SECTION – B [

8 x 5=40]

Q.2-a) Design a circular sewer and hence the equivalent egg-shaped sewer, so as to cater a residential colony in town, having the following data: i) Area of the colony=36 hectares ii) Population=8,000 iii) Water Consumption=170lpcd iv) Peak storm run-off = 2.2 cumecs

Example 4.15. (*a*) *Design a circular sewer so as to cater to a residential colony in town, having the following data :*

Area of the colony	*= 36 hectares*
Population	*= 8,000*
Per capita water consumption	*= 170 lphd*
Critical design rainfall intensity	*= 4 cm / hr.*
General available ground slope	*= 1 in 900*

Assume any other data, not given, and if needed.

(*b*) *What will be the dimensions of an equivalent egg shaped sewer if adopted in this case.*

Solution. *Sewage Discharge computations*

Average quantity of water consumed per day

$= 170 \times 8000$ litres/day.

Average quantity of water consumed in cumecs

$$= \frac{170 \times 8000}{1000 \times 24 \times 60 \times 60} \text{ cumecs} = 0.0157 \text{ cumecs.}$$

Assuming that 80% of water consumed appears as sewage, we have

Average quantity of sewage discharge

$= 0.8 \times 0.0157$ cumecs $= 0.0126$ cumecs.

Assuming the peak sewage discharge to be three times the average discharge, we have

Maximum rate of sewage produced

$= 3 \times 0.0126$ cumecs $=$ **0.038 cumecs.**

Storm run-off computations

Assuming the coefficient of run-off (K) for the area as 0.55, we have, by using Rational formula,

Peak storm run-off

$$Q_p = \frac{1}{36} K p_c . A$$

$$= \frac{1}{36} \times 0.55 \times 4 \times 36 \text{ cumecs} = 2.2 \text{ cumecs.}$$

Combined Maximum discharge

$= 2.2 + 0.038 =$ **2.238 cumecs**

Now, assuming that the sewer while carrying this combined peak discharge possesses 10% extra capacity, we have

The design discharge which the sewer should carry while flowing full

$$= \frac{2.238}{0.9} \text{ cumecs} = \textbf{2.49 cumecs}$$

Now, using Manning's formula, we have

$$Q = \frac{1}{N} . A . R^{2/3} \sqrt{S}$$

Using the same gradient as is available, *i.e.* $\frac{1}{900}$ as the first proposition, and Manning's $N = 0.013$ for smooth concrete or vitrified clay sewer, we have

$$2.49 = \frac{1}{0.013}\left(\frac{\pi D^2}{4}\right)\left(\frac{D}{4}\right)^{2/3} \cdot \frac{1}{\sqrt{900}}$$

where D is the dia of the equivalent circular section.

$$\therefore \quad D^{8/3} = \frac{2.49 \times 0.013 \times 4 \times 2.52 \times 30}{\pi}$$

or $\quad D^{8/3} = 3.12$

or $\quad D = (3.12)^{\frac{3}{8} = 0.375} = 1.533$ m ; say 1.54 m.

Now, velocity generated

$$= \frac{Q}{A} = \frac{2.49}{\frac{\pi}{4} \cdot (1.54)^2} = 1.33 \text{ m/sec.}$$

This is satisfactory.

Note. The velocity can be increased further by steepening the slope and changing the size of the sewer accordingly. This will no doubt increase the ground excavations but will make the sewer more efficient at low flows, as the presently designed sewer may give very low velocities at low flows during non-monsoon seasons.

Check for lone sewage discharge

When maximum sewage is passing (once a day) in non-monsoon periods, the $\frac{q}{Q}$ will be equal to $\frac{0.038}{2.49} = 0.0152$. For this ratio of $\frac{q}{Q} = 0.0152$, from Fig. 4.3, we have

$$\frac{v}{V} = 0.3.$$

or $\quad v = 0.3 \times 1.35$

$= 0.4$ m/sec. (which is just sufficient for non-silting)

Hence, in this sewer, deposition will take place during average and minimum lone sewage flow. The efficiency can be further increased by providing a steeper gradient, or by providing egg shaped section, which provide comparatively larger proportionate velocities at low depths.

(b) Equivalent egg-shaped sewer

Now $\quad D = 1.54$ m

If D' is the width of the standard equivalent egg shaped sewer, then by Eq. (4.28), we have

$D' = 0.84\, D$

or $\quad D' = 0.84 \times 1.54$

$= 1.295$ m

Say 1.3 m

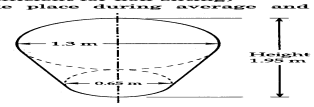

Fig. 4.9

HYDRAULIC DESIGNS OF SEWERS AND S.W. DRAIN SECTIONS 75

Using the same gradient as is available, *i.e.* $\frac{1}{900}$ as the first proposition, and Manning's $N = 0.013$ for smooth concrete or vitrified clay sewer, we have

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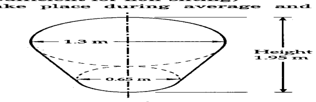

Fig. 4.9

Q.2-b) i) Self Purification of River :

(5)
5.0 mg/l
5.0 mg/l
5.0 mg/l
0.2 mg/l
0.01 mg/l
2.0 mg/l
2.0 mg/l
1.0 mg/l
2.0 mg/l
3.0 mg/l
15 mg/l
0.05 mg/l
5.0 mg/l
0.2 mg/l
15 mg/l
—
icrocurie/ml icrocurie/ml
rvival of fish 6 hrs in 100% t
2 mg/l
3 mg/l
.2 mg/l
0 mg/l

(1)	(2)	(3)	(4)	(5)
34.	Pesticides			
	(*i*) Benzene hexachloride	10 μg/l	—	10 mg/l
	(*ii*) Carboxyl	10 μg/l	—	10 μg/l
	(*iii*) DDT	10 μg/l	—	10 μg/l
	(*iv*) Endosulfan	10 μg/l	—	10 μg/l
	(*v*) Diamethoate	450 μg/l	—	450 μg/l
	(*vi*) Penitrothion	10 μg/l	—	10 μg/l
	(*vii*) Malathion	10 μg/l	—	10 μg/l
	(*viii*) Phorate	10 μg/l	—	10 μg/l
	(*ix*) Methyl parathion	10 μg/l	—	10 μg/l
	(*x*) Phenthoate	10 μg/l	—	10 μg/l
	(*xi*) Pyrethrums	10 μg/l	—	10 μg/l
	(*xii*) Copper oxychloride	9600 μg/l	—	9600 μg/l
	(*xiii*) Copper sulphate	50 μg/l	—	50 μg/l
	(*xiv*) Ziram	1000 μg/l	—	1000 μg/l
	(*xv*) Sulphur	30 μg/l	—	30 μg/l
	(*xvi*) Paraouat	2300 μg/l	—	2300 μg/l
	(*xvii*) Proponil	7300 μg/l	—	7300 μg/l
	(*xviii*) Nitrogen	780 μg/l	—	780 μg/l

8.3. Dilution in Rivers and Self Purification of Natural Streams

When sewage is discharged into a natural body of water, the receiving water gets polluted due to waste products, present in sewage effluents. But the conditions do not remain so for ever, because the natural forces of purification, such as *dilution*, *sedimentation*, *oxidation-reduction in sunlight*, etc., go on acting upon the pollution elements, and bring back the water into its original condition. This automatic purification of polluted water, in due course, is called the *self-purification phenomenon*. However, if the self-purification is not achieved successfully either due to too much of pollution discharged into it or due to other causes, the river water itself will get polluted, which, in turn, may also pollute the sea where the river outfalls.

