of the filtrate is placed in an evaporation dish whose tare mass has been determined to be 327.485g. The contents of the dish are evaporated to dryness, and the total mass of the dish and solids is found to be 327.517g. Determine the total suspended solids and total dissolved solids. 7

Ans.: Refer Example-16

c) What type of setting governs the design of primary setting tank in wastewater treatment? Describe the setting column analysis carried out on a sample of wastewater. How the setting column analysis data is analyzed for the design of wastewater primary setting tank? 7

Ans.: Refer Q-14

(d) A 2% solution of a sewage sample is incubated for 5 days at 20°C. The depletion of oxygen was found to be 4 mg/L. Determine the BOD of the sewage. What will be 3-day BOD of this sewage in summer when the temperature is 37°c? Take the BOD rate constant (base 10) as 0.1 per day at 20°c. 7

Ans.: Refer Example-9

CSVTU April-May 2010

Q.2 (a) What do you mean by most probable Number (MPN) in a wastewater sample? 2

Ans.: Refer Q-22

(b) Explain the procedure of determination of total solids suspended solids and settleable solids for a wastewater sample. How one can determine the organic and inorganic part of these solids? 7

Ans.: Refer Q-3

(c) Draw a wastewater treatment flow diagram showing various treatment unit. Clearly show the preliminary treatment. Primary treatment and secondary treatment units on it. How and why the setting of solid in wastewater treatment primary setting tank is different than water treatment in plain sedimentation tank? 7

Ans.: Refer Q-23

(d) The 5-day 20°C BOD of a wastewater is 210 mg/l. What will be the ultimate BOD? What will be the 10-day BOD? Tank the rate constant (natural log) as 0.23 per day. 7

Ans.: Refer Example-4

CSVTU Nov.- Dec 2009

Q.2 (a) What is Muffle Furnace? 2

Ans. The furnace in which the solid waste water is boiled.

(b) Explain the procedure of determination of total solids, suspended solids, and sattleable solids for a wastewater sample. How will you separate the organic and inorganic part of these solids? 7

Ans.: Refer Q-3

(c) Draw a wastewater treatment flow diagram showing various treatment units. Clearly show the preliminary treatment, primary treatment and secondary treatment units on it. How and why the setting of solids in wastewater treatment in primary setting tank is different than water treatment in plain sedimentation tank 7

Ans.: Refer Q-23

(d) A 2% solution of a sewage sample is incubated for 5 days at 20°C. The depletion of oxygen was found to be 4 mg/L. Determine the BOD of the sewage. What will be 3-day BOD if this sewage in summer when the temperature is 37°C? Take the BOD rate constant (base 10) as 0.1 per day at 20°C. 7

Ans.: Refer Example-9

CSVTU April-May 2009

UNIT – II

Q.2 (a) What do you understand by "chemical oxygen demand"? 2

Ans.: Refer Q-8

(b) Disuses various physical properties of sewage. 7

Ans.: Refer Q-1

(c) What will be 5 day 20°C BOD if BOD of sewage in incubate for day at 30°C in 110 ppm.K_{20} = 0.1. 7

Ans.: Refer Example-10

(d) Design an oxidation pond for treating sewage from a hot climate residential colony with 5,000 persons contributing sewage @120 litre/capita/day. The 5 day BOD of sewage is 300 mg/L. 7

Ans.: Refer Example-21

CSVTU Nov.- Dec 2008

UNIT – II

Q.2 (a) Define Bio-chemical oxygen demand. 2

Ans.: Refer Q-4

(b) State and describe four important test that may be carried out to know the characteristics of sanity sewage.

(c) The 5-day 30°C BOD of sewage sample is 110 mg/l. Calculate its 5 days 20°C BOD. Assume the de–oxygenation constant at 20°C, K_{20} as 0.1.

Ans.: Refer Example-15

(d) Design the dimension of septic tank for small colony of 150 persons provided with an assured water supply from municipal work at a rate of 120 litres/ person/day. Assume any data you may need. 7

Ans.: Refer Example-23

UNIT-III SECONDARY TREATMENT SYSTEMS

Secondary treatment systems-(i) Attached growth process-Trickling filters, standard and high rates, efficiency (NRC) formula, operational problems of trickling filters (ii) Suspended growth process, principle of suspended growth process, Activated sludge process, Oxidation ditch aeration and mixing techniques, Operational problems of activated sludge systems, stablisation tools aerobic, anaerobic and facultative lagoon.

Q.1 What is the basic principle behind the working of the secondary treatment systems? What do you understand by attached growth process. (Nov-Dec.,2010)

Ans: Attached growth processes (or fixed film processes): These are the biological treatment processes in which the microorganisms 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 include the followings:

(i) Intermittent sand filters;
(ii) Tricking filters;
(iii) Rotating biological contactors;
(iv) Packed bed reactors;
(v) Anaerobic lagoon(ponds);
(vi) Fixed denitrification.

Principle of biological treatment: Sewage can remain in aerobic or aerobic condition depending on the availability or non-availability of oxygen. In aerobic condition the bacteria consume oxygen and remain active without causing any foul smell on the other hand in aerobic condition foul smell is created, due to which only aerobic conditions are preferred. When the sewage is passed through the beds, where aerobic action takes place following actions are done by the aerobic bacteria.

(a) The colloidal and dissolved putrescible organic matters present in the sewage are absorbed within few minutes in the tricking filters and within about one hour in the activated sludge process.

(b) The bacteria feed the organic matters so absorbed which are necessary for their life.

(c) The bacteria convert the organic matters into stable inorganic forms by oxidizing them.

Q.2 What is trickling filter? Explain its working with neat sketch. **(Nov-Dec.,2010)**

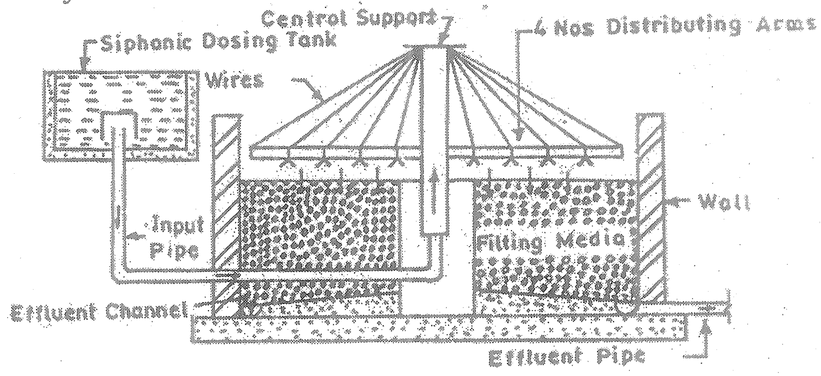
Ans. Trickling filters are used for the biological treatment of domestic sewage and industrial wastes, which are amenable to aerobic biological processes. These are used for the complete treatment or moderately strong wastes and as roughing filter for strong wastes prior to activated sludge units. They possess a unique capacity to handle shock loads and provide dependable performance with minimum supervision.

The trickling filter is always preceded by primary sedimentation so that settle able solids in the sewage may not clog the filter. The trickling filter is always following by a final settling tank to remove from the filter effluent. The settable organic solids produced in the filtration process.

A bacterial film known as a bio-film is formed around the particles of filtering media and for the existence of this, the oxygen is supplied by the intermittent working of the filter and by the provision so suitable ventilation facilities in the body of the filter The color of this film is blackish, greenish.

A bacterial film known as a bio-film is formed around the particles of filtering media. As the sewage trickles through the filter media a biological slime consisting of aerobic bacteria and other biota builds up around the media surfaces normally in two weeks period making filter ready for use. Organic material in the sewage is absorbed on the biological slime, where they are partly degraded by the biota thus increasing the weight and thickness of the slime. Eventually there is a scouring of the slime and a fresh slime layer begins

to grown on the media. This phenomenon of scouring of the slime is called sloughing or unloading of the filter. Filter sloughing helps ventilation by keeping the filter media open. It also continuously reviews the biota, maintain it active for the efficient functioning of the filter. The degree of filter sloughing to be given depends on the organic loading and the hydraulic loading which will influence its scour.



Q.3 Explain the merits and demerits of tricking filter?

Ans: Merits: (1) The effluent obtained from trickling filters is highly nitrified and stabilized. The effluent can, therefore, be disposed of in smaller quantity of dilution water.

(2) It has good dependability to produce good effluent under very widely varying weather and other conditions. It possess unique capacity to handle shock loads. Even if they are over loaded, they can recouped after rest.

(3) They can remove about 80% of suspended solids and about 75 to 80% of BOD.

(4) The rate of filter loading is relatively higher, in comparision to contact beds of intermittent sand filter. Hence it requires lesser land space.

(5) The working of trickling filter is simple and cheap and does not require any skilled supervision.

(6) They are self-cleansing.

(7) As it contains less mechanical equipment, mechanical wear and tear is small.

(8) Operation of trickling filters requires less electrical power to run the mechanical equipment.

(9) The moisture content of sludge obtained from tricking filter system is as high as 99%

Demerits:

(1) The loss of head through the filter system is high, thus making the automatic dosing through siphoaic dosing tanks necessary.
(2) The cost of construction of the filter is high.
(3) They require large area in comparison to other biological treatment processes.
(4) They require preliminary treatment and therefore cannot treat raw sewage as such.
(5) Final settlement in humus tank is necessary
(6) The process may develop odour and fly nuisance due to Psyched which may be carried away into human habitation. Proving serious nuisance and health problem.

Q.4 what do you understand by term recirculation ?

(April-May,2011)

Ans: RECIRCULATION: 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 recalculated flow to the flow of raw sewage is called recirculation ratio(R). This ratio determines the required capacity of recalculating pumps and the hydraulic load placed upon the filter. Thus, we have

Capacity of recalculating pump = R× (influent sewage flow)

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

Recirculation factor: The number of effective passes through filter is known as recirculation factor (f) and is given by the equation:

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

Where F = treatability factor(= 0.9 for sewage)

Hydraulic : recirculation factor: The number of hydraulic passes of recalculated sewage through the filter is called hydraulic recirculation factor(F_h) and is given by

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

Advantage of Recirculation ratio:

(1) Recirculation keeps the self propelled distributors running at the time of reduced flow(i.e. during night hours).
(2) The thickness of biological film on contact media is reduced by forced film sloughing
(3) The filter influent is freshened due to which foul odour is prevented.
(4) The filter influent is diluted and weakened so that filter work at a constant efficiency and the quality of filter effluent is improved.
(5) The applied sewage is seeded with active organisms and enzymes of effluent, due to which the efficiency of filter is increased.
(6) Recirculation loads deeper portions of the filters more effectively.

Q.5 Draw the single stage and two stage recirculation systems.

(Nov-Dec.,2009)

Ans: Recirculation of sewage is an essential and important feature of high rate filters. The recirculation consists in returning a portion of the treated or partly treated sewage to the treatment process. Usually the return is from the secondary settling tank to the primary settling tank, or to the dosing tank of the filter, as shown in fig. 9.21. Sometimes, the effluent from the filter itself, before it enters the secondary clarifier, may be sent back to the primary clarifier.

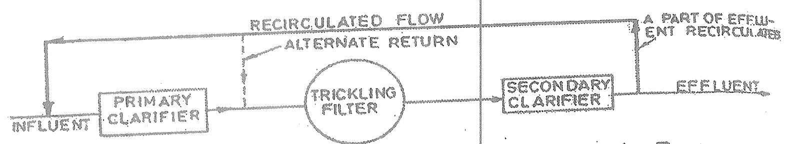


Fig. Single Stage commonly adopted Recirculation Process.

In some other cases, and to obtain better efficiency, two stage recirculation process may be adopted. A two stage recirculation process consists of having two filters arranged in series, as shown in Fig. 9.22 Various other combinations are possible.

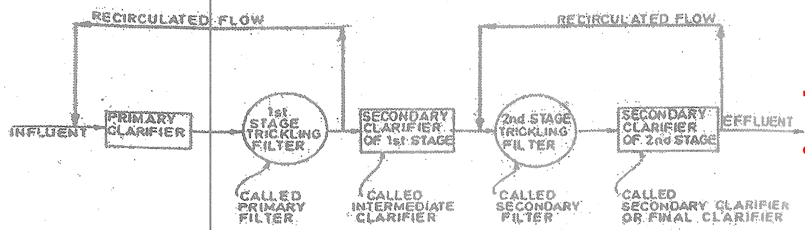


Fig Two stage commonly adopted Recirculation Process.

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

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

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

(iii) Recirculation provides longer contact of the applied sewage with the bacterial film on the contact media, thereby seeding it with bacteria, and accelerating the biological oxidation process.

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

Q.6 Distinguish between standard rate and high rate tricking filter

Ans:

S.N.	Particulars	Standard rate or Low	High rate trickling filter
i)	Cost of operation	More	Less
ii)	Interval of dosing.	It should not be more than 5 minutes (Intermittent type).	It should not be more than 15 seconds (continuous types)
iii)	Depth of filter	1.8 m to 2.4 m.	0.9 m to 1.8 m.
iv)	Effluent	The effluent is highly nitrified and stabilize.	The effluent is nitrified upto nitrite stage only and hence it is of an inferior
v)	Land	It requires more area of land.	It requires less area of land.
vi)	Method of operation	Less flexible and requires less skilled supervision	More flexible and required more skilled supervision.
vii)	Quality of secondary sludge produced.	Black and highly oxidized with slight fine particles.	Brown and not fully oxidized with fine particles.
viii)	Rate of filter loading	1000-2200 kg/ha.m/day	8000-14000 kg/ha. m/day.
ix)	Recirculation system.	Usually not provided, but it can be provided if the hydraulic load does not exceed the limit.	It is always provided.
x)	Size of filter media.	30 mm to 80 mm.	30 mm to 60 mm.

Q.7 Write the NRC formula for efficiency of trickling filter. (April-May,2012)

Ans: NRC Equation: The NRC equation for trickling filter performance are empirical expressions developed from a study of operation results of trickling filters serving military installations in USA. These equations are applicable both for low rate as well as high rate filters. The efficiency(E) of single stage filter or first stage of two stage filters is given by

$$E = \frac{100}{1 + 0.44\sqrt{W/VF}}$$

$$E = \frac{100}{1 + 0.44\sqrt{U}}$$

For the second stage of the two stage filters, efficiency(E′) is given by

$$E' = \frac{100}{1 + \frac{0.44}{1-e}\sqrt{W'/V'F'}}$$

$$E = \frac{100}{1 + \frac{0.44}{1-e}\sqrt{U'}}$$

Where E = Percentage efficiency in BOD removal of the single stage or first stage of the two stage filter

e = E/100

E′ = Percentage efficiency of second stage filter

W = BOD loading of settled raw sewage in the single stage or first stage of the two stage filter(kg/day)

V = Volume of first stage filter(m^3)

F = Recirculation factor, or number of effective passes for the first stage filter

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

$$= \frac{1+R}{[1+0.1\,R]^{2\prime}} \text{ taking } f = 0.9$$

$\frac{W}{VF}$ = U = first stage unit or organic loading(kg/m^3/day)

R = recirculation ratio for the first stage filter

f = treatability factor (= 0.9 for sewage)

W' = W(1 – e) = BOD loading on second stage filter(kg/day)

V' = Volume of second stage filter (m^3)

F' = recirculation factor or number of effective passes for second stage filter

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

$\frac{W}{V'F'}$ = U' = second stage unit organic loading (kg/m^3/day)

R = recirculation ratio for the second stage filter.

Q.8 What do you understand by suspended growth process? Explain the principle of treatment in treatment units belaying to these processes. **(Nov-Dec.,2009)**

Ans: Suspended growth process: 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 most processes, the required volume is reduced by returning bacteria from the secondary clarifier in order to maintain a high solid concentration. The suspended growth processes include the following.

(i) Activated sludge processes;

(ii) Aerated lagoons;

(iii) Sludge digestion systems;

(iv) Suspended growth nitrification and suspended growth denitrification .

Principle of biological treatment: Sewage can remain in aerobic or aerobic condition depending on the availability or non-availability of oxygen. In aerobic condition the bacteria consume oxygen and remain active without causing any foul smell on the other hand in aerobic condition foul smell is

created, due to which only aerobic conditions are preferred. When the sewage is passed through the beds, where aerobic action takes place following actions actions are done by the aerobic bacteria.

(a) The colloidal and dissolved putrescible organic matters present in the sewage are absorbed within few minutes in the tricking filters and within about one hour in the activated sludge process.

(b) The bacteria feed the organic matters so absorbed which are necessary for their life.

(c) The bacteria convert the organic matters into stable inorganic forms by oxidizing them.

Q.9 What is meant by the term 'Activated Sludge process? What is the process of it ? **(Nov-Dec.,2008)**

Ans : The activated sludge process is an aerobic, biological sewage treatment system. The essential units of the process are an aeration tank, a secondary settling tank, a sludge return line from the secondary settling tank to the aeration tank and an excess sludge waste line.

The activated sludge is the sludge which is obtained by settling sewage in presence of an abundant oxygen, The activated sludge is biologically active and it contains a great number of aerobic bacteria and other micro-organisms which which have got an unusual property to oxidize the organic matter. Following are the properties of the activated sludge

(i) The activated sludge contains fertilizing constituents.

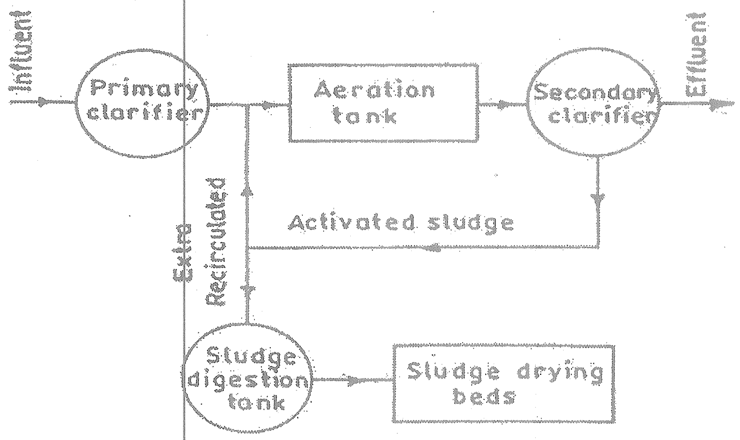
(ii) The colour of activated sludge indicates the degree of aeration. The colours of under-aerated sludge, well aerated sludge and over-aerated sludge are respectively light brown, golden brown and muddy brown.

(iii) The moisture content of activated sludge is found to be relatively high. It contains about 95to97 % of water.

Process: Figure shows the flow diagram of activated sludge process. Following three basic operations are involved in the activated sludge process.

(i) Mixing of activated sludge: The activated sludge is mixed properly with raw or settled sewage. The activated sludge is added to the effluent of primary clarifier.

(ii) Aeration: The mixed liquor containing activated sludge and effluent is agitated or aerated in the aeration tank or aeration chamber. This is the main operation of activated sludge process and various method are found out to achieve it successfully



(iii) Settling in secondary clarifier: The mixed liquor after agitation is taken to the secondary clarifier. The sludge is allowed to settle in this tank. The settled sludge is the activated sludge and a portion of it is sent for recirculation. The extra activated sludge is taken to the sludge digestion tank and then to the sludge drying beds for further treatment.

Advantages of activated sludge process:

(1) Clear sparking and non-putrescible effluent possible.
(2) No odours during the process as compared to other biological processes.
(3) No fly nuisance
(4) Highly efficient. Removal of SS, BOD and bacteria are around 90% each.
(5) Degree of stabilization or nitrification is controllable between limits, so as to match with the quantity and character of receiving waters. The treatment may be partial or full as desired/required.
(6) Relatively low cost of installation, as compared to the total cost of tricking filter installations, cost of land, cost of huge filtering material, cost of distribution mechanism etc.

(7) Smaller area required, as compared to trickling filters.
(8) The excess sludge other treatment method. The excess activated sludge may contain 6.3% Nitrogen, 1.44% phosphorous, and 75% volatile matter, on the basis of dry weight.
(9) Amount of hydraulic head consumed by the process is less.

Disadvantage:

(i) Very sensitive to variations in the quality of sewage, particularly in respect of industrial wastes which may cause sludge bulking. Trickling filters are the best in this repect.
(2) High cost of operation.
(3) Necessity of constant skilled attendance.
(4) Uncertainly of the expected result under all conditions.
(5) Large quantity of sludge is produced which is difficult to dewater, digest and dispose of.

Q.10 State the significance of the following terms:

(i) Sludge Volume Index(SVI)
(ii) Mixed Liquor Supported Solids(MLSS)
(iv) Aeration period
(v) Sludge age. **(Nov-Dec.,2011)**

Ans: (I) SVI: If the volume occupied by 1 gm of settled sludge and is expressed as million liters per gram (ml/g.)

It is a measure of the settle ability of the activated sludge.

$$SVI = \frac{V_s \times 1000}{MLSS}$$

V_s = Volume of settled sludge(ml/l) over a period of 30 minutes.

(II) MLSS: The sludge solids contained in the mixed liquor are designated as MLSS

The MLSS in an aeration tank is an index of the activity of the micro-organisms as these metabolize biologically

(III) F/M ratio: BOD loading are expressed either in kg of BOD per day per hector-meter liquid volume in the aeration tank or in terms of kg of BOD applied per day per kg of MLSS in the aeration tank. The letter is commonly referred to as sludge loading ratio or food to micro-organisms ratio (F/M ratio).

$$F/M = \frac{Q \times BOD}{V \times MLSS}$$

Q = Raw sludge flow rate, mld
V = Volume of aeration tank, million litres.

(IV) **Aeration period:** Aeration period is the detention time of the raw sewage flow in the aeration tank

$t = V/Q \times 24$

t = Aeration period in hours.

(V) **Sludge age:** The solid retention period in an activated sludge system is termed as sludge age:

$$\text{Sludge age (days)} = \frac{V \times MLSS}{Q \times SS}$$

SS = Suspended solids in influent sewage mg/l

Q.11 Explain the following terms. **(Nov.-Dec.,2010)**

Ans: (1) Autotrophy: They prepare their organic food from the inorganic materials obtained from the outside environment with the help of energy obtained from outside source. The energy needed for the process is either obtained from the sunlight or from the oxidative chemical reactions accruing in their surrounding medium

(2) Autotrophy: They are unable to synthesize their own food. They draw their organic food in readymade form from outside Sources. These are require at least one organic compound as a source of carbon for their growth and energy.

(3) Prototroph : Prototroph are anaerobic and use light energy to reduce carbon dioxide. No oxygen is required for photosynthesis.

(4) Facultative heterotrophy: They can operate either as aerobically or as an aerobically. Hence they can survive and cause decomposition of organic matter, either in the presence or in the absence of free dissolved oxygen in wastewater

Q.12 Write notes on the following. **(April-may,2010)**

Ans: (i) Aerobic ponds (Algae ponds): In aerobic stabilization ponds (also known as algae ponds), the oxygen is supplied by natural surface aeration and by algal photosynthesis. The pond is kept shallow(0.5 to 1.2 m), so that it functions aerobically throughout the depth. Shallower levels will encourage growth of rooted aquatic plants while greater depth may interfere with mixing and oxygen transfer from the surface. Very shallow depth of aerobic pond(of depth 0.15 m to 0.45 m) is used for the treatment of irrigation return water or any other industrial waste where the aim is the removal of nitrogen by algal growth. However for the treatment of domestic waste, the depth is kept between 1 to 1.2 m The

length to width ratio of the pond depends on the geometry of the land but should be maximized to approach but not be exceed 3:1 This tends to prevent short circuiting. The influent and effluent structures of the tank are stirred occasionally to prevent anaerobic conditions in the settled sludge. Except for the algal population, the microbiological population present in the ponds are similar to that in activated sludge system. The daily flow of sewage containing organic material provides necessary food to the aerobic population which stabilizers the putrescible matter by oxidizing it to form nitrates and CO_2 The algal population use these products for their growth to produce more algal cells and, during daylight, oxygen which is again used by the aerobic population to decompose the original waste. The action taking place in these ponds is known as 'bac trial-algal-symbiosis' . Thus the symbiotic relation between bacteria and algae leads to the stabilization of the incoming waste. The algae -bacterial interplay in an aerobic lagoon is shown in Fig.