The various natural forces of purification which help in effecting self-purification process are summarised below :

1. Physical forces are :
   (*i*) *Dilution and dispersion,*
   (*ii*) *Sedimentation,* and
   (*iii*) *Sunlight (acting through bio-chemical reactions).*
2. Chemical forces aided by biological forces (called bio-chemical forces) are :
   (*iv*) *Oxidation (Bio),*
   (*v*) *Reduction.*

These forces are described below :

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n, etc.
temperature
are enhanced
The dissolved
g aquatic life
position and
so influenced
tain the D.O.
activities are
d to anaerobic
r is heavy.

The turbulence in the body of water helps in breaking the surface of the stream or lake, and helps in rapid re-aeration from the atmosphere. Thus, it helps in maintaining aerobic conditions in the river stream, and in keeping it clean/ Too much of turbulence, however, is not desirable, because it scours the bottom sediment, increases the turbidity, and retards algae growth, which is useful in reaeration process. Wind and undercurrents in lakes and oceans cause turbulences which affect their self-purification.

The Hydrography affects the velocity and surface expanse of the river stream. High velocities cause turbulence and rapid reaeration, while large surface expanse (for the same cubic contents) will also have the same effects.

The larger the *amount of dissolved oxygen* present in water, the better and earlier the self-purification will occur.

The *amount and the type of organic matter and biological growth* present in water will also affect the rate of self-purification. Algae which absorbs carbon dioxide and gives out oxygen, is thus, very helpful in the self-purification process.

The *rate of reaeration i.e.* the rate at which the D.O. deficiency is replenished, will considerably govern the self-purification process. The greater is this rate, the quicker will be the self-purification, and there will be no chances of development of anaerobic conditions.

8.3.1. Zones of Pollution in a River-Stream. A polluted stream undergoing self-purification can be divided into the following four zones :

(*i*) *Zone of degradation* ;
(*ii*) *Zone of active decomposition* ;
(*iii*) *Zone of recovery* ; and
(*iv*) *Zone of cleaner* water.

These zones are discussed below :

(*i*) **Zone of degradation or Zone of pollution.** This zone is found for a certain length just below the point where sewage is discharged into the river-stream. This zone is characterised by water becoming dark and turbid with formation of sludge deposits at the bottom. D.O. is reduced to about 40% of the saturation value*. There is an increase in carbon dioxide content; reoxygenation (*i.e.* re-aeration) occurs but is slower than de-oxygenation.

These conditions are unfavourable to the development of aquatic life ; and as such, algae dies out, but fish life may be present feeding on fresh organic matter. Moreover, certain typical bottom worms such as *Limondrilus* and *Tubifex* appear with *sewage fungi*, such as *sphaerotilusnatans*.

(*ii*) **Zone of active decomposition.** This zone is marked by heavy pollution. It is characterised by water becoming greyish and darker than in the previous zone. D.O. concentration falls down to zero, and anaerobic conditions may set in with the evolution of gases like methane, carbon dioxide, hydrogen sulphide, etc., bubbling to the surface, with masses of sludge forming an ugly scum layer at the surface. As the organic decomposition slackens due to stabilisation of organic matter, the re-aeration sets in and D.O. again rises to the original level (*i.e.* about 40%).

*Saturation value at 30°C = 7.63 mg/l. (Pl. see Appendix Tables A-3 given at the end of the book).

In this zone, bacteria flora will flourish. At the upper end, anaerobic bacteria will replace aerobic bacteria ; while at its lower end, the position will be reversed. Protozoa and fungi will first disappear and then reappear. Fish life will be absent. Algae and Tubifex will also mostly be absent. Larvae of *maggots* and *psychoda* (sewage fly) will, however, be present in all but the most septic sewage.

(*iii*) **Zone of recovery.** In this zone, the river stream tries to recover from its degraded condition to its former appearance. The water becomes clearer, and so the algae reappears while fungi decreases. B.O.D. falls down and D.O. content rises above 40% of the saturation value ; *protozoa, rotifers, crustaceans* and *large plants like sponges, bryozons*, etc. also reappear. Bottom organisms will include : tubifex, mussels, snails, etc. The organic material will be mineralised to form nitrates, sulphates, phosphates, carbonates, etc.

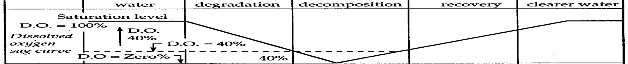
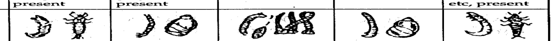
	← Zones of pollution →				
	Clear water	Zone of degradation	Zone of active decomposition	Zone of recovery	Zone of clearer water
Dissolved oxygen sag curve					
Physical Indices	Clear water, no bottom sludge, no colour	Floating solids; bottom sludge present, colour getting turbid	Darker and greyish colour, evolution of gases like CH_4, CO_2 H_2S, etc. A lot of sludge coming to the surface forming an ugly scum layer at top	Turbid with bottom sludge	Clear water with no bottom sludge
Fish presence	Ordinary fish like game, pan, food & forage etc. present	Tolerant fishes like carp, buffalo, gary, etc. present	No fish present	Tolerant fish like carp, buff alo, etc. are present	Ordinary fish like game, pan, food, and forage, etc, present
Bottom Animals					
Algae & Protozoa etc. called plankton					

Fig. 8.1. Showing Zones of Pollution along a River stream.

(*iv*) **Zone of**
conditions **with**
attractive in **app**
D.O.) and **usual**
however, **surviv**
a river water **h**
properly **treated**
8.3.2. Indices
can be **determin**
water. Colour
suspended **solid**
purification. **M**
indicate the **stag**
organisms will
in the previous
The different
process) and **the**
each zone, are **sh**
8.3.3. The Oxyg
D at any time **in**
D.O. content of
water **temperatu**

[**Oxy**

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must be nil, **and**
and **re-oxygenati**
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per Eq. (7.12).
Re-oxygenati
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the atmosphere
(*i*) the **depth**
(*ii*) the **conditi**
in a **quiesc**

*It means the
with oxygen. The
7.6 mg/l for **temper**

Q.2-b) ii) Street inlets :

Answer:

5.9. Clean-Outs

A clean-out is an inclined pipe extending from the ground and connected to the under-ground sewer, as shown in Fig. 5.22. A cleanout is used for cleaning sewer pipes.

A clean-out is generally provided at the upper ends of lateral sewers in place of manholes.

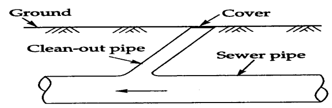

Fig. 5.22. Clean-out.

The functioning of a clean-out is very simple, and consists in removing the top cover and forcing water through the clean-out pipe to lateral sewers to remove obstacles in the sewer line. If obstructions are large enough, a flexible rod may be inserted through the clean-out pipe and pushed forward and backward to remove such obstacles.

5.10. Street Inlets, called Gullies

Inlets are gullies or openings on the road surface at the lowest point for draining rain water from roads, and admitting it into the underground storm water sewers (drains) or combined sewers.

These inlets are, therefore, located along road sides on straight roads at an interval of 30 m to 60 m or so. At intersection points, they are usually located, as shown in Fig. 5.23. In this figure, the slope of the streets is shown by the arrows, and the inlets are placed in such a way that the cross walks will not be flooded. Placing of inlets at the corners not only requires the pedestrians to step across flooded gutters, but also subjects the inlets to considerable traffic wear and damage.

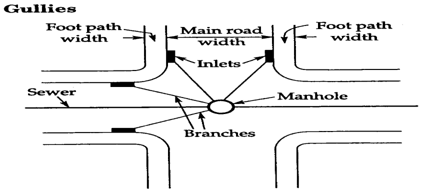

Fig. 5.23. Showing the locations of storm sewer inlets at street intersections. [*Note.* Branch lines enter at manholes. The arrows show the direction of storm runoff in the streets.]

The inlets are connected to the nearby manholes by pipe lines (**branches**) as shown in Fig. 5.23.

A street inlet is a simple concrete box having gratings or openings in vertical or horizontal direction. The inlet having vertical openings is known as *the vertical inlet or the curb inlet*, and the inlet having horizontal openings is known as the *horizontal inlet*. The typical details of both these types of inlets are shown in Fig. 5.24 and 5.25.

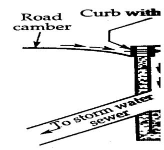

Fig. 5.24. Verti

5.11. Catch I Catch Pi

Catch basins
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settling basins,
Fig. 5.26.
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these basins,
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this, a hood,
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5.12. Flushin

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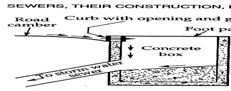


Fig. 5.24. Vertical inlet or curb inlet.

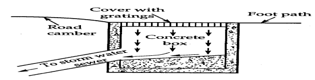


Fig. 5.25. Horizontal inlet.

5.11. Catch Basins or Catch Pits

Catch basins are nothing but street inlets provided with additional small settling basins, as shown in Fig. 5.26. Grit, sand, debris, etc., do settle in these basins, and their entry into the sewer is thus prevented. In addition to this, a hood, as shown, is also provided, which prevents the escape of foul gases, which may find its way through the sewer line.

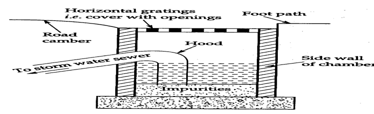


Fig. 5.26. Catch basins or catch pits.

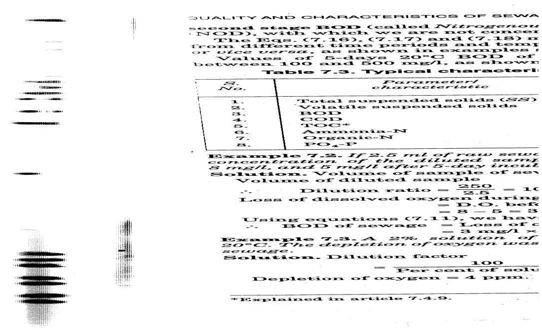
Catch basins need periodical cleaning, as otherwise, the settled organic matter may decompose, producing foul odours, and may also become a breeding place for mosquitoes.

Catch basins were considered necessary in old combined sewerage systems, but, however, in modern days, they are *not* considered as very essential, because the modern well paved streets offer very less grit and debris with storm run off, and the same can be conveyed easily in storm water sewers (drains) laid at suitable gradients to provide self cleansing velocities. Moreover, the problem of eruption of foul gases from S.W. sewers (drains) is very less ; and as such, there is not much necessity of providing such basins in the modern separate sewerage systems.

5.12. Flushing Tanks

Wherever, there are any chances of blockage of sewer pipes, such as in the case of sewers laid on flat gradients not producing self cleansing velocities, or near the dead end points of sewers, flushing devices are installed. These devices store water temporarily, and throw it into the sewer for the purpose of flushing and cleaning the sewer. Such devices are called flushing tanks.

Q.3-a) i) If 2.5 ml of raw sewage has been diluted to 250 ml and the D.O. concentration of the diluted sample at the beginning of the BOD test was 8mg/l and 5mg/l after 5 days of incubation at 20°C; find BOD of raw sewage.



QUALITY AND CHARACTERISTICS OF SEWA

second stage BOD (called *Nitrogenou* (NOD), with which we are not concer
The Eqs. (7.16), (7.17) and (7.18) m
from different time periods and temp
or *vice versa*, as shown in examples
Values of 5-days 20°C BOD of
between 100 and 500 mg/l, as shown

Table 7.3. Typical characteri

S. No.	*Parameter/ characteristic*
1.	Total suspended solids (*SS*)
2.	Volatile suspended solids
3.	BOD
4.	COD
5.	TOC*
6.	Ammonia-N
7.	Organic-N
8.	PO_4-P

Example 7.2. *If 2.5 ml of raw sew concentration of the diluted samp 8 mg/l, and 5 mg/l after 5-day incub*

Solution. Volume of sample of sev
Volume of diluted sample

∴ Dilution ratio = $\frac{250}{2.5}$ = 1(

Loss of dissolved oxygen during
= D.O. bef
= 8 − 5 = 3

Using equations (7.11), we hav
∴ BOD of sewage = Loss of c
= 3 mg/l ×

Example 7.3. *A 2% solution of 20°C. The depletion of oxygen was sewage.*

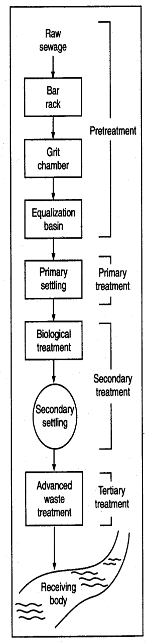
Solution. Dilution factor
= $\frac{100}{\text{Per cent of solu}}$

Depletion of oxygen = 4 ppm.

*Explained in article 7.4.9.

Q-3-b) Draw the schematic flow line diagram for conventional water treatment plant for municipal waste, depicting the various treatment steps of waste water prior to its disposal in perennial river stream.

Answer:



Waste water Treatment Systems

- Pretreatment - removes materials that can cause operational problems, equalization optional.
- Primary treatment - remove ~60% of solids and ~35% of BOD.
- Secondary treatment - remove ~85% of BOD and solids.
- Advanced treatment - varies: 95+ % of BOD and solids, N, P.