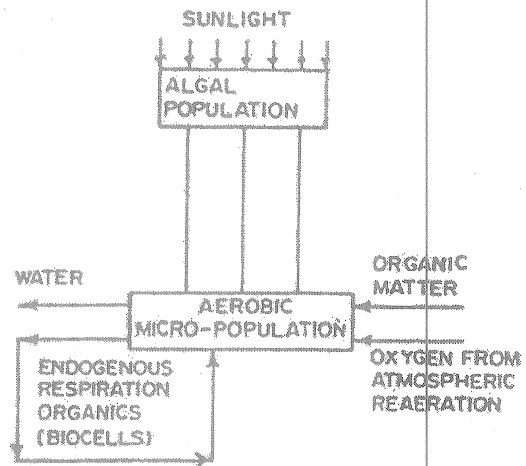


Fig. ALGAL-BACTERIAL INTERPLAY IN AN AEROBIC LAGOON

Anaerobic ponds: In anaerobic pond, the entire depth is in anaerobic condition except an extremely shallow top layer. The anaerobic micro-organisms do not require the presence of dissolved oxygen in the water in order to function. Their requirement is met from the oxygen chemically contained in the organic materials. The anaerobic decomposition takes place in two separate but interrelated steps:

Step 1: Decomposition of dissolved organic waste, by acid-producing bacteria to organic acids(such as acetic, propionic and butyric acid) and,

Step 2: Futher decomposition of these acids to the end products of methane, carbon dioxide and water, by the methane-producig-bacteria.

This is depicted in Fig.

Effective operation requires a balance between step 1 and step2, because the methane produces are sensitive to the concentration of volatile acids. A certain portion of the waste material is used by the anaerobic cells. Sludge or solids buildup is therefore much less in the anaerobic system. The contents of the anaerobic lagoon are black in colour, which is an effective indication that the lagoon is functioning properly.

The process is somewhat attended by septic odors and the effluent will be only partially purified. The obnoxious odors are

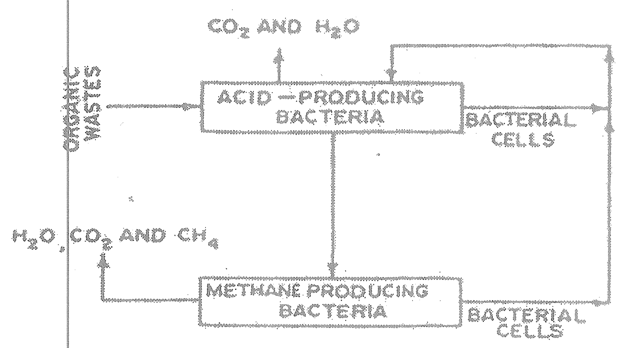


Fig. ANAEROBIC DEGRADATION PROCESS

The results of the reaction of sulphate compounds to hydrogen sulphide (H_2S), by the acid-producing bacteria. At high concentration, H_2S attacks painted surface and is deleterious if inhaled for an extended period. The long term solution of this problem is to limit the concentration of sulphate in the influent

Anaerobic pond requires much less surface area than the aerobic ponds. However, the pond can be as deep as practical. Depths usually range from 2.5 m to 5 m. The relative greater depth of anaerobic lagoon allows for improved heat retention.

The efficient length to width ratio is 2:1 The levee of anaerobic pond is similar to that of aerobic/facultative pond, both in geometry as well as in construction. The BOD loading in summer may be taken at 1000 to 2000 kg per hectare per day with detentions of 2 to 5 days; the BOD_5 reeducation may be expected at 65 to 80%. In winter, BOD loading may be taken at 500 at 1000 kg per hectare per day, with removal of 45 to 65%. For anaerobic ponds, less surface area is required because the organic loading is about 10 times more than for aerobic ponds. The depth can be taken normally upto 3 m instead of 1m, and this will reduce the area required to about 1/30. Deposition and digestion of sewage solids is the chief function of anaerobic ponds. With suspended solids loadings of about 1000 kg/ha/day, sludge may be allowed to accumulate for 10 years or more before removal is necessary. The whole design aspect of anaerobic lagoon is controlled by the detention time whereas that of aerobic lagoon by surface loading rate. The ideal pH range is 6.6 to 7.6. The anaerobic process functions optimally over two temperature ranges: The mesophylic range of 85° to 100° and the hemophilic range of 120° to 135° F . The greater depth provided in anaerobic pond thus help in maximizing heat retention. This type of pond finds use mainly in the treatment of strong industrial wastes and has limited application for the treatment

Q.13 Draw the flow diagram of an STP for a city. Explain the components. (Nov-Dec.,2011- April-May, 2010)

Ans: SLUDGE TREATMENT PROCESSES: Sludge treatment may include all or a combination of the following unit operation and processes:

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

Fig. 16.1 shows the flow chart for sludge treatment and disposal. The arrows in the diagram indicate possible flow paths.

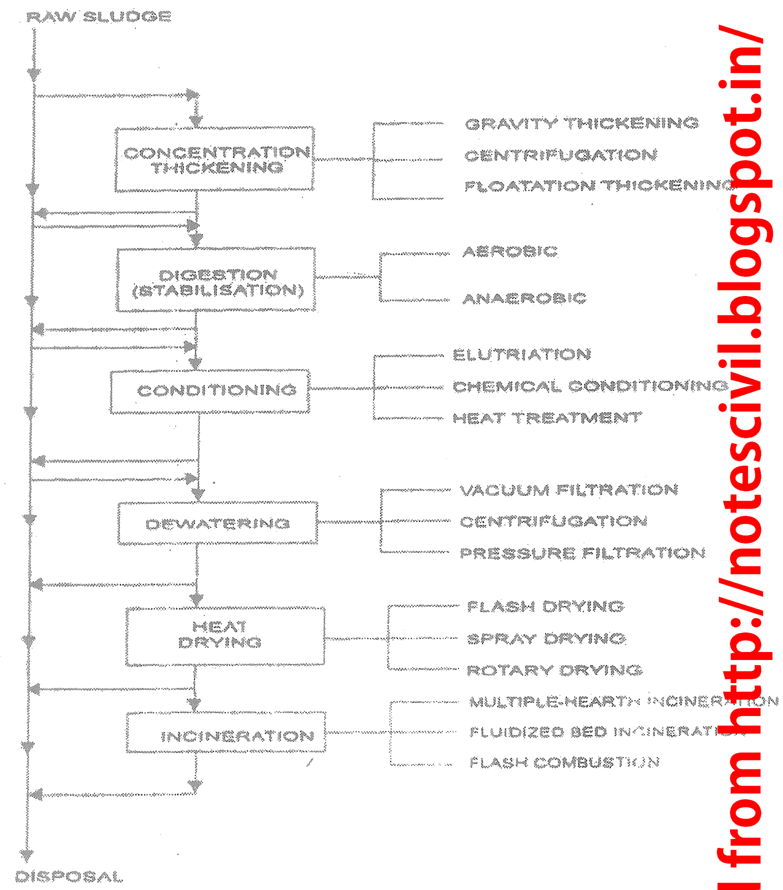


Fig. FLOW CHART FOR SLUDGE TREATMENT AND DISPOSAL

Q.14 Write short notes on.

Ans: COMMINUTORS AND BARMINUTORS: A comminuting device is a mechanically cleaned serene which incorporates a cutting mechanism that cuts retained material enabling it to pass along the sewage. Comminuting devices may be preceded by grit chambers to prolong the life of the equipment Frequently, they are installed in the wet well of pumping stations to protect the pumps against clogging by rags and large objects. However, provision must be made to bypass comminutes in case flows exceed the capacity of the comminatory or in case

there is a power or mechanical failure. The use of comminutes tends to reduce odours, flies and unsightliness.

A comminatory consists of a vertical revolving drum screen with 6 mm to 10 mm slots. The coarse material is cut by cutting teeth and the shear bars on the revolving drum as solids are carried past a stationary comb(Fig 114). The small sheared particles then pass through the slots of the drum out and of a bottom opening through an inverted siphon. The head loss across comminutes depends upon screen details and flow, the normal values being on the order o 50 to 100mm. Another form of comminatory (known as stationary screen type comminatory) consists of a stationary semicircular screen and a rotating circular cutting disk. The grid intercepts the large solid particles where as smaller solids pass through the space between the grid and cutting discs.

Q.15 Explain screening & Their Disposal.

Ans: Screenings and their disposal : The quantity to screenings with the size of the screen used and on the nature of sewage. Gene it has been found that the screening from sanitary sewage from 0.0015 m^3 /ml case of 2.5 cm size. Screenings are disposed of by the following method: (i) Burial (ii) Incineration (iii) Digestion and (iv) Grind

Medium sized screening, particularly in small installation can be disposed of by burial in trenches usually 7.5 cm to cm deep. These are immediately covered with soil after bury At large installations, where sufficient land for burial is not aviation without a reasonable distance from the plant. Screenings are incineration. Before doing so, it's is necessary to dry the screening first, by spread it over the ground and exposing it to the sun. Alternatively screenings, specially obtained from the fine screens, can be plan in sludge digestion tanks. The use of screening grinders is desirable for medium size plants. The reduced size solids are returned the raw sewage or are mixed with the sewage sludge.

NUMERICLS

Example 1 Determine the size of a high rate tricking filter for the following data: **(April-May,2011)**

(i) **Sewage flow** = 4.5 Mld;
(ii) **Recirculation ratio** = 1.5;
(iii) **BOD of raw sewage** = 250 mgll;
(iv) **BOD removal in primary, tank** = 30%
(v) **Final effluent BOD desired** = 30 mg/l.

Solution: Quantity of sewage flowing into the filter day

= 4.5 M.I/day

BOD concentration in raw sewage

= 250 mg/l.

∴ Total BOD present in raw sewage

= 4.5 MI × 250mg/l.

= $1{,}125kg$

BOD removal in primary, tank

= 30%

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

= (1125)0.7

= 787.5 kg

BOD concentration desired in final effluent

= 30mg/l.

∴ Total BOD left in the effluent per day

= 4.5 × 30kg.

= $135\ kg$

∴ BOD removal by the filter

= 787.5 − 135

= $652.5\ kg$

∴ Efficiency of the filter

$$= \frac{BOD\ removed}{Total\ BOD} \times 100$$

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

= 82.85%

Now, using equation(9.34), we have

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

Where η = 82.85%

Y = Total BOD in kg

= $787.5\ kg$

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

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

$$\therefore F = \frac{1+1.5}{[1+0.1 \times 1.5]^2}$$

$$= \frac{2.5}{(1.15)^2}$$

$$= \frac{2.5}{1.322} = 1.89$$

$$\therefore \quad 82.85 = \frac{1000}{1+0.0044\sqrt{\frac{787.5}{V \times 1.89}}}$$

$$\text{or } 1+0.0044v\sqrt{\frac{416.6}{V}} = 1.2$$

$$\text{or } \sqrt{\frac{416.6}{V}} = \frac{0.2}{0.0044}$$

= 45.45

$$\text{or } \frac{416.6}{V} = 2066.1$$

or V = 0.2 hectare -m.

= $2000m^3$

Assuming the depth of the filter as 1.5 m, we have
The surface area required

$$= \frac{2000}{1.5}\ m^2$$

= $1333.3\ m^2$

∴ Dia of the circular filter required

$$= \sqrt{1333.3 \times \frac{4}{\pi}}$$

= 41.2m.

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

Example 2 Determine the size of a high rate trickling filter for the following data:

Flow $= 4.5\ Mld.$
Recirculation ratio $= 1.4$
BOD of raw sewage $= 250\frac{mg}{l}$
BOD removed in primary clarifier $= 25\%$
Find effluent BOD desired $= 50\%$

Calculate also the size of the standard rate trickling filter to accomplish the above requirement.

Solution: Total BOD present in raw sewage per day

$= 4.5Ml \times 250\ mg/l$

BOD removed in the primary clarifier

$= 20\%$

$\therefore$ BOD entering per day in the filter units

$= 0.75 \times 1125\ kg$

$= 843.75$ kg

Permissible BOD concentration in the effluent

$= 50mg/l.$

$\therefore$ BOD allowed to go into the effluent

$= 50mg/l \times 4.5$ Ml

$\therefore$ BOD removed by the filter per day

$= 843.75 - 225$

$= 618.75\ kg$

$\therefore$ Efficiency of the filter

$$= \frac{BOD\ removed}{Total\ BOD\ entering} \times 100$$

$$= \frac{618.75}{843.75} \times 100$$

$= \mathbf{82.85\%}$

Now, efficiency of the filter is given be Eq.(9.34)a=

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

Where Y = Total BOD applied to the filter per day in kg.

$= 843.75\ kg$

F = Recirculation factor

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

Here = R = 1.4(given)

$$\therefore F = \frac{1+1.4}{(1+0.1 \times 1.4)^2}$$

$$= \frac{2.4}{(1.14)^2}$$

$$= \frac{2.4}{1.3} = 1.85.$$

$$\therefore \quad 73.3 = \frac{1000}{1+0.0044\sqrt{\frac{843.75}{V \times 1.85}}}$$

$$\text{or } 1 + 0.0044v\sqrt{\frac{456}{V}} = \frac{100}{73.3} = 1.364$$

$$\text{or } \sqrt{\frac{416.6}{V}} = \frac{0.364}{0.0044}$$

$= 82.78$

$$\text{or } \frac{416.6}{V} = 6853$$

$$\text{or } V = \frac{45.6}{6853}\text{hectare -m.}$$

$$= \frac{45.6}{6853} \times 10^4 m^3$$

$= 665.4m^3$

Using 1.5 m depth of the filter, we have

$$\text{Area required} = \frac{665.4}{1.5}$$

$= 413.6\ m^2$

$\therefore$ Dia of the filter tank required

$$= \sqrt{\frac{413.6 \times 4}{\pi}}$$

$= 23.8m.$

For an equivalent standard rater filter; F=1

$$\therefore \quad 73.3 = \frac{1000}{1+0.0044\sqrt{\frac{843.75}{V}}}$$

$$\text{or } 1 + 0.0044v\sqrt{\frac{843.75}{V}} = \frac{100}{73.3} = 1.364$$

or $\sqrt{\frac{843.75}{V}} = 82.78$

or $\frac{843.75}{V} = 6853$

or $V = \frac{843.75}{6853}$ ha-m.

$= 0.1231$ ha – m

$= 1231 m^3 \because$ ha-m $= 10^4$ sq. m m

$= 10^4 m^3$

Using depth of the filter as 1.5 m, we have

Surface Area required $= \sqrt{\frac{123.1}{1.5}}$

$= 820.8 m^2$

$\therefore$ Dia of the filter tank required

$= \sqrt{\frac{820.8 \times 4}{\pi}}$

$= 32.3$m.

Example 3 A single stage filter is to treat flow of 3.79 M.l.d. of row sewage with BOD of 240 mg/l. It is to be designed for a loading of 11086 kg of BOD in raw sewage per hectare meter. And the recirculation ratio is to be 1. What will be the strength of the effluent, according to the recommendations of the National Research council of U.S.A

(Nov-Dec.,2009-2011, April-May,2010)

Solution: Total BOD present in raw sewage

$= 3.79 Ml \times 240$ mg/l

Now, filter volume required

$= \frac{\text{Total BOD in raw sewage in kg}}{\text{Given BOD loading rate of 11.086 kg/ha-m}}$

$= \frac{909.6}{11086}$ ha-m

$= 0.082$ ha-m

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

The amount of BOD applied to the filter

$= 0.65 \times 909.6\, kg$

$= 591.24\, kg$

Now, using equation(9.34) we have

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

Where Y = Total BOD applied to the filter in kg.

$= 591.24\, kg$

$\therefore$ V= Vol of the filter in ha – m

$= 0.082$ ha – m

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

Here $= \frac{R}{I} = 1$(given)

$\therefore F = \frac{1+1}{(1+0.1)^2}$

$= \frac{2}{1.21}$

$= 1.65.$

$\therefore \quad \eta = \frac{100}{1+0.0044\sqrt{\frac{591.24}{0.082 \times 1.65}}}$

$= \frac{100}{1+0.291}$

$= \frac{100}{1.291}$

$= 77.45\%$

$\therefore$ The amount of BOD left in the effluent

$= 591.24[1 - 0.7745]\, kg$

∴ BOD concentration in the effluent

$$= \frac{\text{Total BOD}}{\text{Sewage volume}}$$

$$= \frac{133.32\times10^6}{3.79\times10^6}\ \text{mg/l}$$

$$= 35.18\ \text{mg/l}$$

Example 4 An average operating data for conventional activated shadge treatment treatment plant is as follows. (Nov-Dec.,2008)

1. **Wastewater flow** $= 50000\ m^3/d$
2. **Volume of aeration tank** $= 15500 m^3$
3. **Influent BOD** $= 200\ mg/l$
4. **Effluent BOD** $= 25\ mg/l$
5. **Mixed liquor suspended solids (MLSS)** $= 3000\ mg/l$
6. **Effluent suspended solids** = 40 mg/l
7. **Waste sludge suspended solids** = 12000 mg/l
8. **Quantity of waste slugde** $= 250\ m^3/d$

Based on the information above, determine:

(a)Aeration period (hours)
(b)Food to mico-organisms ratio(F/M) (kg BOD per day/kg MLSS)
(c)Percentage efficiency of BOD removal
(d)Sludge age (days)

Solution: In this example, all the data about solids are in terms of suspended solids (SS) and not in term of volatile suspend solids(VSS)

(a) Aeration period: The aeration period(T) or hydraulic retention time(HRT) is given by Eq. 14.8:

$T = \frac{V}{Q} \times 24$ (where Q is m^3/day)

$= \frac{15500}{50000} \times 24 = 7.44$ hours

(b)F/M ratio: F/M ratio is to be expressed in terms of MLSS(as desired) Eq. 14.10

$F = Q = L_a = 50000 \times 200$ g/day

$= \frac{50000\times200}{1000} = 10000$ kg/day

M = Total mass of MLSS

$= V.x_t = 155500(m^3) \times 3000(gm/m^3)$

$= \frac{15500\times3000}{1000} = 46500$ kg.

$\therefore$ F/M ratio $= \frac{10000}{46500}$

= 0.215 kg BOD per day/kg of MLSS

Then

$$M = V.x = \frac{155500 \times 2400}{1000} = 37200\text{kg}$$

$\therefore$ F/M ratio $= \frac{10000}{37200}$

$= 0.265$ kg BOD per $\frac{\text{day}}{\text{kg}}$ of MLSS.

(c) Percentage efficiency of BOD removal

$\eta = \frac{200-25}{200} \times 100 = 87.5\%$

(d) Sludge age: Sludge age can be found by Eq. by expressing the equation in terms of suspended solids(SS), rather than in terms of volatile suspended solids(VSS).

$$\theta_c = \frac{Vx_t}{Q_w x_t + (Q - Q_w)x_e}$$

$$= \frac{15500\times3000}{(250\times12000)+(50000-250)40}$$

$= 9.32$ days

Example 5 Design of conventional activated sludge plant

Design a conventional activated sludge plant to treat settled domestic sewage with diffused air aeration system, for the following data

(i)	**Population**	......	**1,20,000**
(ii)	**Per capita sewage contribution**	......	**160 lped**
(iii)	**Settled sewage BOD_5**	......	**200 mg/l**
(iv)	**Effluent BOD_5 required**	......	**15 mg/l**

Solution:

1. Influent flow and process efficiency required

Average flow $= 120000\times160 = 19.2 \times 10^6$ lpd

$= 19.2$ mLd $= 19200 m^3/d$

Efficiency required $= \frac{200-15}{200} \times 100 = 92.5\%$

2. Determination of volume of aeration tank

From Table 14.3, select F/M = 0.2 and MlSS (x_t) = 3000 mg/l

Now, $\frac{F}{M} = \frac{Q.L_a}{(V/1000)x_t}$

$\therefore 0.2 = \frac{19.2\times200\times1000}{V\times3000}$

From which V= 6400m^3

3. Check for hydraulic retention time

$$HRT = \frac{V}{Q\times1000}\times 24$$

$$= \frac{6400}{19.2\times1000}\times 24 = 8 \text{ hrs}$$

(This is within the prescrible range of 4 to 8 hours)

4.Check for volumetric loading

Volume loading $= \frac{Q.L_a}{V}$

$$= \frac{19.2\times200}{6400} = 0.6\, kg\, BOD_5/m^3$$

(This is within the prescrible range of 0.3 to 0.7 hours)

5. Return sludge ratio

$$\frac{Q_r}{Q} = \frac{x_t}{(10^6/SVI)-x_t}$$

Taking SVI = 100, we get

$$\frac{Q_r}{Q} = \frac{3000}{(10^6/100)-3000} = 0.429$$

∴ r = 0.429 %

(This is within the prescribed range of 25 to 50%)

6. Tank dimensions:

Let us adopt a depth of 3 m and width of 4.5 m

∴ Length of aeration tank $= \frac{6400}{3\times4.5} = 474$ m

Provide a continuous channel with six baffles, so as to get seven sections, the length of each of section being 68 m to give a total length of 68×7 = 476 m. Let the thickness of each baffle be 0.25 m.

∴ Total width of tank = $(7\times4.5)+(6\times0.25) = 33$ m

Provide a free board = 0.5 m

Hence overall inner dimensions of the tank are 68 m× 33 m× 3.5 m.

7.Check for horizontal welocity

$$Q+Q = \frac{19200(1+0.429)}{24\times60} = 19.0\, m^3/nin$$

$$V = \frac{19.05}{3\times4.5} = 1.41\, m/min.$$

(OK)

8.Air requirement and arrangement of diffuser plates

Air needed = 100 m^3/day per kg BOD_5 removed

$$= \frac{100(200-15)19.2}{24\times60}$$

$= 246.7\, m^3/min \approx 250 m^3/min$(say)

Choose standard diffuser plates of 0.3 m× 0.3 m×25 mm, passing 1.2 m^3 of air/min/m^3 of air/min/m^2 with 0.3 mm pores.

∴ No. of plates required $= \frac{250}{0.3\times0.3\times1.2} = 2315$

Let us provide 2320 plates.

A plate concentration of 30% extra is provided in the first half of the tank to take care of more frequent clogging of this zone.

∴ No. of plates needed in the first half = 1.3 [2320/2]

Let us provide clear distance between the plates of 0.9 m to avoid interference from the rising streams of bubbles.

Hence c/c rows in the first half length (of 234 m) $= \frac{234}{1.2} \approx 195$ rowa.

Provide 8 plates in a row of 1.2 m spacing.

Hence plate provided in the first 234 m length = 195 rows×8 in each row = 1560

Balance plates to be provided = 2320 − 1560 = 760

This is to be provided in the balance length of 476−234 = 242 m.

$$Hence\ spacing = \frac{242\times8}{760} = 2.55 \text{ m (or say 2.5 m)}$$

9.Check for minimum air availability

In the second half, 760 diffuser plates give air

$= 760\times0.3\times0.3\times12 = 82.08\, m^3/min$

This is in a length of 242 m.

∴ Air available per meter length of channel

$= \frac{82.08}{242} = 0.34 m^3/min/m$ length

This is more than the prescribed value of $0.25 m^3/min/m$ length.

Hence satisfactory

Example 6 It is proposed to install a two stage trickling filter for treatment of 4.0 med of raw wastewater having the influent BOD of 180 my/l. Assuming that the primary treatment removed 30% of the BOD, the recirculation ratio is 1.2 for cach filter, and if two filter are provided to equally share the load determine the BOD of the effluent. (Nov-Dec.,2010)

Solution: Total BOD present in raw sewage

= 4 × 180

= 720 kg.

Now filter vol. required

$$= \frac{\text{total BOD in raw sewage in kg}}{\text{Given BOD loading rate of 1000 gm/m}^3}$$

Give BOD loading rate = 1000 gm/m^3

$$= \frac{1000\times10^3}{10^{-4}} = 10000\, kg/ha-m$$

$= \frac{720}{10000} = 0.072\ ha - m$

Now 30% of BOD is removed in primary clarifier.

We have

The amount of BOD applied to the filter $= 0.70 \times 720$

$= 504kg$

Now

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

Where Y = Total BOD applied to the filter in kg.