Fig. 10.1. Typical flow diagram of various groups of waste water treatment methods

10.3. PRELIMINARY TREATMENT OPERATIONS

Few preliminary treatment operations are detailed below:

Screening

The screening of waste water, one of the oldest treatment methods, removes gross pollutants from the waste stream to protect downstream equipment from damage, avoid interference with plant operations and prevent objectionable floating material from entering the primary settling tanks. Screening devices may consist of parallel bars, rods or wires,

Q.4-a) An average operating data for conventional activated sludge treatment plant is as follows: i) Waste water flow = 35000 m^3/d ; ii)Volume of aeration tank = 10900 m^3; iii) Influent BOD=250ppm; iv) Effluent BOD = 20ppm; v) MLSS = 2500ppm; vi)Effluent suspended solids= 30ppm; vii) Waste sludge suspended solids= 9700ppm; viii) Quantity of waste sludge = 220m^3/d. Determine: I) Aeration Period; II) F/M ratio; III) % Efficiency of BOD removal and IV) Sludge Age.

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...(9.50)

(per day)

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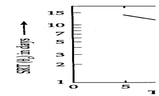


Fig. 9.44. SRT as a function of aerat

Typical values of different typ
other types of Activated sludge pl

Example 9.29. *An average opera*
treatment plant is as follows :

(1) *Wastewater flow*
(2) *Volume of aeration tank*
(3) *Influent BOD*
(4) *Effluent BOD*
(5) *Mixed liquor suspended sol*
(6) *Effluent suspended solids*
(7) *Waste sludge suspended sol*
(8) *Quantity of waste sludge*

Based on the information abov

(a) *Aeration period (hrs)*
(b) *Food to microorganism rati*
(c) *Percentage efficiency of BO*
(d) *Sludge age (days).*

Solution. Given values are sy

$Q = 35000$ m^3/d ;
$Y_0 = 250$ mg/l ;
$X_T = 2500$ mg/l ;
$X_R = 9700$ mg/l ;

These values are now used to
(a) Aeration period (t) in hr is

$t = \frac{V}{Q} \cdot 24 = \frac{10,90}{35,00}$

(b) F/M ratio F = Mass o
$= Q \cdot Y_0$

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

$$M = \text{Mass of MLSS}$$

$$= V \cdot X_T = 10900 \text{ m}^3 \times 2500 \text{ mg/l } (i.e. \text{ gm/m}^3)$$

$$= \frac{10900 \times 2500}{1000} \text{ kg} = \mathbf{27{,}250 \text{ kg}}$$

$$\therefore \quad F/M \text{ ratio} = \frac{8750}{27{,}250}$$

$$= \mathbf{0.32} \text{ kg BOD per day/kg of MLSS.} \quad \textbf{Ans.}$$

(c) *Percentage efficiency of BOD removal*

$$= \frac{\text{Incoming BOD} - \text{Outgoing BOD}}{\text{Incoming BOD}}$$

$$= \frac{250 - 20}{250} \times 100\% = \frac{230}{250} \times 100\% = \mathbf{92\%}. \quad \textbf{Ans.}$$

(d) Sludge age in days (θ_c) is given by Eq. (9.48) as

$$\theta_c = \frac{V \cdot X_T}{Q_W \cdot X_R + (Q - Q_W) \cdot X_E}$$

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

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

$$= \frac{27250}{2134 + 1043.4} = \frac{27250}{3177.4} = \mathbf{8.58 \text{ days.}} \quad \textbf{Ans.}$$

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

The term *sludge volume index* or ***sludge index*** is used to indicate the physical state of the sludge produced in a biological aeration system. It represents the degree of concentration of the sludge in the system, and hence decides the rate of recycle of sludge (Q_R) required to maintain the desired MLSS and *F/M* ratio in the aeration tank to achieve the desired degree of purification.

S.V.I. is defined as the volume occupied in ml by one gm of solids in the mixed liquor after settling for 30 minutes, and is determined experimentally.

The standard test, which is performed in the laboratory to compute SVI of an aeration system involves collection of one litre sample of mixed liquor from the aeration tank from near its discharge end in a graduated cylinder. This 1 litre sample of mixed liquor is allowed to settle for 30 minutes and the settled sludge volume (V_{ob}) in ml is recorded as to represent sludge volume. This volume V_{ob} in ml per litre of mixed liquor will represent the quantity of sludge in the liquor in ml/l.

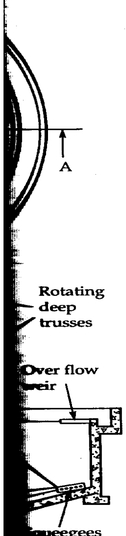
The above sample of mixed liquor, after remixing the settled solids, is further tested in the laboratory for MLSS by the standard procedure adopted for measuring the suspended solids in sewage. Let this concentration of suspended solids in the mixed liquor in mg/*l* be X_{ob}. Then SVI is given by the equation

Q-4-b) Discuss: i) Sludge bulking in ASP and its control.

ii) Biological principle of trickling filter

iii) Rotating Biological Contactor

i) **Sludge bulking in ASP and its control:**



The process of sludge digestion, using a sludge thickener before the digestion tank, helps in reducing the capacity of the digestion tank ; and by proper control of digestion conditions, lower detention periods are used, which further reduce their capacities, and the rate of digestion is also made high. Such a digestion, which is used in modern large sized plants, is called **high rate digestion.**

It may also be pointed out that in an activated sludge treatment plant, special provision must be made for removing the activated sludge quickly from the secondary settling tank (and for resending it to the head of the aerator), so as to prevent it from becoming anaerobic.

9.34. Bulking and Foaming Sludge in an Activated Sludge Treatment Plant

Foam formation and poorly settling sludge are the two most common problems of the activated sludge process. A sludge that exhibits poor settling characteristics is called a *bulking sludge*. *Filamentous micro-organisms* have been found to be responsible for a bulked sludge. Large surface area to volume ratios of these micro-organisms retard their settling velocities. *Fungi* are the most familiar filamentous micro-organisms. The vegetative structure of most fungi is composed of filaments, which actually contain a number of nuclei. Fungi, however, are not commonly significant in wastewater treatment. Some other bacteria, particularly of type *021 N* bacteria are among the most frequently reported filamentous micro-organisms found in bulking sludges. These bacteria are usually found to develop in activated sludge systems which are characterised by the low or variable nutrient concentrations. These bacteria may live on variety of carbon and nitrogen sources present in the activated sludge system.

Organic acids form an important class of carbon sources for the growth of filamentous sulphur bacteria. These bacteria, however, do not develop well at low pH values. The other types of bacteria which are most commonly found in foaming and bulking sludges of activated plants are : *Nocardia amorae, Microthrix parvicella, N. amarae* like organisms, *N. pinesis* like organisms, and *type 0092*, etc. *Nocardia growth is supported by high sludge ages, low F : M ratios, and higher waste temperatures*. The most successful methods to control these organisms, as per latest research, are :

(i) reduction of the sludge age to less than 6 days* ; and

(ii) chlorination of return activated sludge.

Foam removal is also a logical and beneficial control measure, since *Nocardia filaments* are usually concentrated in foam compared to the mixed liquor.

Classical control measures like *adjustment of the F : M* (Food : Micro-organism) ratio**, *raising or lowering D.O.*, or *applying a disinfectant (chlorine)* are found to help in controlling filamentous bacteria. *Carbohydrate-rich waters* are more prone to give rise to filamentous populations. Exclusion of such wastewaters may, therefore, sometimes help in controlling sludge bulking.

*Pl. see the article 9.35.4

**Pl. see article 9.35.3

Q-4-b) Discuss: i) Sludge bulking in ASP and its control.

ii) Biological principle of trickling filter

iii) Rotating Biological Contactor

ii) Biological principle of trickling filter:

treatment to sewage. These filters, also called as *percolating filters* or *sprinkling filters*, consist of tanks of coarser filtering media, over which the sewage is allowed to sprinkle or trickle down, by means of *spray nozzles* or *rotary distributors*. The percolating sewage is collected at the bottom of the tank through a well designed *under-drainage system*.

The decomposition of the organic matter and the resultant purification of the sewage is brought about by a population of micro-organisms. Micro-organisms and bacteria, which are naturally present in sewage, get attached to the filter media. Organic matter from the sewage influent is also adsorbed on the **biological film**, which is formed by the micro-organisms around the filtering media particles (*i.e.*, sand particles). In the outer portions of this film of biological mass or **slime layer**, the organic matter is degraded by the aerobic bacteria. As the micro-organisms grow, the thickness of the slime layer increases, and the diffused oxygen is consumed by the upper portions of the slime layer, thereby creating an anaerobic environment near the surface of the media particles. As the slime layer increases in thickness, the adsorbed organic matter is metabolised before it can reach the micro-organisms near the media face. This creates shortage of external source of organic carbon near the media face, due to which, the micro-organisms near the media face enter into an endogenous phase of growth, and lose their ability to cling to the media surface. The liquid sewage, exerting a ***shearing action***, then breaks up some biological mass (slime) from the media, but the new slime layer continues to grow. The continuing growth and break up of biological mass from this **biofilm** (slime layer), infact, creates a balance in the thickness of the formed biofilm. *The break up or detachment of the biomass (biological solids) from the slime layer is known* as **sloughing**.

The *sloughing*, infact, imparts turbidity to the filter effluent, and the sloughed material (biological solids) is separated from the treated sewage in the secondary settling tank.

The extent of *sloughing* is primarily a function of organic and hydraulic loading on the filter. The hydraulic loading accounts for shear velocities that are developed in the filter (which causes sloughing); while the organic loading accounts for the rate of metabolism in the slime layer (which loosens the biological mass in the slime layer, leading to sloughing).

In order to ensure the large scale growth of the aerobic bacteria in the biofilm, sufficient quantity of oxygen is supplied by providing suitable ventilation facilities in the body of the filter ; and also to some extent by the intermittent functioning of the filter.

The effluent obtained from the under-drains of the filter, must be taken to the secondary sedimentation tank for settling out the sloughed biomass. This secondary tank thus, separates the treated sewage from the biological solids. A portion of the filter effluent or the settled effluent is recycled, usually to dilute the incoming wastewater. The sewage influent entering the filter must, of course, be given pre-treatments, including screening and primary sedimentation.

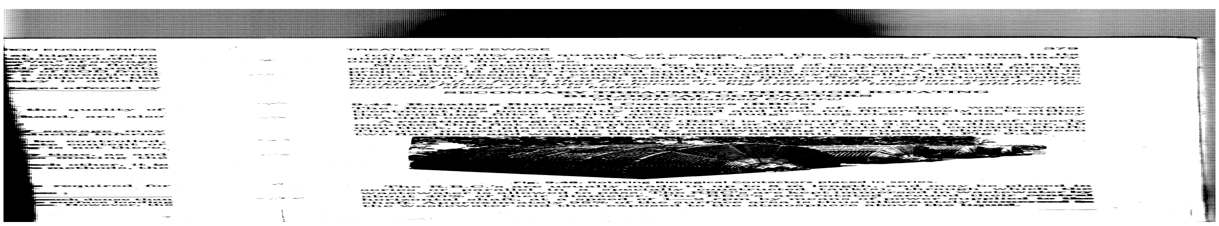
9.21.1. Construction and Operation of Trickling Filters. Trickling filter tanks are generally constructed above the ground. They may either be rectangular or more generally *circular* [Refer Fig. 9.18 (*a*) and (*b*)]. Rectangular filters are provided with a network of pipes having fixed nozzles,

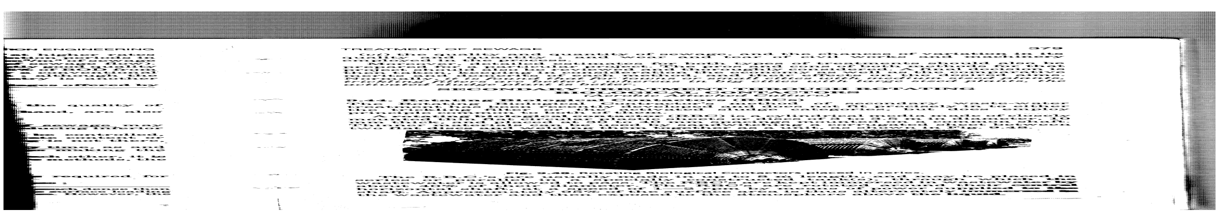
Q-4-b) Discuss: i) Sludge bulking in ASP and its control.

ii) Biological principle of trickling filter

iii) Rotating Biological Contactor

iii) <u>Rotating Biological Contactor:</u>





When the process is operated, the microorganisms of the waste-water begin to adhere to the rotating surfaces and grow there, untill the entire surface area of the discs gets covered with 1 to 3 mm layer of biological slime. As the discs rotate, they carry a *film of wastewater* into the air, where it trickles down the surface of the discs, absorbing oxygen. As the discs complete their rotation, this film mixes with the wastewater in the tank, adding to the oxygen of the tank and mixing the treated and partially treated wastewater. As the *attached microorganisms* pass through the tank, they absorb other organics for breakdown. The excess growth of microorganisms is sheared from the discs, as they move through the wastewater tank. The dislodged organisms are kept in suspension by the moving discs. This suspended growth finally moves down with the sewage flowing through the tank to a downstream settling tank for removal. The effluent obtained is of equal or even better quality than what is obtained from other secondary treatments. The quality of the effluent can further be improved by placing several contractors in series along the tank. The method can thus provide a high degree of treatment, including biological conversion of ammonia to nitrates.

As is evident, a given set of discs (*i.e.* an RBC) serves the following purposes :

(*i*) They provide media for build up of *attached microbial growth*.

(*ii*) They bring the growth of microbes in contact with the waste-water.