V= Vol. of the filter in ha – m

$= \frac{0.072}{2} = 0.036$ ha – m

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

Here $= \frac{R}{I} = 1$(given)

$$\therefore F = \frac{1+1}{(1+0.1)^2}$$

$$= \frac{2}{1.21}$$

$= 1.65.$

Now

For each filter F= 1.65

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

$$\eta = \frac{100}{1 + \frac{0.0044}{1-n}\sqrt{\frac{504}{0.036 \times 1.65}}}$$

$$= \frac{100}{1.40}$$

$= 71.16\%$

∴ Percentage of BOD removed in 1st stage filter

$= 71.16\%$

∴ Amount of BOD left in the effluent from that filter

$= 504[1 - 0.7116]$

$= 145.35$ kg

Now

For the 2nd stage filter the efficiency is given by

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

Where Y' = 145.35 kg

V' = 0.036

F' = 1.65

n = 0.7116

$$\therefore \quad \eta' = \frac{100}{1 + \frac{0.0044}{1-0.7116}\sqrt{\frac{145.35}{0.036 \times 1.65}}}$$

$\eta' = 80.79\%$

∴ The amount of BOD left in the effluent from the plant

$$= 145.35\left[\frac{100 - 80.79}{100}\right]$$

$= 27.91\ kg.$

∴ BOD concentration in the effluent

$$= \frac{\text{Total BOD}}{\text{Sewage volume}}$$

$$= \frac{27.91 \times 10^6}{4 \times 10^6}$$

$= 6.9775$ mg/lit

Example 7 Design a conventional activated sludge plant to treat domestic sewage given the following data:

Population $= 35,000$

Average sewage flow $= 180\ lpcd$

BOD of sewage $= 220\ mg/l$

BOD removed in primary treatment $= 30\%$

Overall BOD reduction desired $= 85\%$ **(April-May,2009)**

Solution: Daily sewage flow

$= Q = 180 \times 35000 l/day = 6300 m^3/day$

BOD of sewage coming to aeration

$= Y_0 = 70\% \times 220 \frac{mg}{l} = 154 mg/l$

($\because$ 30% BOD is removal in primary settling)

BOD left in effluent $= Y_E = 15\% \times 220\ mg/l = 33\ mg/l$

($\because$ *Overall* 85% *BOD removal is desired*)

$\therefore$ BOD removed in activated plant

$= 154 - 33 = 121\ mg/l$

$\therefore$ Efficiency required in Activated plant

$= \frac{121}{154} = 0.79$

From table 9.10, for efficiency of 85%–92%, we use F/M ratio as 0.4 to 0.3, and MLSS between 1500 to 3000. Since efficiency required is on lower side, we can use moderate figures or F/M ratio and MLSS

So let us adopt F/M = 0.35

Similarly adopt MLSS(X_t) = 2000 mg/l

Using equation(9.44), we have

$\frac{F}{M} = \frac{Q.Y_0}{V.X_t}$

where $\frac{F}{M} = 0.35$ (assumed)

$Q = 6300\ m^3/day$

$Y_0 = 154\ mg/l = 154\ gm/m^3$

$X_t = 2000 \frac{mg}{l}$ *(assumed)*

$\therefore 0.35 = \frac{6300 \times 154}{V \times 2000}$

V = volume of aeraiion tank

$= \frac{6300 \times 154}{2000 \times 0.35} = 1386\ m^3$

(*i*) Check for Aeration period or H.R.T.(t)

Using Eq. (9.41), we have

$t = \frac{V}{Q} \times 24\ h = \frac{1386}{6300} \times 24h$

= 5.28(within the limit of 4 to 6 h) O.k.

(ii) Check for S.R.T. (θ_c)

From equation (9.56), we have

$V.X_t = \frac{\alpha_y.Q(Y_0 - Y_E)\theta_c}{1 + k_e.\ \theta_c}$

Where $V = 1386\ m^3$

$X_t = 2000\ mg/l$ *(assumed)*

α_y = yield coefficient = 1.0 w.r.t MLSS

$Q = 6300\ m^3/d$

K_e = Endorgeneous respiration constant = $0.06 d^{-1}$

Y_0 = BOD of influent in aeration tank = 154 mg/l

Y_E = BOD of effluent = 13 mg/l

Substituting the values, we get

$1386 \times 200 = \frac{0.5 \times 6300(154 - 33)\theta_c}{1 + 0.06 \times \theta_c}$

Or $1 + 0.06\theta_c = \left(\frac{1.0 \times 6300 \times 121}{1386 \times 2000}\right)\theta_c = 0.275\theta_c$

or $1 + 0.06\theta_c = 0.275\theta_c$

$1 = (0.275 - 0.06)\theta_c$

or $1 = 0.215\theta_c$

$\theta_c = \frac{1}{0.215} = 4.65\ days = 5\ days; ok,$

(iii) Check for volumetric loading

Using equation (9.42), we have

Volumetric loading = $\frac{Q.Y_0}{V}$ gm of BOD/m^3 of tank vol.

$= \frac{6300 \times 154}{1386}$ gm/m^3 = 700 gm/m^3 = 0.7 gm/m^3

(within the permissible range of 0.3-0.7 gm/m^3); O.K.

(v) Check for Return sludge ratio(for SVL ranging between 50-150 ml gm; say 100 ml/gm).
Using equation(9.55), we have

$= \frac{Q_R}{Q} = \frac{X_t\ (i.e. MLSS)}{\frac{10^6}{SVI} - X_t}$

Where SVI = 100 ml/gm

X_t = 2000 mg/l

$= \frac{2000}{\left[\frac{10^6}{100} - 2000\right]}$

= 0.25

(i.e within the permissible range of 25-50); O.K.

We will, for conservative purposes, however provide 33% return sludge giving SVI = 125, O.K The sludge pumps for bringing recalculated sludge from the secondary sedimentation tank will thus have a capacity = 33%×Q=33%×6300 m^3/d = 2100 m^3/d

Tank dimensions. Adopt aeration tank of depth 3 m and width 4.5 m. The total length of the aeration channel required

$= \frac{\text{Total Volume required}}{B \times D} = \frac{1386}{4.5 \times 3}$ m

Provide a continuous channel, channel, with 3 aeration chambers, each of 35 m length. Total width of the unit, including 2 baffles each of 0.25 m thickness= $3 \times 4.5m + 2 \times 0.25 = 14m$.
Total depth provided including free board of 0.6 m will be 3+0.6= 3.6m.

Overall dimensions of the Aeration tank will be 35m×14m×3.6.

CSVTU April-May 2012

UNIT–III Part - A

Q.3 (a) Which of the following is NOT a unit physical unit operation: 2
(i) Equalization (ii) Mixing (iii) Adsorption (iv) Screening
Ans.: (iii) Adsorption

Part – B

(b) Draw the flow diagram of an STP for a developed city. Explain the components. 7

Ans.: Refer Q-13

(c) Write a detailed note on tertiary waste water treatment. 7

(d) Write short notes on : 7

(i) Disposal of screenings
(ii) Comminutors (Sketch essential)

Ans.: Refer Q-14&15

CSVTU Nov.- Dec 2011

UNIT-III Part- A

Q.3 (a) (i) Average BOD removal efficiency in an Imhoff tank is 2
(1). 70% (2). 50 % (3). 30 % (4). 60%
(ii). DP for a Grit chamber is :
(i). 1 min (2). 5 min (3). 2-4 min (4) 1 hr 2

Part- B

(b) A single stage filter is designed for anorganic loading of 10,000 kg of BOD in raw sewage per hectare metre/ day with a recirculation ratio of 1.2 This filter treats a flow of 4 mld of raw sewage with a BOD of 220 mg/I . Use NRC formula, determine the strength of effluent 7
Ans.: Refer Example-3
(c) Define:
(1) SVI (2) F/M ratio (3) MLSS (4) MLVSS
Ans.: Refer Q-10
(b) Explain briefly the flow chart of sludge treatment & disposal 7
Ans.: Refer Q-13

CSVTU April-May 2011

Unit-III

Q.3 (a) What do you understand by term recirculation? 2
Ans.: Refer Q-4
(b) What do you understand by contact bed? What are the operations of contact bed? Draw a neat sketch of contact bed. 7
Ans.: Refer Q-9

(c) Describe with sketches the treatment of sewage of activated sludge process. Mention the advantages and disadvantages of this system. 7

Ans.: Refer Q-9

(d) Determine the size of high rate trickling filter for following data: 7

Flow = 4.5 MLD
Recirculation ratio = 1.4
BOD of raw sewage = 250 mg/L.

Ans.: Refer Example-2

CSVTU Nov.- Dec 2010

Q.3 (a) What do you mean by high rate tricking filters? 2

Ans.: Refer Q-2

(b) What is the basic principle behind the working of the secondary treatment systems? What do you understand by attached growth process and suspended growth process? Explain giving two examples. 7

Ans.: Refer Q-1

(c) Example the following terms: 7

(i) Autotrophs (ii) Heterotrophs (iii) Phototrophs
(iv) Facultative hetrerotrophs

Ans.: Refer Q-11

(d) It is proposed to install a two stage trickling filter for treatment of 4.0 mld of raw wastewater having the influent BOD of 180 mg/I Assuming that the primary treatment removes 30% of the BOD, the filter loading rate is 1000 gm/m^3 of BOD, the recirculation ratio is 1.2 for each filter, and if two filters are provided to equally share the load, determine the BOD of the effluent. 7

Ans.: Refer Example-6

CSVTU April-May 2010

Q.3 (a) Case of Tricking Filters? 2

(b) What do you understand by suspended growth process and attached growth process? Explain the principle of treatment in treatment units belonging to these processes. 7

Ans.: Refer Q-8

(c) A single stage filter is designed for an organic loading of 12000 kg BOD in raw sewage per hectare meter per day with a

recirculation ration of 1.5. This filter treats a flow of 5 MLD of raw sewage with a BOD of 200 mg/L. Using NRC formula, determines the strength of the effluent. 7

Ans.: Refer Example-3

(d) Write notes on the following. 7

(i) Activated Sludge Process.
(ii) Oxidation ditch.
(iii) Facultative Lagoon.

Ans.: Refer UNIT-2

CSVTU Nov.- Dec 2009

Q.3 (a) What is re-circulation ratio? 2

Ans.: Refer Q-4

(b) What do you understand by suspended growth process and attached growth process? Explain the principle of treatment in treatment units belonging to these processes. 7 **Ans.:** Refer Q-8

(c) A single stage filter is designed for an organic loading of 12000 kg of BOD in raw sewage per hectare meter per day with a recirculation ratio of 1.5. This filter treats a flow of 5 MLD of raw sewage with a BOD of 200 mg/L. Using NRC model; determine the strength of the effluent. 7

Ans.: Refer Example-2

(d) Explain the arrangement and working principle of a trickling filter. Draw the single stage and two stage recirculation systems. 7

Ans.: Refer Q-2

CSVTU April-May 2009

UNIT – III

Q.3 (a) Define "Sludge Age". 2

Ans.: Refer Q-10

(b) Distinguish between standard rate and high rate tricking filter.

Ans.: Refer Q-10

(c) Explain in brief principle of working of aerobic, anaerobic and facultative type of stabilization pond. 7

Ans.: Refer Q-12

(d) Design the activated sludge unit treatment with following data for town of population of 65,000. 7

(i) Average sewage flow =210 litres/capita/day
(ii) BOD of raw sewage =210mg/l
(iii) Suspended solid in raw sewage =300mg/l
(iv) BOD removal in primary treatment = 40%
(v) Over all BOD removed desired = 90%

Ans.: Refer Example-7

CSVTU Nov.- Dec 2008

UNIT - III

Q.3 (a) Define activated sludge process.

Ans.: Refer Q-9

(b) Explain in brief, various operation problem commonly encountered in activated sludge plants. 7

Ans.: Refer Q-9

(C) An average operation data for conversional activated sludge treatment plant is as following.

(i) Waste water flow = 50,000m^3/day
(ii) Volume of aeration tank= 15,000m^3
(iii) Influent BOD = 200mg/l
(iv) Effluent BOD = 25mg/l
(v) Mixed liquor suspended solid (MLSS) =3,000 mg/l
(vi) Effluent suspended solids = 40 mg/l
(vii) Quantity of waste sludge =250mg/l

Based on information above determine:

(a) Aeration period (hours)
(b) Food to micro organism ratio (F/M)(kg BOD per day kg MLSS).
(c) Percentage efficiency of BOD removal.
(d) Sludge Age (days).

Ans.: Refer Example-4

(d) Determine the size of high rate trickling filter for following data:7

(i) Sewage flow = 5MLD
(ii) Recirculation ratio = 1.5
(iii) BOD of raw sewage = 230 mg/L
(iv) BOD removals in primary clarifier = 30%
(v) Final effluent BOD desired = 25 mg/l

Ans.: Refer Example-1

UNIT – IV Sewage Sludge Treatment

Sewage sludge treatment-Importance, amount and characteristics of sludge, sludge digestion, Anaerobic digestion, aerobic digestion, sludge drying beds. Sewage disposal: disposal by dilution, self purification of polluted streams, factors affecting self purification, Sag curve, disposal on land surfaces. Stream standards, Effluent standards, theories of waste treatment (Volume reduction, strength reduction, new Equalization and proportioning) Summery of Industrial waste, it origin, character and treatment.

INTRODUCTION:

CONSTITUENTS OF SEWAGE

Sewage or wastewater is a dilute mixture of various wastes from residential, commercial, industrial and other public places. Before we can decide about the line of its treatment and disposal, it is essential to know its composition, quality and characteristics. Though the characteristics of sewage or wastewater depends up to the source of its discharge, sewage in general contains organic matter, inorganic matter and living organisms. The organic and inorganic matter may be in dissolved, suspended and colloidal state. The inorganic or mineral matter consists of ash, cinder, sand, grit, mud and other mineral salts. The organic matter may be either nitrogenous or nitrogen-free. The chief sources of nitrogenous matter are urea and protein, while the nitrogen free compounds include carbohydrates fats and soaps. The living organisms may be divided into plant life (such as algae fungi etc.) and animal life consisting of various types of micro-organisms such as protozoa, bacteria, virus etc. the bacteria convert the complex organic constituents of sewage into simpler, more stable, organic and mineral compounds.

Q.1 Explain the characteristic of Industrial waste water? **(April-May, 2009)**

TABLE 8.1 TYPICL COMPOSITION OF DOMESTIC WASTEWATER.

Constituent	Concentration		
	Strong	Medium	Weak
Solids: Total (mg/l)	1200	720	350
Dissolved, total (mg/l)	850	500	250
Fixed (mg/l)	525	300	145
Volatile (mg/l)	325	200	105
Suspended, total (mg/l)	350	220	100
Fixed (mg/l)	75	55	20
Volatile (mg/l)	275	165	80
2. settleable solids (mg/l)	20	10	5
3. biochemical oxygen demand (BODS, 20°C) (mg/l)	400	220	110
4. Total organic carbon (TOC) (mg/l)	290	160	80
5. Chemical oxygen demand (COD) (mg/l)	1000	500	250
6. Nitrogen (total as N) (mg/l)	85	40	20
Organic (mg/l)	35	15	8
Free ammonia (mg/l)	50	25	12
Nitrites (mg/l)	0	0	0
Nitrates (mg/l)	0	0	0
7. Phosphorus (Total as P) (mg/l)	15	8	4

Organic (mg/l)	5	3	1
Inorganic (mg/l)	10	5	3
8. Chlorides (mg/l)	100	50	30
9. Alkalinity (as $CaCO_3$)*			
10. Grease (mg/l) (mg/l)	150	100	50

Depends upon its amount in domestic water supply.

CHARACTERISTICS OF WASTEWATER

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

(a) Physical characteristics
(b) Chemical characteristics
(c) Biological characteristics.

The most important physical characteristic of water is its total solids content, consisting of floating matter, matter in suspension, colloidal matter and matter in solution. Other physical characteristics are:

(i) smell or odour
(ii) colour and
(iii) temperature.

Sewage contains complex organic matters derived from urine, faces etc. and inorganic chemicals. Fresh domestic sewage is slightly alkaline but tends towards acidic as it becomes stale. Important chemical characteristics of sewage are: (i) pH value, (ii) chloride content (iii) nitrogen content (iv) fat, grease and oil content (v) sulphides, sulphates and H_2S gas (vi) dissolved oxygen, (vii) chemical oxygen demand, and (viii) biochemical oxygen demand.

Biological characteristics relate to various micro-organisms found in wastewater, some of which may be pathogenic. However, all bacteria present in wastewater are not harmful; some of these help to treat the wastewater and reduce the cost of treatment plants.

Table gives a summary of physical, chemical and biological characteristics of wastewater and their sources.

TABLE CHARACTERISTICS OF WASTEWATER AND THEIR SOURCES.

	Characteristic	Sources
1.	**Physical characteristics**	
	(i) Colur	Domestic and industrial wastes; natural decay of organic materials.
	(ii) Odour	Decomposing wastewater: industrial wastes
	(iii) Solids	Domestic water supply ; domestic and industrial wastes; soil erosions; inflow-infiltration
	(iv) Temperature	Domestic and industrial wastes.
2.	**Chemical characteristics**	
	(a) Organic	
	(i) Carbohydrates	Domestic, commercial industrial wastes
	(ii) Fats, oils and greases	Domestic, commercial and industrial wastes
	(iii) Pesticides	Agricultural wastes.
	(iv) Phenols	Industrial wastes
	(v) Proteins	Domestic and commercial wastes
	(vi) Surfactants	Domestic and industrial wastes
	(vii) Others	Natural decay of organic materials.
	(b) Inorganic	
	(i) Alkalinity	Domestic wastes, domestic water supply, ground water infiltration.
	(ii) Chlorides	Domestics water supply, domestic wastes, groundwater infiltration, water softeners.
	(iii) Heavy metals	Industrial wastes.
	(iv) Nitrogen	Domestic and agricultural wastes.
	(v) pH	Industrial wastes.
	(vi) Phosphorus	Domestic and industrial wastes, natural runoff
	(vii) Sulfur	Domestic water supply, domestic and industrial wastes.
	(viii) Toxic compounds	Industrial wastes.
	(c) Gases	
	(i) Hydrogen sulfide	Decomposition of domestic wastes
	(ii) Methane	Decomposition of domestic wastes
	(iii) Oxygen	Domestic water supply, surface water infiltration
3.	**Biological characteristics**	
	(i) Animals	Open water courses and treatment plants
	(ii) Plants	Open water courses and tremens plants
	(iii) Protista	Domestic wastes; treatment plants.
	(iv) Viruses	Domestic wastes.

Q. 2 Differentiate between aerobic and anaerobic digestion.

(Nov-Dec., 2009)

(i) Aerobic decomposition (also called aerobic oxidation) and

(ii) Anaerobic decomposition (also called putrefaction).

Aerobic decomposition may be caused by both aerobic bacteria as well facultative bacteria operating aerobically, in presence of air or oxygen which is available in the wastewater in the dissolved form. During this process, organic matter is broken up and oxidized to form stable and non objectionable end products like carbon dioxide, nitrates, sulphates etc. Treatment units which works on aerobic decom-position alone are aeration tanks, trickling filters, contact beds, oxidation ponds etc.

Anaerobic decomposition or putrefaction is caused by anaerobic bacteria, as well as facultative bacteria, operating an aerobically. The end products of putrefaction include black residue, nitrogen, hydrogen etc. The anaerobic bacteria survive by extracting and consuming the bounded molecular oxygen present is compounds like nitrates (NO_3) and sulphates (SO_4). Treatment units which works on putrefaction alone are septic tanks, Imhoff tanks, and sludge digestion tanks.

Example Change in concentration of organic matter L, with time t, is given by $\frac{dL}{dt} = -KL$. Calculate the organic matter remaining after 4 days if the initial concentration was 300mg/d and $K = 0.3$ per day.

Solution. $\frac{dL}{dt} = -KL.$

$\therefore \quad \int \frac{dL}{L} = -K \int dt$

$\therefore \quad \log_e L = -Kt + C$

Or $\quad 2.303 \log_{10} L = -Kt + C$

When $t = 0,\ L = 300 mg/l.$

Hence C= $2.303 \log_{10}(300) \approx 5.7$

Substituting this value of C in Eq. (a), we get

$2.303 \log_{10} L = -Kt + 5.7$ .... (b)

(where K=0.3 per day)

Hence the value of L after 4 days is gives by

$2.303 \log_{10} L_4 = -0.3 \times 4 + 5.7 = 4.5$

$\log_{10} L_4 = 1.954$

From which $L_4 = 10^{1.954} = 89.9 mg/l.$

$\therefore$ Organic matter left after 4 days = 89.9 mg/l

Q.3 Explain Advantage & Disadvantage of aerobic process ?

Advantages

1. Lower BOD concentration in digester supernatant
2. Production of odourless and easily dewaterable biologically stable digested sludge.
3. Recovery of more basic fertilizer value in digented sludge
4. Lower capital cost
5. Fewer operational problems.

Disadvantages

1. Higher power costs generate higher operating costs comparable with anaerobic digestion.
2. Gravity thickening processes following aerobic digestion tend to generate high solids concentration in the supernatant.
3. Some aerobically digested sludges donot dewater easily in vacuum filtration.
4. 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.

Q.4 Write short note on the treatment of industrial wastes.

(Nov-Dec.,2009)

Ans: The industrial wastes are usually treated by the following process.

(i) The suspended solids are removed by screening or settling tanks.

(ii) Oils, grease and facts are removed by floatation and skimming. This process can be aided by chemical treatment if necessary.

(iii) Colloidal matter is removed by floatation with coagulants and electrolytes following by sedimentation and filtration.

(iv) Excessive alkalinity or acidity is removed by adding chemicals or mixing acidic waste with alkaline waste or vice versa.

(v) Reoxygeneation of wastes are done by aeration.

(vi) Decolonization of waste is done by chemical treatment with sedimentation or filtration or both.

Q.5 Write short note on industrial effluent standards for disposal on land.

Ans: The use of industrial effluent for irrigation purposes has been quite popular, particular from food processing industries pharmaceutical industries, pulp and paper industries. While using the effluent for irrigation. Care should be taken that it should percolate into the field and do not create the problem of mosquito and fly breeding. The industrial wastes can be treated in oxidation ponds or lagoons and disposed of accordingly. The maximum quantity of effluent to be disposed off by this method depends on the effluent holding capacity of soil. Topography of land, crop, field area and climatic conditions etc.

According to IS: 3307 -1965 Following are the tolerance limits for industrial effluents discharged on land for irrigation purposes.

(1) The total dissolved inorganic solids should not exceed 2100 mg/l.
(2) 5-day BOD at 20°C should not exceed 500 mg/l.
(3) pH value of effluent should be between 5.5 to 9.0.
(4) Quantity of boron should not exceed 2 mg/l.

Q.6 What are the tolerance limits for industrial effluents, discharged into public sewers?

Ans: According to IS: 3306-1965, the tolerance limits for industrial effluents discharged into public sewer are as follows:

(i) Its pH value should be between 5.5 to 9.0
(ii) 5-day BOD at 20°C should not exceed between 5.5 to 9.0.
(iii) Lead, copper and zinc should not exceed 1,3 and 15 mg/l respectively.
(iv) Effluent temperature should not exceed 45°C.
(v) Quantity of suspended solids should not exceed 600 mg/l.
(vi) Chromium, nickel and cyanide should not exceed 2% each.
(vii) Effluent containing solids such as straw, plastic, wood, paint, residue, gross solid from cannery/wastes cinder, ash, sand, rag, hair, metal shavings, garbage, broken glass etc. should not be discharged into public sewers.
(viii) Suspended solids should not exceed 600 mg/l
(ix) Chloride and boron should not exceed 600 and 2 mg/l respectively.

Q.7 Define sludge digestion and mention the products formed after digestion.

(April-May, 2011-2009/ Nov-Dec., 2008)

Ans. Sludge digestion is defined as the decomposition of complex organic substances present in sludge into simpler stable compounds by bio-chemical reactions brought about by the anaerobic bacteria. At the end of decomposition the following three products are obtained.

(i) Digested sludge: The digested sludge settles at the bottom of tank and it can be easily deride and converted into sludge cakes on drying beds. The digested sludge dries easily. Iterates no offensive odours during drying and drains quickly. It also flows rapidly and presents no difficulty in pumping.

(ii) Gas: The decomposition also produces sewage gas which can be utilized as fuel. It is accumulated near the top of tank.

(iii) Supernatant liquid: The space between gas and digested sludge is occupied by the supernatant liquid. This liquid contains unstable colloidal matter and hence, after proper treatment it is added to the raw sewage or to the natural supernatant liquid is in a better condition and it can be added without any treatment to the raw sewage or to the natural waters or it can be utilized for the purpose of irrigating the land.

Q.8 State the objects of sludge digestion.

Ans. Following are the various reasons or purposes for which the sludge is to be digested.

i) The digested sludge is of better quality and can therefore be conveniently handled and treated easily subsequently.
ii) The digestion destroys the pathogenic bacteria
iii) The digestion gives fertilizer and other valuable by products which without digestion would have gone to waste.
iv) The digestion results in the recovery of combustible gases which may be used as fuel or power.
v) The volume of sludge is reduced and hence it becomes easier to dispose it off.

Q.9 Explain the three distinct stages which occur in the process of sludge digestion.