(*iii*) They aerate the wastewater and the suspended microbial growth in the wastewater tank.

In this process, the attached growths are similar in concept to a trickling filter, except that here the microorganisms are passed through the wastewater, rather than the wastewater passing over the microbes, as happens in a trickling filter. This method realises some of the advantages of both the trickling filter and the activated sludge process.

The sludge produced in the process contains about 95—98% moisture, and may amount to about 0.4 kg per kg of BOD_5 applied. The theoretical model of the process is similar to that for trickling filter, *but actual design is still empirical* and based on the data from the successful working plants and as developed by the process manufacturers.

The *hydraulic loading* rates may vary between 0.04—0.06 m/day, and *organic loading rates* between 0.05—0.06 kg BOD_5/m^2 per day, based upon the disc surface area. Sloughing of biological solids is more or less continuous and the effluent contains a relatively constant concentration. The solids settle well and clarifier surface overflow rates of about 33 m^3/m^2 per day are reported to be satisfactory.

AEROBIC STABILISATION UNITS

(Aerobic Suspended Culture)

9.45. Oxidation Ponds and Stabilisation Ponds

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

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Q.5-a) i) Discuss Working and design consideration for a Septic Tank.

Answer i) <u>Working and design consideration for a Septic Tank</u> :

390 SEWAGE DISPOSAL AND AIR POLLUTION ENGINEERING

Parameters of Treated Effluent Sewage

BOD_5 = 30-40 mg/L

COD = 50-60 mg/L

TSS = 30 mg/L

ANAEROBIC STABILISATION UNITS

9.48. Anaerobic and Facultative Stabilisation Ponds

As stated under article 9.45, the deeper stabilisation ponds, usually operating under the action of anaerobic bacteria, are called the *anaerobic stabilisation ponds*. These ponds generally receive untreated sewage, and are deep enough to restrict the penetration of light to reduce the algae growth to a negligible level. The photosynthesis, which primarily causes stabilisation of wastes in an oxidation pond, can be reduced by decreasing the surface area and increasing the depth of the pond. Deeper ponds, usually in the depth range of 2.5 to 4.0 m are, therefore, sometimes used for anaerobic decomposition of wastes. The anaerobic conditions are further ensured by applying BOD load that exceeds oxygen production from photosynthesis.

Anaerobic treatment of complex wastes involves *two distinct stages*. In the first stage, known as ***acid fermentation***, complex organic materials are broken down mainly to short-chain acids and alcohols. In the second stage, known as ***methane fermentation***, these materials are converted to gases, primarily methane and carbon dioxide. The proper design of anaerobic ponds must result in environmental conditions favourable to methane fermentation.

Anaerobic ponds may primarily be used as a pre-treatment process, and are particularly suited for the treatment of high temperature, high strength industrial wastewaters. However, they have been used successfully to treat municipal wastewaters as well. *Such ponds are, however, generally avoided, unless the process is used in a close bodied tank, due to evolution of foul odours in the process of anaerobic decomposition of wastes.*

9.49. Septic Tanks

A septic tank may be defined as *a primary sedimentation tank**, with a longer detention period (12 to 36 hours, against a period of 2 hours in an ordinary sedimentation tank), and *with extra provisions for digestion of the settled sludge*. Since the digestion of the settled sludge is carried out by anaerobic decomposition process, *the septic tank unit is generally classified under the units which work on the principle of anaerobic decomposition*. Moreover, due to anaerobic decomposition of the settled sludge, foul gases will be evolved in the tank, and as such, a septic tank will be a completely covered tank, provided with a high vent shaft for escape of gases.

A septic tank, is thus, a horizontal continuous flow type of a sedimentation tank, directly admitting raw sewage, and removing about 60 to 70% of the dissolved matter from it. The effluent from such a tank will be sufficiently foul in nature, and will have to be disposed of either for sub-surface irrigation or in cess-pools or soak pits, or to be treated in trickling filters before disposing it of

*Horizontal continuous flow type of sedimentation tank, of course.

TREATMENT OF SEWAGE 391

in water courses, as will be discussed a little later. *The sludge settled at the bottom of the tank, and the oils and greasy matter rising to the top surface of sewage as scum, are allowed to remain in the tank for a period of several months*, during which they are decomposed by the anaerobic bacteria to form gases and liquids by the process of sludge digestion. The resultant sludge so obtained, will consequently be much less than that obtained in ordinary settling tanks (the quantity is reduced because of digestion). The digested sludge from the tank is periodically (at intervals of 6 to 12 months, and in no case exceeding 3 years) removed, and taken to a nearby sump, from where it may be pumped up to the ground, and disposed of in a sanitary manner, preferably after drying it.

Septic tanks are generally provided in areas where sewers have not been laid and for catering to the sanitary disposal of sewage produced from isolated communities, schools, hospitals, hotels, other public institutions, etc.

9.49.1. Construction Details. The plan and section of a typical septic tank are shown in Fig. 9.54. The tank is designed to prevent direct currents between the tank inlet and outlet. This ensures effective sedimentation, and is achieved by using pipe tees with submerged ends as inlet and outlet, as shown in Fig. 9.54 or alternatively, a better arrangement is to provide hanging baffles in front of inlet and before the outlet, as was shown in sedimentation tank of Fig. 9.12(*a*). The T-pipe or the baffle at the outlet will also help in retaining the *scum* (*i.e.*, oily and greasy matter floating to the surface, due to evolution of gases produced by anaerobic decomposition of sludge at bottom) in the tank.

It may be noted that holding of scum in the tank not only frees the effluent from it, but is also desirable to hold back odours and to create a sort of heat insulation which aids the bacterial action. The tank is generally covered at top with a R.C.C. slab. Manhole covers are provided in the top slab, so as to permit inspection and maintenance. Sometimes, stairs or cast iron steps may also be provided to go into the tank, if needed. The R.C.C. cover prevents the escape of foul gases and odours from the tank on to the ground ; prevents the chances of accidents due to falling of children or animals ; and prevents wind agitation, thus keeping the sewage warm, and helping in bacterial activity. The foul gases produced by the anaerobic decomposition of deposited sludge are separately removed through a vent pipe projecting sufficiently high above the ground, so as not to cause any nuisance to the neighbouring areas. The sludge deposited and digested, is removed at an interval of 6 to 12 months, into a side sump-well through a pipe under hydrostatic head or with the help of a portable pump. In rural areas, and in case of small septic tanks, the sludge may be removed by manual labour. The sludge from the sump well is then lifted up by pumps, etc. ; and disposed of suitably after drying, as pointed out earlier.

9.49.2. Design Considerations. The septic tanks will be designed like ordinary sedimentation tanks with the following data :

(*i*) ***Capacity of Septic Tanks.*** The volume of liquid which a septic tank can accommodate is called its capacity. A septic tank should be capable of storing the sewage flow during the detention period, and an additional volume of sludge for 6 months to 3 years, depending upon the periodicity of cleaning.

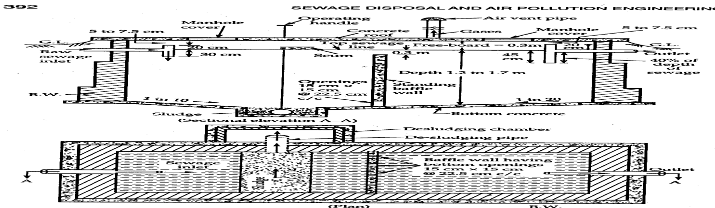

Fig. 9.54. Septic Tank.

If only water closets are connected to the septic tank, the sewage flow will be about 40—70 litres/capita/day. But when sullage is also discharged in to the septic tank, the sewage flow may be as much as 90 to 150 litres/capita/day. Where a large quantity of sludge is expected, it may separately be disposed of in the manner as the effluent from the septic tank.

The sludge and the scum will accumulate in the tank at varying rates, depending upon the characteristics of raw sewage, and the efficiency of the sedimentation and digestion. *The rate of accumulation of sludge has been recommended as 30 litres/person/year.*

The minimum capacity of a septic tank for about 8 to 10 persons, may be kept 2,250 litres (when all liquid wastes are discharged into the tank) and 1,400 litres (when only water closet wastes are discharged).

Q.5-a) ii) Discuss various stages in the sludge digestion Process. Enlist various factors affecting sludge digestion.

Answer ii) <u>various stages in the sludge digestion Process :</u>

TREATMENT OF SEWAGE 319

treatment, the organic matter may decompose, producing foul gases and a lot of nuisance, pollution, and health hazards. In order to avoid such pollutions, the sludge is, first of all, *stabilised by decomposing the organic matter under controlled anaerobic conditions**, and then disposed of suitably after drying on drying beds, etc. The process of stabilisation is called the *sludge digestion*; and the tank where the process is carried out is called the *sludge digestion tank*. In a sludge digestion process, the sludge gets broken into the following three forms :

(*i*) **Digested sludge.** It is a stable humus like solid matter, tary black in colour, and with reduced moisture content, and, is therefore, having reduced volume (about $\frac{1}{3}$ times the undigested sludge volume). Moreover, the quality of digested sludge is much better than that of the undigested sludge, and it is free of pathogenic bacteria which are killed in the digestion process. It may still, however, contain cysts and eggs of bacteria, protozoa and worms.

(*ii*) **Supernatant liquor.** It includes the liquified and finely divided solid matter, and is having high BOD (about 3000 ppm).

(*iii*) **Gases of decomposition.** Gases like methane (65 to 70%), carbon dioxide (30%), and traces of other inert gases like nitrogen, hydrogen sulphide, etc. are evolved. They may be collected (particularly the methane which has a high calorific value) and used as a fuel.

The sludge gas, having 70% methane, has a fuel value of about 5800 kilo calorie/cu. m (*i.e.* 650 Btu per cu. ft. app.). The amount of gas produced, on an average, is about 0.9 cu. m. per kg of volatile solids reduced in digestion. The gas produced thus varies with the sewage produced, and works out to about 14 to 18 litres per capita per day (usually 17 *l/c/d*).

The digested sludge is *dewatered, dried up, and* used as fertiliser ; while the gases produced are also used for fuel or for driving gas engines. The supernatant liquor contains about 1500 to 3000 ppm of suspended solids ; and is, therefore, re-treated at the treatment plant along with the raw sewage.

9.27. Stages in the Sludge Digestion Process

Three distinct stages have been found to occur in the biological action involved in the natural process of sludge digestion. These stages are :

(*i*) *Acid fermentation* ;

(*ii*) *Acid regression* ; and

(*iii*) *Alkaline fermentation*.

These stages are briefly summarised here :

(*i*) **Acid Fermentation Stage or Acid Production Stage.** In this first stage of sludge digestion, the fresh sewage-sludge begins to be acted upon by *anaerobic and facultative bacteria*, called **acid formers**. These organisms solubilize the organic solids through *hydrolysis*. The soluble products are then fermented to volatile acids and organic alcohols of low molecular weight like propionic acid, acetic acid, etc. Gases like methane, carbon dioxide and

*40 to 60% of the organic solids are converted by bacteria into carbon dioxide and methane gases. The organic matter which remains, is chemically stable and practically odourless, and contains 90 to 95% moisture.

hydrogen sulphide are also evolved. *Intensive acid production makes the sludge highly acidic, and lowers the pH value to less than 6. Highly putrefactive odours are evolved during this stage, which continues for about 15 days or so* (at about 21°C). BOD of the sludge increases to some extent, during this stage.

(*ii*) **Acid-Regression Stage.** In this *intermediate stage,* the volatile organic acids and nitrogenous compounds of the first stage, are attacked by the bacteria, so as to form acid carbonates and ammonia compounds. Small amounts of hydrogen sulphide and carbon-dioxide gases are also given off. The decomposed sludge has a very offensive odour, and its pH value rises a little, and to be about 6.8. The decomposed sludge, also, entraps the gases of decomposition, becomes foamy, and rises to the surface to form scum. *This stage continues for a period of about 3 months or so* (at about 21°C). BOD of the sludge remains high even during this stage.

(*iii*) **Alkaline Fermentation Stage.** In this *final stage* of sludge digestion, more resistant materials like proteins and organic acids are attacked and broken up by anaerobic bacteria, called **methane formers,** into simple substances like ammonia, organic acids and gases. *During this stage, the liquid separates out from the solids, and the digested sludge is formed.* This sludge is granular and stable, and does not give offensive odours. (It has a musty earthy odour). This digested sludge is collected at the bottom of the digestion tank, and is also called **ripened sludge.** Digested sludge is alkaline in nature. The pH value during this stage rises to a little above 7 (about 7.5 or so) in the alkaline range. *Large volumes of methane gas (having a considerable fuel value) alongwith small amount of carbon dioxide and nitrogen, are evolved during this stage. This stage extends for a period of about one month or so (at about 21°C). The BOD of the sludge also rapidly falls down during this stage.*

It is, thus, seen that several months (about $4\frac{1}{2}$ months or so) are required for the complete process of digestion to take place under natural uncontrolled conditions at about 21°C. This period of digestion is, however, very much dependent upon the temperature of digestion, and other factors. If these factors are controlled, quicker and effective digestion can be brought about, as discussed below.

9.28. Factors Affecting Sludge Digestion and Their Control

The important factors which affect the process of sludge digestion, and are, therefore, controlled in a digestion tank, are :

1. *Temperature ;*
2. *pH value ;*
3. *Seeding with digested sludge ; and*
4. *Mixing and stirring of the raw sludge with digested sludge.*

Besides these important factors, certain other minor conditions like quality of water supply ; presence of copper, fluorides, and radio active substances, etc., may also affect the rate of digestion, but not to any appreciable extent. The important factors which are largely responsible for controlling the rate and effectiveness of sludge-digestion are discussed below :

Q-5-b) Design a digestion tank for the primary sludge with the help of following data: i) Average flow=20 Mld ii) Total suspended solids in raw sewage=300 ppm iii)Moisture content of digested sludge=85%. iv) Assume any other suitable data (if reqd).