Ans. The biological action involved in the process of sludge digestion occurs in the following three distinct stages.

(i) Acid production stage
(ii) Acid regression stage
(iii) Alkaline fermentation stage

i) **Acid production stage:** In this stage, the simple compounds like cellulose, starch, sugar, soluble nitrogenous compounds etc. are attacked by bacteria. Such action of bacteria starts fermentation and the products of decomposition are organic acids and gases. The main gases produced are methane, carbon dioxide and hydrogen sulphide. During this stage the sludge remains acidic. The pH value is about 5 to 6. The BOD increases to some extent. This stage continues for about 15 days or so.

ii) **Acid regression stage:** In this stage, the organic acids nitrogenous compounds are attacked by bacteria and converted into acid carbonates and ammonia compounds. The decomposed sludge has very offensive odour. It entraps the gases of decomposed and hence it is foamy in character tends to rise to the surface to form scum. This is the intermediate stage. The pH value rises and it remains between 6 and 7. The BOD still remains high. This stage extends for several months usually 3 months or so.

iii) **Alkaline fermentation stage:** In this stage, the more resistant substances like proteins and some organic acids like aminoacids are attacked by bacteria and they are broken down into ammonia organic acids and gases. This is the final stage of sludge digestion and during this stage the liquid separates out from the solids and the digested sludge is formed. This sludge is granular and stable and it does not give out offensive odour. It is also known as the ripened sludge and it is collected at the bottom of tank. The digested sludge in alkaline in nature. The pH value rises and remans stationary at about 7.5. The BOD is also greatly reduced. This stage extends for a period of about one month or so.

Q.10 What factors influence the stages of sludge digestion? Explain them.

(April-May, 2011-2010-2009/ Nov-Dec., 2008)

Ans. Following factors influence the stages of sludge digestion

i) Temperature
ii) Sludge seeding
iii) Mixing
iv) pH value and
v) Miscellaneous condition.

i) **Temperature:** The anaerobic decomposition of organic solids in the sewage is greatly influenced by the temperature at which it takes place. There are two distinct temperature zones in the sludge digestion.
(a) Zone of thermophilic digestion
(b) Zone of thermophilic digestion.

In zone of thermophilic digestion, the heat loving or thermophilic organisms are more active and it ranges from 35°C to 60°C. At this temperature, the digestion period can be brought down to about 7 to 10 days only.

In zone of mesophilic digestion, the common or mesophilic organisms are more active and its practical range if 26°C to 35°C. At this temperature, the digestion period can be brought down to about 30 days only.

ii) **Sludge seeding:** The process of adding or introducing fresh sludge into previously well digested sludge is known as the sludge seeding and it should be done in such a way that ultimately alkaline condition may prevail in the tank. The proper seeding of sludge develops favourable conditions for micro-organisms and the digestion of sludge takes place in a short period.

iii) **Mixing:** The incoming fresh raw sludge should be thoroughly mixed with digested sludge by some effective method of mechanical agitation. This is generally achieved by stirring the sludge by a slow moving device. The excessive stirring produces harmful effects. The proper stirring results in even distribution of the incoming sludge maintenance of biniform temperate in the tank, reduction of scum and increase in the production of gas.

iv) **pH value:** The desired range of pH, value for the efficient digestion of sludge is 6.8 to 7.2 and to maintain the pH value within this range, the following remedies may be applied.
(a) Adding of lime,

(b) Introducing the required quantity of raw sludge.

(c) Controlling the removal of digested sludge.

(iv) Miscellaneous conditions: The other factors which influence the process of sludge digestion are as follows:

(a) Quality of public water supply.

(b) Presence of copper, fluorides, radioactive substances etc.

Q.11 Explain the process of drying in drying beds and mention the uses of dried sludge.

Ans. In this method of sludge disposal, the sludge is dried by spreading over the land. Air drying of sewage can be done in open air of under glass covered roof. The open drying beds are generally 30-40 cm deep and are filled with graded gravel or stone ballast over which 10-15 cm thick layer of sand is spread. In some case cinder coke, breeze and blast furnace slags are also used for the above purpose. The sewage sludge is applied on these beds in about 20-30 cm depth and is allowed to dry. After about one week or so, the surface of sludge cracks and at this stage, the sludge is ready for removal. The sludge at this stage contains about 70% moisture. The sludge cakes are then removed by spades and they are dumped into a pit for further drying or they may even be kept on the drying beds for a period of about 3 to 4 weeks. The liquid that has percolated through the drying bed is collected and conveyed by underdrains to the sumps. The different sumps are suitably connected with each other and the percolated liquid is thus either conveyed to the influent of the treatment plant or to the natural stream or river. The conveyance of liquid may be achieved either by gravity or by pumping.

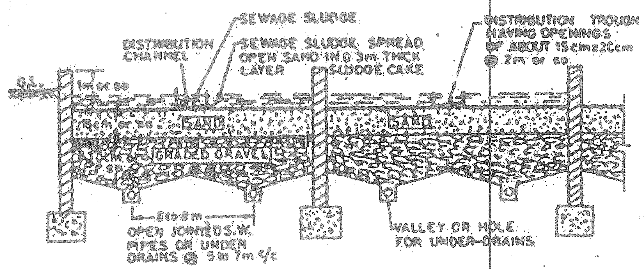
Uses of dried sludge: The sludge cakes formed on the surface of drying beds should be carefully removed. It should be observed that the sand is not being taken out along with the sludge cakes. This sludge has got the fertilizing value as it contains nitrogen, phosphoric acid and potash. It can therefore be utilized as fertilizer it can also be dumped into low lying areas or buried or incinerated.

Q.12 How will you determine the area required for drying beds?

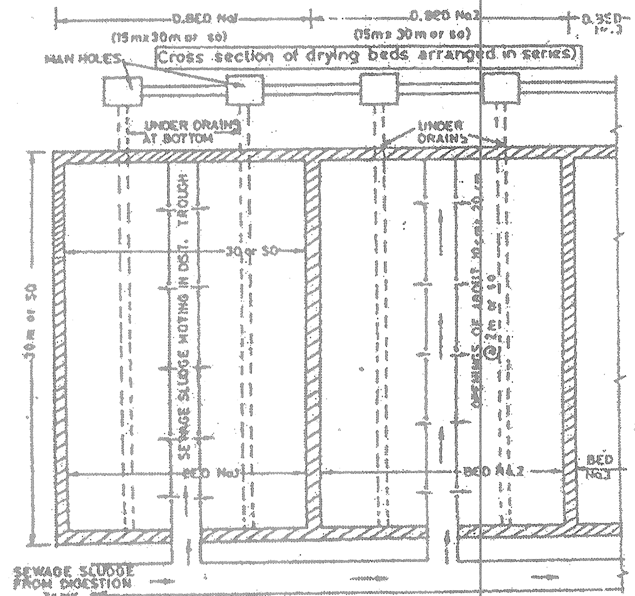
Ans. The area required for drying beds will depend on the quantity of sludge, quality of sludge and weather conditions prevailing at the site of drying beds. In general the area of drying bed is determined on per capita basis. For sewage treatment plant of capacity of about 10 MLD or more, the usual provision made for drying beds is about 0.05 m^2 per capita. For smaller plants, the usual provision is about 0.06 to 0.07 m^2 per capita.

Following table shows the tentative figures to be adopted for working out the area of drying beds in relation to the quality of sludge and protection from weather.

S. No.	Source of sludge	Area in m^2/ capita	
		Open beds	Covered beds
1.	Primary clarifiers	0.10	0.08
2.	Intermittent sand filters	0.10	0.08
3.	Standard rate trickling filter	0.12	0.10
4.	High rate trickling filter	0.15	0.12
5.	Activated sludge process	0.18	0.14
6.	Coagulated sludge	0.20	0.15



Cross section of drying beds arranged in series)



(TOP PLAN)

Q.13 What is meant by disposal of sewage by dilution? What are the conditions favourable for it? (April-May, 2010)

Ans. The disposal of sewage by discharging it into water courses such as streams, rivers or large body of water such as lake, sea is called dilution. This method of disposal is only possible when the natural water in required quantity is available near the town. While discharging the sewage in this way, care should be taken that the sewage may not pollute the natural water and render it unfit for any other purposes such as drinking, bathing fish culture, rough industrial use and irrigation.

The method of sewage disposal by dilution is most suited under the following circumstances.

i) When the city is situated near the sea, river or lake.

ii) When the sewage reaching the point of disposal is fresh or non septic.

iii) When at the point of disposal the depth of water is sufficient and the current can prevent the disposition near the outfall.

iv) When the volume of receiving water is large enough to take the load of sewage safely without causing its pollution.

v) When during flood the receiving water will not cause backward flow in sewers.

Q.14 Why is it necessary to treat the sewage sludge?

Ans. The sewage treatment is done due to the following necessity.

1) To destroy all the pathogens, that it may not pollute the receiving water and make them unsafe for use.

2) To reduce the volume of sewage sludge, so that it can be easily disposed off.

3) To reduce the percentage of water for facilitating its handling and transporting upto disposal places.

4) To stabilize the organic matter, so that it may not cause difficulties later on.

5) To recover the industrial value of the slidge.

Q.15 Enumerate the various method of sludge disposal. Explain in short. (April-May, 2011)

Ans. Following are the various method which are adopted for the disposal of sludge.

i) **Disposal on land:** - The disposal of sludge is usually done on land as manure to the soil or as a soil conditioner.

ii) **Distribution by pipe lines:** - In this method, the sludge is conveyed through pipe line to the nearby farm and it is utilized as fertilizer.

iii) **Drying on drying beds:** - In this method of sludge disposal, the sludge is dried by spreading over the land.

iv) **Dumping into the sea:** - In this method, the sludge is conveyed and discharged into the sea. This method is useful where sea is near the locality.

v) **Heat drying:** - In this method, the sludge is actually heated so that it may become dry.

vi) **Incineration:** - In this method, the studge is burnt in incinerators.

vii) **Lagooning or Ponding:** - In this method the wet sludge is brought into the lagoon (pond) and it is left there to dry by natural processes such as evaporation and percolation.

viii) **Press filters and Vacuum filters:** - In this method, the sludge is filled in jute or cotton bags and these bags are then placed between the plated. Then the plates are pressed under a pressure of 0.4 to 0.5N/ mm^2. The pressing of plates removes the water from sludge and consequently the sludge cakes are formed.

ix) **Digestion followed by drying:** - In this methods, the sludge is first digested in specially designed sludge digestion tanks and it is then dried on sludge drying beds.

Q.16 Write a short note on disposal by dilution.

Ans. Disposal by dilution: - After treating the waste water to a desired limit or without any treatment, the waste water will be discharged into some water body like river, lake, sea having comparatively very large volume of fresh water. The water body into which the waste water is disposed gets purified in due course of time by natural process of purification. The amount and type of treatment to be given to raw waste-water depends on.

1) Quality and quantity of raw waste water
2) Quality and quantity of dilution water.
3) Self purification capacity of the dilution water.
4) The intended use of dilution water.

Q.17 Explain the process of Sludge Digestion.

Ans. This is the process of decomposing organic matter of waste sludge anaerobically under condition of adequate operational control.

The sludge is broken up into three different forms.

(1) Digested sludge which is stable humus like solid matter with reduced moisture content.
(2) Supernatant liquor which includes liquefied and finely divided solid matter.
(3) Gases of decomposition-Methane, CO_2 and Nitrogen etc.

The digested sludge is dewatered, dried up and used as manure while the gases produced are used as fuel or for driving gas engines. The supernatant liquor is retreated at the treatment plant along with the raw sewage.

The tank in which sludge digestion is carried out are called involved in the process of sludge digestion as:

(1) Acidification or period of intensive acid production.
(2) Liquefaction or a period of intensive acid production.
(3) Gasification or a period of intensive digestion and stabilization.

Factors affecting sludge digestion (Control of digestion):

In order to have an adequate control over the process of sludge digestion, it is important to maintain a few optimum conditions in the operation of these tanks.

There are- (a) Maintenance of temperature most favourable for developing and digesting organisms of sludge.

(b) Maintenance of the alkaline range of pH of the sludge.

(c) Seeding of the digested sludge with the raw sludge through proper mixing, dosing and withdrawal of sludge.

Q.18 State and explain the various stages in sludge digestion process. (Nov-Dec,2009)

Ans. The following three stages are known to occur in the biological action involved in the process of sludge digestion:

(1) Acidification or a period of intensive acid production.
(2) Liquefaction or a period of acid digestion.
(3) Gasification or a period of intensive digestion and stabilization.

(1) Acidification: As the fresh sewage-sludge begins to decompose anaerobically, bacteria attacks easily on available food substances such as carbohydrates and soluble nitrogenous compounds. Intensive acids are produced which lowers pH value to less than 6.

(2) Liquification: In this stage, organic acids and nitrogenous compounds or the first stage are liquefied i.e. transformed from large solid particles to either a soluble or finely dissolved form.

The pH value rises a little to about 6.8 odour is extremely offensive and decomposing sludge entraps gases of decomposition, becomes forming and rises to surface to from scum. This stage is known to last much longer than the proceeding stage of acidification. Hence also termed as acid regression.

(3) Gasification: In this, due to breaking of more resistance materials like proteins and organic acids, large volume of methane gas of high calorific value, along with comparatively smaller volume of CO_2 are evolved.

The pH value goes to the alkaline range i.e. above '7' and tarry odour appears.

Finally, gasification becomes very slow, sledge becomes well adjusted and is stable enough for disposal. This stage is also termed as alkaline termination.

Q.19 What is self-purification? What are the factors affecting self-purification of polluted streams? Explain oxygenation and deoxygenation. (Nov-Dec.,2009)

Ans. From the point of disposal of sewage in stream, the tream water is examined toward downstream, it will be observed that the quality of stream water successively changes. As near the place of disposal, water will be polluted and after some travel from the point of disposal, stream water becomes free from sewage pollution and comes into its natural purified state due to natural forces of purification.

This process of purification of stream water due to natural forces of purification is called self-purification.

Factors affecting self-purification:

The following condition affected the self-purification or stream.

(1) Dilution: As the putrescible organic matter is discharged into the flowing water, it is rapidly dispersed or diluted in it the action resulting in diminishing the potential nuisance of sewage.

(2) Sedimentation: This also helps in self-purification by the separation of the settle solids in sewage in the form of sludge deposits.

(3) Oxidation: As soon as the organic matter meets the water, it starts getting oxidized owing to development of the oxidizing organisms in water. The process continues till the organic matter has been completely oxidized, oxygen demand is then fully satisfied and stream is said to have purified itself.

(4) Reduction: It occurs due to the hydrolysis of organic matter either chemically or biologically

(5) Sunlight: The pathogens are killed if they are exposed to sunlight, therefore sunlight helps in self-purification.

(6) Current: The self-purification of stream directly depends on current. It classified under: -

(i) **No current:** - Sewage deposited near outfall causing formation of sludge bank and foul odours.

(ii) **Heavy current:** - Sewage mixed with stream water preventing all nuisances.

(iii) **Slow current:** - Sedimentation takes place and causing growth of algae result in reduction of oxygen, therefore slow current is better for self-purification.

(7) Temperature : As activities of organism depends on temperature, the self purification will also depend on temperature.

Explanation:-

(i) **Deoxygenation:** The phenomenon of depletion of dissolved oxygen content of the stream water in order to meet the biological requirement (BOD) of the sewage, is known as deoxygenation.

The rate depends on volume of BOD of the sewage, time available for decomposition and temperature of the stream.

(ii) **Oxygenation:** The process of absorption of oxygen by the stream water is known as oxygenation.

Its rate depends on the condition of the body of water, the deficit of DO consumption of oxygen and the depth of the stream.

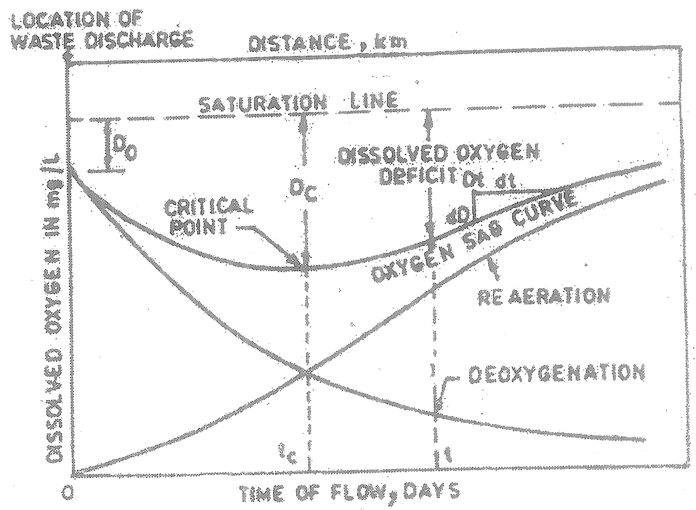


Fig. The Oxygen Sag Curve

Q.20 State and explain the various zones in an oxygen sag curve.

OR

State and explain the zones of purification.

Ans. A polluted stream undergoing self-purification presents the following four distinct zones of pollution: -

(1)Zone of degradation: This usually occurs below the outfall sewer when discharging its contents into the stream. The zone is characterized by water becoming dark and turbid with the formation of sludge deposits on the bottom.

Dissolved oxygen gets reduced to 40%. There is an increase in carbon dioxide content, reaction occurs but is slower than deoxygenating. Conditions are unfavorable to the development of aquatic life.

(2) Zone of active decomposition: It is marked by heavy pollution and characterized by the absence of dissolved oxygen Water is grayish and darker with active anaerobic organic decomposition accompany.

Fish life is practically absent, fungi and bacteria disappear. As the organic decomposition slackens reiteration sets in and D.O. again rises to its original level (i.e. 40%)

(3) Zone of recovery : The stream tries to recover its former appearance. Most of the organic matter has been settled as sludge, BOD falls and the D.O. content rises above 40%. Microscopic aquatic life reappears, water becomes clearer, fungi decreases and algae reappear.

Mineralization is active and products such as nitrates, sulphates and carbonates are formed.

(4) Clear water zone: The natural stream condition is restored the D.O. is higher than the BOD oxygen balance [(D0) – total BOD in tje first stage is attained and recovery is said to be complete.

Water becomes attractive in appearance. Some pathogenic organisms may, however, be present.

(5) Perennial rivers and streams: The perennial rivers and streams possess some flow throughout the year. But it may have maximum and minimum limits. The minimum limit generally occurs in summer. The dilution of sewage in summer therefore becomes difficult due to the fact that in summer, the high temperature of water results in low Solubility of oxygen. The sewage under such circumstance should be properly treated before allowing dilution with perennial rivers and streams

Q.21 Write a short note on land treatment of sewage. Explain the actions involved in this process.

Ans : When the sewage is evenly spread on the surface of land the method is called land treatment. The water of sewage percolates in the ground and the suspended solids remain at the surface of the ground. The organic suspended solids are partly acted upon by the bacteria and are partly oxidized by exposure to atmospheric actions of heat, light and air

The land treatment can be further classified as-

(i) Filtration and

(ii) Sewage farming or broad irrigational.

The natural process of sewage purification in both the methods of land treatment is the same, viz. filteration of sewage by straining action of ground soil and oxidation and biochemical action of organic matter. The complex compounds of sewage are connected harmless mineral salts which serve as a valuable fertilizer.

The capacity of soil for purifying sewage depends on the following three actions.

(i) Biological action

(ii) Chemical action and

(iii) Physical action.

1. **Biological action:** When sewage is applied on land the soil bacteria attack on it and convert the contents of sewage into plant food. Is utilized by roots of crops. The decomposition of organic matter of sewage may occur under aerobic conditions or under anaerobic condition. It is preferable to provide aerobic conditions for the disposal of sewage by land treatment.
2. **Chemical action and:** When sewage is applied on land its organic matter is oxidized by the soil bacterial by the chemical process of oxidation
3. **Physical action:** The physical action involved in the purification of sewage by land treatment is the process of filtration. The sewage as it passes through the layers of soil gives out suspended particles which are caught in the voids of soil. If proper aeration of these voids exist, the suspended particles are oxidized by the aerobic action. The physical action mainly depends on the nature of soil.

Q.22 What are the conditions which are considered to be favorable for the disposal of sewage by land treatment

Ans : Land treatment of sewage is suitable is suitable under the following circumstances.

(i) When the overall rainfall is very low, the lands can be irrigated by sewage.

(ii) When there is no river or natural water courses in which sewage can be discharged.

(iii) When the quantity of sewage is more which will pollute the river water.

(iv) When rivers usually run dry or having very small flow during summer.

(v) When the water table is much deep even during monsoon and there are no chances of its pollution by land treatment of sewage.

(vi) When vegetables have good market, the land treatment will have good income in return also.

(vii) When large of land is sandy, loamy or alluvial soil over soft murmur, the land treatment is most suited because porous soil will allow good aeration.

Q.23 What are the advantage and disadvantages of land treatment?

Ans: Advantage:

(i) The disposal of sewage is done by natural treatment.

(ii) The natural water courses are prevented from pollution.

(iii) The method is cheap and does not require the sewage treatment plants, requiring high initial and maintenance cost.

(iv) The land is irrigated and receives the high value-fertilizing substance without extra cost.

(v) The disposal of sewage is done without natural water courses.

Disadvantage :

(i) Large area of land is required for this type of disposal.

(ii) If the land is used for growing crops, special attention against the spared of disease shall have to be taken.

(iii) During application of sewage to the land it is to be properly supervised, otherwise the land may become sick.

(iv) The disposal of sewage cannot be done by this method if the land consists of clayey soil.

Q.24 Write short notes. (Nov-Dec, 2009)

Ans. The Oxygen Sag Curve: The oxygen deficit in a stream is a function of both oxygen utilization and resection. Inspection of Eqs. and shows that these two processes have

Table : Reiteration constants

Water body	Ranges of K_2 at 20°C base e
Small ponds and back water	0.1-0.23
Sluggish streams and large lakes	0.23-0.35
Large streams of low velocity	0.35-0.46
Large stream of normal velocity	0.46-0.69
Swift streams	0.69-1.15
Rapids and waterfalls	Greater than 1.15

Opposite effects on the deficit. This is shown graphically in fig. The rate of change in the deficit is the sum of the two reactions

$$\frac{dD}{dt} = r_d + r_R$$

$$= k_1 L_t - k_2 D$$

The actual oxygen concentration $(C_s - D_1)$ has a characteristic dip as shown in fig, resulting in the term oxygen sag curve, commonly used to describe the process.

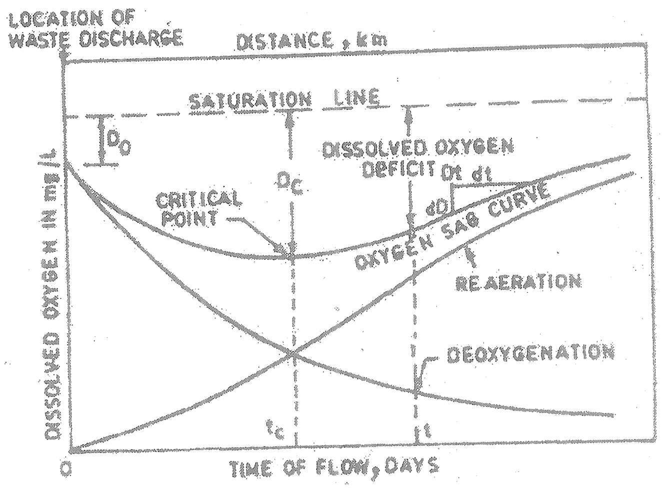


Fig. The Oxygen Sag Curve

Q.25 Write short notes on. **(Nov-Dec, 2009)**

Ans : EFFLUENT STANDARDS: The water pollution Act of 1972 (Public 92-500) mandated the Environmental protection Agency to establish standards for wastewater discharge. Current standard requite that municipal wastewater be given secondary treatment and that most effluents meet the conditions shown in Table D-7 of the appendix. Secondary treatment of municipal wastewater is generally assumed to include setting, biological treatment, and disinfection, along with sludge treatment and disposal. Thus, the principal components of municipal wastewater, suspended solids, biodegradable material, and pathogens should be reduced to acceptable levels through secondary treatment. Industrial dischargers are required to treat their wastewater to the level obtainable by the "best available technology" for wastewater treatment in that particular type of industry.

The EPA regulations further define receiving streams as "effluent-limited " and "water-quality". An effluent-limited stream is a stream that will meet its in-stream standards if all discharges to that stream meet the secondary-treatment and "best-available-technology" standards. Municipalities and industries discharging to effluent-limited streams are assigned discharge permits under the National pollution Discharge Elimination System (NPDES); these permits reflect the secondary treatment and best-available-technology standards.

A water-quality –limited stream would not meet the proposed in-stream stand arts, even if all discharges met scenery-treatment and best-available-technology levels.

Q.26 Describe the characterizers of waste generated from a dairy milk and also mention, the treatment methodology to be adopted for such waste? **(April-May, 2009)**

Table: Pollution characteristics of Certain Typical Indian Industries

Industry Type (2)	Pollution characteristics (3)	Suggested Treatments (4)
Dairy (Milk processing industry)	(i) moderate BOD (800-1000 mg/l) (ii) $\frac{BOD}{COD} \approx 0.6$ (iii) Heavy oil and grease (200 – 300 mg/l) (iv) High suspended solids (100 mg/l or so) (v) High suspended solids (80 mg/l or so) (vi) High nitrogen Very strong, though bio-degradable.	Aerobic Biological treatment; either in the form of High rate trickling filters or Activated sludge plant will generally suffice for this industry. Still however. Due to intermitted nature of wastewater discharge, an Equalization tank with or without aeration may preferably be used. In unadvanced locations Oxidation ditch or Aerated lagoon may also help ensure good disposal.

Q.27 Describe the characterizers of waste generated from o distillery and also mention, the treatment methodology to be adopted for such waste? **(Nov-Dec.,2010)**

Ans :

Industry Type (2)	Pollution characteristics (3)	Suggested Treatments (4)
Distillery and Brewery wastes (Wines; alcohols and brandy producing mdustry)	(i) Extremely high BOD (12000–73000 mg/i) (ii)very high COD (28000-73000 mg/l) (iii) high chlorides and sulphates-dissolved solids (7000-10000 mg/l) (iv) highly colored brownish yellow	Brewery wastewaters being less strong, can be generally treated by two stage aerobic biological treatment units like High rate trickling fillers, after screening and neutralization (Fig 11.1) But yeast sludge Distillery wastewaters generally wastewaters generally make it highly polluted, as shown in col (3);

			thereby necessitating two stage treatment; consisting of biological anaerobic treatment followed by aerobic treatment (Fig. 11.2)

Q.28 Describe the characteristic of waste generated from a paper pulp mill and also mention the treatment methodology to be adopted for such waste.

Ans :

(2)	(3)	(4)
Paper and pulp Mills	(i) Moderate BOD (150-1250 mg/l) (ii) Low $\frac{BOD}{COD}$ ratio (0.25-0.20) (iii) Highly coloured (4000-8000 unit) (iv) Acidic for sulphite plants, and alkaline for other processes; (v) Lignin, which is highly resistant to biological treatment is present in paper mill wastewaters, especially in planet based on "Sulphite technology". (vi) Low nitrogen.	(i) Chemical Recovery of lignin (produced in plants using sulphite process), as a useful by product. (ii) Chemical treatment for color removal. Massive lime treatment process is widely used for this purpose Actuated carbon at pH lower than 3 is also found to serve as good color remove (iii) Physical treatment like Mechanically cleaned circular clarifier is used for removing suspended solids. (iv) Final Biological treatment for reducing BOD. Both conventional for low cost processes (such as Lagoons, Stabilisation ponds etc.)can be used. The process also helps in reducing also helps in reducing colour. Flow diagram shown in Fig. 11.5

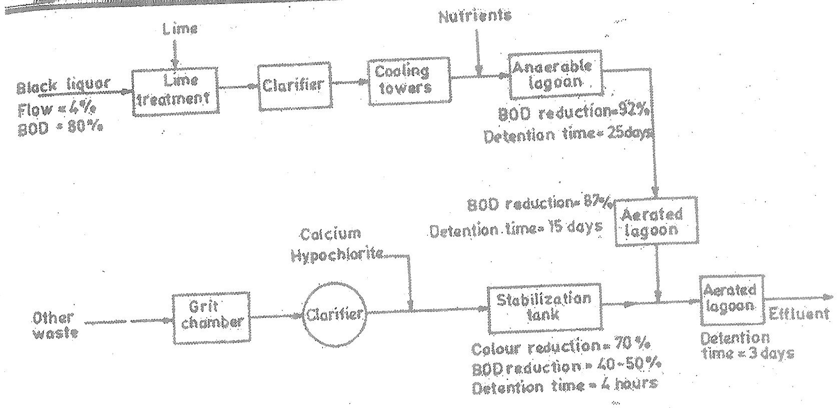


Fig. Flow chart for treating wastewaters of a typical Pulp Mill.

Q.29 Describe the characteristics of waste generated from a sugar factory and also mention the treatment methodology to be adopted for such waste **(April-May, 2010)**

Ans :

(1)	(2)	(3)	(4)
8	**Sugar Industry**	(i) Moderate BOD (300-2000 mg/i) (ii) High COD (600-4400 mg/l) (iii) High volatile solids (400-2200 mg/l) (iv) Low pH (4.6-7.1)	(b) For synthetic drug plants, very careful plant ning is required due to excessive pollution potential Highly specialize. Be quince of operation necessary. An aerobic treatment using Digesters lagoon is found to be very effective and economical. Biological treatment, however, needs to be preceded by Screen and Grease traps. Where sufficient land available two stage biological treatment

			with Anaerobic lagoons flow lowed by Aerobic stabilization ponds gives very good effluent for Indian condition. Flow sketch show in Fig.

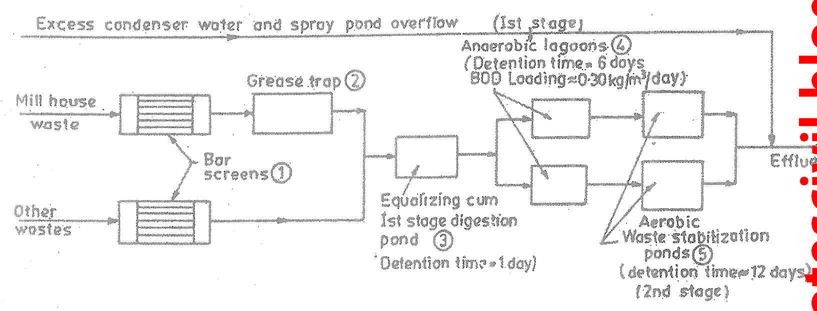


Fig. Flow chart for treating wastewaters of a Sugar Mill—*Anaerobic treatment followed by Aerobic treatment is suggested.*

NUMERICLS

Example 1. The domestic sewage of a town is to be discharged into a stream after treatment. Determine the maximum permissible affluent

BOD and the percentage required in the treatment plant, given the following particulars:

Population of town : 50000.

D.W.F. of sewage : 150 liters per capita per day

BOD contribution per capita : 0.075 kg per day.

Minimum flow of stream : 0.20 m^3/s

BOD of stream : 3 mg/l

Max. BOD of stream on downstream : 5 mg/l

Solution:

D.W.F. of sewage : 150×50000 liters per day.

$$= \frac{150\times500000}{24\times60\times60\times1000} = 0.0868 m^3/s$$

Stream discharge = 0.20 m^3/s

The BOD (y_m) of the mixture at the downstream is

$$y_m = \frac{y_1Q + y_2Q_2}{Q_1+Q_2}$$

Where y_m = 5 mg/l (given), y_1 is the BOD of the effluent having discharge Q_1 and y_2 is the BOD of the stream having discharge Q_2

$$\therefore 5 = \frac{(y_1\times0.0868)+(3\times0.2)}{0.0868+0.2}$$

From which y_1 = BOD of effluent = 9.608 mg/l

Now BOD per captain per day = 0.075 × 1000 × 1000= 75000 mg/day.

Sewage DWF = 150 litres/day

$$\therefore \text{Actual BOD of effluent} = \frac{500-9.608}{500}\times100$$

$$\approx 98.1\%$$

Example 2. A stream, saturated with DO, has a flow of 1.2 m^3/s, BOD of 4 mg/l and rate constant of 0.3 per day. It receiver an effluent discharge or 0.25 m^3/s having BOD 20 mg/l, DO 5 mg/l and rate constant 0.13 per day. The average velocity of flow of the stream is 0.18 m/s. Calculate the DO deficit at point 20 km and 40 km downstream Assume that the temperature is 20°C throughout and BOD is measured at 5 days. Take saturation DO at 20°C as 9.17 mg/l.

Solution: Let y_5 = BOD of the mix

Q_s = Stream flow = 1.2 m^3/s

y_5 = BOD of stream = 4 mg/l.

Q_e = Effluent discharge = 0.25 m^3/s

y_e = BOD of effluent = 20 mg/l

$$\text{Then } y_s = \frac{Q_sy_s+Q_ey_e}{Q_s+Q_e} = \frac{1.2\times4+0.25\times20}{1.2+0.25}$$

$= 6.759\ mg/l.$

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

$6.759 = L_0(1-10^{-0.13\times5})$

Or From which $L_0 \approx 8.71\ mg/l$ .... (i)

Again $(DO)_s$ = Saturation DO of stream at 20°C

$(DO)_e$ = DO of effluent = 5 mg/l.

$$\therefore (DO)_e = \frac{(DO)_s\times Q_s+(DO)_e\times Q_e}{Q_s+Q_e}$$

$$= \frac{(9.17\times1.2)+(5\times0.25)}{1.2+0.25} = 8.45\ mg/l.$$

$\therefore$ Initial DO deficit = $D_0 = 9.17 - 8.45 = 0.72\frac{mg}{l}$ ....(ii)

(a) DO deficit at a point 20 km downstream

$t = \frac{distance}{velocity} = \frac{20\times1000}{0.18\times60\times60\times24} = 1.286\ day$

Using streeter-Phelps Equation (Eq.9.5)

$D_t = \frac{KL_0}{R-K}[10^{-kt} - 10^{-R.t}] + D_0 10^{-R.t}$

$= \frac{0.13\times8.71}{0.3-0.13}[10^{-0.13\times1.286} - 10^{-0.13\times1.286}] + 0.72\times10^{-0.3\times1.286}$

$\approx 2.089\ mg/l$

(b) DO deficit at a point 40 km downstream

$t = \frac{20\times1000}{0.18\times60\times60\times24} = 2.572\ day$

$D_t = \frac{0.13\times8.71}{0.3-0.13}[10^{-0.13\times2.572} - 10^{-0.13\times2.572}] + 0.72\times10^{-0.3\times2.572}$

$= 2.079\ mg/l$

Example 3. A city discharges sewage at the rate of 1200 liters per second, into a stream whose minimum flow is 5000 liters per second, the temperature of both being 20°C. The 5 day BOD 20°C for sewage is 160 mg/l and that of river water is 2 mg/l. The DO content of sewage is zero while that of stream is 90% of the saturation DO. Find out the degree of treatment required if the minimum DO to be maintained in the stream is 4 mg/l. Assume deoxygenating coefficient as 0.3. Given saturation DO at 20°C as 9.17 mg/l.

Solution: DO of stream = 90% of saturation DO

$= 0.9\times9.17 = 8.253\ mg/l.$

Do of the mix $= \frac{8.253\times5000+0\times1200}{5000+1200} = 6.656$ mg/l.

$\therefore$ Initial DO deficit $= D_0 = 9.17 - 6.656 = 2.514\ mg/l$

Min DO to be maintained in the stream $= 4\ mg/l.$

$\therefore$ max, permissible saturation deficit is

$D_c = 9.17 - 4 = 5.17\ mg/l.$

Now, the first stage BOD of mixture of sewage and stream is

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

Where $f_s = R/K = 0.3/0.1 = 3$

$D_0 = 2.514$ mg/l and $D_c = 5.17$ mg/l

$\therefore \left(\frac{L_0}{3\times5.17}\right)^{3-1} = 3\left[1 - (3-1)\frac{2.514}{L_0}\right]$

or $\frac{L_0^2}{240.56} = 3\left[1 - (3-1)\frac{2.514}{L_0}\right]$

Solving this by trial and error, we get $L_0 = 23.86$ mg/l.

Now $y_s = L_0(1 - 10^{-k.t})$

$= 23.86\,(1 - 10^{-0.1\times5}) = 16.31\ mg/l.$

This is permissible BOD of the mix.

$\therefore 16.31 = \frac{(2\times5000)y_e\times1200}{5000+1200}$

From which $y_e = 75.94$ mg/l.

Hence permissible BOD of effluent $= y_e = 75.94$ mg/l.

Actual BOD of effluent= 160 mg/l

$\therefore$ Degree of treatment required $= \frac{160-75.94}{160}\times100$

$= 52.5\%$

Example 4. A town discharges 80 cusecs of sewage into a stream having a rate of flow of 1200 cusecs during lean days. At a 5-day BOD of sewage at the given temperature is 250 mg/l. Find the amount of critical DO deficit and its location in the downstream portion of the stream. Assume deoxygenating coefficient K as 0.1 and coefficient of self purification (f_s) as 3.5 Assume saturation DO at given temperature as 9.2 mg/l

Solution: $(DO)_{stream} = 9.2$ mg/l; $(DO)_{stream} = 0$

$\therefore (DO)_{mix} = \frac{(9.2\times1200)+(0\times80)}{1200+80} = 8.625$ mg/l.

$\therefore$ Initial DO deficit $= D_0 = 9.2 - 8.625 = 0.575\ mg/l$

$y_s = \frac{(0\times1200)+(250\times80)}{1200+80} = 15.625$ mg/l.

But $y_s = L_0(1 - (10)^{-k\times5})$

$6.759 = L_0(1 - (10)^{-0.1\times5})$

From which $L_0 = 22.85$ mg/l.

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

$= \frac{1}{0.1(3.5-1)} \log_{10}\left[3.5\left\{1-(3.5-1)\frac{0.575}{22.85}\right\}\right]$

$= 2.063$ days

Also, $D_c \frac{L_0}{f_s} (10)^{-k.t_c}$

$= \frac{22.85}{3.5}(10)^{-0.1\times 2063} = 4.06$ mg/l

Hence $x_e = V\times t_c = 0.12(2.063\times 24\times 60\times 60)\times 10^{-3}$

$= 21.39\ km$

Example 5. The population of a town is 60000 and the domestic sewage is 160 liters/capita/day, having per capita BOD of 70 g/day The dairy waster of the town is 2.5×10^6 liters/day with a BOD of 1600 mg/l and the waste from other industries is 1.7×10^6 liters/day with BOD of 2000 mg/l. An overall expansion factor of 15% is to be provided. The wastewater is discharged in the natural stream having a minimum discharge of 7500 liters/sec and a saturation dissolved oxygen content of 9.0 mg/l. It is necessary to maintain a dissolved oxygen content of 4 mg/l in the stream. Determine the degree of treatment required to the wastewater prior to its discharge into the stream. Assume suitable values of coefficients of de-oxygenation and reoxygenation.

Solution: Domestic sewage $= 60000\times 160 = 9.6\times 10^6$ liters/day

Per capita BOD of domestic waste $= 70\times 1000\ mg/day$

Per capita sewage = 160 liters/day

$\therefore$ BOD of domestic waste $= \frac{70\times1000}{160} = 437.5\ mg/l.$

Average BOD of effluent $= \frac{437.5\times9.6+1600\times2.5+2000\times1.7}{9.6+2.5+1.7}$

$= 840.6\ mg/l$

Total effluent $= (9.6+2.5+1.7)10^6 = 13.8\times10^6$ liters/day

= 159.7 liters/sec.

Using an expansion factor of 15%

Design effluent $= 1.15\times 159.7 \approx 184$ liters/day

Initial DO of stream $= 9.0\ mg/l$

$\therefore (DO)_{mix} = \frac{9.0\times7500+0\times184}{7500+184} = 8.78$ mg/l.

$\therefore$ Initial DO deficit $= D_0 = 9-8.78 = 0.22\ mg/l$

Critical DO deficit $= D_c = 9-4 = 5\ mg/l$

Now from Eq. 9.12

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

Where $D_c = 5$ mg/l and $D_0 = 0.22$ mg/l

$\therefore \left(\frac{L_0}{3\times5}\right)^{3-1} = 3\left[1-(3-1)\frac{0.22}{L_0}\right]$

or $\frac{L_0^2}{675} = 1-\frac{0.44}{L_0}$

Solving this by trial error, we get $L_0 = 25.76$ mg/l

Hence $y_s = L_0(1-(10)^{-0.1\times5})$

$= 25.76(1-(10)^{-0.5}) = 17.61$ mg/l

Hence 5-day BOD of the mixture $= 17.61\ mg/l.$

$\therefore 17.61 = \frac{y_s\times184+0\times7500}{184+7500}$

or $y_s = 736.4\ mg/l$

$\therefore$Degree of treatment required $= \frac{840.6-736.4}{840.6}\times 100$

$= 12.5\%$

Example 6. If in the previous example, no treatment is provided determine the stream discharge (and hence the dilution ratio).

Solution: If no treatment is provided, $y_e = 840.6$ mg/l

$\therefore 17.61 = \frac{840.6\times184+0\times Q_s}{184+Q_s}$

From which $= Q_s$ litres/sec

The above calculation are based on the assumption that $(DOC)_{max}$ does not change appreciably and hence D_0 remains the same.

Actually, as Q_s increases, $(DOC)_{max}$ will increase and hence D_0 will decrease. This will require repeat of calculation to obtain precise result. For example, for $Q_s = 8599$ litres/sec.

$$(DOC)_{max} = \frac{9.0 \times 8599 + 0 \times 184}{8599 + 184} = 8.812 \text{ mg/l}$$

$$D_0 = 9 - 8.812 = 0.188\ mg/l$$

$$D_c = 5 \text{ mg/l(as befoe)}$$

$$\therefore \left(\frac{L_0}{3 \times 5}\right)^{3-1} = 3\left[1 - (3-1)\frac{0.188}{L_0}\right]$$

Solving this by and trial error, we get $L_0 = 25.79$ mg/l

$$y_s = 25.79(1 - (10)^{-0.5}) = 17.634 \text{ mg/l}$$

$$\therefore \quad 20 = \frac{250 \times 92.59 + 6 \times Q_R}{92.59 + Q_R}$$

$$or \quad Q_R = 1521\ mg/l$$

Example 7. A city discharge 1500 litres per second of sewage into a stream whose minimum rate of flow is 6000 litres per second. The temperature of sewage as well as water is 20°C. The 5 day B.O.D. at 20°C for sewage is 200 mg/l and that of river water is 1 mg/l. The D.O. content of sewage is zero, and that of the stream is 90% of the saturation D.O. If the minimum D.O. to be maintained in the stream is 4.5 mg/l, find out the degree of sewage treatment required. Assume the de-oxygenation coefficient as 0.1 and re-oxygenation coefficient as 0.3.

Solution: From the table given at the end of the book, the value of saturation D.O. at 20°C is found out as 9.17 mg/l

D.O. content of the stream

= 90% of the saturation D.O.

$$= \frac{90}{100} \times 9.17$$

$$= 8.25\ mg/l$$

D.O. of mix at the start point (i.e. at t=0)

$$= \frac{8.25 \times 60000 + 0 \times 1500}{60000 + 1500}$$

($\because$ D.O. of sewage is zero)

$$= 6.6 mg/l$$

$\therefore D_0$ = initial D.O. deficit

= [Saturation D.O. at mix temp. − D.O. of mix.]

$$= 9.17 - 6.6 = 2.57\ mg/l$$

(Assume instantaneous mixing)

Minimum D.O. to be maintained in the stream

$$= 4.5\ mg/l$$

$\therefore$ Max permissible saturation deficit (i.e., critical D.O. deficit)

$$= D_c = 9.17 - 4.5$$

$$= 4.67\ mg/l$$

Now, using equations (8.11), the first stage B.O.D. of mixture of sewage and stream (L) is given by

$$\left[\frac{L}{D_c f}\right]^{f-1} = f\left[1(f-1)\frac{D_0}{L}\right]$$

Substituting the values as :

$D_0 = 2.57$ mg/l amd $D_c = 4.67$ mg/l

$$f = \frac{K_R}{K_D} = \frac{0.3}{0.1} = 3$$

we get

$$\left[\frac{L}{4.67 \times 3}\right]^{3-1} = 3\left[1(3-1)\frac{2.57}{L}\right]$$

Or

$$\left[\frac{L}{14.01}\right]^2 = 3\left[1 - \frac{5:14}{L}\right]$$

Solving by hit and trial, we get the value

$$L = 21.1\ mg/l$$

Now, using $Y_t = L[1 - 10^{-K_D.t}]$, we have

Max. permissible 5 day B.O.D. of the mix (at 20°C)

$Y_5 = 21.1[1 - 10^{-0.1\times5}]$ (where k_D at 20°C = 0.1)

$= 14.43\ mg/l$

Now, using equation (8.1), we have

$$C = \frac{C_s Q_s + C_R Q_R}{Q_s + Q_R}$$

Where C stand for concentration of B.O.D

Substituting the values, we get

$$14.43 = \frac{C_s\times1500+1\times6000}{1500+6000}$$

Where C_s will represent the permissible B. O. D.$_5$ (at 20°C of couruse) of the discharged wastewater.

Solving, we get

$C_s = 68.16\ mg/l$

∴ Degree of treatment required (Per cent)

$$= \frac{\text{Oiriginal B.O.D.of sewage} - \text{Permissible B.O.D}}{\text{Original B.O.D.}} \times 100$$

$$= \frac{200 - 68.16}{200}$$

$$= \frac{131.84}{200}$$

$= 65.9\%$

Example8. A city discharges 100 cusecs of sewage into a river which is fully saturated with oxygen and flowing at the rate of 1500 cusecs during its lean days with a velocity of 0.1 m/sec. The 5-days BOD of sewage at the given temperature is 280 mg/l. Find where and where the critical D.O. deficit will occur in t he downstream portion of the river, and what is its amount. Assume confiscation of the stream(f) as 4.0, and coefficient of de-oxygenation (K_D) as 0.1.

Solution: The initial D.O. of river

= Saturation D. O. at the given kemp. = 9.2 mg/l(say)

D.O. of mix at t= 0 i.e., at start

$$= \frac{9.2 \times 1500 + 0 \times 100}{1500 + 100}$$

(assuming that D.O. of sewage is nil)

$= 8.62\ mg/l$

Initial D.O. deficit of the stream

$D_0 = 9.2 - 8.62 = 0.58$ mg/l

Also 5-day BOD of the mixture of sewage and stream is given by

$$C = \frac{C_s Q_s + C_R Q_R}{Q_s + Q_R}$$

$$= \frac{280 \times 100 + 0 \times 1500}{100 + 1500}$$

$$= \frac{280 \times 100}{1600}$$

$= 17.5\ mg/l$

5 day BOD of mix at the given temp. = $Y_5 = 17.5\ mg/l$

$Y_5 = L[1 - 10^{-k_D\times5}]$ and $k_D = 0.1$(at 20°C)

∴ Thus ultimate BOD of the mix (i.e L)

$$= \frac{17.5}{0.684}$$

Now, using equation (8.11), we have

$$\left[\frac{L}{D_c . f}\right]^{f-1} = f\left[1(f-1)\frac{D_0}{L}\right]$$

or $$\left[\frac{25.58}{D_c \times 4}\right]^3 = 4\left[1 - \frac{3 \times 0.58}{25.58}\right]$$

or $D_c = 4.12$ mg/l

Now, from equation (8,8), we have

$\therefore \quad t_c = \frac{1}{K_D(f-1)} \log_{10}\left[f\left\{1-(f-1)\frac{D_0}{L}\right\}\right] \qquad t_c =$

$\frac{1}{0.1(4-1)} \log_{10}\left[4\left(1-\frac{3\times0.58}{25.58}\right)\right]$

$= \frac{1}{0.3} \times 0.571$

$= 1.905$ days

Now, distance = Velocity of rivedr × Travel time

$= 0.1\ m/sec \times (1.905 \times 24 \times 60 \times 60sec)$

$= 16{,}460\ m$

$= 16.46$ km

Explain 9. A town with a population of 30.000 has to design a sewages treatment plant to handle industrial as well as domestic wastewaters of the town. A sanitary survey revealed the following:

Dairy wastes of 3 million liters per day with BOD of 1100 mgl. And sugar mill waste of 2.4 million liters per day with BOD of 1500 mg/l are produced. In addition, domestic sewage is produced at the rate of 240 liters per capita per day. The per capita BOD of domestic sewage being 72 gm/day. An overall expansion factor of 10 per cent to be provided. The sewage effluents are to be discharged to a river stream with a minimum dry weather flow of 4500 litre per second and a saturation dissolved oxygen content of 9 mg/l. it is necessary to maintain a dissolved oxygen content of 4 mg/l. in the stream. Determine the degree of treatment required to be given to the sewage. Assume suitable values of coefficients of de-oxygenation and re-oxygenation.

Solution. Per capita B.O.D. of the domestic sewage

$= 72gm/day$

$= 72 \times 1000mg/day.$

The per capita sewage produced

$= 240litre/day.$

$\therefore$ B.O.D. per litre of the domestic sewage

$= \frac{72\times1000}{240} mg/i.$

$= 300mg/l.$

Amcunt of domestic wastewater produced per dya

$= 30{,}000 \times 240$ litres

$= 7.2$ million litres

Net B.O.D. of all wastewaters (i.e. domestic + industrial)

$= \left[\frac{7.2\times300+3\times1100+2.4\times1500}{7.2+3+2.4}\right]$

$= 719$mg/l.

Total wastewater discharge

$= \frac{\text{Vol.of wastewaters entering per day}}{\text{No.of secs in 1 day}}$

$= \frac{3ML+2.4ML+7.2ML}{1\times24\times60\times60sec}$

$\frac{12.6\times10^6}{24\times3600} l/s$

$= 145.8l/s$

Total wastewater discharge with 10% expansion factor

$= 1.1 \times 145.8l/s$

$= 160l/s$

Initial D.O. of saturated stream water

$= 9mg/l$(i.e. saturation D.O. as given)

$\therefore$ D.O. of maxture at t= 0 i.e. at start point

$= \frac{D.O.of\ river\times Q_R.of\ sewage\times Q_s}{Q_R+Q_S}$

$= \frac{9\times4500+0\times160}{4500+160}$

(assuming that the D.O. of wastewater is Nil)

$= 8.69mg/l$

Initial D.O. deficit

$= D_o = 9 - 8.69$

(assuming in stantaneous mixing)

$= 0.31 mg/l$

Now, using equ. (8.11), we have

$\left[\frac{L}{D_c \cdot f}\right]^{f-1} = f\left[1-(f-1)\frac{D_o}{L}\right]$

Where $D_c = 5mg/l$,

$D_o = 0.31mg/l$,

$K_D = 0.1; K_R = 0.3; f = 3$

(assumed values at mix. Temp)

$\therefore \left[\frac{L}{5\times3}\right]^2 = 3\left[1-\frac{2\times0.31}{L}\right]$

Solving by hit and trial,

L = 25.65mg/l

Max. permissible 5 day B.O.D. of mix at mix temp.

$= Y_5 = L[1-(10)^{-1.0\times5}]_{(K_D \text{ at mix temp. is assumed} - 0.1)}$

$= 0.684L$

$= 0.684 \times 25.65$

$= 17.54mg/l$

Using eqn. (8.1) as

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

We get $17.54 = \frac{C_S \times 160 + 0 \times 4500}{160+4500}$

Where C_S = Max. permissible B.O.D.$_5$ of wastewaters

Or $C_S = 510.99mg/l$.

∴ Permissible B.O.D. of wastewaters

$= 510.99mg/l$

Initial B.O.D. of city wastewaters

$= 719mg/l$

∴ Degree of treatment reqd.

$= \frac{719-510.99}{719}$

= 28.93% Ans.

Example 10. In the previous example determine what should be the dilution ratio if no treatment was required and thus determine the river discharge for such a condition.

Solution: When no treatment is required the value of max. permissible BOD_5 of wastewaters, i.e. c_s should be 719, Q_R can then be determined as :

$17.54 = \frac{719\times160+0\times Q_R}{160+Q_R}$

Or $17.54[160 + Q_R] = 719 \times 160$

Or $160 + Q_R = \frac{719\times160}{17.54} = 6559$

Or $Q_R = 6399$ l/s (say)

Dilution ratio $= \frac{6399}{160}$

$= 39.99; say\ 40\ times$

Hence when the dilution ratio is 40 and the minimum river discharge is 6400 l/s, no treatment will be required.

Example 11. A waste water effluent of 560t/s with a BOD= $50mg/l$, $Do = 3.0mg/l$ and temperature of 23°C enters a river where the flow $28m^3/$ sec, and BOD= $\frac{4.0mg}{l}$, $DO = 8.2mg/l$, and temperature of 17°C K_1 of the wast is 0.10per day at 20°C. The vel. Of water in the river downstream is 0.18m/s and depth of 1.2m. determine the following after mixing of waste water with the river water:

(i) Combined discharge;
(ii) BOD
(iii) DO; and
(iv) Temperature

Solution.

Particulars of Sewage thrown	Particulars of River
$Q_s = 560 l/s$	$Q_R - 28m^3/sec$
$= 0.56m^3/sec$	
Concentrations (C_S)	Concentrations (C_R)
BOD $= 50mg/l$	BOD$= 4.0mg/l$
DO $= 3.0mg/l$	$DO = 8.2mg/l$
Temp. 23°C	Tempt = 17°

K_1 at 20°= 0.1 per day

(i) Combined discharge

$Q_s + Q_R$

=0.56+28

$28.56m^3/sec.$

Now, using equation (8.1), for conc. Of mix as

$C = \frac{C_S \cdot Q_S + C_R \cdot Q_R}{0.56+Q_R}$, we have

(ii) BOD of mix

$\frac{50\times0.56+4.0\times28}{0.56+28}$

$= \frac{140}{28.56} = 4.9mg/l$. Ans.

(iii) DO of mix $= \frac{3.0\times0.56+8.2\times28}{0.56+28}$

$= 8.098mg/l$. Ans.

(iv) Temp. of mix $= \frac{23\times0.56+17\times28}{0.56+28}$

$= 17.12°C.$

Example 12. 125 cumecs of sewage of a city is discharged perennial river which is fully saturated with oxygen and flows and minimum rate of 1600 cumecs with a minimum velocity of 0.1m/sec. if the 5 day BOD of the sewage is 300mg/I, find out where the critical DO will occur in the river. Assume.

(i) The coefficient of purification of the river as 4.0,

(ii) The coefficient of DO as 0.11; and

(iii) The ultimate BOD as 125% of the 5 day BOD of the mixture sewage and river water.

Solution. Assume Saturation D.O. Concentration of the given river = 9.2

The D.O. of the river at the mixing point after disposal of sewage (D)

$= \frac{125\times0+1600\times9.2}{125+1600}$

$= 8.53mg/l$

Initial D.O. deficit $(D_o) = D_s - D$

$= 9.2 - 8.53$

=0.67mg/I

BOD₅ of the river at the mixing point after disposal of sewage (Y_5)

$= \frac{125\times300+1600\times0}{125+1600}$

=21.74mg/I

The ultimate BOD of river (mix) at mixing point (L)

125% BOD₅

[*as per given in assumption (iii)*]

1.25×21.74

$27.17mg/l$

Now, using eqn. (7.16), we have

$\text{BOD}_5 = L[1-(10)^{-K_D\times5}]$

or $21.74 = 27.17[1-(10)^{-K_D\times5}]$

or $0.8 = [1-(10)^{-5K_D}]$

or $(10)^{-5K_D} = 0.20$

or $-5K_D \log 10 = \log 0.20$

or $K_D = 0.14.$

The coefficient of DO or BOD (K_D) is given in assumption No. (ii) to be 0.11, as against its values of 0.14 computed above on the basis of assumption (iii). Eventually, there is some inconsistency in the given data, and the Examiner should have given only one of the two assumptions, i.e. either (ii) or (iii), which would have suffice the purpose. Under such a difficult situation, we may solve the question by both the values of K_D i.e. 0.11 as well as 0.14. The K_D value 0.14 will, however, give more D.O. deficit and will displace the point upstream; and will thus provide more conservative design values:

Case (1) : When $K_D = 0.11$. Using eqn. (8.8) as

$t_c = \frac{1}{K_D(f-1)} \log\left[\left\{1-(f-1)\frac{D_o}{L}\right\}f\right]$. We get

$t_c = \frac{1}{0.11(4-1)} \log\left[\left\{1-(4-1)\frac{0.67}{27.17}\right\}4\right]$. We get

$= 1.723 days.$

The distances along the river, where the critical D.O. deficit will occur

$= S = Velocity \times Time$

$= 0.12 m/sec \times (1.723 \times 24 \times 3600 sec)$

$= 17.86 km$; Say 18km

Hence, critical D.O. deficit will occur at 18km downstream of the wage disposal point. Ans.

Case (2) : When $K_D = 0.14$

$t_c = \frac{0.11}{0.14} \times 1.723 = 1.354 days$

$S = 17.86 \times \frac{1.354}{1.723} = 14.04 km$

Hence, critical D.O. deficit will occur at 14km downstream of sewage disposal point.

Example 13. A wastewater treatment plant disposes of its effluents into a stream at a point A. characteristics of the stream at a location farly upstream of A and of the effluent are as below:

Item	Units	Effluent	Stream
Flow	m^3/s	0.20	0.50
Dissolved oxygen	Mg/l	2.00	8.00
Temperature	°C	26	22
BOD_5 at 20°C	Mg/l	40	3

Assume that the deoxygenation content K_1 at 20°C (base e) = $0.20\ d^{-1}$ and the re-aeration constant K_2 at 20°C $(base\ e) = 0.40d - d^{-1}$ for the mixture. Equilibrium concentration of dissolved oxygen C_s for the fresh water is as follows:

Temperature °C	18	20	22	23	24	25	26
C, (mg/l)	9.54	9.17	8.99	8.83	8.53	8.38	8.22

The velocity of the atream downstream of the point A is 0.2m/s Determine the critical oxygen deficit and its locations.

[Use temperature coefficients of 1.04 for K_1 and 1.02 for K_2]

Solution. K_1 at 20°C(base e)

$= 0.2 d^{-1}$

$= 0.2$ per day

$\therefore K_D$ at $20°C$ (base 10)

$\frac{K_1}{2.3} = 0.434 K_1$

$= 0.434 \times 0.2$ *per daY*

$= 0.087$ *per day*

Similarly, K_R at 20°C

$= 0.434 \times 0.4 d^{-1}$

$= 0.174$ *per day*

The formulas to be used in this question for converting K_D and K_1 at any other temperature ($T°C$) will be

$K_D(T°) = K_D(20°)[1.04]^{T°-20°}$; and

$K_R(T°) = K_R(20°)[1.02]^{T°-20°}$

(as per the given values)

(i) We will now determine DO, BOD and temperature of mixture as below:

DO of mixture = $= \frac{D.O. of\ sewage \times Q_S . DO\ of\ river \times Q_R}{Q_S+Q_R}$

$$= \frac{2 \times 0.20 + 8 \times 0.50}{0.20 + 0.50}$$

$$= 6.29 mg/l$$

BOD_5 of mixture ($i.e. 5\ day\ BOD\ at\ 20^{\circ}C$)

$$= \frac{40 \times 0.20 + 3 \times 0.50}{0.20 + 0.50}$$

$$= 13.57 mg/l$$

Temperature of mixture

$$= \frac{26 \times 0.20 + 22 \times 0.50}{0.20 + 0.50}$$

$$= 23.14^{\circ}C$$

(ii) Ultimate BOD of mixture (L)

$$L = \frac{Y_5 (i.e. 5\ day\ BOD\ of\ mixture\ at\ 20^{\circ}C)}{1-(10)^{-K_D \times 5}}$$

Where K_D is at 20°C = 0.087 per day

$$= \frac{13.57}{1-(10)^{-0.087 \times 5}}$$

$$= \frac{13.57}{0.633} = 21.45 mg/l.$$

(iii) Initial D.O. Deficit of mixture,
D.O. of mixture = $6.29 mg/l$
Saturation D.O at mixture temperature of 23.14°C
$= 8.79 (interpolated\ from\ given\ values)$

$\therefore \quad D_o = D.O.$ deficit

$$= 8.79 - 6.29$$

$$= 2.50 mg/l$$

(iv) Corrected values of K_D and K_R are:
$K_{D(23.14^{\circ})} = K_{D(20^{\circ})}[1.04]^{T-20}$

$$= 0.087[1.04]^{3.14}$$
$$= 0.098$$
$$K_{R(23.14^{\circ})} = K_{R(20^{\circ})}[1.02]^{T-20}$$
$$= 0.174[1.02]^{3.14}$$
$$= 0.185$$

(v) The time (t_c) after which critical D.O. deficit (D_o) occurs is given by eqe. (8.8) as

$$t_c = \frac{1}{K_D(f-1)} \log 10 \left[\left\{ 1 - (f-1) \frac{D_o}{L} \right\} f \right]$$

Where $K_R = 0.185$

$K_D = 0.098$

$\therefore \quad f = \frac{K_R}{K_D}$

$$= \frac{0.185}{0.098} = 1.888$$

$L = 21.45 mg/l$

$D_o = 2.5 mg/l.$

$$\therefore \quad t_c = \frac{1}{0.098(1.888-1)} \log 10 \left[\left\{ 1 - \frac{0.888 \times 2.5}{21.45} \right\} 1.888 \right]$$

$$= \frac{1}{0.098(0.8888)} \times 0.228$$

$$= 2.625\ days.$$

(vi) Now, Distance = Velocity× Travel Time
$0.2 m/s \times (2.625 \times 24 \times 60 \times 60 sec)$
$= 45.36 km.$ Ans.

(vii) D_c is now giving by eqn. (8.11) as

$$\left(\frac{L}{D_c . f}\right)^{f-1} = f\left(1 - (f-1)\frac{D_o}{L}\right)$$

Or $\left(\frac{21.45}{D_c \times 1.888}\right)^{0.888} = 1.888\left(1 - \frac{0.888 \times 2.5}{21.4}\right)$

Or $\frac{21.45}{1.888 D_c} = (1.692)^{\frac{1}{0.888}}$

$= (1.692)^{1.126} = 1.808$

Or $D_c = \frac{21.45}{1.888 \times 1.808}$

$= 6.28 mg/l.$

Hence, the critical D.O. deficit equal to 6.28 mg//l occurs at 45.36 km downstream of A, after 2.625 day.

Example. 14 A sedimentation tank is treating 4.5 million litres of sewage per day containing 275 ppm of suspended solids. The tank removes 50% of suspended solids. Calculate the quantity of sludge produced per day

in bulk and weigth, if (a) moisture content of sludge is 98%; (b) moisture content of sludge is 96%.

Solution. Volume of sewage treated

= 4.5M-litres/day

Since suspended solids amounts to 275 mg/I, we have the mass of suspended solids present in sewage

$= \frac{275\times4.5}{10^6} \times 10^6 kg/day$

$= 1237.5 kg/day$

Since 50% of solids are removed in sedimentation tank, we have The mass of solids removed in sedimentation tank

$1237.5 \times \frac{50}{100}$

$= 618.75 kg/day$

(a) When moisture content of sludge is 98%, then 2 kg of solids (dry sludge) will make

$= 100kg$ of wet sludge

$618.75kg$ *of* solids (dry sludge) will make

$\frac{100}{2} \times 618.75$

$= 30937.5kg$

$= 30940kh(say)$

Hence, wet sludge or sludge produced per day

$= 30.940kg$

= 30.94tonnes. Ans.

Assuming the sp. gravity of wet sludge (sludge) as 1.02, we have Unit wt. of sludge $= 1.02 \times \frac{1t}{m^3} = 1.02t/m^3$

$[\because$ *Unit wt. of water* $= 1t/m^3]$

∴ Vol. of wet sludge produced per day

$= \frac{Wt.}{Unit\ wt} = \frac{30.94}{1.02} = 30.33m^3$

∴ Vol. of sludge (when its m.c. is 98%)

$= 30.33m^3$

Hence, the vol. of sludge when its m.c. is 98%

$= 30.33 cu.m.$ Ans.

(b) When moisture content is 96%, then 4 kg of solids will make

$= 100kg$ of wet sludge

$618.75kg$ of solids will make

$= \frac{100}{4} \times 618.75kg$ of wet sludge

$= 15468.75kg$ of wet sludge

$= 15,470kg(say)$ of wet sludge

$= 15.47$ *tonnes* of wet sludge.

Hence, wt. of sludge (when its m.c. is 96%)

$= 15.47 tonnes.$

If sp. gravity of siudge is 1.02, then

Vol. of sludge (when its m.c. is 96%)

$= \frac{15.47}{1.02} m^3$

$= 15.17m^3$

Hence, the vol. of sludge at 96% m. c.

= 15.17cu. m.

Note: If shown that the sludge is reduced to half its volume when its m. c. is lowered from 98% to 96%.

Example 15. A sedimentation take treats 6 mLd conitaining 250 mg.l of suspended solids. The tank removes 60% of the suspended solids. Compute the weight and volume of the sludge produced daily if the moisture content of sludge is (a) 97.5% (b) 95%.

Solution: weight of solids in sewage $= \frac{(6\times10^6)\times250}{10^6}$ $1500\ kg/day$

Since only 60% of the influent solids are removed, weight of solids removed in sedimentation tank = 0.6 × 1500 = 900 *kg/day*.

Hence W_s = 900 kg/days

Now volume of sludge is given by

$V_{sl} = \frac{W_s}{pw.Sd.Ps}$ .... (16.3)

Where p_w 1000 kg/m^3 and $S_{sl} = 1.02$,

(a) At moisture content (m) = 97.5

$P_s = 1 - 0.975 = 0.025$

$V_{sl} = \frac{900}{1000\times1.02\times0.025} \approx 35.3m^3$

Weight of sludge W_{sl} = Vol.× unit weight of sludge

$= 35.3(1.02 \times 1000) = 36000\ kg$

(b) At moisture content of 95%

$P_s = 1 - 0.975 = 0.05$

$V_{sl} = \frac{900}{1000\times1.02\times0.05} = 17.65m^3$

$W_{sl} = 17.65(1.02 \times 1000) = 18000$ kg

And above results show that the volume is reduced to half when its moisture content is lowered from 97.5% to 95%

Example 16 Determine the liquid volume before and after digestion and percentage reduction for 600 kg (dry basis) of primary sludge having the following characteristics.

		Primary	Digested
(i)	Solids(%)	6	12
(ii)	Volatile matter (%)	65	65(destroyed)
(iii)	Specific gravity of fixed Solids	2.5	2.5
(iv)	Specific gravity of Volatile solids	≈ 1.0	≈ 1.0

Solution:

(1)Computations of average specific gravity of all the solids in primary sludge

$$\frac{100}{S_s} = \frac{35}{2.5} + \frac{65}{1.0}$$

From which $s_s = 1.266$ (primary solids)

(2i)Computations of specific gravity of primary sludge(Eq.)

$$\frac{100}{S_{sl}} = \frac{6}{1.266} + \frac{94}{1}$$

From which $s_{sl} = 1.013$

(3)Computations of volume of primary sludge(Eq.)

$$V_{sl} = \frac{W_s}{pw.Sd.Ps} = \frac{600}{1000 \times 1.013 \times 0.06}$$

$$= 9.874\ m^3$$

(4)Computations of % volatile matter after digestion

Fixed matter in primary sludge $= 0.35 \times 600 = 210kg$

Volatile matter in primary sludge $= 0.65 \times 600 = 390\ kg$

Volatile matter after digestion

$= 0.35 \times 390(Since\ 65\%\ of\ 390\ kg\ has\ been\ destroyed\ in\ digestion)$

∴ Total matter after digestion= 210+0.35(390)

% Volatile matter $= \frac{0.35(390)}{210+0.35(390)} \times 100 = 39.39$

(5)Computations of average specific gravity of all the solids in disgusted sludge

$$\frac{100}{S_s} = \frac{60.61}{2.5} + \frac{39.39}{1}$$

From which $s_s = 1.571$ (digested solids)

(6)Computations of specific gravity of digested sludge(Eq.)

$$\frac{100}{S_{sl}} = \frac{12}{1.571} + \frac{88}{1}$$

From which $s_{sl} = 1.046$

(7)Computations of volume of digested sludge(Eq.)

$$V_{dsl} = \frac{W_{ds}}{pw.Sd.Ps}$$

Where $W_{ds} = 200 + 0.35(390) = 336.5$ kg

$$V_{dsl} = \frac{336.5}{1000 \times 1.046 \times 0.12}$$

$$= 2.681\ m^3$$

(8)Computations of sludge volume after digestion

$$\%reduction = \frac{9.874-2.681}{9.874} \times 600 = 72.85\%$$

CSVTU April-May 2012

UNIT – IV Part – A

Q.4 (a) Write the NRC formulae for efficiency of trickling filter. 2

Ans.: Refer Q-7 UNIT-3

Part – B

(b) Differentiate with neat sketches the difference is SRTF and HRTF. 7

Ans.: Refer Q-6 UNIT-3

(c) Write notes on : 7

(i) SVI & F/M Ratio (ii) Extended Aeration Process

Ans.: Refer UNIT-3

(d) With a neat sketch explain working, advantages and disadvantages of an oxidation ditch. 7

Ans.: Refer Q-20 UNIT-2

CSVTU Nov.- Dec 2011

UNIT-IV Part- A

Q.4 (a) (i) Main gases generated during anaerobic digestion of sewage sludge. 2

(1). CO_2 & CH_4 (2). CH_4 , H_2S

(3). CO_2 & H_2S (4). None

(ii). Correct relationship given is as : 2

(i) TOD > BOD > COD (ii) TOD > COD > BOD

(iii) COD> BOD > TOD (iv) BOD> COD > TOD

Part- B

(b) Write short notes on: 7

(i). Stream Standards & Effluent Standards.

(ii). Equalization & Proportioning

Ans.: Refer Q-25

(c) The sewage discharge of a town is 1.72 m^3/Sec if the sewage is discharged into a river, whose minimum discharge is 7240 lps. If the minimum DO to be maintained in the river is 4.4 mg/l, determine the degree of sewage treatment to be done. 7

Temperature of sewage and river = 20°c

$k_1 = 0.1$ $k_2 = 0.5$

$BOD_5(s) = 225$ mg/l $BOD_5(R) = 1.2$ mg/l

[at T = 20°c]

$DO_R = 80\%$ DO_{sat} DO_{sat} 20°c = 9.17 mg/l

Ans.: Refer Example-12

(d) Write short notes on : 7

(i). DO Sag Curve.

(ii). Zones of Pollution in a Stream,

(iii) TOC and ThOD

Ans.: Refer Q-24

CSVTU April-May 2011

Unit-IV

Q.4 (a) What is sewage sludge? 2

Ans.: Refer UNIT-1

(b) Discuss the effect of pH and temperature on sludge digestion. 7

Ans.: Refer Q-10

(c) Explain in brief various methods of final disposal of sludge. 7

Ans.: Refer Q-15

(d) The domestic sewage of a town is to be discharged into a stream after treatment. 7

Determine the maximum permissible effluent BOD and the percentage purification required in the treatment plant, given the following particulars:

(i) Population of town: 50,000

(ii) D.W.F. of sewage : 150 litres/capita/day

(iii) BOD contribution per capita : 0.075 kg/day

(iv) Minimum flow of stream : 0.20 m^3/s

(v) BOD of stream : 3 mg/L.

(vi) Max. BOD of stream on downstream : 5 mg/L.

Ans.: Refer Example-1

CSVTU Nov.- Dec 2010

Q.4 (a) What do you mean by stream standards? 2

(b) Discuss the anaerobic digestion of the sludge. 7

Ans.: Refer Q-2

(c) Effluent from a wastewater treatment plant is discharged to a surface stream. The characteristics of the effluent and the stream are as below: 7

Parameter	Effluent	Stream
Flow (m3/day)	240	8000
BOD5(mg/L)	25	1.1
Ammonia (mg/L)	7	0
Nitrate (mg/L)	10	2.0
Chloride (mg/L)	15	3.0

Determine the stream characteristics after mixing with the waste has occurred.

Ans.: Refer Example-9

(d) Describe the characteristics of waste generated from a distillery and also mention the treatment methodology to be adopted for such waste. 7

Ans.: Refer Q-27

CSVTU April-May 2010

Q.4 (a) Explain disposal by dilution in brief. 2
Ans.: Refer Q-16

(b) Differentiate between aerobic and anaerobic digestion. Explain the biological mechanism and its various stages for anaerobic digestion. 7
Ans.: Refer Q-2

(c) Discuss various standards applicable to wastewater treatment in brief. What are the general logic behind these standards? 7
Ans.: Refer Q-10

(d) Describe the characteristics of waste generated from a sugar factory and also mention the treatment methodology to be adopted for such waste. 7
Ans.: Refer Q-29

CSVTU Nov.- Dec 2009

Q.4 (a) what is self purification of a river? 2
Ans.: Refer Q-19

(b) Differentiate between aerobic and anaerobic digestion. Explain the biological mechanism and its various stages of anaerobic digestion 7
Ans.: Refer Q-2

(c) The rate of flow in river is 3 cum/sec and has a BOD_5 of 2 mg/L. The river is saturated with D.O Of 9.2 mg/L at 20°C. Wastewater having BOD_5 of 120 mg/L and D.O content zero with a flow of D, 30cum/sec discharged into river. Assuming temperature of 20°C throughout and deoxygenation coefficient as 0.1 day and reoxygenation coefficient of 0.3/day. Find out the degree of treatment required if the minimum DO to be maintained in the river is 4 mg/L. 7
Ans.: Refer Example-7

(d) Why there is need in adopt effluent standards for wastewater disposal in surface water bodies? Why these standards differ for disposal into a public sewer? What are stream standards? 7
Ans.: Refer Q-5&6

CSVTU April-May 2009

UNIT – IV

Q.4 (a) What do you understand by digestion of sludge? 2
Ans.: Refer Q-17

(b) Explain the factors affecting the sludge digestion.
Ans.: Refer Q-17

(c) The sewage discharge of town 1.72 cum/sec. If the sewage is discharged into river whose minimum discharge is 7240 litres/sec. If the minimum dissolved oxygen to be maintained in the river ip 4.4 mg/litre determine the degree of sewage treatment to be done with the following data.

(i) Temperature of sewage = temperature of river = 20°C
(ii) Value of K_1 = 0.1, and valume of K_2 =0.5
(iii) 5 days BOD at 20°C of river=225mg/L
(iv) 5 day BOD at 20°C of river =1.2mg/L
(v) Dissolved oxygen in sewage = Zero
(vi) Dissolved oxygen at saturation in river = 80%
(vii) Saturation D.O. at 20°C=9.17mg/L 7

Ans.: Refer Example-2

(d) Explain the characteristic of Industrial waste water. 7
Ans.: Refer Q-1

CSVTU Nov.- Dec 2008

UNIT – IV

Q.4 (a) What do you understand by digestion of sludge? 2
Ans.: Refer Q-17

(b) Explain the important factor which affects the process of sludge digestion. 7
Ans.: Refer Q-17

(c) A town discharges 80 cumecs of sewage into a stream having a rate of flow of 1200 cumecs during lean day at a 5 day BOD of sewage at given temperature is 250 mg/l. Find the amount of critical deficit and is location in down stream portion of stream. Assume de-oxygenation coefficient K as 0.1 and coefficient of self purification (f_s) as 3.5. Assume saturations DO at given temperature as 9.2 mg/l. 7
Ans.: Refer Example-4

(d) A sedimentation tank treat 6 MLD containing 250 mg/l of suspended solid. the tank removes 60% of the suspended solids. Compute the weight and volume of sludge produced daily it the moisture content of sludge is (i) 97.5% (ii) 95%. 7
Ans.: Refer Example-15

UNIT-V Solid Waste Management

Solid waste management, source and characteristics, environmental and health implications, refuse characteristics, collection methods, disposal of solid waste by land filling, composting and incineration methods. Collection and disposal of refuse, Composting of refuse.

INTRODUCTION:

Solid west, also known as dry refuse includes house refuse, trade refuse and street refuse, and is practically in a state. Removal and disposal of refuse or sold waste is a very important aspect of environmental satiation. Solid waste consists of (i) garbage (ii) ashes (iii) rubbish (iv) dust etc. Solid waste or dry refuse can be broadly divided into two heads: (1) Organic or combustible matter, and (2) inorganic or mineral or non-combustible matter.

(a) **House refuse** : This consists of vegetable and animal waste matters, ashes, cinders, rubbish, debris from cleaning and demolition of structures.

(b) **Street refuse**: This consists empty packets and bottles, emptily matches and cigarette boxes, fruit peels, tree leaves, street sweepings etc.

(c) **Trade refuse**: This consists of solid wastes from factories commercial and business centers, slaughter houses etc.

Garbage: This consists of all sorts of putrescible organic waste from kitchens, hotels, restaurants, in the form of waste food articles, vegetable and fruit peelings. It is organic in nature and decomposes quickly. It normally weighs from 450 to 900 kg/m^3. It should e handled carefully because files insects, rate etc. breed in it.

Ashes: Ashes are incombustible waste products from houses, industries, hearths and furnaces. With the introduction of kerosene oil and cooking gas, its quantity is now gradually decreasing. It weighs between 700 to 85 kg/m^3

Rubbish: It consists of all non-putrescible wastes, excluding aches. Common items that fall under this category are: rags, paper

Pieces, paper packets, glass and plastic bottles, bracken pieces of glass, broken crockery, broken furniture and stationary items, card boards. It thus includes a wide variety of combustible and non combustible wastes. It is lighter and its weight varies from 50 to 400 kg/m^3.

Organic waste : It includes dry animal and vegetable refuse, cow dung, excreta of birds, tree leaves, sticks, plastic bottles, paper waste, rags. This waste is subject to decay with time and evolve highly offensive odour and gases which are highly determine to health.

Inorganic waste: This consists of non-combustible materials such as grit, dust mud metal pieces, metal containers, broken glass and crockery, tiles waste building material. It is not subject to decay and is therefore not harmful to public health.

IMPORTANT TERMS AND DEFINITIONS

1 **Refuse:** Refuse is a general term used to indicate what is rejected of left out as worthless. It may be in liquid, semi-solid or solid from, and many be divided into six categories: (i) garbage (ii) rubbish (iii) sullage (iv) sewage (v) subsoil water and (vi) storm water.

2. **Garbage:** Garbage indicates dry refuse. It includes waste paper, decayed fruits and vegetables, grass and leaves, and sweepings from streets, markets and other public places. Thus, garbage contains large amounts of organic and putritying matter.

3. **Rubbish:** Rubbish indicates sundry solid wastes from offices, residences and other buildings. It also includes waste building materials, broken furniture, paper, rags etc. Generally, rubbish is dry and is of combustible nature.

4. **Sullage:** Sullage is a term used to indicate the wastewater from bath rooms, kitchens, washing places and wash basins etc. It does not create bad smell since organic matter in it is either absent or is of negligible amount.

5. **Sewage:** Sewage indicates the liquid waste from the community. It includes sullage, discharge form latrines, urinals, stables industrial waste and also the ground surface and storm water that may be admitted into the sewer. It is extremely putrescible; its decom-position produces large

quintiles of main odorous gases, and it may contain numerous pathogenic or disease producing bacteria.

6. **Sub-Soil water:** It is the ground water that finds it entry into sewers through leaks.

7. **Storm water:** It indicates the rain water of the locality.

8. **Sanitary sewage:** Sanitary sewage or domestic sewage indicates sewage mainly derived from the residential building and industrial establishments. It si extremely foul in nature. Sanitary sewage may be classified as (i) domestic sewage and (ii) industrial sewage.

9. **Domestic sewage:** It is the sewage obtained from the lavatory basins, urinals and water closets of residential buildings office buildings, theatres and other institutions. Since it contains human excreta and urine, it is extremely foul in nature.

10. **Industrial sewage:** It is wastewater obtained from the industrial and commercial establishments. It may contain object6ionalble organic compounds that may not be amenable to conventional treatment processes.

11. **Night soil:** It is term used to indicate the human and animal excreta.

12. **Sewer:** It is an under-ground conduit or drain through which sewage is carried to a point of discharge or disposal. Separate sewers are those which carry the house and industrial wastes only. Strom water drains are those which carry rain water from the.

Q.1 What is municipal solid wastes management? Define and explain.

Ans. Solid wastes management: - It involves management of activates associated with generation, storage, collection, transfer & transport, processing and disposal of solid wastes which is environmentally compatible considering principal of economy, aesthetics, energy & conservations.

Municipal Solid Wastes: - Municipal solid wastes includes wastes generated in residential & commercial areas, whereas wastes from industrial & agricultural operations are separately considered.

Functional elements of management:-

(a) Generation: - Wastes differ in the rate of generations, quantity & quality depending upon the area of generation.

This will affect selection of method for its collection, processing & disposal.

(b) Storage: - The generated waste is stored within the premises for the short period & then transfer to community storage bin or directly to the treatment or disposal site.

(c) Collection: - Waste produced from individual households is removed initially by the owner or an employee & later by municipal staff. Wastes from the streets are collected & removed by the conservancy staff.

(d) Transportations: - The material collected in community dustbins is transferred to transport vehicles for transport to the processing or disposal site. In big cities the material is conveyed to a transfer station from where another set of vehicles transport it further to the disposal site.

(e) Processing (Treatment) & recovery: - A large quantity of wastes has to be processed before suitable disposal to reduce its potential nuisance value. Occasionally recovery of useful constituents is also carried out as an independent process.

(f) Disposal: - The wastes may come for disposal either directly after its transpiration or after processing, disposal could be on land or water logged areas for reclamation.

Source and Characteristics

Q.2 Explain the characteristics of municipal solid invests.

April- May, 2012

CHARACTERISTICS OR MUNICIPLA SOLID WASTE:

Municipal waste is distinguished into municipal refuse and sewage sludge. The municipal refuse also called as the municipal garbage, is compose of discarded material by the people in the home and in industry. It is composed of paper plastics, food and paints. An average composition of municipal refuse is given in the table below,

Table Component of municipal refuse

SR. NO.	Component	%
1	Paper	58.5
2	Food Residue	09.2
3	Garden Refuse	10.1
4	Metals	07.5
5	Glass, Ceramics and Ash	08.5
6	Miscellaneous	05.9

Here the paper makes the largest amount of this refuse, whereas the plastic comprises only very few and is considered as a miscellaneous item. The composition of MSW of a developing country and of industrialized countries is different. Here the paper makes the largest amount of this refuse, whereas the plastic comprises only very few and is considered as a miscellaneous item. The composition of MSW of a developing country and of industrialized counties is different.

Physical Properties

The important physical properties of MSW include density (sometimes referred to as specific weight), moisture content, particle size and distribution, field capacity, and porosity. Although talking about MSW, it is important to note that the same fundamentals apply to all types of solid wastes.

This is the weight per unit volume and is expressed as kg/m^3. Density varies because of the large variety of waste constants, the degree of compaction, the state of decomposition, and in landfills because of the amount of daily cover and the total depth of waste. Inert wastes such as construction and demolition materials may have higher densities, and density can change as in landfills where the formation of landfill gas and decomposition may bring about significant mass loss. Density is important because it is needed to assess the total mass and volume of waste, which must be managed. Density varies not only because of the type of treatment it gets (collection vs compaction etc) but also because of geographic location, season, and length of time in storage.

Moisture Content

The most commonly used method of expressing moisture content is as a percentage of the wet weight of material. Moisture content is important in regards to density (as above), compaction, the role moisture plays in decomposition processes, the flushing of inorganic components, and the use of MSW in incinerators. Pre-treatment of waste to ensure uniform moisture content can be carried out prior to landifill disposal

Table Typical Moisture Content Of Wastes

Type of Waste	Moisture Content Range %	Moisture Content Typical %
RESIDENTIAL		
Food Wastes (mixed)	50-80	70
Paper	4-10	7
Plastics	1-4	1.5
Yard wastes	30-80	61
Glass	1-4	2
COMMERCIAL		
Food wastes	50-80	73
Rubbish (mixed)	10-25	14
CONSTRUCTION & DEMOLITION		
Mixed demolition combustible	4-15	8
Mixed construction combustible	4-15	8.5
INDUSTRIAL		
Chemical sludge (wet)	75-99	81
Saw dust	10-40	19
Wood (mixed)	30-60	36

Q.3 Write a brief note giving sources of generation and typical composition of municipal solid waste.

Ans. The quantity of municipal solid waste generated depends upon a member of factors such as food habit, standard of living degree of commercial and industrial activity. Municipal solid waste includes wastes generated in residential and commercial areas; whereas wastes from industrial and agricultural operations are separately considered.

Following are the sources of generation of solid waste:

1) **House refuse:** Waste produced from the houses are called as the house refuse. These consist of vegetable and animal waste, ash, cinders, rubbish, debris, etc.
2) **Street refuse:** These are the dry waste whose main source are street. These consist of empty packets and bottles, empty matches, cigarette boxes, fruit peels, tree leaves and so on.
3) **Trade refuse:** It consist of solid wastage form factories, commercial and business centre, slaughter houses and so on.
4) **Natural waste:** It consists of dust blown from unused land an roads, dead and decayed vegetation. It cannot be controlled as it originates from sources other th...

5) Demolition and construction waste: These are the solid wastage produced due to demolition and construction of structure. It includes piece of wood, concrete waste material, sand, dust and so on.

Composition of solid waste: The solid waste composition consist of the following ingredients.

(a) Garbage: Consist of putrescible organic wastage obtained from kitchen, hotels, restaurants etc. This includes all waste food articles, vegetable peeling etc. This wastage decomposes quickly, hence produces bad smell and health hazard.

(b) Ash: Consist of incombustible waste product from houses and industries. It weighs between 200 to 350 kg/m^3. Its quantity is getting reduced in modern days due to increase in use of cooking gas and kerosene oil and lesser use of cooking coal in houses.

Rubbish: It consist of all non-putrescible waste except ash. It includes all combustible and non-combustible wastage such as pieces of paper, broken pieces of glass, broken pieces of furniture, cardboard, stationary material, etc. Rubbish normally weighs between 50-400 kg/m^3.

Dust or silt: Theses are generally natural waste produced due to dust blown on unused land and roads.

Angular composition in % by weight at disposal site.

Constituent	Typical Indian city	Typical USA city
Garbage	35%	25%
Rubbish	15%	55%
Ashes	10%	10%
Dust sily, sand	20%	10%
Density (kg/m^3)	300-600	250-300
Calorific value (kilo-cal/kg)	1500-1800	3000

Physical characteristics of refuse for Indian cities shown in % age by net weight

Paper → (2.02−7.85)
Plastics → (0.33−0.88)
Metals → (0.20−1.22)
Glass → (0.20−0.96)
Ash and fire → (28.0−50.0)
Total compostable matter → (26.0−50.0)

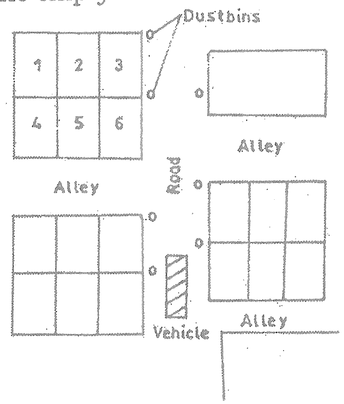
Q.4 Explain the methods of collection of solid wastes? **(April-May, 2010)**

Ans. Following are the various methods of solid waste collection:
1) House to house collection
2) Community bin system

3) Collection of wastes from steers.

1) House to House Collection: - In housed to house collection refuse generated & stored in individual premises is collected by several method. Some of which are indicated below.

(i) Curb Service: - The house owner is responsible for placing the refuse containers at the curb on the scheduled day, when the workmen from refuse vehicles collect & empty the containers in the vehicle & place them back at the curb. The house owner is required to take back the empty containers to his house.



(ii) Alley service: - The containers are placed at the alley line from where they are picked up by workmen from refuse vehicles who deposit back the empty container.

(iii) Set-out, Set-back services:- In this system, set-out men go to individual houses, collect the containers & empty them in the refuse vehicle. Another group of persons return them to house-owners yard.

(iv) Set-out Service: - Refuse vehicles collect the containers from individual houses & empty them in refuse vehicles. The house owner has to take the empty containers.

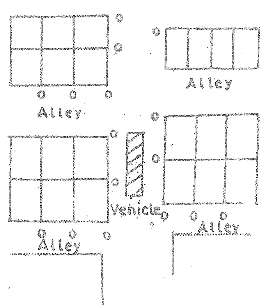


Fig. Alley service

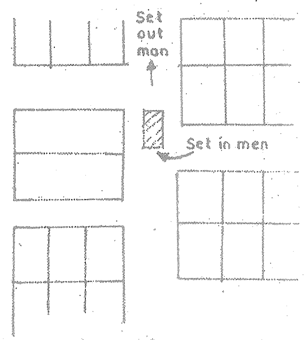
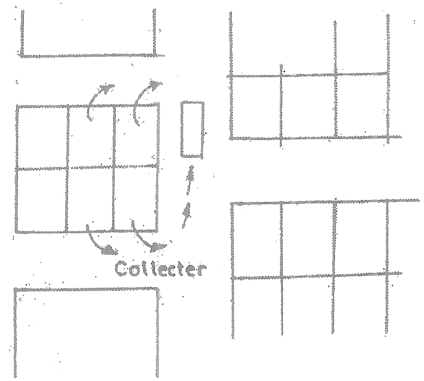


Fig. Set-out, Set-back service

(v) Backyard Service: - The workers with vehicle carry a bin, wheel barrow to the yard & empty the refuse container in it. The wheel barrow or bin is then taken to refuse vehicle where it is emptied.



2) Community Bin System: - In the community bin system, workers sweep the roads & collect the material at specific points. These points should be fixed considering the convenience of local citizens. The capacity of community bins should be at least 50% in excess when collection is daily & 100% in excess for 6 days a week collection.
the spacing of the containers has to be accordingly fixed which in no case should be more than 100m apart. Layer spacing encourages workers to avoid transporting wastes to the community bin & private sweepers start working in such cases.

Collection of wastes from streets: -

In addition to the wastes generated in individual premises, wastes are generated on streets also, the collection of which is the responsibility of civic authorities. In most of the developing countries, collection from streets is by manual labor while in developed countries mechanical equipment is used. In manual methods, the collection from the street is deposited in community storage bin from where separate vehicles collect for transport to processing or disposal site. In this operation minimum three persons should be required in one group. One should clean the footpath, the second to sweep the road & collect the material into heaps & the third person to transfer it to a wheel barrow.

Disposal of solid waste

Q.5 Explain the various method of treatment ad disposal of solid wastes. **(Nov-Dec, 2011)**

Ans. There are various method of treatment & disposal of solid wastes. They are as follows: -

(i) Sanitary landfill method
(ii) Composting
(iii) Incineration
(iv) Pyrolysis

(i) Sanitary Landfill Method: - It is a method of disposing of refuse on land without creating nuisance or hazards to public health or safer by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume & to cover it with a layer of earth at the conclusion of each days operation or at such more frequent intervals as may be necessary .

Sanitary land filling can be practiced for all types of site conditions. To suit the different site conditions, the basic process is modified in three distinct ways which are known as:

1) Trench method
2) Area method
3) Ramp method

1) Trench Method: - This method is best suited for flat land where excavation can be carried out easily and where the ground water table is sufficiently low. A trench 2m deep & 2-5m wide is cut. The length of the trench depends upon the site conditions, no. of trucks likely to arrive simultaneously & is such that it takes a day's refuse quantity. The excavated soil is placed on the sides of the trench and after the refuse has been put in layers are compacted & the trench is used to give the soil cover.

2) Area Method: - This method is best used in areas where natural depressions exist as in quarries, ravines & valleys. The waste is put in the natural depression & compacted. A layer of earth is given on top & compacted. The process is repeated till the depression is filled up. The earth cover has to be excavated from borrow pits at the site itself or imported from elsewhere.

3) Ramp Method: - This is a modified form of area and trench method and used in flat as well as gently rolling areas. A ramp about 15m wide, 30m long and of a suitable height is created. By using a bull clam or similar equipment, a shallow cut is taken at the foot of the ramp. A valley like trench is cut so that the tractors come to the top of the ramp and discharge the contents inside the trench.

Due to the size of the ramp, no of trucks are able to dump their contents simultaneously inside the trench. At the end of the operation, the refuse is compacted by the tractor which also pushes earth on it and compacts it. Thus it becomes a part of the ramp on the top of which vehicles can operate on the next day.

(ii) Composting: - In this method, the decomposable organic matter from refuse is converted into a stable form either aerobically or anaerobically. During aerobic decomposing, aerobic microorganisms oxidize organic compounds to CO_2, NO_2 & NO_3. Carbon from organic compounds is used as a source of energy while nitrogen is recycled. Due to the exothermic reaction, temperature of the mass rises. Anaerobic microorganisms while metabolizing nutrients, breakdown the organic compounds by a process of reduction. A very small amount of energy is released during the process & temperature of the composting mass does not rise much. The gases evolved are mainly CH_4 & CO_2.

The composting system can be broadly classified as

(i) Aerobic-Indore method (ii) Anaerobic – Bangalore method.

Indore Method: - In this method, a layer of coarse refuse is first put at the bottom of a pit to a depth of 15-25 cm which is 7.5cm deeper for a 25cm width at the pit edges.

Night soil is poured to a thickness of 5cm in the depressed portion and an elevated edge prevents its draining to the sides. On the top of this, a second layer of refuse is spread, which sand witches the night soil layer. Such alternate layer of refuse & night soil are repeated till it reaches ground level. Then this material is turned at specific intervals to maintain aerobic condition which will ensure high temp. uniform decomposition as well as absence of flies & odour. White filling with refuse & night soil, about 60cm on he longitudinal side of the pit is kept vacant for starting the turning operations. The first turning is manually carried out after 4-7 days using long handled rakes & the second turning after 5-10 more days. Further turning is not necessary & compositing will be complete in a period of 13-27 days.

Bangalore Method: - In this method, pit are filled similar to the above (as in Indore method) except that it is covered at the top by soil layer to avoid rain water entering the pit and to maintain anaerobic condition. It is allowed to decompose for 4-6 months after which the compost can be taken out for use.

(ii) Incineration Method: - In is defined as the controlled combustion process for burning solid, liquid & gaseous combustible wastes to gases & residue containing non-combustible material. During combustion, moisture is vaporized whereas the combustible portion is vaporized and oxidized. Carbon dioxide, water vapour, ash and non-combustible are the end products. About two third material is given out as gases & one third remains as ash. This method completely destroys all organisms but increases air pollutions.

Q.6 Give the advantages and disadvantages of solid waste disposal by land filling. (April-May,2011)

Ans. The advantages of the method are:

(i) It is simple and economical
(ii) No plant/equipment is required
(iii) Separation of various materials of the refuse is not required
(iv) there are no by-products
(v) The low lying areas can be reclaimed and put to better use by this method.

The disadvantages are: -

(i) Proper site may not be available nearby,
(ii) wind direction may not be be favorable
(iii) large land areas are required
(iv) It may be difficult to get large quantities of convering material and
(v) dumped garbage containing carcinogenic non-biodegradable matter (such as plastics, unused medicines, paints, insecticides, sanitary napkins etc.) may cause trouble later because of leach ate coming out of the dump during rainy season
(vi) leachate from the dumped garbage may pollute surface water as well as ground water.

Q.7 What are the points to be considered while selecting the site for sanitary land filling?

Ans. While selecting a site, following points need to be considered.

(1) Land requirement: The volume of fill required depends upon density, degree of compaction, depth of fill and life for which the site is to be used,. The volume required will change in different cases.

(2) Land use restriction: The town planning authorities should be consulted before selecting a particular site so that it is compatible with their plans.

(3) Approach: The site should be easily accessible for vehicles throughout the year. It is desirable that narrow bridges, steep grades and roads that are likely to be submerged during some periods are avoided.

(4) Haul distance: The site should be as near the area to be served as possible. Larger the haul distance to the site, larger will be the recurring transportation cost.

(5) Cover material: If the required soil cover is available at the site itself, no additional expenditure need be incurred on transporting it to the landfill site. A soil analysis along with the depth to which it is available is also necessary.

(6) Hydrogeological investigation: The rain water percolating through the solid waste tends to carry large amount of pollutants to the ground water if the underlying strata is previous or fissured. To avoid leakage contamination to ground water, an impermeable barrier in the from of a puddle clay blanket should be provided.

(7) Surface water pollution: Surface water during its flow over the deposited waste may carry along some pollutants. Water courses flowing across the site should be diverted and the surface water due to precipitation prevented from reaching the water course by an impermeable barrier.

Q.8 Explain the different method of composting of municipal solid waste. (April-May,2009)

Ans. COMPOSTING: - Composting is a method is which putrescible organic matter in the solid waste/refuse is digested anaerobically and converted into humus and stable mineral compounds. It is a hygienic method which coverts the refuse into manure through the bacterial agencies. Compost is widely used as a manure which is rich in nitrogen content. Due to composting, the volume of refuse is very much reduced, and the resulting matter can be safely handled since it becomes free from pathogenic organisms. In India normally, night soil of the conservancy system is also disposed of simultaneously along with refuse, producing valuable manure.

There are three methods of composting

(i) Composting by trenching
(ii) Open window composting
(iii) Mechanical Composting

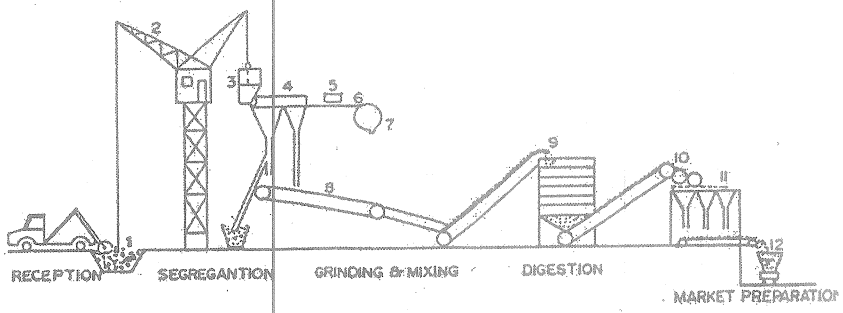
Composting by trenching: - In this method, trenches 4 to 10m long, 2 to 3m wide and 0.7 to1 m deep are excavated with a clear spacing of 2m. the trenches are then filled with refuses/garbage in layers of 15cm. On the top of each layer , 5cm thick sandwiching layer of night soil/animal dung is spread in semi-liquid form. On the top layer, protruding 0.3m above the original ground surface, a 10cm layer of goof carth so that flies do not get access to the refuse and at the same time, the refuse does not get blow off by wind. Within 2-3 days, intensive biological action starts to destroy/reduce organic matter present in the refuse. In this process, considerable heat is generated and the temperature of the composting mass rises to about 75°C. Due to this reason the breeding of files does not take place. The refuse gets stabilized in about 4-5 months period , and gets changed into a brown colored odorless innocuous powdery form known as humus, which has high manure value because of its nitrogen content. The stabilized mass is removed from the trenches, sieved through 12.5mm sieve to exclude coarse inert materials like stones, brick bats, broken stone etc. The sieved material is then sold out as a manure.

Open Window Composting: In this method, a large proportion of mineral matter like dust, stone, broken glass pieces etc. are first removed from the refuse. The refuse is then dumped on the ground in the form of 0.6 to 1 m high, 6m long and 1 to 2 m wide piles at about 60% moisture content. The pile is then covered with night soil, cow dung, cattle urine etc. through which the organisms or germs that are necessary for fermentation are added. Due to biological activity through aerobic bacteria, heat starts developing upto about 75°C in the refuse piles. Due to this the microbial reaction shifts from mesospheric to thermopiles stage. After this, the pile is turned up for cooling and aeration to avoid anaerobic reactions. The temperature of pile again raises to 75°C, and the process of turning, cooling and accretion is repeated. The complete process may take about 4-6 weeks, after which the compost is ready for use as manure when the temperature falls considerably.

Mechanical Composting: - The open window method of composting is very laborious and time consuming process. Also it requires large area of land which may not be available in big cities. These difficulties are overcome by adopting mechanical composting in which the process of stabilization is expedited by mechanical devices of turning the compost. The mechanical method stabilizes the refuse compost only within

3-6 days. The operations involved in a large scale composting plant, shown in Fig. 22.2 are as follows: (1) Reception of refuse, (2) Segregation (3) Shredding or pulverizing. (4) Stabilization, (5) Marketing the humus.

The refuse is received at the plant site in quantities of 2 to 6tonnes per vehicle. Hence the plant site must have a storage capacity of about 25 to 50% of total daily arrival, before it can be segregated and shredded/pulverized. Segregation is done by hand picking on smaller plants and by mechanical devices on large plants, to remove paper, rags, non-ferrous metals and large objects. Ferrous metals are removed by



1. RECEIVING PITS
2. CRANE
3. HOPPER
4. ROTARY/VIBRATING SCREENS
5. MAGNETIC SEPARATOR
6. SORTING BELT/TABLE
8. MIXING OF SLUDGE
9. WINDOW PITS
10. ROLLERS
11. SCREENS
12. MARKET PREPARATION OF FINE, INTERMEDIATE AND COARSE HUMUS

Fig. PROCESSING OF REFUSE BY MECHANICAL COMPOSTING

Magnetic separators. Finer material such as ash, particles of garage etc. are removed by the refuse. Over shaker-screens. The remaining refuse is then shredded and put varied mechanically.

The prepared refuse is then decomposed or stabilized under controlled conditions of temperature and moisture content. Mechanical digesters of various types such as (i) Pits or cells (ii) Windows or stacks and (iii) Vertical cylinder, horizontal cylinder, or silo type closed digesters. Closed digesters are most hygienic and occupy less space in the stores the refuse is digested and into humus and mineral compounds. The digestion period vary between 2 to 5 days for refuse containing low cellulose or low carbon-nitrogen (C/N) ratio, and 7-6 days for refuse having more quantities of cellulose or high (C/N) ratio. The stabilized brown mass

(humus) is collected, sieved and sold in packets. Sometimes the stabilized mass is enriched by adding chemical nutrients like phosphorous, nitrogen.

Q.9 State and explain the factors affecting composting process.

Ans. Factors affecting composting process are as fliowos.

(1)Organisms: Aerobic composting is a dynamic system in which bacteria, actinomycates, fungi and other biological forms are actively involved. It depends upon the constantly changing available food supply, temperature and substate conditions. In this process facultative and obligate aerobic form of bacteria, actinomycates and fungi are most active.

(2)Use of culture: When the environmental conditions are appropriate, indigenous bacteria, better adopted to municipal refuse than forms attenuated under laboratory conditions, rapidly and carry out necessary decompositions.

(3)Moisture: Moisture replaces air from the interspaces between particles. Too low a moisture content reduces the metabolic activity of organisms, whereas anaerobic conditions would set in if the moisture content is too high.

(4)Temperature: Temperature is one of the major factors which affect the composting process. In the temperature range of 50°C-60°C high nitrification and cellulose degradation occur and destruction of pathogens and parasites is also ensured.

(5)C/N ratio: The progress of decomposition in a composting mass is greatly influenced by C/N value. C/N ratio is the ratio of available carbon to available nitrogen. Optimum value of C/N ratio lies between 26 and 31.

(6)Addition of sewage and sewage slides: When initial C/N ratio is high, sewages sludge C/N of 5 to 8 is added to keep C/N ratio of mixture at optimum levels.

(7)Aeration: Aeration by natural process occurs in the superficial layers of the composting mass. While the inner layers tend to progressively turn anaerobic as the rate of oxygen replenishment cannot keep pace with utilization. Hence necessary to bring the inner layers in content with oxygen which is accomplished by aeration by turning the material or by supplying compressed air.

Q.10 Explain the varies method of computing adopted in India? (April- may 2011- Nov.-Dec.,2008)

Ans. Composting adopted in India: In India, there are two methods of mechanical composting:

(i) Indore method and (ii) Bangalore method

Indore method: - refuse, night soil and animal dung etc. are placed in small brick lined pits, 3m×3m×1m deep, in alternate layers of 7.5 to 10cm height, so as to make a total height of 1.5m. Chemicals (such as DDT etc.) are added to prevent fly breeding. The material is turned regularly for a period of about 8 to 12 weeks, and then stored on the ground for 4-6 weeks. In about 6-8 turnings and in aobut 4 months time, the compost becomes ready for use as manure.

Bangalore method: - the refuse is stabilized anaerobically. Earthen trenches of size $10\times1.5\times1.5m$ deep are filled up in alternate layers of refuse and night soil/cow dung. The material is covered with 15cm layer of good earth and left for decomposition. In about 4-5 months, the compost becomes ready for use.

Normally, a city produces 200 to 250 kg/capita/year of refuge and 8 to 10 kg/capita per year of night soil. Hence a town of 10,000 populations will produce about 2000 tubes of refuse and 800 tonnes of night soil annually. The composting will produce about 1400 to 1680 (50 to 60%) of compost annually from the above waste.

Q.11 Explain the Incineration procedure? Give it advantages. Disadvantages. (April-May,2009)

Ans. 6. Incineration: This consists of burning the refuse in the incinerator plant. This is commonly used in disposing of garbage from hospitals and industrial plants. Before incineration, non-com-beatable and inert material like earth, broken glass, chinaware, metal etc are separated, so as to reduce the load on the hearth. The by product of this land filling. The heat generated by burning the dry refuse may be utilized for raising steam power. The heat generated by burning the dry refuse may be utilized for raising steam power. The quantity and quality (moisture and calorific value) of refuse is, however, changing and hence the power generated will fluctuate. Emission of air pollutants from incinerations includes particulates such as flyash, unburnt fact and others. Permissible level of particulate emission from large incinerators is 0.23g per standard cubic metre of exhaust gas corrected to 12% CO_2. Smoke includes all liquid and solid matter in the exhaust that hinders visibility. Smoke can be eliminated by mixing the exhaust with hot air ot complete combustion, but smoke requires fairly high air temperatures.

The following points should be carefully observed during incineration:

1. The refuse charging should be thorough, rapid and as nearly continuous as possible.
2. Each batch of refuse entering should be well mixed.
3. Auxiliary burners are usually installed above the refuse to ignite it to establish the draft at the beginning of the cycle. This is all the more necessary when the moisture content of air is high.
4. Minimum temperature in the combustion chamber should be sufficient (>670°C) so that all the organic matter is incinerated and foul smelling gases are oxidized.
5. After burners are sometimes required together with particular, removal devices such as settling chambers or scrubbers.

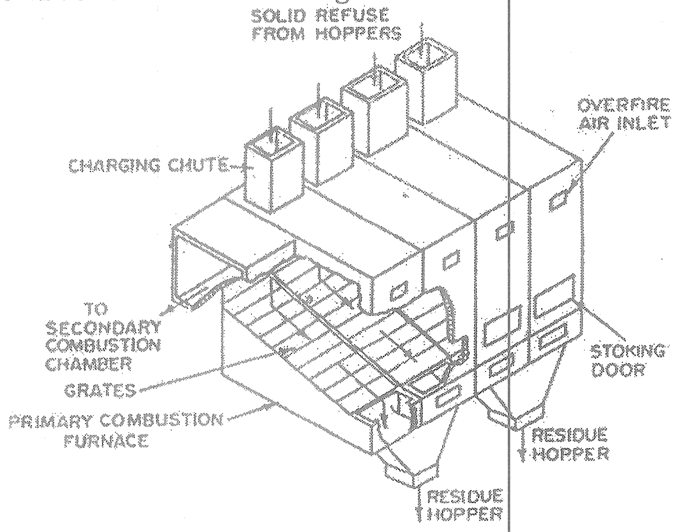


Fig. MULTICELL INCINERATION FURNACE.

Are multiple chamber units which release fluids as the material is being destroyed. These fluids do not evaporate quickly and, therefore solid hearth rather than grating is required.

Advantages of incineration:

(i) This is most hygienic method since it ensures complete destruction of pathogens
(ii) There is no of our trouble or dust nuisance
(iii) The heat generated can be used for raising steam power
(iv) Clinker produced can be used for road purposes
(v) The disposal site (i.e. incineration site) can be located at a convenient distance
(vi) Lesser space is required for disposal of residues
(vii) Modern incinerators can burn a great variety of refuse materials which are otherwise not biodegradable

(viii) Adverse weather conditions have no effect on the incinerator's operation.

Disadvantages:

(i) *Large initial expenditure*
(ii) Improper operation results in air pollution problems and incomplete reduction of the west materials
(iii) Disposal of the remaining residue is required
(iv) High stacks needed for natural draft chimneys present safety problems.

It should be clearly noted that municipal incineration of solid waste of refuse is a volume reduction process and not one of complete or ultimate disposal. Safe disposal of remaining residue is an essential requirement. Also, the plant need be operated properly so that the gases are completely burned and a stable residue is produced.

Q.12 Explain the transportation routes. How it is planned? (April- may 2012)

Ans. Presently in most of the cases, the routes of refuse vehicles are not properly designed but left to the vehicle operator or supervision to use his opinion. It is observed that out of total expenditure spent in solid wastes management, about 60-80% cost contributed to transportation of refuse itself. Therefore, if the routes of refuse vehicles are properly planned, the expenditure can be reduced & better service can be provided.

Following are the various method used for planning the refuse vehicle routes.

1) **Heuristic Methods: -** This is an old system of assigning the routes of refuse vehicles. The routes of refuse vehicles are determined on the basis of experience, and some simple rules. However, their efficiency depends upon the experience of the user. The macro routing is to be done first followed by route balancing & micro routing. In the macro routing, collection area are assigned to disposal facilities. A fair days work has to determined in terms of km to be travelled, trips made & tonnage to be hauled per day. Micro routing is then carried out by using heuristics. The factors to be considered in micro routing are:

i) Routes should not be fragmented or overlapped.
ii) Collection & transport time should be reasonably constant for each route so as to equalize the work load.
iii) The collection route should start as close to the garbage as possible taking into consideration heavily travelled routes.

iv) Routes having heavy traffic should be served before or after rush hours only.
v) Sources where large waste quantities are generated should be serviced during the first part of the day.
vi) Collection routes should be so arranged that the last bin, emptied is nearest to the disposal site in the route.

2) **Deterministic Methods: -** These methods use advanced mathematical techniques for obtaining the optimum route for refuse vehicles. This method is widely used in developed countries. In this method the various information regarding location of collection bins, quantity collected in each individual bin, processing and disposal sites should be made available. This method also consist of macro scale studies. Macroscale studies involves the study & planning the system in order to evaluate alternate solution to the entire solid wastes problems involving generations, collection, processing & economic planning of the whole system. For these cases specific models have also been prepared. The various models prepared for this purposes are:-

i) Models for uniform and continuous generation of solid waste along the street.
ii) Models for use of transfer stations.

Microscale studies are then carried out which consists of location and allotment of transfer stations to different processing & disposal sites. Preparing computer program for the various models & obtaining optimum routes for refuse vehicles.

3) **Modi Methods: -** The models so prepared in deterministic method are used in developed countries. But the models used in developed countries cannot be used directly in developing countries because the wastes collection along the street is not regular & continuous. The collection is not form house to house but from community bin. Also transfer stations are nearly used & refuse vehicles proceed directly to disposal site.

Therefore NEERI prepared a suitable model for India condition for deciding the vehicles routes, such a model prepared by NEERI are called Modified Distribution (MODI) method.

In this method, it is assumed that the cost of transportation is directly proportional to the route length. Hence optimization is carried out for the length of route. In this method it is also assumed that every community bin visited at least once in a day and the quantity collected in a route should be equal to the capacity of the vehicle. As the number of collection points & vehicles are quite large in cities and towns, the above method can be used by preparing a computer program which will help to reduce the requirement & give optimum results.

In this study, macro scale studies consist of study of location of community bin, quantity collected in each community bin, different processing and disposal sites etc. Micro scale studies is then carried out which consist of preparing computer program and obtain optimum routes for refuse vehicles.

Q.13 State the requirements of transportation vehicle & list the various types of transportation vehicles.

Ans. Requirements of transportations vehicles: -

Following are the various requirements of transportations vehicle

i) It should have low loading height which in any case should not exceed 1.5 meters.
ii) It should have a facility for taking portable/ exchangeable containers for house to house collection.
iii) It should have a covered body.
iv) It should have a tipping gear for quick unloading.
v) It should be reliable & economic in operation.
vi) It should have a sufficient carriage capacity.

Types of Transportation Vehicles: -

Following vehicles are used for transpiration of refuse to the disposla site.

i) **Animal Carts:** - Carts driven by bullocks. Buffaloes are used in small towns & cities. The capacity of bullock cart is about Im^3 and due to its slow speed, it tends to obstruct traffic on main roads.

ii) **Short Range Diesel Vehicles:** - As a substitute for bullock carts for short haul small capacity transport vehicles of a number of designs have recently been introduced. These are provided, with a small (5-7.5KP) diesel engine to carry 1-1.5tonnes of material with low lading height ($< 1.5m$).

iii) **Tractor Trailer:** - These are used in medium sized towns and cities. It has low initial cost & easy to operate. It consists of a trailer which hauled by a tractor. Sometimes two trailers can also be hauled by one tractor for economic operation

iv) **Three Wheeler Auto Rickshaws:** - Such type of vehicles with closed body are in use where the transportation distance is not very large. These vehicles can move in narrow lanes and bylanes. These are mostly petrol operated therefore the cost of transportation will be high.

v) **Electric Vehicles:** - These are in use in some developed countries & can operate over short radius of about 2km. The battery has to be charged overnight. These vehicles are

available in India only to a limited extent due to its high capital cost.

vi) **Dumper Placer:** - These unit are used for lifting of heavy materials specially demolition wastes. The vehicle is provided with winch mechanisms with the aid of which the bin is hoisted & placed on the body of the truck.

vii) **Container Carrier System:** - In this system, special types of containers are placed at the collection points. When it is full, the container are removed by a tractor prime-mover which has a hydraulically powered frame chasis. The chasis lifts the container & grips it firmly & transport it to the disposal site.

viii) **Special Municipal Vehicle:** - It consists of a truck provided with special hydraulic arrangement for lifting, placing as well as unloading 8-10 cum container on a truck chasis. The container has low loading height with a number of flaps which are kept open for loading refuse. The prim-mover lifts & locks the container on the body for transpiration to processing/ disposal site.

ix) **Trucks:** - Various types of trucks have been commonly in use in most of the cities in India for transportation of refuse. These truck make 2-4 trips per day covering about 20kms per tarp.

x) **Compaction Vehicles:** - In developed countries the compaction types of vehicles are in use which accept refuse having an initial density of 150-20kg/m^3 & compact it by nearly 2-4 times. Such vehicles are costly & hence will not be economically viable. These are either of the hydraulically operated pressure plate type of mechanically driven screw impeller type.

Q.14 Explain recycling and reuse of municipal solid waste.

Ans. Reuse: Waste using again without drastically changing the commodity.

Recycling: Conversion of waste into entirely new products for use.

Following are the different ways of recycling and reuse of solid water:

(1) **Biogas from solid waste:** - When solid waste with a large proportion of organic matter is subjected to anaerobic decomposition of gaseous mixture (CH_4 & CO_2) known as biogas could be produced under favorable conditions. The process is quite stable and upsets do not easily occur.

(2) Treatment for recovery of useful products: Refuse is a heterogeneous mixture which contains various ingredients, *some of which* have a large resale/ reuse potential. Refuse in developed countries contains glass and ferrous as well as non-ferrous metals in large proportion. The energy required and the pollution caused to obtain a product from virgin material is more than that required for obtaining it from secondary sources as from refuse. Before any reasonable components can be removed from refuse, size reduction in necessary to make it amendable for handling.

(3) Refuse derived fuel: As the solid waste form developed countries contains a large paper fraction, it was felt that it could be used as a good fuel. In the plant, the incoming refuse is first subjected to size reduction after which the magnetic metals are removed by a magnetic separation. The remaining material is then passed through a vertical flow air separator where paper is removed. The material is further subjected to size reduction and burnt in a boiler of 125MW plant. The suspension fired boilers are provided with clusters of 5 jet, 4 out of which use coal and the fifth uses refuse derived fuel (RDF).

Q.15 Deice about the health implications of ill managed municipal solid waste.

1. The management of municipal solid waste is becoming a major public health and environmental concern in urban areas of many developing countries.
2. The improper management of solid wastes represents a source of environmental pollution, and poses risks to human health.
3. Municipal waste in most cities contain human excreta, animal excreta, hazardous chemical pollutants and sharps which can facilitate the spread of disease and injury particularly among children playing near waste dumpsites and employees in waste management sector.
4. Poor disposal of solid waste is associated with spread of vector borne-diseases like malaria and dengue fever.
5. Infrequently disposed refuse tend to become breeding sites for mosquitoes, as pools of rain water collect in discarded cans, bottles and car tires.
6. Mosquitoes are responsible for the transmission of malaria-a life threatening disease through their bites.
7. Malaria accounts for an estimated 300-500 million cases globally; which is an endemic disease in sub-Saharan Africa.
8. It account for about 1.5-2.5 million deaths yearly, most of them among children under five years. Decomposing organic materials can become breeding sites for pests, rats, flies and

vermin that enhance the likelihood of disease transmission like diarrhea and Lassa fever.

9. Lassa fever is a hemorrhagic fever common in four African countries: Guinea, Liberia, Nigeria and Sierra Leone. It is transmitted to humans from contacts with food or household items contaminated with rodent excreta.
10. Uncollected waste left to accumulate or dumped in the streets can block water drains and channels which can cause flooding, posing significant environmental and public health risks.
11. Ground or surface water pollution can occur when rain water combines with decomposing waste and seep through permeable soil, finally contaminating surface and ground water with both lethal materials and pathogenic organisms; this is extremely dangerous as ground water is the main source of drinking water for most cities in the developing world.
12. Incineration of municipal solid waste contributes to air pollution by the release of noxious materials into the air, which may cause ill-health.
13. Uncontrolled incineration of solid waste can also cause fire outbreaks in nearby homes and farms. Other impacts of poor Municipal Solid Waste disposal include disgusting odour, unsightliness and general degradation of the environment

CSVTU April-May 2012

Q.5 (a) Differentiate between "Garbage" and "Refuse". 2

Ans.: Refer INTRODUCTION

Part – B

(b) Explain the different methods of composting of municipal solid wastes. 7

Ans.: Refer Q-8

(c) Explain the characteristics of Municipal solid Wastes. 7

(d) Explain the transportation techniques adopted in solid waste management. 7

Ans.: Refer Q-12

CSVTU Nov.- Dec 2011

UNIT-V Part- A

Q.5 (a) Solids present in sewage are mainly in the form of: 2

(i). Settled Solids (ii). Dissolved Solids
(iii). Suspended Solids (iv). Colloidal Solids

Part- B

(b) Describe the methods of disposal of solid waste 7

Ans.: Refer Q-5

(c) Detail the methods of collection and conveyance method of solid waste 7

Ans.: Refer Q-4&12

(d) Describe the Indore method and the Bangalore Method of composting techniques. 7

Ans.: Refer Q-5

CSVTU April-May 2011

Q.5 (a) Explain the term composting 2

Ans.: Refer Q-5

(b) Define solid waste. Write a brief note on solid work management and explain what is the 3-R strategy for waste management? 7

Ans.: Refer Q-1

(c) Give the advantages and disadvantages of solid waste disposal by land filling. 7

Ans.: Refer Q-6

Environmental Engineering-II

(d) Discuss the methods being adopted in India for collection and disposal of refuse. 7

Ans.: Refer Q-4 & 5

CSVTU Nov.- Dec 2010

Q.5 (a) Give an idea about the per capita solid waste generated in Indian cities. 2

Ans.: Refer Q-2

(b) Describe about the health implications of ill managed municipal solid waste. 7

Ans.: Refer Q-15

(c) Give details about the average composition of municipal solid waste of an Indian city. 7

Ans.: Refer Q-2

CSVTU April-May 2010

Q.5 (a) Give a general idea about the per capita per day quantity of solid waste generated in India and same western countries. 2

Ans.: Refer Q-2

(b) Explain the term 'refuse' and give its composition and classification 7

Ans.: Refer INTRODUCTION

(c) Discuss in detail the health hazard of ill managed municipal solid waste of a city. 7

Ans.: Refer Q-15

(d) Describe briefly the various methods employed for the collection and disposal of the refuse.

Ans.: Refer Q-4 & 5

CSVTU Nov.- Dec 2009

Q.5 (a) What is garbage? 2

Ans.: Refer INTRODUCTION

(b) Explain the term 'refuse' and give its composition and classification. Describe briefly the various method employed for the collection of the refuse. 7

Ans.: Refer INTRODUCTION & Q-4

(c) Describe the various methods used for the ultimate disposal of the refuse. 7

Ans.: Refer Q-5

(d) Discuss the health hazard of ill managed municipal solid waste of a city. 7

Ans.: Refer Q-15

CSVTU April-May 2009

UNIT – V

Q.5 (a) Define refuse: 2

Ans.: Refer INTRODUCTION

(b) Explain the term "composting". Give the different type of composting in use, and describe any one with the aid of sketch. 7

Ans.: Refer Q-8

(c) What are different methods of disposal of solid refuse? Which one must popular in India? Explain the process in detail. 7

Ans.: Refer Q-5

(d) Write a short note on incineration of refuse. What are its advantages and disadvantages ? 7

Ans.: Refer Q-11

CSVTU Nov.- Dec 2008

UNIT – V

Q.5 (a) Explain the term refuse. 2

Ans.: Refer INTRODUCTION

(b) Describe briefly the various methods employed for collection and disposal of refuse. 7

Ans.: Refer Q-4 & 5

(c) Describe briefly method of computing adopted in India. 7

Ans.: Refer Q-10

(d) Describe briefly method of refuse despond by sanitary land filling? 7

Ans.: Refer Q-7