Solution:

∴ Mass of suspended solids in 20 Ml of sewage flowing per day

$$= \frac{300 \times 20 \times 10^6}{10^6} \text{ kg} = 6000 \text{ kg/day.}$$

Assuming, that 65% solids are removed in primary settling tanks, we have
Mass of solids removed in the primary settling tank

$$= 65\% \times 6000 \text{ kg/day} = 3900 \text{ kg/day.}$$

Assuming that the fresh sludge has a m.c. of 95%, we have
5 kg of dry solids will make = 100 kg of wet sludge
∴ 3900 kg of dry solids will make

$$= \frac{100}{5} \times 3900 \text{ kg of wet sludge per day}$$

$$= 78{,}000 \text{ kg of wet sludge per day.}$$

Assuming the sp. gravity of wet sludge as 1.02 (*i.e.* Density = 1020 kg/m³), we have

The volume of raw sludge produced/day

$$= V_1 = \frac{78000}{1020} \text{ m}^3\text{/day} = 76.47 \text{ m}^3\text{/day.} \quad ...(i)$$

The volume of the digested sludge (V_2) at 85% m.c. is given by the formula (9.38) as

$$V_2 = V_1 \left[\frac{100 - p_1}{100 - p_2}\right]$$

or $$V_2 = V_1 \left[\frac{100 - 95}{100 - 85}\right] \quad \text{or} \quad V_2 = V_1 \left[\frac{5}{15}\right]$$

or $$V_2 = \frac{1}{3} \times V_1 = \frac{1}{3} \times 76.47 \text{ cu. m./day} = 25.49 \text{ m}^3\text{/day.}$$

Now, *assuming the digestion period as 30 days*, we have the capacity of the required digestion tank, given by Eqn. (9.40) as :

$$\text{Capacity} = \left[V_1 - \frac{2}{3}(V_1 - V_2)\right] t$$

or $$= \left[76.47 - \frac{2}{3}(76.47 - 25.49)\right] 30$$

$$= \left[76.47 - \frac{2}{3} \times 50.98\right] 30 = 1274.5 \approx \mathbf{1275 \text{ cu. m.}}$$

Now, providing 6.0 m depth of the cylindrical digestion tank, we have

$$\text{Cross-sectional area of the tank} = \frac{1275}{6} = 212.5 \text{ m}^2$$

∴ Dia of tank $$= \sqrt{\frac{212.5}{\pi/4}} \text{ m} = \mathbf{16.45 \text{ m} ; \text{ say } 16.5 \text{ m.}}$$

Hence, provide a cylindrical sludge digestion tank (typical section shown in Fig. 9.28) 6 m deep and 16.5 m diameter, with an additional hoppered bottom of 1 : 1 slope for collection of digested sludge. **Ans.**

TREATMENT O
Example 9.
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Q.6-a) Briefly explain: i) Indore method of refuse disposal

ii) Bangalore method of refuse disposal

<u>Answer i) Indore method of refuse disposal:</u>

DISPOSAL OF MUNICIPAL AND INDUSTR

about 1.5 m to 2 m, usually ab
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windrow, or in the trench, as th
pitchfork can be adopted at sm
mechanical devices like self-pro
may be used to turn the refus
introduce oxygen and to contro
machines are used for reshapin
moisture content of the turning
optimal decomposition of the wa
for about 4 to 5 weeks, during w
are consumed. The waste compo
to 8 weeks without any turning
about 3–4 months time to comple
being taken out for use or for sa

The Bangalore method of
anaerobic decomposition of wa
handling of the mass, and is,
method is, therefore, widely a
India. The refuse and night so
layers in an underground earth
mass is covered at its top by lay
left over for decomposition.

Within 2 to 3 days of burial,
and organic matter begins to b
the process, which raises the t
75°C. This heat prevents the b
about 4 to 5 months (depen
stabilised and *changes into a*
mass, called **humus**. This hum
mm sieves to remove stones, br
the market as manure. The e
further batches of refuse.

The initial C-N ratio* and m
important controlling factors

*Carbon-Nitrogen ratio ; *i.e.*
important factor for the bacterial
building their cell structures (as p
bacteria, developing in this digestio
up nitrogen. Hence, for proper d
digestive material should be betwe
be 30-50 times more than the ni

However, when there is too mu
nitrogen will be used up and carbo
ter incomplete. The digestion will
much of nitrogen, *i.e.* C/N ratio is
exhausted and fermentation stop,
hydrogen to form ammonia (NH_3).
the methane producers. *The anae*
ratio of about 30-50.

<u>ii) Bangalore method of refuse disposal:</u>

s after the
ctive early
Bacillus,
while fungi
during the
about 3—4
up to 50%
st usually,

ntrolled to
will make
re inhibits
ed, so that
, therefore,
urning, for

, *2000* has
quality, to

***compost*,**

re of night
e :

ss (refuse
s method,
depths of
; or above

with cattle
height of

about 1.5 m to 2 m, usually about 2
windrows are conical in cross-secti
composting waste is aerated by peri
windrow, or in the trench, as the cas
pitchfork can be adopted at smaller
mechanical devices like self-propelle
may be used to turn the refuse onc
introduce oxygen and to control the
machines are used for reshaping the
moisture content of the turning mass
optimal decomposition of the waste m
for about 4 to 5 weeks, during which t
are consumed. The waste compost ma
to 8 weeks without any turning. The
about 3-4 months time to complete, af
being taken out for use or for sale.

The **Bangalore method of comp**
anaerobic decomposition of wastes
handling of the mass, and is, hence
method is, therefore, widely adopte
India. The refuse and night soil, in
layers in an underground earthen tr
mass is covered at its top by layer of
left over for decomposition.

Within 2 to 3 days of burial, inten
and organic matter begins to be dest
the process, which raises the tempe
75°C. This heat prevents the breedi
about 4 to 5 months (depending
stabilised and *changes into a brow*
mass, called **humus**. This humus is r
mm sieves to remove stones, broken
the market as manure. The empty
further batches of refuse.

The initial **C-N ratio*** and moistu
important controlling factors in th

***Carbon-Nitrogen ratio** ; *i.e.* C/N o
important factor for the bacterial activity
building their cell structures (as proteins
bacteria, developing in this digestion, use
up nitrogen. Hence, for proper develop
digestive material should be between 30
be 30-50 times more than the nitrogen

However, when there is too much of c
nitrogen will be used up and carbon left o
ter incomplete. The digestion will, thus,
much of nitrogen, *i.e.* C/N ratio is lower
exhausted and fermentation stop, leaving
hydrogen to form ammonia (NH_3). This c
the methane producers. ***The anaerobic***
ratio of about 30-50.

Q.6-b) Discuss in detail about the engineered systems for solid waste management in terms of reuse; recycle, energy recovery, treatment & disposal.

Answer: