PART-1

Fresh Water, Water Demands, Variation in Demands.

CONCEPT OUTLINE

Per Capita Demand : The demand of water per person per day is known as per capita demand or per capita consumption. It expressed in litre/day

Variation of Demand : Following are the three types of variation of demand :

i. Seasonal variation, ii. Daily variation, iii. Hourly variation.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. **Write a short note on fresh water.**

Answer

1. Fresh water is any naturally occurring water except seawater and brackish water.
2. Fresh water includes water in ice sheets, ice caps, glaciers, icebergs, ponds, lakes, rivers, streams, and even underground water called groundwater.
3. Fresh water is generally characterized by having low concentrations of dissolved salts and other total dissolved solids.
4. Fresh water is not the same as potable water (or drinking water).
5. Much of the earth's fresh water (on the surface and groundwater) is unsuitable for drinking without some treatment.
6. Fresh water can easily become polluted by human activities or due to naturally occurring processes, such as erosion.
7. The source of almost all fresh water is precipitation from the atmosphere, in the form of mist, rain and snow.

Que 1.2. **What are the various purposes for which water is required ?**

OR

What do you mean by water demand ? What are various types of water demand ?

Answer

Water Demand : It is equivalent to water use which is volume rate of flow that is applied to some beneficial purpose.

Following are the various types of water demands of a city or town :

1. **Domestic Water Demand :**
i. The quantity of water required in the houses for drinking.
ii. As per IS : 1172-1963, under normal conditions, the domestic consumption of water in India is about 135 litres/day/capita. But in developed countries this figure may be 350 litres/day/capita.

2. **Industrial Demand :**
i. The water required in the industries mainly depends on the type of industries which exists in the city.
ii. The quantity of water demand for industrial purpose is around 20 to 25 % of the total demand of the city.

3. **Institution and Commercial Demand :** As per IS : 1172 – 1963, water supply requirements for the public buildings other than residences are as follows :

Table 1.2.1.

S. No.	Type of Building	Consumption per Capita per Day (litres)
1.	Factories where bathrooms are required.	45
2.	Hospital per bed No. of beds exceeding 100	450
3.	Hostels	135
4.	Office	45
5.	Hotel (per bed)	180
6.	Cinema concert halls and theatres (per seat)	15
7.	Boarding schools	135
8.	Garden, sport grounds (per sq. m)	35
9.	Animal / vehicles	45

4. **Demand for Public Use :**
i. Quantity of water required for public utility purposes such as for washing and sprinkling on roads, cleaning of sewers, watering of public parks, gardens, public fountains etc comes under public demand.
ii. To meet the water demand for public use, provision of 5 % of the total consumption is made during designing the water works for a city.

5. **Fire Demand :**
i. Water required for firefighting is usually known as fire demand.
ii. It is a function of population and may be computed from rational formulae.

Que 1.3. **Write different formulae for estimating fire demand.**

Answer

Following are the various formulae for estimating fire demand :

1. **Buston's Formula :**

$$Q = 5663\sqrt{P}$$

where, Q = Quantity of water in litres per min.
P = Population in thousand.

2. **Kuichling's Formula :**

$$Q = 3182\sqrt{P}$$

3. **John R. Freeman's Formula :**

$$Q = 1136\left(\frac{P}{5}+10\right)$$

and $F = 2.8\sqrt{P}$

where, F = Number of simultaneous fire streams.

4. **National Board of Fire Underwriter's Formula :**

$$Q = 4637\sqrt{P}(1-0.01\sqrt{P})$$

Que 1.4. **What is meant by term per capita demand ?**

Answer

1. **Per Capital Demand :** The demand of water per person per day is known as per capital demand.
2. If 'Q' is the total quantity of water required for various purposes by a town per year and 'P' is population of town, then per capita demand will be

$$\text{Per capita demand} = \frac{Q}{P \times 365} \text{ litres/day}$$

3. Indian town, the requirement of water in various uses is as under :

i.	Domestic purpose	135 litres/c/d
ii.	Industrial use	40 litres/c/d
iii.	Public use	25 litres/c/d
iv.	Fire Demand	15 litres/c/d
v.	Losses, Wastage and thefts	55 litres/c/d
	Total :	270 litres/capita/day

4. The total quantity of water required by the town per day shall be 270 multiplied with the total population.

Que 1.5. **How would include the requirement of water in the estimation of water demand for a municipal area ? What is coincident draft ?**

AKTU 2013-14, Marks 03

Answer

A. Requirement of Water in the Estimation of Water Demand :

1. The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data :
   i. Water consumption rate (per capita demand in litre per day per head)
   ii. Population to be served.
   Quantity of water = Per capita demand × population
2. It may be depends on following three factors :
   i. Type of demand.
   ii. Factors affecting the water demand.
   iii. Population forecasting.

B. Coincident Draft : The maximum daily demand (*i.e.*, 1.8 times the average daily demand) when added to fire draft for working out total draft, is known as coincident draft.

Que 1.6. Discuss various factors which affect the rate of demand.

AKTU 2013-14, Marks 03

Answer

Following are the factors affecting per capita demand :

1. **Climatic Conditions :** The quantity of water required in hotter and dry places is more than cold countries.
2. **Size of Community :** Water demand is more with increase of size of town.
3. **Living Standard of the People :** The per capita demand of the town increases with the standard of living of the people.
4. **Industrial and Commercial Activities :** As the quantity of water required in certain industries is much more than domestic demand, their presence in the town will enormously increase per capita demand of the town.
5. **Distribution Pressure :**
   i. If the distribution pressure is very high, the water consumption will be more.
   ii. Maximum water is lost unnecessarily when the tap is opened for bathing, face washing, etc.
6. **System of Sanitation :** Per capita demand of the towns having water carriage system will be more than the town where this system is not being used.
7. **Cost of Water :** If the cost of water is more, less quantity of water will be used by the people as compared when the cost is low.

Que 1.7. Discuss fluctuation or variation of demand.

Answer

Following are the various types of variation of demand :

1. **Seasonal Variations :** The water demand varies from season to season.
   i. In summer the water demand is maximum, because the people will use more water in bathing, cooling, lawn watering and street sprinkling.
   ii. This demand will become minimum in winter because less water will be used in bathing and there will be no lawn watering.
   iii. The variations may be up to 150 % of the average demand of the year.
2. **Daily Variations :**
   i. This variation depends on the general habits of people, climatic conditions and character of city as industrial, commercial or residential.
   ii. More water demand will be on Sundays and holidays due to more comfortable bathing, washing etc., as compared to other working days.
   iii. The maximum daily consumption is usually taken as 180 % of the average daily consumption.
3. **Hourly Variations :**
   i. On Sundays and other holidays the peak hours may be about 8 AM due to late awakening where as it may be 6 AM to 10 AM and 4 PM to 8 PM and minimum flow may be between 12 AM to 4 AM when most of the people are sleeping.
   ii. The maximum consumption may be rise up to 200 % that of average daily demand.
   ii. The determination of this hourly variation is most necessary, because on its basis the rate of pumping will be adjusted to meet up the demand in all hours.

PART-2

Population Forecasting by Various Methods.

CONCEPT OUTLINE

Method of Population Forecasting : Following are the methods of population forecasting :
i. Mathematical method, ii. Graphical method, iii. Comparative graphical method, iv. Decreasing rate of growth method, v. Master plan, vi. Logistic curve method.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.8. **Discuss various population forecasting methods in detail.**

AKTU 2015-16, Marks 15

OR

What are various method of forecasting the population growth in an area ? Explain suitability of any four methods.

AKTU 2017-18, Marks 10

Answer

Following are the population forecasting methods :

A. Mathematical Method : Following are the various mathematical methods of population forecasting :

1. Arithmetical Increase Method :

i. This method is based on the assumption that the population is increasing at a constant rate.

ii. The rate of change of population with time is constant. The population after 'n' decades can be determined by the formula : $P_n = P + n\,\bar{x}$

where, P = Population at present.

n = Number of decades.

$\bar{x}$ = Constant determined by the average of increase of 'n' decades.

2. Geometrical Increase Method :

i. This method is based on the assumption that the percentage increase in population from decade to decade remains constant.

ii. In this method the average percentage of growth of last few decades is determined, the population forecasting is done on the basis that percentage increase per decade will be the same.

iii. The population at the end of 'n' decades is calculated by, $P_n = P\left(1 + \frac{I_G}{100}\right)^n$

where, I_G = Average percentage increase per decade.

3. Incremental Increase Method :

i. This method is improvement over the above two methods.

ii. The average increase in the population is determined by the arithmetical method and to this is added the average of the net incremental increase once for each future decade.

iii. Population after n^{th} decode, $p_n = P + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$

where $\bar{x}$ = Average increase in population.

$\bar{y}$ = Incremental increase in population.

B. Graphical Method :

1. In this method, the populations of last few decades are correctly plotted to a suitable scale on graph.

2. The population curve is smoothly extended for getting future population. This extension should be done carefully and it requires proper experience and judgment.
3. The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition.

C. Master Plan Method :

1. In this method, a master plan of the city should be prepared by dividing the city into various zones such as residential, industrial and commercial zone, etc.
2. The future expansion of the city should also be regulated with the by-laws of the corporation.
3. The population densities of different zones are predetermined.
4. When the city will be fully developed, the probable population may be forecast by studying the master plan.

Que 1.9. **Draw and discuss the logistic curve from population growth.**

AKTU 2013-14, Marks 03

OR

With diagram explain briefly logistic curves.

AKTU 2016-17, Marks 10

Answer

1. A logistic growth curve is an S-shaped (sigmoidal) curve that can be used to model functions that increase gradually at first, more rapidly in the middle growth period, and slowly at the end, leveling off at a maximum value after some period of time.
2. The initial part of the curve is exponential; the rate of growth accelerates as it approaches the midpoint of the curve.
3. At the midpoint (K/2), the growth rate begins to decelerate but continues to grow until it reaches an asymptote, K which is called the "Carrying Capacity" for the environment.
4. The curve is S-shaped, as shown in Fig. 1.9.1, and is known as logistic curve.

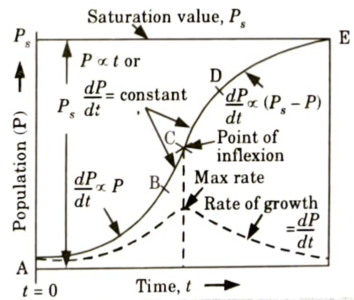

Fig. 1.9.1. Ideal population growth curve, (logistic curve).

5. The curve represents early growth AB at an increasing rate $\left(i.e., \text{ geometric of log growth, } \frac{dP}{dt} \propto P\right)$; and late growth DE at a decreasing rate $\left[i.e., \text{ first order curve } \frac{dP}{dt} \propto (P_s - P)\right]$ as the saturation value (P_s) is approached.
6. The transitional middle curve BD follows an arithmetic increase $\left[i.e. \frac{dP}{dt} = \text{contsant}\right]$.
7. A mathematical expression of logistic curve is given by

$$\log_e \frac{P_s - P}{P} - \log_e\left(\frac{P_s - P_0}{P_0}\right) = -KP_s t$$

$$P = \frac{P_s}{1 + m \log_e^{-1}(nt)}$$

where, $m = \frac{P_s - P_0}{P_0}$, $n = -KP_s = \frac{2.3}{t_1} \log_{10} \frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}$

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

P_s = Saturated population.

P_0, P_1 and P_2 = Population at time t_0, t_1 and t_2 respectively ($t_2 = 2t_1$)

Que 1.10. **Predict the population from the years 2012, 2021, 2031 and 2041 from the following census figures of a town by incremental increase method.**

Year	1951	1961	1971	1981	1991	2001	2011
Population (thousands)	93	111	132	161	191	212	223

AKTU 2014-15, Marks 03

Answer

1. The future population p_n is given by,

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

2. Value of P_0, n, $\bar{x}$ and $\bar{y}$ take from Table 1.10.1,

i. $$P_{2021} = 223 + 1 \times 21.67 - 1 \times \left(\frac{1+1}{2}\right) \times 1.4$$
$$= 243.27 \quad \text{(thousands)}$$

ii. $$P_{2031} = 223 + 2 \times 21.67 - 2\left(\frac{2+1}{2}\right) \times 1.4$$
$$= 262.14 \quad \text{(thousands)}$$

iii. $$P_{2041} = 223 + 3 \times 21.67 - 3\left(\frac{3+1}{2}\right) \times 1.4$$
$$= 279.61 \quad \text{(thousands)}$$

iv. $$P_{2012} = 223 + 0.1 \times 21.67 - 0.1\left(\frac{0.1+1}{2}\right) \times 1.4$$
$$= 225.09 \quad \text{(thousands)}$$

Table 1.10.1.

Year	Population (in thousands)	Increase in Population (in thousands)	Incremental Increase (in thousands)
1951	93		
		18	
1961	111		+ 3
		21	
1971	132		+ 8
		29	
1981	161		+ 1
		30	
1991	191		− 9
		21	
2001	212		−10
		11	
2011	223		
Total		130	− 7
Average Per Decade		$\bar{x}$ = 130/6 = 21.67	$\bar{y}$ = −7/5 = − 1.4

Que 1.11. **The population of 5 decades from 1930 to 1970 are given. Find out the population after one, two and three decades beyond the last known decade by using arithmetic mean method.**

Year	1930	1940	1950	1960	1970
Population	25,000	28,000	34,000	42,000	47,000

AKTU 2015-16, Marks 10

Answer

Given : Population of 5 decades given in question table.

To Find : Population in 1980, 1990 and 2000.

1.

Year	Population	Increase in Population (x)
1930	25,000	3000
1940	28,000	6000
1950	34,000	8000
1960	42,000	5000
1970	47,000	
	Total	22,000
	Average/Decade	$\bar{x} = \frac{22,000}{4} = 5,500$

2. The expected populations of the end of year are computed by following equation.

$$p_n = p_0 + n\bar{x}$$

3. Population after 1 decade beyond 1970,

$$p_{1980} = 47000 + 1 \times 5500 = 52500$$

4. Population after 2 decade beyond 1970,

$$p_{1990} = 47000 + 2 \times 5500 = 58000$$

5. Population after 3 decade beyond 1970,

$$p_{2000} = 47000 + 3 \times 5500 = 63500$$

Que 1.12. **Population of a town as obtained from the census report is as follows :**

Year	1971	1981	1991	2001
Population (In thousands)	242	345	770	1090

Estimate the population of the town in the year 2015 & 2021

1. **Arithmetic increase method.**
2. **Geometric increase method.**
3. **Incremental increase method.**

AKTU 2017-18, Marks 10

Answer

1. **Arithmetical Increase Method :**

i. The future populations are calculated as, $P_n = P_o + n\,\bar{x}$

(Value of P_o, $\bar{x}$ and n taken from the table 1.12.1)

ii. Population after 1.4 decade beyond 2001,

$$P_{2015} = P_{1.4} = P_{2001} + 1.4\,\bar{x} = 1090 + 1.4 \times 282.67 = 1485.738$$

iii. Population after 2 decade beyond 2001,

$$P_{2021} = P_2 = P_{2001} + 2 \times \bar{x} = 1090 + 2 \times 282.67 = 1655.34$$

2. **Geometric Increase Method :**

i. Population growth rate, $r = \sqrt[3]{42.56 \times 123.48 \times 41.56} = 60.22\ \%$

ii. The future population is given by, $P_n = P_o\left(1 + \frac{r}{100}\right)^n$

iii. Population after 1.4 decade ($n = 1.4$),

$$P_{1.4} = 1090\left(1 + \frac{60.22}{100}\right)^{1.4} = 2108.77$$

iv. Population after 2 decade ($n = 2$),

$$P_{2021} = 1090\left(1 + \frac{60.22}{100}\right)^{2} = 2798.08$$

Table 1.12.1.

Year	Population (in thousand)	Increase in population (x)	% Increase in Population $\frac{\text{col (3)}}{\text{col (2)}} \times 100$	Incremental Increase (y)
(1)	(2)	(3)	(4)	(5)
1971	242	103	$\frac{103}{242} \times 100 = 42.56$	
1981	345	425	$\frac{425}{345} \times 100 = 123.48$	322
1991	770	320	$\frac{320}{770} \times 100 = 41.56$	– 105
2001	1090			
Total	2447	848	207.6	217
Average		$\bar{x} = \frac{848}{3} = 282.67$		$\bar{y} = \frac{217}{2} = 108.5$

3. **Incremental Increase Method :**

i. The future population (P_n) is given by, $P_n = P_o + n\,\bar{x} + n\left(\frac{n+1}{2}\right)\bar{y}$

ii. Population after 1.4 decade,

$$P_{2015} = 1090 + 1.4 \times 282.67 + 1.4\left(\frac{1.4+1}{2}\right) \times 108.5$$
$$= 1668.018$$

425
103
322

iii. Population after 2 decade,

$$P_{2021} = 1090 + 2 \times 282.67 + 2\left(\frac{2+1}{2}\right) \times 108.5 = 1980.84$$

PART-3

Basic Needs and Factors Affecting Consumption.

CONCEPT OUTLINE

Affecting Factors of Consumption : Following are the factors responsible for water consumption :
i. Population, ii. Availability of water, iii. Quality of the water, iv. Presence of water demanding industries, v. Climate, vi. Cost of delivery.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.13. **Discuss the basic needs of water in a city.**

Answer

Following are the various basic needs of water :
1. Drinking and cooking.
2. Bathing and washing.
3. Watering of lawns and gardens.
4. Heating and air-conditioning systems.
5. Growing of crops.
6. Street washing.
7. Fire fighting.
8. Reaction in swimming pools, fountains and cascades.
9. Steam power and various industrial processes, etc.

Que 1.14. **What are the various factors responsible for variation in water consumption ?**

Answer

Following are the factor responsible for water consumption :
1. **Population :** If population will be more, the demand of water will be more and thus increase in water consumption.
2. **Availability of Water :** If availability of water is limited then water consumption will decrease.

3. **Quality of the Water :** Clean water will be more consumed as composed to contaminated water.
4. **Presence of Water Demanding Industries :** Water demanding industries increase the consumption of water.
5. **Climate :** High consumption in dry season than wet season because of dehydration.
6. **Cost of Delivery :** If cost production of water is high then higher tariff-reduction will be seen in the rate of consumption.
7. **Standard of Living of the Consumers :** Comfort household appliances like air conditioners, air coolers etc., affects the water consumption.
8. **Management and Efficiency of Water Works :** Good management provides better service (delivers) and thus high consumption.
9. **Pressure of the Water :** Low pressures leads to low consumption of water.
10. **Metering of Water Instead of Flat Rate :** This decreases the tariff and is controls consumption.
11. **Characteristics of the Population :** Culture, age distribution and religion are also responsible factor for this.

PART-4

Design Period.

CONCEPT OUTLINE

Design Period : The future period for which is provision is made in the water supply scheme is known as the design period.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.15. **What is design period ? Also explain its affecting factor and necessity.**

Answer

Design Period : It is the number of years in future for which the given facility is available to meet the demand.

Factor : Following are the affecting factors of design period :
1. **Life of the Structure :** Life of structure is the number of years in future for which the design period is physically suitable to provide the intended facility. So it should be less than life of structure.
2. **Ease or Difficulty in Extension :** For the projects whose extension is easily possible, it is kept low. *E.g.*, tube wells.

But for the projects whose extension is difficult, their design period is kept greater, *e.g.*, dams and reservoir.

3. **Rate of Population Growth :** If the rate of population growth is higher, then for that region shorter design period is required.
4. **Lead Time :** It is the time from the commencement of a project to its completion. Design period should be greater than lead time.
5. **Economy of Scale :** If the economy of scale is small, smaller design period will be used. It is economical to build a large structure, for longer design period.

PART-5

Various Types of Conduits.

CONCEPT OUTLINE

Type of Conduit :
i. Canals, ii. Aqueducts and tunnels, iii. Free flow pipelines, iv. Pressurised pipeline.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.16. **What is conduit ? What are the various types of conduits ?**

Answer

A. Conduit :

i. Conduit, channel or pipe for conveying water or other fluid or for carrying out certain other purposes, such as protecting electric cables.
ii. In water-supply systems the term is usually reserved for covered or closed sections of aqueduct, especially those that transport water under pressure.

B. Types of Conduit : Following are the various types of conduit :

1. **Canals :**
   i. Canals are laid in areas, where the required slope of the conduit more or less coincides with the slope of the terrain.
   ii. Generally they have a trapezoidal cross-section but the rectangular form will be more economical when the canal traverses solid rock.
2. **Aqueducts and Tunnels :**
   i. Aqueducts and tunnels are constructed in hilly areas. They should be of such a size that they are approximately three-quarters full at the design flow rate.

   ii. Tunnels for free-flow water transmission are frequently horseshoe shaped.
3. **Free-flow Pipelines :**
   i. Free-flow pipelines are used for transport of smaller quantities of water than tunnels.
   ii. Compared with canals and aqueducts they offer better protection from pollution.
4. **Pressurised Pipelines :**
   i. The routing of pressurised pipelines is much less limited by the topography of the area to be traversed, than in the case of canals, aqueducts or free-flow pipelines.
   ii. A pressure pipeline may run up and downhill and there is considerable freedom in selecting the pipeline alignment.
   iii. Such pipelines often follow the topography quite closely, being buried at a similar depth for the length of the route.

Que 1.17. **What are the advantages and disadvantages of pressure conduits (or pipes) over gravity conduits (or pipes) ?**

Answer

A. Advantages : Following are the advantages of pressure conduits over gravity conduit :

1. Pressure pipes are more economical than canals or flumes, because they follow shorter routes.
2. Water moving through pressure pipe is not exposed everywhere, so there is less chances of getting polluted.
3. Pressure pipes are used for water supply but gravity pipes are adopted for carrying sewage and drainage.
4. In pressure pipes water is saved from percolation, evaporation etc.
5. Permitting increased pressure for fire fighting.

B. Disadvantages : Following are the disadvantages of pressure conduits over gravity conduit :

1. Power failure and pressure will fluctuate substantially with variation in flow.
2. The flow must be constantly varied to match an unpredictable demand.
3. Increasing power costs.

PART-6

Capacity and Sizes Including Economical Sizes of Rising Main.

CONCEPT OUTLINE

Economical Size of Rising Main : The pipe diameter corresponding to least cost is then selected as economical size of conduit.

$$D = a\sqrt{Q}$$

$$a = 0.97 \text{ to } 1.22$$

Formula for Head Loss in Pipes :
i. Darcy-Weisbach formula, ii. Manning's equation, iii. Hazen-Williams formula. iv. Modified Hazen-William's formula :

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.18. **How to determine economical diameter of pumping mains ?**

Answer

1. If the diameter of the pipe is increased, it will lead to the higher cost of the pipe line.
2. If the diameter of the pipe is reduced, the increased velocity will lead to higher frictional head loss and will require most horse-power for the required pumping, thereby increasing the cost of pumping.
3. For obtaining the optimum efficiency it is utmost necessary to design the diameter of the pumping main, which will be overall most economical in initial cost as well as maintenance cost for pumping the required quantity of water.
4. It can be calculated as :

$$D = 0.97 \text{ to } 1.22\ \sqrt{Q}$$

where, D = Economical diameter of pipe in m.
Q = Required discharge of water to be pumped in m^3/sec.

Que 1.19. **What are the various methods for determination of head loss in pipes ?**

OR

Discuss the modified Hazen William's formula compute velocity of flow and head loss due to friction in a pipe.

OR

Write down : Darcy Weisbach formula, Hazen William formula, modified Hazen William formula and Manning's formula.

AKTU 2013-14, Marks 03

OR

Write down various formulae used in pipe/sewer network hydraulic calculations. Also explain various term used.

AKTU 2014-15, Marks 05

Answer

Following are the various formulae used to calculate head loss in pipes :

1. **Darcy-Weisbach Formula :**

Head loss, $$H_L = \frac{f' L}{d} \frac{v^2}{2g}$$

where, L = Length of pipe.
d = Diameter of pipe.
v = Mean velocity of flow through pipe (m/sec),
f' = Dimensionless friction factor varying between 0.02 (for smooth pipe) to 0.075 (for old rough pipes).

$$f' = 0.04\left[1 + \frac{1}{35d}\right] \text{ for old pipe}$$

$$f' = 0.02\left[1 + \frac{1}{35d}\right] \text{ for new pipe.}$$

2. **Manning's Equation :** It is basically used for gravity conduits but also applicable to turbulent flow in pressure conduits.

Head loss, $$H_L = \frac{n^2 v^2 L}{R^{4/3}},\ v = \frac{1}{n} R^{2/3}\sqrt{S}$$

where, n = Manning's roughness coefficient.
R = Hydraulic mean depth of pipe.

$$= \frac{\text{Area}}{\text{Perimeter}} = \frac{d}{4}$$

3. **Hazen-Williams Formula :**
Mean velocity of flow (m/sec),

$$v = 0.849\ C_H R^{0.63}\ S^{0.54}$$

C = Coefficient of roughness hydraulic capacity.

4. **Modified Hazen-William's Formula :**

It states $$v = \frac{3.83 C_R [d^{0.6575} (g\ \ S)^{0.5525}]}{v^{0.105}}$$

where, C_R = Dimensionless coefficient of roughness.
S = Friction slope = H_L/L.
v = Viscosity of liquid. = 10^{-6} m^2/sec for H_2O at 20 °C
v = $143.534\ C_R\ R^{0.6515}\ \ S^{0.5525}$

$$H_L = \frac{L(Q/C_R)^{1.81}}{994.62 d^{4.81}}$$

5. **Chezy's Formula :** v = $CR^{1/2}\ S^{1/2}$

Que 1.20. **How to determine head loss when pipes are in series or in parallel ?**

Answer

A. Head Loss when Pipes in Series :

1. When pipes of different diameter are connected in series, the total head loss is equal to the summation of the individual head losses in different pipes.
2. In addition to the frictional head loss, the minor losses in bends, valves, gates, contraction/expansion also come into play and if the length of pipe line is short these minor losses may be quite significant in comparison to friction losses.

B. Head Loss when Pipes in Parallel :

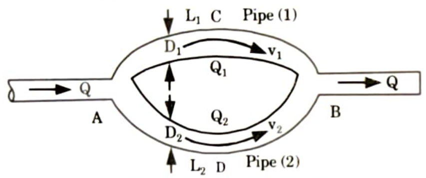

Fig. 1.20.1. Pipes in parallel.

1. When pipes are laid in parallel, as shown in Fig. 1.20.1, the head loss through each pipe will be the same. Also, the total discharge Q will be equal to the sum of the discharge in each pipe.
$$Q = Q_1 + Q_2$$
2. If d_1, d_2 and L_1, L_2 are the diameters and the lengths of the pipe (1) and (2) respectively; then the velocity of flow v_1 and v_2 in the two pipes must be such as to give
$$H_L = \frac{f' L_1 v_1^2}{2gd_1} = \frac{f' L_2 v_2^2}{2gd_2}$$
3. The head loss H_L may also be expressed in a general form as :
$$H_L = r\,Q^n$$
where r depends on length, diameter and roughness of the pipe, and the exponent n is equal to 1.852 (For Hazen-William's formula) and 2 (For Darcy-Weisbach and Manning's formulae).

Que 1.21. **What is to be supplied to a town of 2 lakh population from a source 1.5 km away ? "The per capital demand of town is 200 lpcd". If town is situated at a higher level than the source and the difference in elevation between the lowest water in the source to the point of inlet at the water works is 27 m. Determine the size of the rising main and HP of the pump. The value of C_H = 110 and the pump works for 18 hours.**

AKTU 2016-17, Marks 15

Answer

Given : Per capita demand = 200 lpcd, Population = 2 Lakh, Distance = 1.5 km, Difference in elevation = 27 m, C_H = 110, Time duration = 18 hrs.

To Find : Size of the rising main and HP of the pump.

1. Average quantity of water required
$$= 200 \times 200000 \text{ litres per day} = 40 \text{ Mld}$$
2. Assuming the maximum demand to be 1.8 times the average demand, we have
Maximum demand = 40 × 1.8 Mlpd = 72 Mlpd
$$= \frac{72 \times 10^6}{10^3 \times 24 \times 60 \times 60} = 0.83 \text{ cumecs}$$
$$\text{Maximum draft required} = 0.83 \times \frac{24}{18} = 1.107 \text{ cumecs}$$
3. Assuming the velocity of flow through the pipe to be 1.5 m/sec, we have
$$\text{Area of the pipe required, } A = \frac{Q}{v} = \frac{1.107}{1.5} = 0.74 \text{ m}^2$$
$$\text{Diameter of the pipe required, } d = \left(\frac{0.74}{\pi/4}\right)^{1/2} = 0.97 \text{ m} \approx 1000 \text{ mm}$$
Thus, use pipes of diameter 1000 mm, which is the nearest standard size of the available pipes.
4. $$\text{Actual area provided} = \frac{\pi}{4} \times (1.0)^2 = 0.785 \text{ m}^2$$
$$\text{Actual velocity of flow, } v = \frac{Q}{A} = \frac{1.107}{0.785} = 1.41 \text{ m/sec}$$
5. Head loss can be calculated by using,
Hazen-Williams formula, $v = 0.849\, C_H R^{0.63} S^{0.54}$ ...(1.22.1)
Take, C_H = 110, and $R = \frac{d}{4} = \frac{1.0}{4}$
By substituting in the above eq. (1.22.1), we get
$$1.41 = 0.849 \times 110 \times \left(\frac{1.0}{4}\right)^{0.63} \times S^{0.54}$$
$$1.41 = 39 \times S^{0.54}$$
$$S = 0.00214$$
6. $$S = \frac{H_f}{L}$$
$$\frac{H_f}{L} = 0.00214$$
$$H_f = 0.00214 \times L$$
7. Head loss from the source to the service reservoir in a length of 1.5 km or 1500 m
$$= 0.00214 \times 1500 = 3.21 \text{ m}$$

8. The head difference between the lowest water level in the sump well and the service reservoir is given as 27 m.
   Total lift or head required for the pump, $H = (27 + 3.21) = 30.21$ m
9. Power of the pump required, $P = \dfrac{\gamma_w QH}{\eta}$
10. Assuming the efficiency of the pump as 60 %, we obtain

$$P = \frac{9810 \times 1.107 \times 30.21}{0.60}$$

$$= 546784.4 \approx 546.78 \text{ kW} \qquad (\because 1 \text{ HP} = 746 \text{ Watt})$$

$$P = \frac{546784.4}{746} = 732.955 \text{ HP}$$

PART-7

Laying and Testing of Water Supply Pipelines.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.22. **What is the procedure of laying water supply pipeline ?**

Answer

Procedure :
1. Pipes are laid either above the ground or below the ground.
2. The pipes bringing water from the source to the city are laid on ground, whereas the distributing mains taking water within localities are laid below the roads and streets.
3. When pipes are laid on ground, they must be laid on well compacted formation of suitable width to avoid future settlements. When pipes are buried under the ground they are laid in trenches excavated up to required depths.
4. Top of pipe is generally kept under 1 m below the road surface to minimise the impact and traffic loads transmitted to pipe width of trench is generally kept 30-50 cm more than outside diameter.

Que 1.23. **What are the various external and internal pressure that a pipe bears during its laying and operation ?**

AKTU 2013-14, Marks 03 | **AKTU 2014-15, Marks 05**

Answer

Following forces are generally come into the pressure pipes :

1. Internal pressure of water and water hammer pressure. It is resisted by using materials strong in tension.
2. Pressure due to external loads in the form of traffic loads, backfill etc., are resisted by using material strong in compression.
3. Longitudinal temperature stresses created when pipes are laid above the ground. It is resisted by providing expansion joints.
4. Longitudinal stresses created due to unbalanced pressure at bends or at points of changes of cross-section. It is resisted by holding the pipe firmly by anchoring it in massive block of concrete or stone masonry.
5. Flexural stresses produced when pipes are supported over trestles.

Que 1.24. **How to perform testing on pipelines after laying process ?**

Answer

After laying of a pipe line, the pipe line will be tested for the soundness in its construction. The procedure follows :
1. At a time only one particular section laying between two sluice valves is taken up for testing.
2. Downstream sluice valve is closed and water is admitted into pipe through upstream sluice valve.
3. The upstream valve then closed to isolate the pipe section from rest of pipe.
4. Pressure gauge is then fitted along the length of pipe section through holes.
5. The pipe section is then connected to the delivery side of a pump through a small by pass valve and pump is started to develop pressure in pipe. It continues up to the pressure inside pipe reaches the desired value that can be read from pressure gauges, fixed on pipe.
6. The bypass valve is then closed and discontinues pumping.
7. Pipe is thus kept under pressure for 24 hours and inspected for possible defects, leakage etc.
8. Pipe is then emptied through drain valves and observed defects are rectified.

PART-8

Pipe Materials, Joints.

CONCEPT OUTLINE

Types of Pipes : Following are the various types of pipes :
i. Cast iron pipes, ii. Cement concrete pipes, iii. Galvanized iron pipes, iv. Plastic pipes, v. Steel pipes, vi. Wrought iron pipes, vii. Vitrified clay pipes.

Joints : It provided for continuity in the length of pipe.

Type : Following are the various types of joints :
i. Collar joint, ii. Expansion joint, iii. Flanged joint, iv. Flexible joint, v. Mechanical joint, vi. Spigot and socket joint etc.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.25. **Discuss different types of pipes commonly used in water supply scheme.**

OR

Discuss advantages and disadvantages of cast iron, wrought iron, steel and galvanized iron pipes.

Answer

1. **Cast Iron Pipes :**
   i. It is widely used for city water supplies.
   ii. They are sufficiently resistant to corrosion and may last as 100 years.
   iii. They are manufactured in lengths of about 3.5 m to 6 m.
   iv. They are available in size up about 1.2 m or more diameters.

   Advantages :
   i. Moderate cost and long life (100 years or so).
   ii. Withstand high internal pressure.
   iii. Strong and durable.
   iv. Not subjected to corrosion.

   Disadvantages :
   i. Carrying capacity decreases with age.
   ii. Unsuitable for pressure more than 0.7 N/mm^2.
   iii. Heavy and difficult to transport.
   iv. Break easily due to brittleness.
2. **Cement Concrete Pipes :**
   i. These pipes can be precast or cast in situ.
   ii. They may be plain, reinforced or prestressed.
   iii. Up to 15 m head, plain concrete pipes are used, but reinforced cement concrete pipes can be used up to a head of 75 m, and prestressed for more than 75 m.
   iv. RCC pipes are also called hume pipes / spun pipes.

   Advantages :
   i. Smooth internally, durable, not corrode, and long life (about 75 year).
   ii. Low maintenance cost.
   iii. Cast-in-situ pipes eliminate transport charges.
   iv. They do not collapse under normal traffic loads and unaffected by atmospheric action.

   Disadvantages :
   i. Affected by acids, alkalis.
   ii. Cost of transportation and lying is more.
   iii. May crack during handling and can cause leakage.
   iv. Cannot withstand high pressure.

3. **Galvanized Iron Pipes :** They are widely used for service connection. Diameter varies from 6-75 mm. These are wrought iron pipe with zinc coating.

   Advantages :
   i. Cheap.
   ii. Light in weight, easy to handle.
   iii. Easy to join.

   Disadvantages :
   i. Affected by acids and alkaline.
   ii. Liable to incrustation easily.
4. **Wrought Iron Pipes :** These pipes are made by rolling the flat plates of the metal to proper diameter and welding the edges. Used in interior portions only so that they can be protected from corrosion.

   Advantages : Light in weight and can be easily cut and gives neat appearance.

   Disadvantages :
   i. Costly.
   ii. Less durable and easily corroded.
5. **Steel Pipes :** These are used occasionally at places where pressure is high and diameter is more. Outside and inside surface are generally galvanised.

   Advantages :
   i. Durable and strong.
   ii. Flexible and can be laid on curves.
   iii. Light in weight and easy to handle and transport.

   Disadvantages :
   i. High maintenance cost.
   ii. Can be rusted by slightly acidic or alkaline water.
   iii. Atmospheric agencies may have adverse effect.

Que 1.26. **What is hume pipe ? How is it manufactured ?**

AKTU 2013-14, Marks 03

Answer

Hume Pipe : Hume pipe is a process to make concrete pipe through RCC pipe making machine. The process is also known as spun pipe. Hume pipe are the traditional reinforced concrete cement pipes make from years old traditional pipe making machine.

Manufacturing Process:
1. The reinforced cage is first prepared on the cage-winding machine by hand process.
2. The cage is then placed inside the pipe mould which is then hoisted up and mounted horizontally on the turn unions.
3. It is rotated by driving shaft with variable speed arrangement, the rotation is kept slow in the beginning and then the speed is increased.

4. The concrete mixture for the RCC spun pipe is prepared by cement, stone, metal and sand.
5. The cement concrete is fed into the moulds during rotation which spreads inside evenly.
6. The time required for completion of this operation depends upon the diameter and class of the pipe.
7. The pipes are kept in the mould for 24 hours. On the following day the pipes are removed from the moulds and submersed in water in the curing tank for about 15-20 days depending upon the class of the pipe.

Que 1.27. **Explain various types of joints used in water supply system.**

AKTU 2015-16, Marks 10

OR

Explain the following with neat sketch – spigot and socket joint.

AKTU 2013-14, Marks 03

OR

Explain the following joints used in water supply pipes with neat sketches.

i. Socket and spigot joint.

ii. Expansion joints.

AKTU 2016-17, Marks 10

Answer

Types of Joints : Following are the various types of joints :

A. Collar Joint :

1. It is mostly used for joining large diameter concrete and asbestos pipes. End of 2 pipes are brought in level.
2. Rubber gasket is placed between curves, as pipes of rope soaked in cement are kept in groove.
3. The collar is placed at the joint so that it has equal laps over joint.

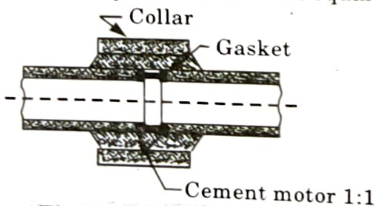

Fig. 1.27.1. Collar joint.

B. Expansion Joint :

1. It is used where pipes expand or contract due to change in temperature.
2. An elastic is tightly pressed between the annular space of spigot and bell ends to make the joint tight (water).
3. The flanged ring is bolted to bell and it expands or contracts along with the bell end.

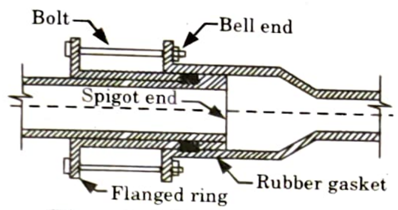

Fig. 1.27.2. Expansion joint.

C. Flanged Joint :

1. It is used for connecting pipes carrying water under high pressure.
2. The ends of pipes are provided with wide flanges which are bolted together.
3. The two ends of pipes to be jointed are brought together in level.
4. Then a hard rubber gasket is inserted between the flanges to make the joint water tight and the flanges are bolted together.
5. These are used at places where it is required to dismantle and reassemble.

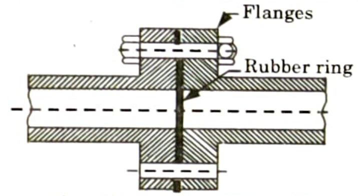

Fig. 1.27.3. Flanged joint.

D. Flexible Joint :

1. It is used at places where settlement is expected after laying and on curves, as the pipes at joint can be laid at angle. Socket end is cast in spherical shape and spigot end is plain but has a bead at the end.
2. Spigot end is placed in spherical shaped socket end and a retainer ring is slipped and stretched over the bead.
3. Outer surface of a rubber gasket ring is same as inner surface of socket end.
4. Over this, cast iron follower ring is moved and is fixed to the socket end by bolt.

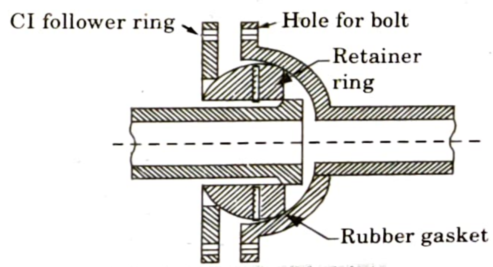

Fig. 1.27.4. Flexible joint.

E. Mechanical Joint : It is used when both ends of pipe are plain or spigot :

1. Victaulic Joint :

i. U shaped rubber ring is slipped over both the ends of pipes to make the joint water tight.

ii. Two half housing / couplings engage grooves near the pipe ends and enclose the rubber ring. Couplings are bolted around pipe.

iii. This joint can bear shocks, vibration, etc.

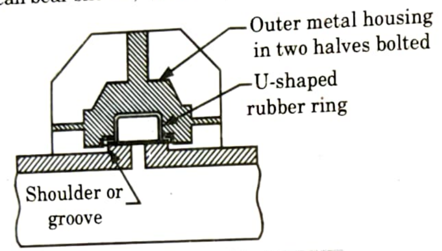

Fig. 1.28.5. Victaulic joint.

2. Dresser Coupling Joint :

i. It is used for connecting small diameter iron pipes. The ends of pipes to be jointed have threads on outside.

ii. The socket or coupling has threads on inner side.

iii. The same socket is screwed on both ends of pipes to be jointed.

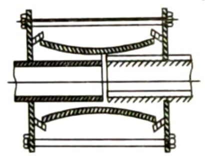

Fig. 1.27.6. Dresser coupling joint.

F. Simplex Joint :

1. In this joint the two plain ends of pipes butt against each other. Then, rubber rings are slipped over pipes.
2. Then, a coupling will be pushed over the rubber rings.
3. It makes a water tight and flexible joint which can be completed easily in dry condition or under water.

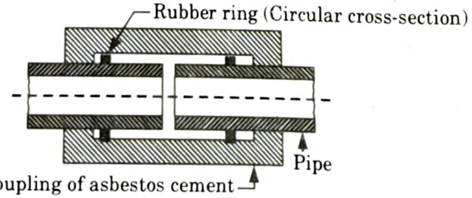

Fig. 1.27.7. Simplex joint.

G. Spigot and Socket Joint :

1. It is used for joining cast iron pipes. Spigot of one pipe is slipped into socket of next pipe.
2. Tarred gasket is then cropped around spigot.
3. A joint runner is formed around barrel and against the face of socket.
4. Molten lead is poured through hole to fill remaining annular space. After hardening of lead runner is removed.

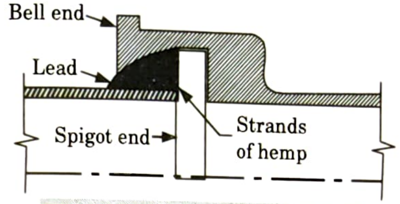

Fig. 1.27.8. Spigot and socket joint.

Que 1.28. **Discuss various classifications of cement concrete pipe as per IS-458 : 2003. Also give suitability of each class of pipes.**

AKTU 2016-17, Marks 10

Answer

Following are the various classes of cement concrete pipe :

Classes	Description	Condition / Suitability of Use
NP1	Unreinforced concrete non-pressure pipes.	For drainage and irrigation use, above ground or in shallow trenches.
NP2	Reinforced concrete, light-duty, non-pressure pipes.	For drainage and irrigation use, for cross drains/culverts carrying light traffic.
NP3	Reinforced and also unreinforced (in case of pipes manufactured by vibrated casting process) concrete, medium-duty, non-pressure pipes.	For drainage and irrigation use, for cross drains/culverts carrying medium traffic.
NP4	Reinforced and also unreinforced (in case of pipes manufactured by vibrated casting process) concrete, heavy-duty, non-pressure pipes.	For drainage and irrigation use, for cross drains/culvert carrying heavy traffic.

P1	Reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.2 MPa (20 m head).	For use on gravity mains, the site test pressure not exceeding two-thirds of the hydrostatic test pressure.
P2	Reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.4 MPa (40 m head).	For use on pumping mains, the site test pressure not exceeding half of the hydrostatic test pressure.
P3	Reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.6 MPa (60 m head).	For use on pumping mains, the site test pressure not exceeding half of the hydrostatic test pressure.

PART-9

Appurtenances and Valves Leakage and Control.

CONCEPT OUTLINE

Types of Appurtenance : Following are the various types of appurtenance :

i. Ferrule, ii. Goose Neck, iii. Stop Cock.

Valves : It control the flow of the water, to regulate air and pressure and prevent back flow of water.

Type : Following are the various types of valves :

i. Sluice valve, ii. Check or reflux valve,
iii. Air valve, iv. Scour valve etc.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.29. Explain the following appurtenances – Ferrule, goose neck and stop cock.

OR

Explain following terms with reference to water connection to a house. Ferrule, goose neck and stop cock.

Answer

A. **Ferrule :**

1. A ferrule is a right angled sleeve made of brass or gun metal, and is joined to a hole drilled in the water main, to which it is screwed down with a plug.

2. Its size usually varies between 10 to 50 mm diameter. For all other connections of more than 50 mm diameter, a tee branch connection, off the water main, is used.

B. **Goose Neck :** Goose neck is a small sized curved pipe made of a flexible material (usually lead) and is about 75 cm in length forming a flexible connection between the water main and the service pipe.

C. **Stop Cock :**

1. The stop cock is provided before the water enters the water meter in the house.
2. It is housed in a suitable masonry chamber with a removable cover, and is fixed in the street close to the boundary wall in an accessible position.
3. Sometimes, it is provided just before the water meter inside the house, keeping both of them in one chamber.

Que 1.30. Discuss in detail all types of valves used in pipeline.

OR

Explain the working of following with neat sketch :

A. Gate valve. B. Reflux valve. **AKTU 2013-14, Marks 03**

OR

Explain the working of following with neat sketch.

A. Gate valve. B. Air valve. **AKTU 2014-15, Marks 05**

Answer

Following are the various types of valves used in pipelines :

A. **Sluice Valves/Gate Valves :**

1. These are also known as gate-valves or stop valves. These valves control the flow of water through pipes.
2. The entire distribution system is decided into blocks by providing these valves at appropriate places.
3. They are provided in straight pipeline at 150-200 m intervals.
4. When two pipes lines intersect valves are fixed in both sides of intersection. When sluice valve is closed, it shuts off water in a pipeline to enable to undertake repairs in that particular block.
5. The flow of water can be controlled by raising or lowering the handle or wheel.

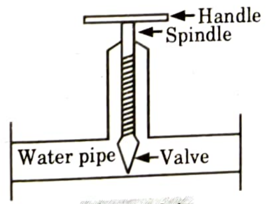

Fig. 1.30.1.

B. Check Valve or Reflux Valve :

1. These valves are also known as non-return valves. A reflux valve is an automatic device which allows water to go in one direction only.

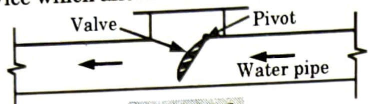

Fig. 1.30.2.

2. When the water moves in the direction of arrow, the valve swings or rotates around the pivot and it is kept in open position due to the pressure of water.
3. When the flow of water in this direction ceases, the water tries to flow in a backward direction. But this valve prevents passage of water in the reverse direction.
4. Reflux valve is invariably placed in water pipe, which obtain water directly from pump.
5. When pump fails or stops, the water will not run back to the pump and thus pumping equipments will be saved from damage.

C. Air Valves : These are automatic valves and are of two types namely :

1. Air Inlet Valves :

i. These valves open automatically and allow air to enter into the pipeline so that the development of negative pressure can be avoided in the pipelines.

ii. The vacuum pressure created in the downstream side in pipelines due to sudden closure of sluice valves.

iii. This situation can be avoided by using the air inlet valves.

2. Air Relief Valves :

i. Sometimes air is accumulated at the summit of pipelines and blocks the flow of water due to air lock.

ii. In such cases the accumulated air has to be removed from the pipe lines. This is done automatically by means of air relief valves.

iii. This valve consists of a chamber in which one or two floats are placed and is connected to the pipe line.

iv. When there is flow under pressure in the pipeline water occupies the float chamber and makes the float to close the outlet.

v. But when there is accumulation of air in the pipeline, air enters the chamber, makes the float to come down, thus opening the outlet.

vi. The accumulated air is driven out through the outlet.

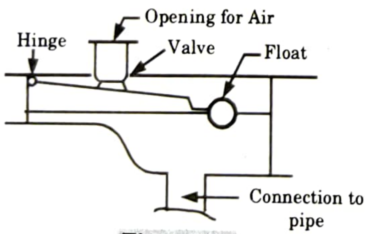

Fig. 1.30.3.

Que 1.31. **What are causes of leakage in mains ? And also describe the leakage detection methods.**

Answer

A. Causes of Leakage : Following are the causes of leakage in mains :

i. Corrosion.　　ii. Cracks.

iii. Faulty joints.

iv. Fixtures in consumer premises : faulty washers, valves and taps.

B. Detection Method : Following are the methods use for detecting leakage points in pipelines.

i. By measuring the pressure difference.

ii. By measuring the mass difference.

iii. By using sensor release to flow with water stream.

iv. By visual inspection.

v. By using sounding rod.

vi. By using radioactive isotopes.

vii. By plotting hydraulic gradient lines.

Que 1.32. **Discuss various factors which affect the losses/waste in water supply.**

AKTU 2014-15, Marks 03

Answer

Following are the various factors which affect the losses/waste in water supply :

1. Water Tight Joints :

i. The joints in the water mains and pipes generally leak due to bed plumbing, leading to high wastage of water.

ii. The leakage of water can be reduced by careful and better plumbing with constant maintenance, and thereby keeping the joints water tight.

iii. The meters when installed in individual house connections should also be periodically checked so as to ensure that they do not leak.

2. Pressure in the Distribution System :

i. High pressure in the distribution pipe leads to higher leakage losses.

ii. An increase in pressure from 20 m head of water to 30 m head of water may increase the leakage by about 20 to 30 per cent.

iii. Hence, in order to keep the leakage less, it is desirable to keep the pressure in the pipes to a minimum possible value.

3. System of Supply :

i. In intermittent system of supplies, the leakage losses are reduced since they do not occur for all the 24 hours but occur only for few hours during the period the supply is restored.

ii. However, it cannot be said with certainty that intermittent supply reduces losses, because in that case, people generally waste more water by throwing the old stored water and also by leaving their taps open.

4. **Metering :** When the supplies are metered, wastage is considerably reduced, because people become more careful in using water, as they have to pay for the volume consumed by them.

Que 1.33. What is water hammer in a pipe network ? What provisions are made to safeguard a network from hammer ?

AKTU 2014-15, Marks 05

OR

Explain water hammer and its control majors.

AKTU 2016-17, Marks 10

Answer

A. Water Hammer :

1. When a liquid flowing in a pipe is abruptly stopped by closing of a valve, etc., the velocity of the water column behind is retarded, and its momentum gets dissipated due to the conversion of kinetic energy into elastic energy.
2. A series of positive and negative pressure waves are produced, which travel back and forth in the pipe, till they are damped out by friction. This phenomenon is known as water hammer.

B. Precautions : Following are the precautions used to safeguard a network from hammer :

1. If the actual time of closure (T) is greater than the critical time T_c, the water hammer pressure is reduced approximately in the proportion T_c / T.
2. Installing automatic valve with closing time of 20-30 sec. Instead of regular check valves, pump stops after valve has closed.
3. Stopping pumps slowly with frequency control.
4. Preventing of simultaneous stopping of two or more pumps.
5. Installing automatic air relief valves at points where negative pressure occurs.

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2

UNIT

Storage and Distribution of Water

CONTENTS

ii. They are generally constructed at high points in the city.

iii. In a gravitational type of distributional system and pumping system used for treated water is filled the reservoirs.

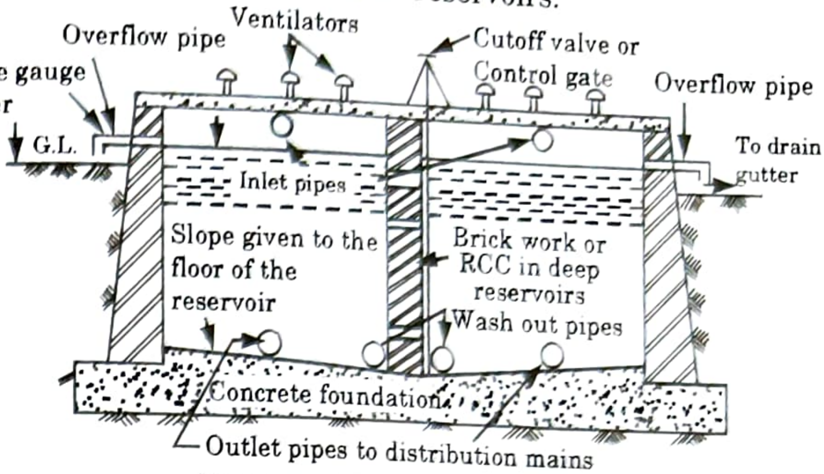

Fig. 2.1.1. Surface reservoir.

2. **Elevated Reservoirs :**

i. These are the elliptical overhead tanks erected at a certain suitable elevation above the GL and supported on towers.

ii. They are constructed in the areas, where combined gravity and pumping system for water distribution is adopted.

iii. Water pumped into these elevated tanks from the filter units or from the service reservoirs and then supplies it to consumers.

iv. These tanks may be made of RCC, steel, or prestressed concrete.

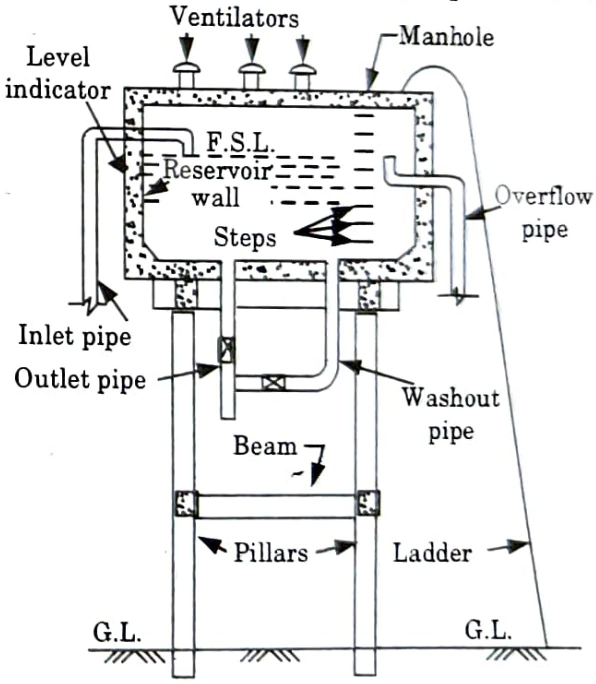

Fig. 2.1.2. Elevated reservoir.

3. **Stand Pipes :**

i. Stand pipes are a kind of elevated tanks without any erected towers for resting the body.

PART-1

Types of Distribution Reservoirs.

CONCEPT OUTLINE

Types of storage and distribution reservoirs :
- i. Surface reservoirs.
- ii. Elevated reservoirs.
- iii. Stand pipes.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. **What is service reservoir and what are their types ? Draw neat sketch of all reservoirs.**

OR

What are storage and distribution reservoirs ? Also discuss their purpose.

Answer

Storage and Distribution Reservoirs : Distribution reservoirs, also called service reservoirs are the storage reservoirs, which store the treated water for supplying water during emergencies (such as during fires, repairs, etc.) and also to help in absorbing the hourly fluctuations in the normal water demand.

Purpose : Following are the purpose of storage and distribution reservoirs :

- i. They absorb hourly variation in demand.
- ii. Provision of reservoirs makes it possible to run the pumps at uniform rate.
- iii. It results in an overall reduction in the sizes of pumps and treatment units.
- iv. It serves as storage for emergencies such as outbreak of fire, failure of pumps or bursting of mains.
- v. They maintain the desired pressure in the main constantly.
- vi. Operation of the distribution system becomes very easy.

Types of Storage and Distribution Reservoirs : Following are the various types of storage and distribution reservoirs :

1. **Surface Reservoirs :**
   - i. Surface reservoirs are circular or rectangular tanks constructed at ground level or below ground level therefore they also called as ground reservoirs.

CONCEPT OUTLINE

Types of Distribution Method : Following are the types of distribution method :

i. Gravity distribution system.
ii. Pressure distribution system.
iii. Combined gravity and pumping system.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.3. What is the purpose of water distribution system ? Also write the requirements of good distribution system.

Answer

A. Purpose of Water Distribution System :

i. The purpose of distribution system is to deliver water to consumer with appropriate quality, quantity and pressure.
ii. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage.

B. Requirement of Good Distribution System : A good distribution system should satisfy the following requirements :

1. The system should be capable of supplying water at consumers tap at reasonable pressure head. Also, the head should not be excessive.
2. It should be capable of meeting the fire demand simultaneously.
3. It should maintain the degree of purity.
4. The distribution system should be completely watertight.
5. It should be easy to operate and maintain.
6. Water should be available even during breakdown period.
7. It should be so laid that during repairs, it does not cause obstruction to traffic.
8. The initial cost of the distribution system should be as low as possible.

Que 2.4. Discuss following methods of water distribution :

A. Gravitational system.
B. Pumping system.
C. Combined system.

AKTU 2014-15, Marks 06

Answer

Following are the methods used in water distribution :

ii. They are thus tall cylindrical shells resting directly on the ground.
iii. Hills or high ground will be suitable for a stand pipe location.

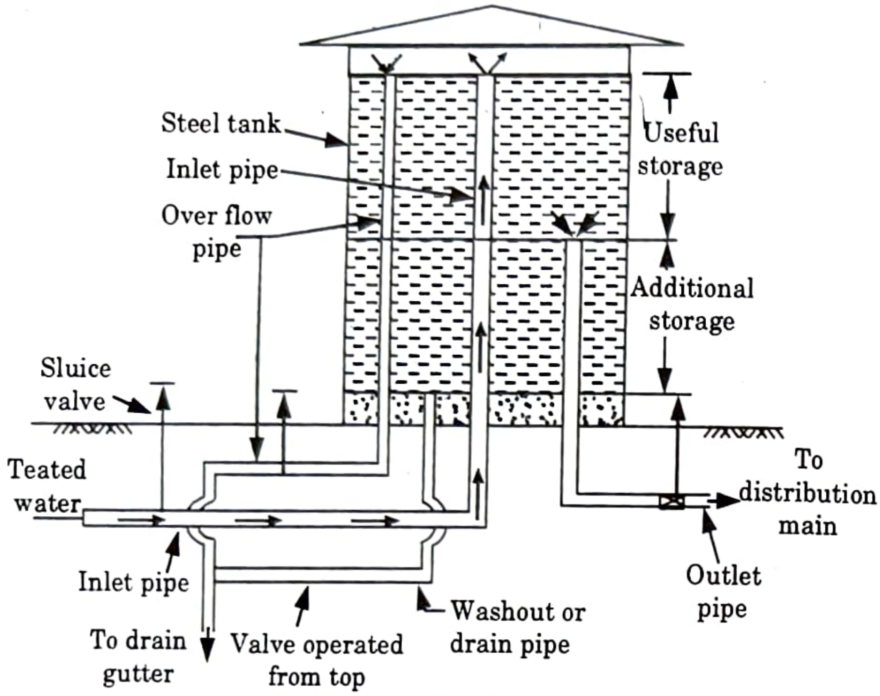

Fig. 2.1.3. Stand pipe.

Que 2.2. **What are the functions of distribution reservoirs ?**

Answer

Following are the function of distribution reservoirs :

1. They absorb the hourly variations in demand, and allow the water treatment units and pumps to operate at a constant rate. This will reduce the RMO costs and improve efficiency.
2. They help in maintaining constant pressure in the distribution mains.
3. The pumping of water in shifts is made possible by them without affecting the supply. Thus, 8 to 16 hours of pumping can be carried out, so as to pump the whole day's demand.
4. The water stored in these reservoirs can be supplied during emergencies, such as break down of pumps, heavy fire demand etc.
5. They lead to an overall economy by reducing the sizes of pumps, pipe lines, and treatment units.

PART-2

Methods of Distribution, Pressure and Gravity Distribution Systems.

A. Gravitational System :

1. When some ground sufficiently high above the city area is available, this can be best utilized for distribution system in maintaining pressure in water mains.
2. This method is also much suitable when the source of supply such as lake, river or impounding reservoir is at sufficiently higher than city.
3. The water flows in the mains due to gravitational forces.
4. As no pumping is required therefore, it is the most reliable system for the distribution of water as shown in Fig. 2.4.1.

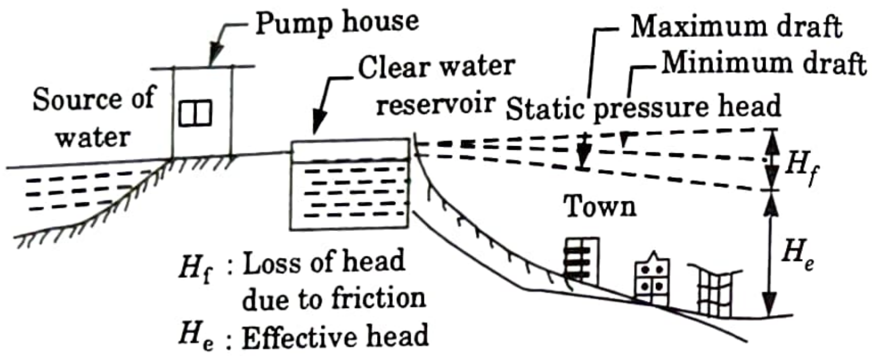

Fig. 2.4.1. Gravity system.

B. Pumping System :

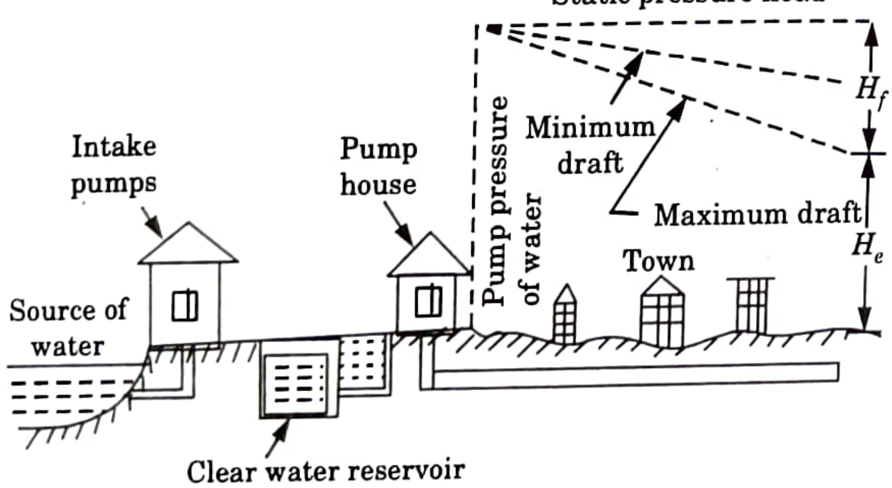

Fig. 2.4.2. Pumping system.

1. Constant pressure can be maintained in the system by direct pumping into mains.
2. Rate of flow cannot be varied easily according to demand unless number of pumps are operated in addition to stand by ones.
3. Supply can be affected during power failure and breakdown of pumps.
4. Hence, diesel pumps also in addition to electrical pumps as stand by to be maintained.
5. During fires, the water can be pumped in required quantity by the stand by units.

C. Combined (Pumping and Gravity) System :

1. This is also known as dual system. The pump is connected to the mains as well as elevated reservoir.

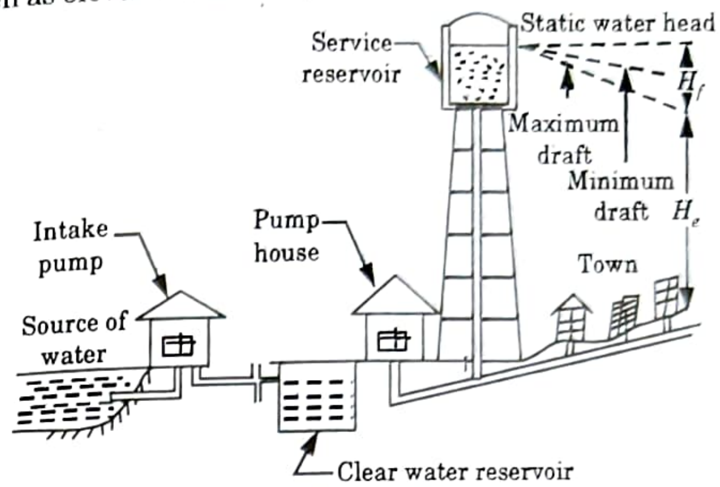

Fig. 2.4.3. Dual system.

2. In the beginning when demand is small the water is stored in the elevated reservoir, but when demand increases the rate of pumping, the flow in the distribution system comes from both the pumping station as well as elevated reservoir.
3. This system is more reliable and economical, because it requires uniform rate of pumping but meets low as well as maximum demand.
4. The water stored in the elevated reservoir meets the requirements of demand during breakdown of pumps and for fire fighting.
5. The water may be supplied to the consumers by either of the two systems :

i. Continuous System :

a. This is the best system and water is supplied for all 24 hours.
b. This system is possible when there is adequate quantity of water for supply.
c. In this system, sample of water is always available for fire fighting and due to continuous circulation water always remains fresh.

ii. Intermittent System :

a. If plenty of water is not available, the supply of water is divided into zones and each zone is supplied with water for fixed hours in a day or on alternate days.
b. As the water is supplied after intervals, it is called intermittent system.

Que 2.5. **Compare the advantages and disadvantages of continuous and intermittent systems of water supply scheme.**

AKTU 2013-14, Marks 3.5

OR

Compare marits and demerits of the continuous and intermittent system of water supply.

AKTU 2014-15, Marks 3.5

Answer

S. No.	Continuous System	Intermittent System
1.	Water available for all the 24 hours, when needed.	Water is supplied only during peak hours of demands of a day.
2.	There is no requirement for storage of water.	There is requirement of storage of water in the house for use of water in non supply hours.
3.	In this system the water is stored in very large quantity in reservoir.	In this system less volume of water is stored in the reservoir.
4.	There is no requirement of dividing the city in various zones.	Due to less pressure available, the city is divided into various zones.
5.	Sufficient quantity of water available for any other demands such as fire fighting etc.	In this system the water for fire demand is not quickly available.
6.	There is more quantity of water available, it increase the wastage of water.	There is less volume of water waste.
7.	Any defect in distribution system may affect the water supply of whole city.	The default in water supply system in any zone will not affect the water supply in other zone of city.
8.	The fresh water is supplied for all 24 hour.	There is no fresh water available for supply.

PART-3

Concept of Service and Balancing Reservoirs.

CONCEPT OUTLINE

Method for calculating the capacity of the balancing reservoirs :

i. Mass curved method.

ii. Analytical method.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.6. **Explain total capacity of distribution reservoir.**

Answer

Total Capacity of Distribution Reservoir : The total storage capacity of a distribution reservoir is the summation of :

1. **Balancing Storage :**
   i. The primary function of a distribution reservoir is to fulfill the fluctuating demand with constant rate of supply from the treatment plant.
   ii. The quantity of water to be stored in the reservoir for equalizing or balancing this variable demand against the constant supply is known as the balancing reserve or balancing storage.
2. **Break-down Storage :**
   i. It also called as emergency storage.
   ii. It is the storage preserved in order to tide over the emergencies posed by the failure of pumps, electricity, or any other mechanism driving the pump.
3. **Fire Storage :** In case of fires, sufficient amount of water must remain available in the reservoir for throwing it over the fire place.

Que 2.7. **Explain the balancing reservoir. Describe the method of calculating capacity of balancing reservoir.**

OR

Explain with a neat sketch as to how municipal water is connected to private buildings and houses for giving water supply connections. Describe the method of estimating capacity of balancing reservoir.

Answer

A. **Balancing Reservoir Concept of Service :** Refer Q. 2.6, Page 2–9B, Unit-2.

B. **Method for Calculating the Capacity of the Balancing Reservoir :** Following are the two methods :

1. **Mass Curve Method :**
   i. In this method a mass curve of supply is prepared with from available data.
   ii. The accumulated inflow (supply) or outflow (demand) is taken on Y-axis and time taken on X-axis.

iii. The mass curve of supply (*i.e.*, supply line) is therefore, first of all drawn and is superimposed by the demand curve.

iv. The amount of balancing storage can then be easily determined by adding the maximum ordinate between the demand and the supply line.

The procedure of mass curve method as follows :

a. From the past records, determine the hourly demand for all 24 hours typical days.

b. Estimates the cumulative demand and plot the cumulative demand against time, thus plot the mass curve of demand.

c. Plot the supply mass curve (supply line).

d. Read the two maximum ordinate from demand curve and supply line and add both the ordinates.

e. Repeat the procedure for all the typical days. Determine the maximum storage required for worst day.

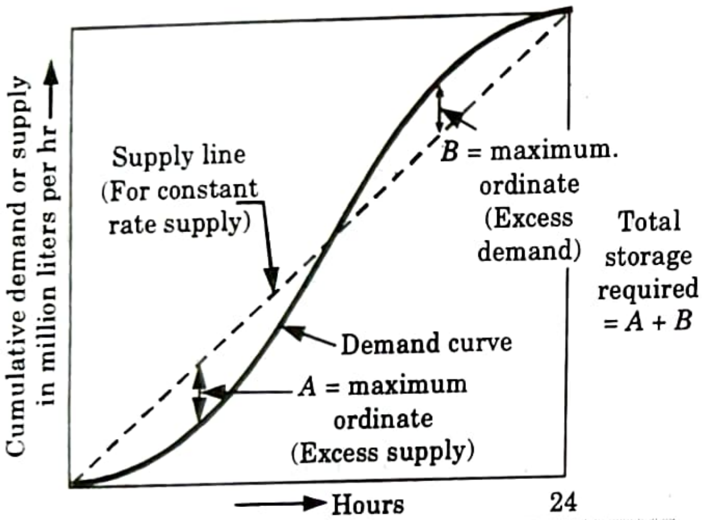

Fig. 2.7.1. Mass diagram for 24 hours pumping.

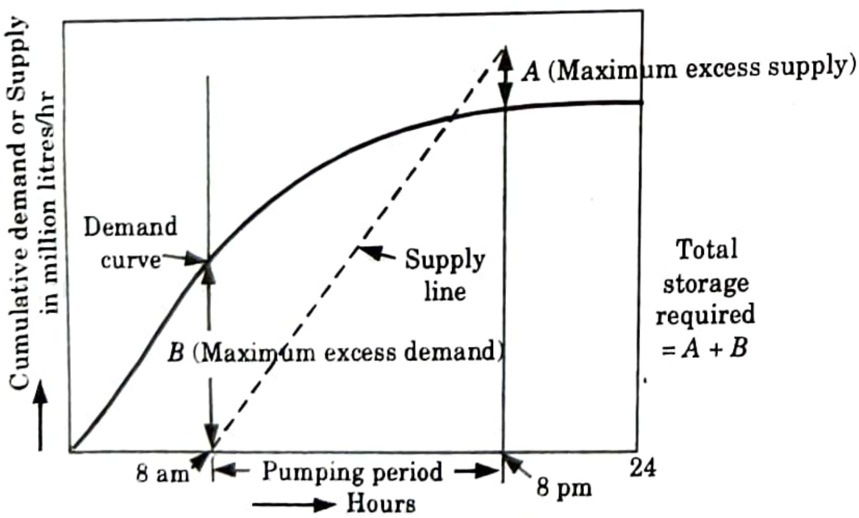

Fig. 2.7.2. Mass diagram for pumping during limited period.

2. **Analytical method :**
   i. In this method, the cumulative hourly demand and cumulative hourly supplies are tabulated for all the 24 hours.
   ii. The hourly excess demand and hourly excess supply are determined.
   iii. The sum of the maximum of excess of demand and maximum of excess of supply will give the required storage capacity of balancing reservoir.

Que 2.8. **A town with a population of 1 million has continuous water supply. Average supply is 270 lpcd, the water being supplied by direct pumping. The total supply of 270 lpcd is phased as follows :**

Time	lpcd
5 AM to 11 AM	90
11 AM to 3 PM	54
3 PM to 9 PM	81
9 PM to 1 AM	27
1 AM to 5 AM	18

Water is supplied from the treatment plant at a uniform rate of 11.25 million litres per hours, for all 24 hours. Find the capacity of the reservoir required for distribution of water.

AKTU 2014-15, Marks 10

Answer

Given : Population = 1 millions, Average supply = 270 lpcd
Supply rate = 112.5 Ml/hr
To Find : Capacity of reservoir

1. Total daily supply = Rate of supply × Population
   $= 270 \times 10^6$ litre = 270 M litre
2. Now, the given demand pattern is converted into cumulative demand, as shown in table 2.8.1.

Table 2.8.1.

Time	Per Capita Consumption in lpc	Consumption in M Litre	Cumulative Demand in Million Litre
(1)	(2)	(3)	(4)
5 AM to 11 AM	90	90	90
11 AM to 3 PM	54	54	144
3 PM to 9 PM	81	81	225
9 PM to 1 AM	27	27	252
1 AM to 5 AM	18	18	270

The mass curve of demand is now plotted from the data of column (1) and column (4) of the Table 2.8.1, as shown in Fig. 2.8.1.

4. The supply line on the mass diagram will be a straight line with its slope of 11.25 million litre per hour, as shown in Fig. 2.8.1.
5. The two maximum ordinates A and B enclosed between the demand line and the supply line are read out from Fig. 2.8.1, as :

$$A = 0 \text{ million litre}, B = 41 \text{ million litre}$$

6. Total storage required = $A + B$ = 41 million litre.

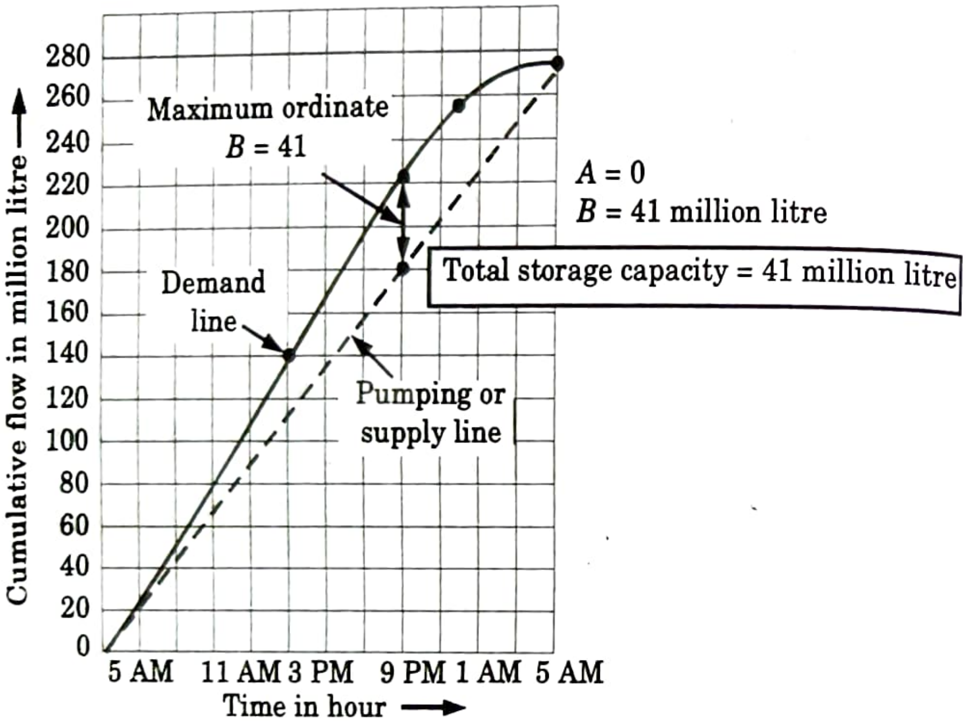

Fig. 2.8.1.

Que 2.9. **A distribution reservoir is to be designed for a locality of a town for 1200 persons. The average supply may be assumed 250 lpcd. The pattern of demand is as follows :**

7 AM to 8 AM .... 30 % of day supply
8 AM to 5 PM .... 35 % of day supply
5 PM to 6.30 PM .... 30 % of day supply
6.30 PM to 7 AM .... 5 % of day supply

The pumping is to be done at a constant rate of 8 hour per day (8.0 AM to 4 PM). Determine the capacity of reservoir.

AKTU 2017-18, Marks 05

Answer

Given : Population, P = 1200, Per capita demand = 250 lpcd
Pumping time = 8 hr
To Find : Capacity of reservoir.

1. Total daily requirement = 1200 × 250 = 300000 l/hr
2. Now, the given demand pattern is converted into cumulative demand as shown in Table 2.9.1.

Table 2.9.1.

Time	Rate of Demand in %	Demand in Litre Col. (2) × 300 × 10^3	Cumulative Demand in 10^3 Litre
(1)	(2)	(3)	(4)
7 AM to 8 AM	30	90	90
8 AM to 5 PM	35	105	195
5 PM to 6.30 PM	30	90	285
6.30 PM to 7 AM	05	15	300

3. The mass curve of demand is now plotted from the data of Col. (1) and Col. (4) of the above table 2.9.1, as shown Fig. 2.9.1.

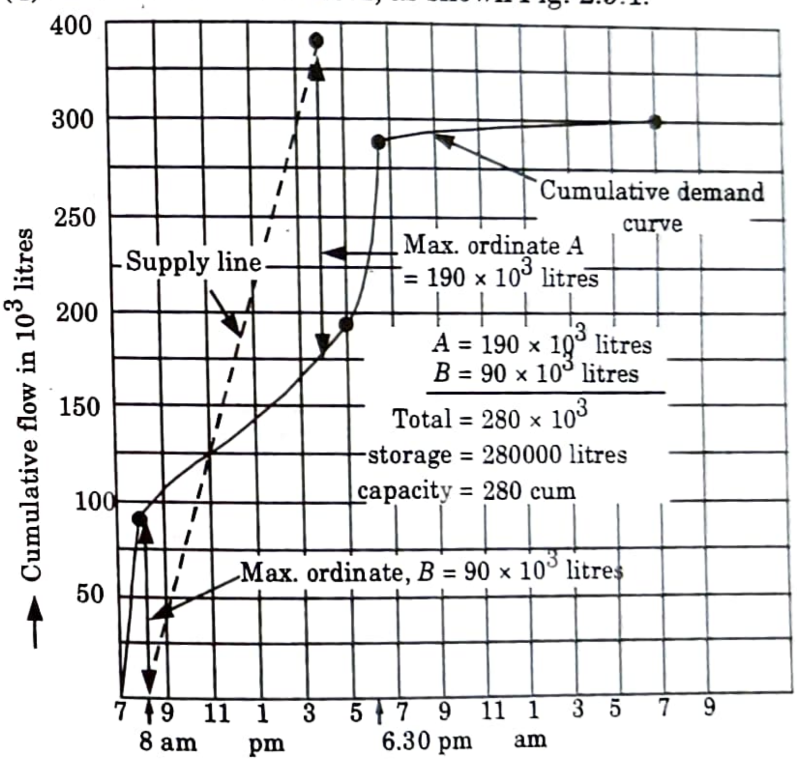

Fig. 2.9.1.

4. Total supply is obtained in 8 hr at a rate

$$= \frac{300000}{8} = 37500 \text{ l/hr}$$

5. The supply line on the mass curve diagram will therefore, be a straight line with its slope as 37500 l/hr as shown by the dotted line in Fig. 2.9.1.
6. The two maximum ordinate A and B enclosed between the demand and the supply lines are read out from mass curve.

$$A = 190 \times 10^3 \text{ litre}$$
$$B = 90 \times 10^3 \text{ litre}$$

7. Total storage required

$$= A + B = 190 \times 10^3 + 90 \times 10^3$$
$$= 280 \times 10^3 \text{ litre} = 280 \text{ cum}$$

Que 2.10. **Calculate the storage required to supply the demand shown in the following tables in the inflow of water to the reservoir is maintained at a uniform rate through 24 hours :**

Time	00 – 04	04 – 08	08 – 12	12 – 16	16 – 20	20 – 24
Demand in million liters	0.48	0.87	1.33	1.00	0.82	0.54

Answer

To Find : Required storage to supply the demand.

1. Average pumping rate = $\dfrac{\text{Total demand}}{\text{Time}} = \dfrac{5.04}{24} = 0.21$ Ml//hr
2. The hourly demand as well as the water drawn from the reservoir tabulated in table 2.10.1.

Table 2.10.1.

Hour Ending	Demand (Million Litre)	Pumping Rate (Million Litres/Hour)	Requirements from Storage (Million Litres)
00 – 04	0.48	0.21	0.27
04 – 08	0.87	0.21	0.66
08 – 12	1.33	0.21	1.12
12 – 16	1	0.21	0.79
16 – 20	0.82	0.21	0.61
20 – 24	0.54	0.21	0.33
Sum	5.04		3.78

3. The required reservoir capacity will be equal to the sum of the hourly requirements from storage. This comes out to be 3.78 million liters.

PART-4

General Design Guidelines for Distribution Reservoirs.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.11. **Write down the design guidelines for distribution system.**

Answer

Guidelines for Design : For economical design of service or distribution reservoirs, site condition is very important. Following are the guideline use in design of distribution system.

1. **Economical Depth :**
   i. The most economical depth can be determined by trial.
   ii. Factors influencing depth for a given storage are :
      a. Depth at which suitable foundation conditions are encountered.
      b. Depth at which outlet main has to be laid.
      c. Slope of ground, nature and type of backfill soil.
      d. The need to make the quantity of excavated material approximately equal to the amount required for banking or filling so as to reduce carting of surplus materials.
2. **Roofing :** Water in a distribution or service reservoir is treated water ready for consumption. Hence, it should not be stored in open space which may cause pollution from the atmosphere.
3. **Walls of Concrete Reservoirs :**
   i. Walls of reservoirs may be classified in three categories. Mass concrete gravity walls, reinforced concrete walls and pre-stressed walls.
   ii. For normal sizes of tank with good ground conditions, the mass concrete or reinforced concrete walls are more common.
   iii. Cracking may be reduced by adopting following measures:
      a. Using a concrete grade not very rich in cement even though some greater thickness of sections is required.
      b. Size of aggregate should be coarser.
      c. Keeping water content of the mix as low as possible and adding an air-entraining agent to assist in producing adequate workability.
      d. Using steel shutters to reduced temperature quickly.

$$A = 190 \times 10^3 \text{ litre}$$
$$B = 90 \times 10^3 \text{ litre}$$

7. Total storage required

$$= A + B = 190 \times 10^3 + 90 \times 10^3$$
$$= 280 \times 10^3 \text{ litre} = 280 \text{ cum}$$

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Demand in million liters	**0.48**	**0.87**	**1.33**	**1.00**	**0.82**	**0.54**

Answer

To Find : Required storage to supply the demand.

1. Average pumping rate $= \dfrac{\text{Total demand}}{\text{Time}} = \dfrac{5.04}{24} = 0.21$ Ml//hr
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Sum	5.04		3.78

3. The required reservoir capacity will be equal to the sum of the hourly requirements from storage. This comes out to be 3.78 million liters.

PART-4

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Questions-Answers

Long Answer Type and Medium Answer Type Questions

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      a. Using a concrete grade not very rich in cement even though some greater thickness of sections is required.
      b. Size of aggregate should be coarser.
      c. Keeping water content of the mix as low as possible and adding an air-entraining agent to assist in producing adequate workability.
      d. Using steel shutters to reduced temperature quickly.

4. **Floors of Reservoirs :** Excepting a small size of tank the floor is cast as a separate structure from walls. Under drains are provided to prevent uplift and these under drains have a free fall to an open outlet. Sometimes, floors are laid in two layers. The joints in the upper layer are staggered in relation to the joints in the lower one.

5. **Piping's :**

i. The inlet to a service reservoir may be kept at any elevation. If provided at the bottom, a non-return valve on the inlet pipe work should be provided so that in case of pipe burst, the water from tank should not flow back through the inlet main.

ii. The outlet pipe should be taken out at low level and can be arranged with its invert at floor level provided a sump is constructed just in front of the outlet into which debris (if at all present) will be trapped instead of being swept into the main.

6. **Testing for Water Tightness :**

i. When a concrete reservoir is first filled, it should be left to stand for at least three days to allow the concrete to absorb water.

ii. Testing procedure states that total drop in water level over the next seven days should not exceed one thousandth of the average water depth of storage and distribution reservoirs.

☺☺☺

3

UNIT

Physical Chemical and Bacteriological Examination of Water and Wastewater

CONTENTS

PART-1

Physical Examination of Water and Waste Water.

CONCEPT OUTLINE

Physical Characteristics : Following are the physical characteristics of wastewater :

i. Turbidity.
ii. Colour.
iii. Odour.
iv. Temperature.
v. Suspended solids.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. **Write a note on various physical properties of waste-water.**

AKTU 2013-14, Marks 05

Answer

Following are the physical properties of wastewater :

1. **Temperature :** Temperature affects biological activity of bacteria present in sewage, viscosity and solubility of gases in sewage. The average temperature of sewage in India is 20° C.
2. **Colour :** Colour can be detected by naked eye and it indicates the freshness of sewage. Colours may be formed due to presence of some specific industrial wastes.
3. **Odour :** Fresh sewage is odourless but in 3-4 hours it becomes stale with all oxygen present in sewage being exhausted and starts producing offensive odours.
4. **Solids :**

i. Though sewage contains only about 0.1 percent solids, the rest being water, still the nuisance caused by the solids cannot be overlooked, as these solids are highly putrescible and therefore need proper disposal.

ii. The sewage solids may be classified into dissolved solids, suspended solids and volatile suspended solids.

iii. The estimation of suspended solids, both organic and inorganic, gives a general picture of the load on sedimentation and grit removal system during sewage treatment.

iv. Dissolved inorganic fraction is to be considered when sewage is used for land irrigation or any other reuse is planned.

5. **Turbidity :** Dirty water or wastewater from baths having floating matter like faecal matter, paper piece, greases, soaps etc. Degree of turbidity can be measured by turbidity rods or by turbidimeters.

Que 3.2. **What is turbidity ? How is it measured and expressed ? What is 1 NTU ?**

Answer

1. **Turbidity :** Refer Q. 3.1, Page 3–2B, Unit-3.
2. **Measurement :** The turbidity is measured by a turbidity rod or by a turbidimeter with optical observations, and is expressed as the amount of suspended matter in mg/l or ppm. The standard unit is that which is produced by 1 mg of finely divided silica in 1 litre of distilled water.
3. **NTU :** The units of turbidity from a calibrated nepheiometer are called nepheiometric turbidity units (NTU). Water containing 1 milligram of finely divided silica per liter has a turbidity of 1 NTU.

Que 3.3. **Explain the importance of determination of solids in sewage. How do you determine the suspended solids in a given sample of waste water ?** **AKTU 2015-16, Marks 10**

Answer

Importance of Determination of Solids in Sewage :

i. Solids may affect water or effluent quality in a number of ways.
ii. Water with high dissolved solids is generally of inferior palatability and may induce unfavorable physiological response (intestinal distress).
iii. Highly mineralized waters are unsuitable for many industrial applications.
iv. High suspended solids content can also be detrimental to aquatic plants and animals by limiting light and deteriorating habitat.

Determine the Suspended Solids : The amount of various kinds of solids can be determined as :

1. **Total Amount of Solids (S_1) :**
   i. It can be determined by evaporating a known volume of sewage sample and weighing the dry residue left.
   ii. The mass of residue divided by volume of evaporated sample will represent total solids.
2. **Suspended Solids (S_2) :**
   i. These solids are retained by a filter of 1μm pores.
   ii. Their quantity can be determined by passing a known amount of sewage sample through a glass fibre filter apparatus and weighing the dry residue left.

iii. The mass of residue divided by volume of sample filtered will represent suspended solids.

3. **Dissolved Solids (S_3) :** This can be determined by difference between total solids and suspended solids.

$$S_3 = S_1 - S_2$$

4. **Settleable Solids :**

i. The quantity of settleable solids can be determined with the help of conical glass vessel called Imhoff cone.

ii. Sewage is allowed to stand in this Imhoff cone for a period of 2 hours, and the quantity of solids settled in bottom of cone can be directly read out.

iii. To obtain precise amount of settleable solids, the liquid from the cone should be decanted off and the settleable solids collected at the bottom of cone should be dried and weighed.

PART-2

Chemical Examination of Water and Waste Water.

CONCEPT OUTLINE

Chemical Characteristics : Following are the chemical characteristics of wastewater :

i. Dissolved solids.	ii. pH value.
iii. Hardness.	iv. Chloride content.
v. Nitrogen content.	vi. BOD.
vii. COD.	viii. ThOD, etc.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.4. **Enumerate and explain the physico-chemical characteristics of waste water.** **AKTU 2017-18, Marks 10**

OR

What are various chemical characteristics of waste water which affect the selection and operation of various types of treatment process ? Explain in detail. **AKTU 2016-17, Marks 15**

Answer

A. **Physical Characteristics :** Refer Q. 3.1, Page 3–2B, Unit-3.

B. **Chemical Characteristics :** Following are the chemical characteristics of waste water :

1. **pH Value :**
   i. pH value of sewage indicates the negative log of hydrogen ion concentration present in sewage.

$$[pH] = -\log [H^+]$$
$$[H^+] = (10)^{-pH}$$

   ii. If the pH value is less than 7, the wastewater is acidic and if the pH value is more than 7, the wastewater is alkaline.
   iii. The pH value can be measured quickly and automatically with the help of a potentiometer.
2. **Nitrogen Content :** Presence of nitrogen in wastewater indicates the presence of organic matter and may occur in four forms :
   i. Free ammonia (Ammonia nitrogen).
   ii. Organic nitrogen.
   iii. Nitrate.
   iv. Nitrite.
3. **Chloride Content :**
   i. Chlorides are derived from kitchen wastes, human faeces and urinary discharges, etc.
   ii. Normal chloride content for domestic sewage is 120 mg/l whereas permissible unit for water supply is 250 mg/l.
   iii. The chloride content may be measured by titrating the wastewater with standard silver nitrate solution using potassium dichromate as indicator.
4. **Fats, Oils and Greases :**
   i. These are derived in sewage from discharges of animals and vegetable matter.
   ii. They interfere with the normal treatment method and need proper detection and removal.
   iii. To estimate their amount, a sample of sewage is evaporated. The residual solids left are then mixed with ether. The solution is then poured off and evaporated, leaving behind the fats and greases as residue that can be weighed.
5. **Dissolved Oxygen :**
   i. It is necessary to ensure at least 4 ppm of DO in treated sewage before discharging into river stream.
   ii. Only fresh sewage contains some DO which is soon depleted by aerobic decomposition.
   iii. DO content is determined by Winkler's method which is an oxidation reduction process, carried out chemically to liberate iodine in amount equivalent to quantity of dissolved oxygen originally present.
6. **Chemical Oxygen Demand :** It is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals.

7. **Biological Oxygen Demand :** It is defined as the amount of oxygen required by bacteria in decomposing organic material in a sample under aerobic condition at 20°C over a period of 5 days.

Que 3.5. **Write notes on :**

A. Cycles of decay of waste organic substances.
B. Concentration of solids in sewage.
C. COD and BOD.
D. Composition of municipal sewage.
E. BOD/COD ratio.

AKTU 2015-16, Marks 10

Answer

A. Cycles of Decay of Waste Organic Substances :

1. The matter of the universe remains constant, but its form changes because of bio-chemical reactions.
2. The complex organic compounds of biodegradable nature are broken up by biochemical reaction into simple compounds which are in turn consumed by animal and plant life for their growth.
3. From sewage treatments point of view, the cycles of decomposition of the following five elements are of importance : i. Nitrogen cycle, ii. Carbon cycle, iii. Sulphur cycle, iv. Calcium cycle, v. Phosphorus cycle.

B. Concentration of Solids in Sewage :

1. Suspended solids are those solids which remain floating in sewage.
2. Dissolved solids are those which remain dissolved in sewage just as salt in water.
3. Colloidal solids are finely divided solids remaining either in solution or in suspension.
4. Settleable solids are that portion of solid matter which settles out, if sewage is allowed to remain undisturbed for a period of 2 hours.
5. The proportion of these different types of solids is generally found to be as given below :
   It has been estimated that about 1000 kg of sewage contains about 0.45 kg of total solids, out of which 0.225 kg is in solution, 0.112 kg is in suspension, and 0.112 kg is settleable.

C. COD and BOD : Refer Q. 3.3, Page 3–3B, Unit-3.

D. Composition of Municipal Sewage.

1. The composition of municipal wastewater is roughly 99.33 % water and 0.07 % total (dissolved and suspended) solids.
2. Further more of the 0.07 % total solids (TS), only half are organic in nature, the other half are inert.
3. Typical municipal wastewater contains about 200 mg/l of both suspended solids and BOD.
4. The organic composition of this wastewater is approximately 50 % proteins, 40 % carbohydrates, 10 % fats and oils, and trace amounts of priority pollutants and surfactants.

5. Of the trace components, surfactants may be the largest constituent.

E. BOD/COD Ratio :

1. This ratio is commonly used as indicator of the degree of biodegradation of the wastewater.
2. As wastewater is degraded, the concentrations of all two measures decrease. Since BOD decreases faster than COD the ratio can approach zero.
3. The $\frac{\text{BOD}}{\text{COD}}$ ratio will always be less than 1.0.
4. If this ratio is found to be between 0.92 & 1.0, the wastewater can be considered to be fully biodegradable.

Que 3.6. **Deduce an expression for BOD with curve.**

AKTU 2014-15, Marks 05

Answer

1. We know that, $\frac{dL_t}{dt} = -KL_t$ ...(3.6.1)
2. Integrating above eq. (3.6.1), we get

$$\int \frac{dL_t}{L_t} = \int - Kdt$$

$$\log_e L_t = -Kt + C \quad ...(3.6.2)$$

3. When $t = 0, L_t = L$

$$\log_e L = -K(0) + C$$

$$C = \log_e L$$

4. Substituting this value in eq. (3.6.2), we get

$$\log_e L_t = -Kt + \log_e L$$

$$\log_e L_t - \log_e L = -Kt$$

$$\log_e \frac{L_t}{L} = -Kt$$

$$2.3 \log_{10} \frac{L_t}{L} = -Kt$$

$$\log_{10} \frac{L_t}{L} = -\frac{Kt}{2.3} = -0.434\, Kt$$

$$\log_{10} \frac{L_t}{L} = -K_D t \quad (\because 0.434\, K = K_D)$$

$$\frac{L_t}{L} = 10^{-K_D t} \quad ...(3.6.3)$$

5.

$$y_t = L - L_t$$

$$y_t = L\left[1 - \frac{L_t}{L}\right] \quad ...(3.6.4)$$

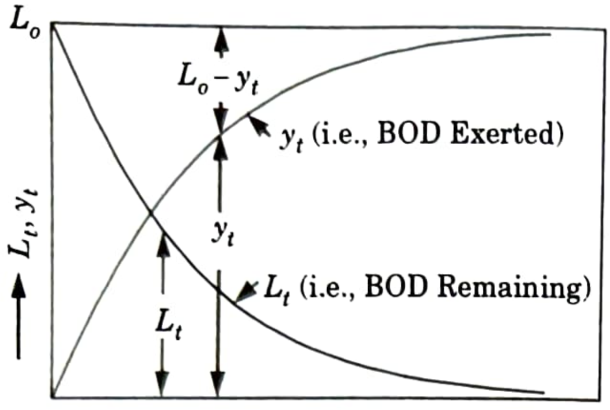


Fig. 3.8.1. First stage BOD curve.

6. Value from eq. (3.6.3) put in eq. (3.6.4), we get

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

Que 3.7. **What is carbonaceous BOD ? How the probable interference of nitrogenous oxygen demand is inhibited during BOD measurement ?** **AKTU 2017-18, Marks 05**

Answer

1. **Carbonaceous BOD :**
i. The ultimate carbonaceous BOD of a liquid waste is the amount of oxygen necessary for the micro-organisms in the sample to decompose the carbonaceous materials that are subject of microbial decomposition.
ii. This is the first stage of oxidation and the corresponding BOD is also sometimes called the first stage demand.

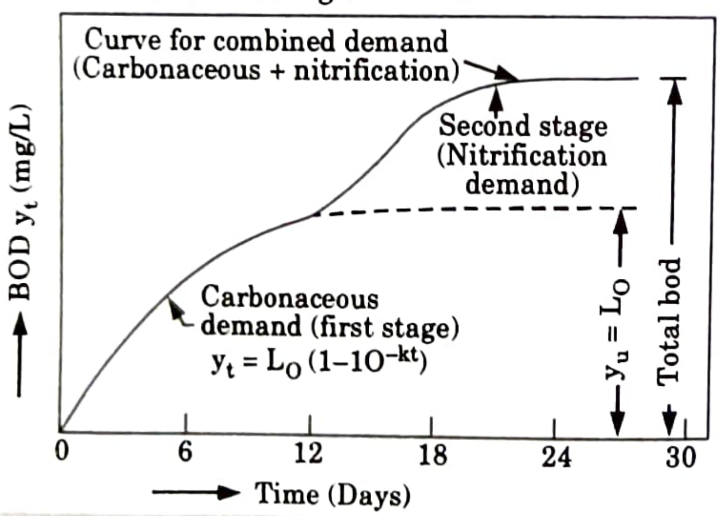


Fig. 3.7.1. Combined carbonaceous and nitrification demand.

2. **Interference of NOD in BOD measurement :**
i. Carbonaceous matter is oxidised in the first stage of biochemical reaction, while nitrogenous matter is oxidised in the second stage.

ii. Some of the autotrophic bacteria are capable of using oxygen to oxidize non carbonaceous matter, such as ammonia to nitrites and nitrates.

iii. This second stage reaction is called nitrification.

iv. Thus, the nitrogenous oxygen demand caused by the autotrophic bacteria is called second stage BOD. Fig. 3.7.1 shows the influence of nitrification on BOD curve.

iv. It should be noted that at 20 °C, the reproduction rate of nitrifying bacteria is very slow and it takes about 6 to 10 days to reach significant numbers and to exert a measurable oxygen demand.

Que 3.8. **How BOD is measured ? Discuss the difference between modified Winkler's azide method and azide method of DO measurement in laboratory.**

Answer

Methods : Following are the methods used to measured BOD :

1. **Direct Method :** The test consists of keeping the sample of wastewater in contact with a definite air or oxygen, in a specially prepared vessel. The BOD is then measured manometrically.
2. **Dilution Method :**
   i. In this method the sample is suitably diluted with specially prepared dilution water.
   ii. The water is aerated to saturate it with oxygen before mixing it with the sewage sample. The initial DO of this diluted sample is measured.
   iii. The diluted sample is then incubated for 5 days at 20°C in an air tight glass vessel.
   iv. The DO of the sample is then again measured.
   v. The loss of oxygen or the oxygen consumed during incubation is then found out by calculating the difference between the initial content of DO and the final content of DO.
   vi. BOD is then computed from the relation.

$$BOD_5 = \text{Oxygen consumed} \times \text{Dilution ratio} \quad ...(3.8.1)$$

$$\text{where, dilution ratio} = \frac{\text{Volume of diluted sample}}{\text{Volume of undiluted sewage sample}}$$

Difference :

1. In azide method, ferrous ion, ferric ion, nitrite, microbial mass and high suspended solids constitute the main sources of interference.
2. In modified method, the reagent $NaOH + KI + NaN_3$ is used to eliminate interference caused by NO_2. This method also reduces interference due to higher concentration of ferric ion.

Que 3.9. **Change in concentration of organic matter L, with time t, is given by $dL/dt = -KL$. Calculate the organic matter remaining after 4 days if the initial concentration was 300 mg/l and $K = 0.3$ per day.**

AKTU 2013-14, 2017-18; Marks 05

Answer

Given : Initial concentration, L_0 = 300 mg/l, K = 0.3/day

To Find : Organic matter remaining after 4 days.

1. We know that,

$$\frac{dL}{dt} = -KL$$

$$\frac{dL}{L} = -Kdt$$

2. On integration

$$\log_e L = -Kt + C$$

3. when $t = 0, L = L_0 = 300$ mg/l

$$\log_e 300 = 0 + C$$

$$C = 5.7$$

4. when $t = 4$, $\log_e L = -Kt + C$

$$\log_e L = -0.3 \times 4 + 5.7$$

$$L = 90 \text{ mg/l}$$

Que 3.10. **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 = 0.12 (base 10) at 20°C.**

AKTU 2016-17, Marks 05

Answer

Given : One day BOD of sewage, $y_{1, 30°}$ = 110 mg/l, $K_{D(20°)}$ = 0.12

To Find : 5 day BOD at 20°, $y_{5\,(20°)}$

1. We know that, $K_{D(T°)} = K_{D(20°)}\,[1.047]^{T-20°}$

$$K_{D(30°)} = 0.12 \times [1.047]^{30°-20°}$$

$$K_{D(30°)} = 0.19$$

2. We also know that, $y_t = L[1 - 10^{-K_D \times t}]$

$$y_{1(30°)} = L\,[1 - 10^{(-0.19 \times 1)}]$$

$$110 = L\,[1 - 0.645]$$

$$L = 310.5 \text{ mg/l}$$

3. For calculating $y_{5(20°)}$,

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

$$= 310.5\,[1 - 10^{(-0.12 \times 5)}] = 232.5 \text{ mg/l}$$

Que 3.11. **The BOD_5 of a waste has been measured as 500 mg/l. If the rate constant $K = 0.26$ / day (base e), what is the ultimate BOD of the waste ? What proportion of BOD_u would remain unoxidized after 20 days ?**

AKTU 2016-17, Marks 05

Answer

Given : BOD_5 of waste = 500 mg /l, K = 0.26 /day

To Find : Ultimate BOD of waste, Proportion of BOD_u after 20 days.

1. We know that, $K_D = 0.434K = 0.434 \times 0.26 = 0.113$
2. The ultimate BOD is calculated as :

$$y_5 = L\,[1 - 10^{-K_D \times t}]$$
$$500 = L\,[1 - 10^{(-0.113 \times 5)}]$$

3. Ultimate BOD, (y_u) L = 687.07 mg/l
4. Now BOD after 20 days,

$$y_{20} = L\,[1 - 10^{-K_D \times t}]$$
$$y_{20} = y_u\,[1 - 10^{-0.113 \times 20}]$$
$$y_{20} = 0.9945\,y_u$$

5. It means that 99.45 % of BOD_u is utilized in 20 days and hence only 0.55 % of ultimate BOD would be left unoxidized after 20 days.

Que 3.12. **The average sewage flow from a city is 80×10^6 l/d. If the average 5 day BOD is 285 mg/l. Compute the total daily 5 day oxygen demand in kg and the population equivalent of sewage. Assume per capital BOD of sewage per day = 75 g.** **AKTU 2013-14, Marks 05**

Answer

Given : Average flow = 80×10^6 l/d, BOD_5 = 285 mg/l

Per capita BOD =75 gm/day

To Find : 5 days BOD and Population equivalent.

1. Oxygen demand = $80 \times 10^6 \times 285 \times 10^{-6}\ \dfrac{kg}{l} \times \dfrac{l}{d}$ = 22,800 kg/d

2. Population equivalent = $\dfrac{22,800}{75 \times 10^{-3}}$ = 3,04,000

Que 3.13. **Determine ultimate BOD for a sewage having 5 day BOD at 20°C as 160 ppm. Assume the deoxygenation constant as 0.2 per day. Determine 2 day BOD for the same sewage.**

AKTU 2013-14, Marks 05

Answer

Given : $BOD_5 = 160$ mg/l, $K_D = 0.2$/day
To Find : BOD_2

1. We know that, $y_t = L(1 - 10^{-K_D \times t})$

$$160 = L(1 - 10^{-0.2 \times 5}]$$
$$L = 177.78 \text{ mg/l}$$

2. Ultimate BOD = 177.78 mg/l
3. 2 days BOD, $y_2 = 177.78(1 - 10^{-0.2 \times 2}) = 107$ mg/l

Que 3.14. **Calculate one day 37°C BOD of sewage sample whose 5-days 20°C BOD is 100 mg/L.**

AKTU 2015-16, Marks 02

Answer

Given : 5 day 20 °C BOD, $y_{20°} = 100$ mg/l
To Find : One day 37°C BOD

1. The BOD at 20 °C is given by,

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

Assume, $K_{D(20°)} = 0.1$

$$100 = L\ [1 - (10)^{-0.1 \times 5}]$$
$$100 = L\ [1 - (10)^{-0.5}]$$
$$L = 146.2 \text{ mg/l.}$$

2. We know that, $K_{D(T°)} = K_{D(20°)}\ [1.047]^{T - 20°}$

$$K_{D(37°)} = 0.1\ [1.047]^{37° - 20°} = 0.1\ [1.047]^{17}$$
$$= 0.1 \times 2.2 = 0.22$$

3. We know that, $y_t = L\ [1 - (10)^{-K_D t}]$

$$y_1\ (37\ °C) = 146.2\ [1 - (10)^{-K_{D(37°C)} \times 1}] \qquad [\because t = 1 \text{ day}]$$
$$= 146.2\ [1 - (10)^{-0.22 \times 1}] = 58.1 \text{ mg/l}$$

Que 3.15. **For a wastewater sample, 5 day BOD at 20°C is 200 mg/l and is 67 % of the ultimate. What will be the 4 day BOD at 30°C ?**

AKTU 2013-14, Marks 05

Answer

Given : $BOD_5 = 200$ mg/l, $BOD_5 = 0.67 \times BOD_4$
To Find : BOD_4 at 30°C

1. 5 days BOD, $y_5 = 0.67 \times L$

$$200 = 0.67 \times L$$

Ultimate BOD, $L = 298.5$ mg/l

2. BOD is given by, $y_t = L(1 - 10^{-K_D \cdot t})$

$$200 = 298.5\,(1 - 10^{-K_D \times 5})$$

$$K_D = 0.1$$

3. $$K_{D(T°C)} = K_{D(20°C)}\,(1.047)^{T - 20°}$$

$$K_{D(30°C)} = 0.1\,(1.047)^{30 - 20}$$

$$K_{D(30°C)} = 0.16$$

4. $$y_{(t=4)} = 298.5\,(1 - 10^{-0.16 \times 4}) = 230.12 \text{ mg/l}$$

Que 3.16. **Differentiate between BOD, COD and THOD.**

AKTU 2013-14, Marks 05

Answer

BOD and COD : Refer Q. 3.3, Page 3–3B, Unit-3.

THOD :

1. This a theoretical method of computing the oxygen demand of various constituents of the organic matter present in wastewater.
2. If the chemical formulae of the constituents of the organic matter are known, THOD can be easily computed.
3. Following steps should be follow to compute THOD :
   i. In the first step, carbon is converted to CO_2 and nitrogen is converted to ammonia.
   ii. In the second step, ammonia is oxidized to nitrite.
   iii. In the third step, nitrite is oxidized to nitrate.
   iv. The THOD will then be the sum of the oxygen required for all the three steps of reactions, mentioned above.

Que 3.17. **Discuss advantages and disadvantages of BOD and COD tests.**

AKTU 2014-15, Marks 05

Answer

Advantages of BOD Test : Following are the advantages of BOD test :

i. This test provides a quantitative measure of the amount of oxygen required to maintain the growth and activities of the biological organisms.
ii. It measures only the organics which are oxidized by the bacteria.
iii. This test measures biodegradable organic matter.

Disadvantages of BOD Test : Following are the disadvantages of BOD test :

i. The 5 day time lag and the difficulty in obtaining consistent repetitive values.
ii. The BOD results also may be affected by lack of seed acclimation, giving erroneously low readings.

iii. Many organic compounds which are non biochemically oxidizable, certain inorganic substances, such as sulphides, sulphites, thiosulphates, nitrites and ferrous iron are oxidized by dichromate, creating an inorganic COD, which is misleading when estimating the organic content of the wastewater.

Advantages of COD Test : Following are the advantages of COD test :

i. COD results are available much sooner.
ii. The COD test requires fewer manipulations of the sample.
iii. The COD test oxidizes a wider range of chemical compounds.
iv. It can be standardized more easily.

Disadvantages of COD Test : Following are the disadvantages of COD test :

i. The COD test results are not directly applicable to the 5-day BOD results, without correlation studies over a long period of time.
ii. The samples used for the COD analysis may be grab or composite.
iii. Preservation of the sample can be accomplished by adding sulfuric acid to depress the pH to 2 and the holding time with preservation is 7 days.

Que 3.18. How are the organic content measured in wastewater sample ? Discuss any one method in detail.

AKTU 2014-15, Marks 05

Answer

1. The amount of organic matter present may be determined by the total organic carbon (TOC) test and total oxygen demand (TOD) test.
2. Organic matter is assessed in terms of oxygen required to completely oxidize the organic matter to CO_2, H_2O and other oxidized species.

A. Total Organic Carbon (TOC) :

1. TOC is used to evaluate the amount of organic matter present in the wastewater.
2. The total organic carbon test (TOC test) is especially applicable to small concentrations of organic matter.
3. The TOC test consists of acidification of the wastewater sample to convert inorganic carbon to CO_2 which is then stripped.
4. The sample is then injected into a high temperature furnace where it is oxidised in the presence of a catalyst.
5. The CO_2 that is produced is quantitatively measured by means of an infrared analyser, and converted instrumentally to original organic carbon content.

B. Total Oxygen Demand (TOD) :

1. This is another instrumental method to measure the organic content of wastewater.
2. The TOD method is based on the quantitative measurement of the amount of oxygen used to burn the organic substances and to a minor extent, inorganic substances.
3. It is thus a direct measure of the oxygen demand of the sample.

Que 3.19. **The BOD of sewage incubated for 5 days at 30 °C is 130 mg/l. Calculate the BOD at 20 °C. Assume K_{20} = 0.1.**

AKTU 2014-15, Marks 05

Answer

Given : $K_{20°C}$ = 0.1, BOD_5 at 30°C, y_5 = 130 mg/l
To Find : BOD_5 at 20°C

1. We know that,

$$K_{30°C} = K_{20°C}(1.047)^{T-20°}$$
$$K_{30°C} = 0.1\,(1.047)^{30-20}$$
$$K_{30°C} = 0.16$$
$$K_D = 0.434\,K_{30°C} = 0.434 \times 0.16$$
$$K_D = 0.07$$

2. BOD_5 at 30°C,

$$y_5 = L\,(1 - 10^{-K_D t})$$
$$130 = L\,(1 - 10^{-0.07 \times 5})$$
$$L = 234.95 \text{ mg/l}$$
$$BOD_{20°C},\ y = 234.95\,(1 - 10^{-0.1 \times 5})$$
$$y = 160.65 \text{ mg/l}$$

Que 3.20. **A town has an average domestic sewage flow of 41,650 m³/day with a BOD concentration of 250 ppm. A neighboring industrial estate adds about 12,325 m³/day of sewage having 9080 kg of BOD to it. Find out :**
i. The concentrations of BOD in industrial and the combined sewage.
ii. The probable population and per capita flow of sewage.

AKTU 2015-16, Marks 7.5

Answer

Given : Discharge of domestic sewage = 41650 m³/day
BOD of domestic sewage = 250 ppm
Discharge of industrial sewage = 12325 m³/day
BOD of sewage = 9080 kg
To Find : BOD of industrial and combined sewage, population and per capita flow.

i. **Concentrations of BOD in Industrial and Combined Sewage :**

a. BOD in industrial sewage

$$= \frac{9080 \times 10^6}{12325 \times 10^3} \text{ mg/l}$$
$$= 736.71 \text{ mg/l (ppm)}$$

b. BOD in combined sewage

$$= \frac{250 \times 41650 \times 10^3 + 736.71 \times 12325 \times 10^3}{41650 \times 10^3 + 12325 \times 10^3}$$

$= 361.14$ ppm

ii. Probable Population and Per Capita Flow of Sewage :

a. Average BOD = 250 ppm = 250 mg/l

b. Average sewage flow = 41650×10^3 l/day

c. Total BOD in sewage = $250 \times 41650 \times 10^3$ l/day

$= 250 \times 41.650 \times 10^6$ mg/day

$= 250 \times 41.65$ kg/day

d. Assume the domestic sewage quantity to be 0.08 kg/person/day

Population $= \frac{\text{Total BOD}}{0.08} = \frac{250 \times 41.65}{0.08} = 130157$

e. Flow of sewage $= \frac{0.08}{\text{BOD}}$

BOD = 250 mg/l (ppm) = 250×10^{-6} kg/l

f. Per capita flow of sewage,

$$= \frac{0.08}{250 \times 10^{-6}} \text{ kg/person/day} = 320 \text{ l/person/day}$$

PART-3

Bacteriological Examination of Water and Wastewater.

CONCEPT OUTLINE

Microscopical Characteristics :

1. Bacteria and other microorganisms :
   - i. Aerobic bacteria.
   - ii. Anaerobic bacteria.
   - iii. Facultative bacteria.
2. Microscopic plants :
   - i. Algae.
   - ii. Plankton.
   - iii. Fungi.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.21. Describe the purpose of bacteriological examination of water.

Answer

Following are the purposes of bacteriological examination of water :

1. To detect and assess the degree of excremental pollution in the sources of supply.

2. To assess the amount of treatment required to render a source of supply safe for consumption.
3. To ascertain the efficiency of the purification treatment at various stages.
4. To locate the cause of any sudden deterioration in quality.
5. To establish the bacterial purity of final water as it leaves the purification works and to demonstrate the persistence of this high quality in the distribution system and in the premises of consumers.

Que 3.22. **What is MPN ? How is it measured ?**

Answer

Most Probable Number (MPN) :

1. Most probable number (MPN) analysis is a statistical method based on the random dispersion of microorganisms per volume in a given sample.
2. In this method, measured volumes of water is added to a series of tube containing a liquid indicator growth medium.
3. The media receiving one or more indicator bacteria show growth and a characteristic colour change.
4. Colour change is absent in those receiving an inoculums of water without indicator bacteria.

Measurement of MPN : Following are the three method for measuring the MPN :

1. **Presumptive Test :**
   i. It is used for detection and estimation of coliform in water sample.
   ii. For estimation of coliforms, lactose containing broth medium is used.
   iii. Commonly used medium is MacConkey broth that contains the indicator bromocresol purple. An inverted Durham's tube is placed.
   iv. The colour of media changes into yellow and on collection of gas in Durham's tube, bacteria are assumed to be coliform.
   v. Number of positive tubes are counted and referred to the standard chart to find MPN of total 100 ml water sample.
2. **Confirmed Test :**
   i. Some spore forming bacteria give false positive test in presumptive test.
   ii. Confirmed test is done to determine that the coliforms are of fecal origin or not. And they are E. coli or not.
   iii. Presence of typical colonies at 37°C confirms positive coliform test and those at 44.5°C confirms the presence of E. coli.

   Completed test :
   i. Subculture typical colonies in lactose containing medium and incubated at 37° C and 44.5 °C.
   ii. Presence of E. coli is confirmed by the production of gas at 44.5 °C.

Que 3.23. **What is an indicator organism ? Discuss the characteristics of the ideal pathogen indicator and indicate which organisms most nearly exhibit these characteristics.**

AKTU 2017-18, Marks 10

Answer

Indicator Organism : An indicator organism is that organism whose presence/detection in water, leads us to presume that water has been contaminated. It also helps us to reflect the type and degree of contamination.

Characteristics of ideal pathogen indicator :

i. An ideal pathogen indicator should therefore always be present whenever pathogens are present in water and vice-versa.

ii. It should in itself, be not a pathogen, so as not to cause hazards to laboratory technicians.

iii. It should be easily applicable to all types of waters.

iv. It should be easily detectable on easy testing, without being interfered with by other organisms.

Examples :

i. The E-coli (Escherichia coli) organisms; belonging to the fecal coliform group of organisms is the principal pathogen indicator.

ii. Another group of coliform organisms particularly Helminths, found in the soils and decaying vegetations, also serve as good pathogen indicators.

iii. Total coliform count or MPN of coliforms (including both of fecal as well as non-fecal coliforms) also serve as a good-pathogen indicator to indicate the sanitary quality of water.

Que 3.24. During a MPN test, a set of three test tubes were used with sample of 1 ml in each, out of which tube two test tubes were positive. Estimate the MPN.

Answer

Given : Sample size = 1 ml
To Find : MPN.

1. For the 2 sample +ve out of 3 sample, the MPN Number = 7
(From MPN table)

2. Actual MPN value = 7 × 10 = 70

Que 3.25. Discuss briefly about the laboratory test conducted on sewage and their importance in the treatment and disposal of sewage.

AKTU 2015-16, Marks 10

Answer

Following are the laboratory test conducted on sewage :

1. **Physical Test :** Following are the various physical tests :

i. Temperature : It is measured by ordinary thermometer.

ii. Colour : Colour can be measured against various standards or scales such as Hazen or platinic chloride scale, Burgess scale or cobalt scale using a tintometer.
iii. Turbidity : It is measured by turbidimetres.
iv. Odours : It is measured by sense of smell.
v. Specific conductivity of water : It is determine by means of portable dionic water tester.
2. **Chemical Test :** The chemical tests involve the determination of total solids, hardness, pH value, chlorides, residual chlorine, iron and manganese, organic matter etc.
3. **Biological Test :** In a biological test or bacteriological analysis the following two tests are done :
i. **Total Count of Bacteria :** In this test total number of bacteria present in a millilitre of water is counted.
ii. **Bacteria Coil (B-coil or E-coil) Test :** There are two test, first is presumptive and second confirmative test.

Importance : Following are the importance of laboratory test :
i. To determine the state of decomposition of sewage.
ii. To determine presence of toxic or other similar substances which may cause difficulties at the treatment plants, or may kill the aquatic life of the stream, in which sewage is disposed off.
iii. The load which the treatment plants have to bear and the required efficiency.
iv. The maximum load put on discharging river or stream, whether they shall be able to attain the self-purification by natural process or not.

PART-4

Quality Requirements.

Questions-Answers
Long Answer Type and Medium Answer Type Questions

Que 3.26. Discuss the qualitative requirements of water which are missing for human needs.

Answer

The Following are important requirements of water for domestic use :
1. It should be colourless, and sparkling clear. It must be free from solids in suspension and must not deposit sediment on standing.
2. It should be of good taste, free from odour.
3. It should be reasonably soft.
4. It should be plentiful and cheap.
5. It should be free from disease producing bacteria or organisms.

6. It should be free from objectionable dissolved gases, such as sulphuretted hydrogen.
7. It should, have sufficient quantity of dissolved oxygen.
8. It should be free from harmful salts.
9. It should be free from objectionable minerals, such as iron, manganese, lead, arsenic and other poisonous metals.
10. It should be free from radio-active substance such as radium, stronsium etc.
11. It should be reasonably free from phenolic compounds, chlorides, fluoride and iodine.
12. It should not lead to scale formation and should be non-corrosive.

Que 3.27. **Discuss the standards of drinking water according to Indian standards.**

Answer

S. No.	Substance or Characteristic	Requirement (Desirable Limit)	Permissible Limit
1.	Colour, Hazen unit	5	25
2.	Odour	Unobjectionable	–
3.	Taste	Agreeable	–
4.	Turbidity, NTU	5	10
5.	pH value	6.5 to 8.5	No
6.	Total hardness (as $CaCO_3$) mg/l	300	600
7.	Iron (as Fe) mg/l,	0.3	1.0
8.	Chlorides (as Cl) mg/l	250	1000
9.	Residual, free chlorine, mg/l	0.2	–
10.	Fluoride (as F) mg/l	1.0	1.5
11.	Dissolved solids mg/l	500	2000

12.	Magnesium (as Mg), mg/l	30	100
13.	Calcium (as Ca) mg/l	75	200
14.	Copper (as Cu) mg/l	0.05	1.5
15.	Sulphate (as SO_4) mg/l	200	400
16.	Nitrate (as NO_3) mg/l	45	100
17.	Phenolic compounds (as C_6H_5OH) mg/l	0.001	0.002
18.	Mercury (as Hg) mg/l	0.001	No relaxation
19.	Cadmium (as Cd), mg/l	0.01	No relaxation
20.	Arsenic (as Se), mg/l	0.01	No relaxation
21.	Lead (as Pb), mg/l	0.05	No relaxation

PART-5

Disposal of Waste Water on Land and Water Bodies.

CONCEPT OUTLINE

Disposing of the Wastewater Effluents : There are two general methods of disposing the wastewater effluents :

i. Dilution *i.e.*, disposal in water, and
ii. Disposal on load :

Oxygen Deficit : It is the difference between the actual DO content of water at that time and the saturation DO content at the water temperature.

Oxygen deficit (D) = Saturation DO – Actual DO

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.28. **Discuss the disposal of wastewater by dilution.**

Answer

Disposal by Dilution :

1. Disposal by dilution is the process whereby the treated wastewater or effluent from treatment plants is discharged either in large static water bodies (such as lake or sea) or in moving water bodies such as rivers or streams.
2. It is based on the self purification capacity of water bodies.
3. Following are the water bodies used for dilution process :

i. **Perennial Rivers and Streams :** These are probably the best type of receiving waters, since the water is in continuous motion.

ii. **Lakes :** When perennial streams are not available, lakes may be used for dilution.

iii. **Ocean or Sea :** Ocean has abundant water and the dilution factor is unlimited.

iv. **Creek :** A creek is in the form of an inlet on sea coast, which may not have dry weather flow during some part of the year. Due to this, great care should be taken in disposal of effluent into it.

v. **Estuary :** It is wide lower tidal part of a river. Hence the dilution in a estuary is affected both by ocean water as well as river water.

Que 3.29. **Discuss the condition favourable for dilution process.**

Answer

1. **Conditions Favouring Dilution without Treatment :**

i. Where the wastewater is quite fresh.

ii. Where the floating matter and settleable solids have been removed.

iii. Where water body has large volume in comparison to the volume of wastewater.

iv. Where the wastewater does not contain industrial wastewater having toxic substances.

v. Where the diluting water has high content of DO.

2. **Conditions Essential for Treatment before Dilution :**

i. Where the wastewater discharge is detrimental to aquatic life.

ii. Where the volume of diluting water is insufficient.

iii. Where the receiving waters are used for inland navigation.

iv. Where the receiving water is a source for drinking water.

v. Where wastewater is not fresh but is stale.

Que 3.30. **Explain the land treatment method of disposal of wastewater.**

Answer

Disposal by land treatment :

1. When the wastewater, either raw or partly treated, is applied or spread on the surface of land, the method is called disposal by land treatment.
2. Some part of the wastewater evaporates while other part percolates in the ground leaving behind suspended solids which are partly acted upon by the bacteria and partly oxidised by exposure to atmospheric actions of air, heat and light.
3. Following are the processes of land treatment of wastewater :

Broad Irrigation or Sewage Farming :

i. The nutrients in sewage like nitrogen, phosphorous and potassium along with the micro-nutrients as well as organic matter add to the fertilizing value of the land, and crops can be profitably raised on such land.
ii. Due to this, the disposal by land treatment is also sometime called as sewage farming.

Rapid Infiltration :

i. It may be used for waste disposal, ground water recharge or both.
ii. For this process, wastewater is discharged into large basin underlined by sand and soils of high permeability.
iii. Bottom of the basin may be covered with grass like bermuda which can persist in wet or dry condition.
iv. The grass assists in nitrogen removal and helps maintain the infiltration capacity of the surface.

Overland Runoff :

i. This technique is applied when soils have poor permeability.
ii. It is not a true disposal system since wastewater must be collected after passage over the soil.
iii. Plant or tree cover is essential to minimize and assist in nutrient removal.

Que 3.31. **Discuss the conditions under which lands treatment is suitable.**

Answer

Conditions Favourable for Land Treatment :

1. When rivers run dry or have a very small flow during summer.
2. When plentiful land with sandy, loamy or alluvial soil overlying soft murram, sand or gravel is available.
3. When climate is arid, land treatment is favoured.
4. Land treatment is favoured when subsoil water table is low even during the wet season.
5. When large open areas in the surround locality are available.
6. Cash crops can be easily grown on sewage farms.

Que 3.32. **Explain the phenomenon of the oxygen deficit of a polluted river stream.**

Answer

The Oxygen Deficit of a Polluted River-Stream :

1. The oxygen deficit D at any time in a polluted river-stream is the difference between the actual DO content of water at that time and the saturation DO content at the water temperature ; *i.e.*,

   Oxygen deficit (D) = Saturation DO – Actual DO

2. In order to maintain clean conditions in a river-stream, the oxygen deficit must be nil, and this can be found out by knowing the rates of deoxygenation and reoxygenation.

1. Deoxygenation Curve :

i. In a polluted stream, the DO content goes on reducing due to decomposition of volatile organic matter.

ii. The rate of deoxygenation depends upon the amount of the organic matter remaining to be oxidised at the given time (*i.e.*, L_t) as well as on the temperature of reaction (*i.e.*, t). Hence, at a given temperature, the curve showing depletion of DO with time, *i.e.*, deoxygenation curve (Refer curve 1 of Fig. 3.29.1 is similar to the first stage BOD-curve.

iii. It can also be expressed mathematically as $\dfrac{dL_t}{dt} = KL_t$.

2. Reoxygenation Curve :

i. In order to counter-balance the consumption of DO due to deoxygenation, atmosphere supplies oxygen to the water, and the process is called reoxygenation.

ii. The rate at which the oxygen is supplied by the atmosphere to the polluted water depends upon :

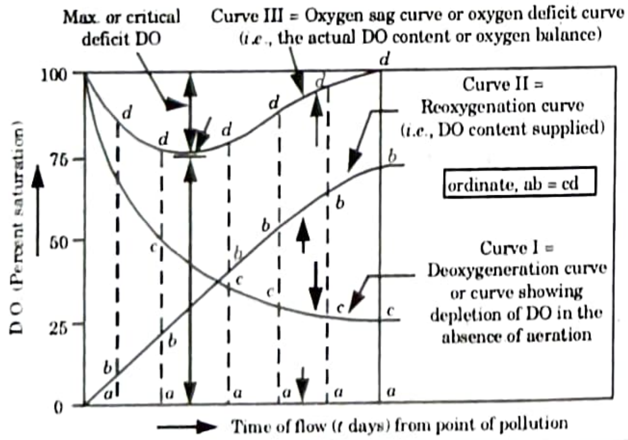


Fig. 3.32.1. Oxygen sag curve in a river receiving discharge of sewage.

a. The depth of the receiving water (rate is more in a shallow depth).

b. The condition of the body of water (rate is more in a running stream than in a quiescent pond).

c. The saturation deficit or the oxygen deficit (*i.e.*, the deficit of DO below the saturation value).

d. The temperature of water.

iii. Depending upon these factors, the rate of reoxygenation can also expressed mathematically and plotted in the form of a curve called reoxygenation curve.

3. **Oxygen Deficit Curve :**

i. In a running polluted stream exposed to the atmosphere, the deoxygenation as well as the reoxygenation goes hand in hand. An oxygen deficit results if deoxygenation is more rapid than the reoxygenation.

ii. The amount of resultant oxygen deficit can be obtained by algebraically adding the deoxygenation and reoxygenation curves.

iii. The resultant curve so obtained is called the oxygen sag curve or the oxygen deficit curve.

☺☺☺

4

UNIT

Water Treatment

CONTENTS

PART-1

Unit Operations, Processes, and Flow Sheets.

CONCEPT OUTLINE

Unit Operations : The means of treatment in which the application of physical forces predominates are known as unit operations. It includes :

i. Screening,
ii. Mixing,
iii. Flocculation,
iv. Sedimentation, etc.

Unit Processes : The types of treatment in which the removal of contaminants is brought about by the addition of chemicals or the use of biological mass or microbial activities are known as unit processes.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. What do you understand by unit operations and processes ? What are the advantages in water and wastewater treatment ?

Answer

1. **Unit Operation :** Method of treatment in which the application of physical forces predominates are known as unit operations.
2. **Unit Processes :** Methods of treatment in which chemical or biological activities are involved are known as unit processes.

There are three types of unit operations and processes :

1. Physical unit operations,
2. Chemical unit processes, and
3. Biological unit processes.

Advantages : Following are the advantages of unit operation in water and wastewater treatment :

1. It gives better understanding of the processes inherent in the treatment, and of the capabilities of these processes in attaining the objectives.
2. It helps in the development of mathematical and physical models of treatment mechanisms and the consequent design of treatment plants.

3. It helps in the co-ordination of effective treatment procedure to attain desired plant performance and effluent quality.

Que 4.2. **Describe the applications of physical unit operations in wastewater treatment.**

Answer

S. No.	Operation	Application
1.	Screening	Removal of coarse and settleable solids by surface straining.
2.	Mixing	Mixing of chemicals and gases with wastewater, and maintaining solids in suspension.
3.	Flocculation	Promotion of the aggregation of small particles into larges particles.
4.	Sedimentation	Removal of settleable solids and thickening of sludges.
5.	Floatation	Removal of finely divided suspended solids and particles with densities close to that of water. Also thickens biological sludges.
6.	Filtration	Removal of fine residual suspended solids remaining after biological or chemical treatment.

Que 4.3. **Define chemical unit processes and also describe the applications of chemical unit processes in wastewater treatment.**

Answer

Chemical Unit Processes : Chemical unit processes are those in which removal of contaminants are brought about by chemical activity.

S. No.	Operation	Application
1.	Chemical precipitation	Removal of phosphorous and enhancement of suspended solids removal in primary sedimentation.
2.	Gas transfer	Addition and removal of gases.
3.	Adsorption	Removal of organics.
4.	Disinfection	Disinfection of disease-causing organisms.
5.	Dechlorination	Removal of total combined chlorine residuals.

PART-2

Screening.

CONCEPT OUTLINE

Screening : It is a first process, and consists of passing the sewage through different types of screens so as to trap and remove the floating matter.

Types of Screens : Following are the three types of screens :

i. Coarse screens (Racks).

ii. Medium screens.

iii. Fine screens.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.4. What do you mean by screening ? What are classifications of screening ?

Answer

Wastewater Screening :

1. Wastewater screening is the first unit operation in all wastewater treatment plants. Screen is the device used to retain solids found in the influent wastewater to the treatment plant.
2. The main purpose of screening is to remove solid materials that could :

i. Cause damage to other process equipment.

ii. Cause reduction in efficiency of the whole system.

iii. Contaminate waterways.

3. The materials that are removed using screens are called screenings.

Classification of Wastewater Screens :

1. **Coarse Screens :** Coarse screens have a clear openings ranging from 6 to 150 mm. Coarse screen consist of parallel bars, rods or wires, wire mesh or a perforated plates with openings generally of circular or rectangular shapes.
2. **Fine Screens :** In Wastewater Screening, Fine screens have clear openings less than 6 mm. They consisted of perforated plates, wire

cloth, wedge wire elements that have smaller openings. They are also used to remove the fine solids present in the primary effluent.

PART-3

Sedimentation, Determination of Settling Velocity.

CONCEPT OUTLINE

Sedimentation : It is the physical separation of suspended material from water or wastewater by the action of gravity.

Settling Velocity : Velocity can be calculated by two formula :

i. **Stoke's Law :** $$v_s = \frac{g}{18}(G-1)\frac{d^2}{\nu}$$

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.5. What is sedimentation ? Also explain its principle and process.

Answer

1. **Sedimentation :** Plain sedimentation is the process of removing suspended matters from the water by keeping it quiescent in tanks, so that suspended matter may settle down in the bottom due to force of gravity.
2. **Principle of Sedimentation :**
   i. All the particles having more specific gravity than the liquid will move vertically downward due to gravitational force.
   ii. When any discrete particle is falling through a quiescent fluid, it will accelerate until the frictional resistance or drag force becomes equal to the gravitational forces acting upon the particle.
   iii. At such stage the particle will settle at uniform velocity.
3. **Process :**
   i. In the process of treating water by plain sedimentation the water is retained in a basin so that the suspended particles may settle down due to force of gravity only.
   ii. After the settlement of suspended particles has taken place, the water is taken out from the basin without causing any disturbance to the suspended impurities.
   iii. Plain sedimentation is suitable for relatively pure water which contains undesirable amounts of suspended matters.

Que 4.6. **Derive stokes law for the settling velocity of a discrete particle in dilute sample suspension. Discuss the limitations.**

AKTU 2014-15, Marks 10

Answer

Derivation of Stoke' Law :

1. When a solid particle settles down in water, its downward settlement is opposed by the drag force offered by the water.
2. The effective weight of the particle (i.e. actual weight – buoyancy) causes the particle to accelerate in the beginning, till it attains a sufficient velocity (v_s) at which the drag force becomes equal to the effective weight of the particle.
3. Drag force offered by the fluid is given by,

$$F_D = C_D A \rho_w \frac{v^2}{2} \quad ...(4.6.1)$$

4. The effective weight of the particle

$$= \text{Total weight} - \text{Buoyancy}$$

$$= \frac{4}{3}\pi r^3 \gamma_s - \frac{4}{3}\pi r^3 \gamma_w \quad [\because \text{Weight} = \text{Volume} \times \text{Unit weight}]$$

$$= \frac{4}{3}\pi r^3 [\gamma_s - \gamma_\omega] \quad ...(4.6.2)$$

5. Eq. (4.6.1) and eq. (4.6.2) will become equal when v becomes equal to v_s in eq. (4.6.1).

$$C_D A \rho_w \frac{v_s^2}{2} = \frac{4}{3}\pi r^3 [\gamma_s - \gamma_\omega] \quad [\because A = \pi r^2, r = d/2]$$

$$v_s^2 = \frac{4/3(\gamma_s - \gamma_w)\, d}{\rho_w C_D} \quad [\because \gamma_s = \rho_s g, \gamma_w = \rho_w g \text{ and } \rho_s/\rho_w = G]$$

$$v_s = \left[\frac{4/3\, gd\,(G-1)}{C_D}\right]^{1/2} \quad ...(4.6.3)$$

6. The value of coefficient of drag (C_D) changes and depends upon the laminar, turbulent and transitional flow.
   Drag coefficient, $C_D = 0.4$ (for $R_e > 10^4$)

$$C_D = 24/R_e \text{ (for } R_e < 0.5)$$

$$C_D = \frac{24}{R_e} + \frac{3}{\sqrt{R_e}} + 0.34 \text{ (for } R_e \text{ between 0.5 to 10,000)}$$

7. Settling velocity for small spherical particles falling under laminar condition, from eq. (4.6.3)

$$v_s = \left[\frac{4/3\, g\,(G-1)d}{24/R_e}\right]^{1/2} \quad [\because R_e = vd/\nu]$$

$$v_s^2 = \frac{4}{3} g(G-1)d \frac{\text{Re}}{24}$$

$$v_s^2 = \frac{g}{18}(G-1)d \frac{(Vsd)}{\nu}$$

$$v_s = \frac{g}{18}(G-1)\frac{d^2}{\nu}$$

Limitations : Following are the limitations of Stoke's law :

1. Stoke's law is applicable only when the liquid is infinite. The presence of walls of the jar affects the results to some extent.
2. In Stoke's law, it has been assumed that only one sphere settles, and there is no interference from other spheres. In the sedimentation analysis, as many particles settle simultaneously, there is some interference.
3. The sedimentation analysis cannot be used for particles larger than 0.2 mm as turbulent conditions develop and Stoke's law is not applicable.
4. The sedimentation method is not applicable for particles smaller than 0.2 μ because Brownian movement takes place and the particles do not settle as per Stoke's law.

Que 4.7. **Find the settling velocity of a discrete particle in water under conditions when Reynold's number is less than 0.5. The diameter and specific gravity of the particle is 5×10^{-3} cm and 2.65, respectively. Water temperature is 20°C (Kinematic viscosity of water at 20°C = 1.01×10^{-2} cm²/sec).**

AKTU 2016-17, Marks 10

Answer

Given : Specific gravity, $G = 2.65$, Diameter of particle, $d = 5 \times 10^{-3}$ cm
Kinematic viscosity, $\nu = 1.01 \times 10^{-2}$ cm²/sec.

To Find : Settling velocity, v_s.

Settling velocity is calculated as :

$$v_s = \frac{g}{18}(G-1) \times \frac{d^2}{\nu} \text{ when } d < 0.1 \text{ mm}$$

$$g = 981 \text{ cm/sec}^2$$

$$v_s = \frac{981}{18}(2.65-1)\frac{(5 \times 10^{-3})^2}{1.01 \times 10^{-2}} \text{ cm/sec}$$

Settling velocity, $v_s = 0.22$ cm/sec.

Que 4.8. **Design a plain sedimentation tank for an average flow of water 250 m^3/hr. The minimum size of particle to be removed 0.02 mm and expected performance of tank may be taken as 'good'. Kinematic viscosity of water at 20° C = 1.01×10^{-6} m^2/s and specific gravity of particle = 2.65.**

AKTU 2017-18, Marks 10

Answer

Given : Average discharge, $Q = 250$ m^3/hr, Minimum size of particle = 0.02 mm, Kinematic viscosity of water = 1.01×10^{-6} m^2/sec, Specific gravity, $G = 2.65$.

To Find : Design plain sedimentation tank.

1. Using Stoke's law,

$$\text{Settling velocity} = \frac{g}{18}(G-1)\frac{d^2}{\text{v}} \text{ when } d < 0.1$$

$$v_s = \frac{9.81}{18}(2.65-1)\frac{\left(\frac{0.02}{1000}\right)^2}{1.01 \times 10^{-6}} = 3.5614 \times 10^{-4} \text{ m/sec}$$

2. Assume detention period = 2 hr.
3. Length of the tank required = Velocity of flow × Detention period

$$= 3.5614 \times 10^{-4} \times (2 \times 60 \times 60) = 2.56 \text{ m}$$

   Provide length of tank = 5 m
4. Cross-sectional area of the tank required

$$= \frac{\text{Capacity of tank}}{\text{Length of tank}} = \frac{250}{5} = 50 \text{ m}^2$$

5. Assume the water depth in the as 5 m, the width of the tank required

$$= \frac{50}{5} = 10 \text{ m.}$$

   Using a free board of 0.5 m, the overall depth = 5 + 0.5 = 5.5 m
6. Hence, a rectangular sedimentation tank with an overall size of 5 m × 10 m × 5.5 m can be used.

Que 4.9. **Two million liters of water per day is passing through a sedimentation tank which is 6 m wide, 15 m long and having a water depth of 3 m :**

i. Find the detention time for tank.
ii. What is the average flow velocity through the tank ?

iii. If 60 ppm is the concentration of suspended solids present in turbid raw water, how much dry solids will be deposited per day in the tank, assuming 70 % removal in the basin, and average specific gravity of the deposit as 2.

iv. Compute the overflow rate.

AKTU 2013-14, Marks 10

Answer

Given : Discharge, $Q = 2 \times 10^6$ litres, Width of tank, $B = 6$ m
Length of tank, $L = 15$ m, Depth of tank, $D = 3$ m
Concentration of suspended solid = 60 ppm, Specific gravity = 2
To Find : Detention time, Average velocity.
Overflow rate and amount of deposited solids.

1. The capacity of the tank $= L \times B \times D$

$$= 15 \text{ m} \times 6 \text{ m} \times 3 \text{ m} = 270 \text{ m}^3$$

2. Discharge passing through the tank

$$Q = 2 \text{ million litres per day } \frac{2 \times 10^6}{24} \text{(litre/ hr)}$$
$$= 83.33 \times 10^3 \text{ litres/hr} = 83.33 \text{ cum/hr}$$

3. Detention time $= \dfrac{\text{Capacity of the tank}}{\text{Discharge}}$

$$= 270 / 83.33 \text{ hours} = 3.24 \text{ hours}$$

4. Average velocity of flow through the tank

$$= \frac{\text{Discharge}}{\text{Cross-sectional area, } i.e., B \times H}$$
$$= \frac{83.33}{6 \times 3} \text{ m/hr} = \frac{83.33}{6 \times 3} \times \frac{100}{60} \text{ cm/minute}$$
$$= 7.72 \text{ cm/minute}$$

5. Quantity of water passing per day

$$= 2 \text{ million litres} = 2 \times 10^6 \text{ litres}$$

6. Concentration of suspended solids = 60 ppm.
Quantity of suspended solids entering the tank per day

$$= 2 \times 10^6 \times \frac{60}{10^6} \text{ litres} = 120 \text{ litres} = 0.12 \text{ m}^3.$$

7. Density of deposited materials = 2000 kg/m^3.
Mass of suspended solids deposited (with 70 % removal) per day

$$= 0.12 \times 0.7 \times 2000 \text{ kg} = 168 \text{ kg}$$

8. Overflow rate = Discharge per unit plan area

$$= \frac{Q}{B \times L} = \frac{83.33 \times 10^3 \text{ litres/hr}}{6 \times 15 \text{ m}^2} = 926 \text{ litres/hr/m}^2$$

PART-4

Efficiency of Ideal Sedimentation Tank.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.10. **Discuss about the efficiency of ideal sedimentation tank.**

Answer

1. The hydraulic efficiency of the settling tank is the flow through period (t_d) which can be expected to approach the critical detention period (t_o) only in ideal tanks.
2. Settling tank efficiency is reduced by the following currents :
i. Eddy currents, set up by the inertia of the incoming fluid.
ii. Surface currents, induced due to wind in open tanks.
iii. Vertical convection currents, due to thermal gradient along the depth of the tank.
iv. Density currents causing cold or heavy water to under run the basin and warm or light water to flow across its surface.
3. The efficiency of settling tank is dependent on the above mentioned currents, concentration of particles, shape of the basin and inlet and outlet arrangement.
4. A well designed tank should have volumetric efficiency of atleast 70 %.
5. The efficiency may be mathematically expressed by the following expression,

$$\frac{y}{y_0} = 1 - \left[1 + \frac{nv_s}{Q/A}\right]^{-\frac{1}{n}}$$

where, Q/A = Required surface overflow rate for real basin.
n = Coefficient identifying basin performance.

PART-5

Design of Settling Tanks, Grit Chamber.

CONCEPT OUTLINE

Types of Grit Chamber : Following are the different types of grit chambers :

i. Rectangular horizontal flow type.

ii. Detritus tank
iii. Aerated grit chamber
iv. Square horizontal flow type
v. Vortex flow type.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.11. **What do you understand by grit chamber ? What are uses of grit chamber ?**

Answer

Grit Chamber : Grit chamber is the sedimentation basins placed in front of the wastewater treatment plant to remove the inorganic particles (specific gravity about 2.65), such as sand, gravel, grit, egg shells,

Uses : Following are the uses of grit chamber :

1. The grit chamber is used to remove grit, consisting of sand, gravel, cinder, or other heavy solids materials that have specific gravity much higher than those of the organic solids in wastewater.
2. Grit chambers are provided to protect moving mechanical equipment from abrasion and abnormal wear; avoid deposition in pipelines, channels, and conduits; and to reduce frequency of digester cleaning.
3. The grit chambers are usually placed after the fine screens, to remove particles of size up to 0.2 mm or so.
4. Grit can be disposed off after washing, to remove higher size organic matter settled along with grit particles.

Que 4.12. **Design a conventional grit chamber unit for a design sewage flow of 120Ml/d. Assume suitable data necessary. Draw a schematic diagram of the unit.** **AKTU 2017-18, Marks 10**

Answer

Given : Sewage flow = 120 ML/d
To Find : Size of grit chamber

1. Let us provide a rectangular channel section, since a proportional flow weir is provided for controlling velocity of flow.
2. Horizontal velocity of flow, $v_h = 0.3$ m/sec.
3. Settling velocity is between 0.016 to 0.022 m/sec, and hence let it be 0.020 m/sec.

Now, Q = Velocity × Cross-section = $v_h \times A$

$$\frac{120000}{24 \times 60 \times 60} = 0.3 \times A$$

Aria, $$A = \frac{1.389}{0.3} = 4.63 \text{ m}^2.$$

4. Assuming a water depth (H) of 1 m above the crest of the weir, which is kept at 0.3 m above the channel bottom, we have the width (B) of the basin as

$$1 \times B = 4.63$$

or $$B = 4.63 \text{ m} \text{ ; say 5 m.}$$

5. Overall depth of grit chamber,

= Water depth above the crest of weir + 0.3 m + Free board of 0.45 m

= 1.0 m + 0.3 m + 0.45 m = 1.75 m

6. Detention time = $\dfrac{\text{Water depth in the basin}}{\text{Settling velocity}} = \dfrac{1}{0.02}$ = 50 sec

7. Length of the tank = v_h × Detention time = 0.3 × 50 = 15 m.

Increase 30% length of tank. Hence provide 20 m long tank.

8. Hence, use a rectangular tank, with dimensions :

Length (L) = 20 m
Width (B) = 5 m
Depth (D) = 1.75 m

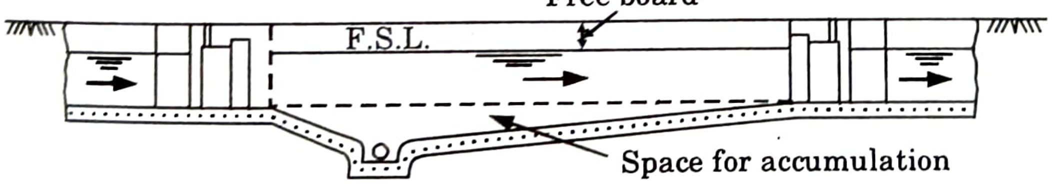


Fig. 4.12.1. Grit chamber.

PART-6

Primary Sedimentation.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.13. **What is the purpose of preliminary treatment of sewage? Write the brief note on various units employed for the same.**

AKTU 2016-17, Marks 10

Answer

Purpose of Preliminary Treatment :

1. Preliminary treatment consists solely in separating the floating materials (like dead animals, tree branches, papers, pieces of rags, wood, etc.), and also the heavy settleable inorganic solids.
2. It also helps in removing the oils and greases, etc. from the sewage.
3. This treatment reduces the BOD of the wastewater, by about 15 to 30 %.

Treatment Units : Following are the main units in preliminary treatment :

1. **Screening :** Refer Q. 4.4, Page 4–4B, Unit-4.
2. **Grit Removal Basins :** Refer Q. 4.11, Page 4–11B, Unit-4.
3. **Skimming Tanks :**

i. Skimming tanks are sometimes employed for removing oils and grease from the sewage, and placed before the sedimentation tanks.

ii. They are used where sewage contains too much of grease or oils, which include fats, waxes, soaps, fatty acid, etc.

iii. These materials may enter into the sewage from the kitchens of restaurants and houses, from motor garages, oil refineries, soap and candle factories, etc.

iv. If such greasy and oily matter is not removed from the sewage before it enters further treatment units, it may form unsightly and odorous scums on the surface of the settling tanks, or interfere with the activated sludge treatment process, and inhibit biological growth on the trickling filters.

v. These oil and greasy materials may be removed in a skimming tank, in which air is blown by an aerating device through the bottom.

PART-7

Coagulation.

CONCEPT OUTLINE

Coagulation : It is a chemical technique which is directed towards the destabilization of the charged colloidal particles. The chemical compounds which are used in coagulation process, known as coagulants. Following are the coagulants used in coagulation :

i. Alum

ii. Ferrous sulphate

iii. Sodium aluminate etc.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.14. **Why coagulants are used in the sewage treatment ? Mention few common coagulants.** **AKTU 2015-16, Marks 10**

OR

Why are coagulants used in the sewage treatment ? List various coagulants used along with their effectiveness in sedimentation of sewage. **AKTU 2013-14, 2017-18; Marks 10**

Answer

Necessity of Coagulants :

1. As pointed out very fine suspended mud particles and the colloidal matter present in water cannot settle down in plain sedimentation tank of ordinary detention period.
2. They can, however be removed easily by increasing their size by changing them into flocculated particles. For this purpose certain chemical compounds called coagulants are added to the water which on mixing form a gelatinous precipitate called 'floc'.
3. The very fine colloidal particles present in water, get attracted and absorbed in these flocs, forming the bigger sized flocculated particles.

Common Coagulants & effectiveness : The following are chemicals and their effectiveness :

1. **Alum :** Generally not used for sewage treatment because of spongy floc resulting in large volume of sludge.
2. **Sulphate (Chlorinated Copperas) :** Effective for producing sludge for activated sludge process.
3. **Ferric Chloride :** Forms heavy, dense floc which settles rapidly. Hence used widely for a sewage treatment.
4. **Ferric Sulphate :** Found to be more effective than chlorinated copperas if used in conjunction with lime.

Que 4.15. **Differentiate between coagulation and flocculation used in water treatment plant.** **AKTU 2014-15, Marks 10**

Answer

S. No.	Coagulation	Flocculation
1.	Coagulation involves the addition of coagulant to enhance the clotting of suspended particles in water.	Flocculation involves the formation of visible flocs by mechanical or physical mixing.
2.	Coagulation is a chemical process.	Flocculation is a physical process.
3.	Coagulants such as inorganic salts of aluminum or iron that neutralize the suspended particles are added during coagulation.	Flocculant such as an organic polymer that is added which involves bridging and strengthening the flocs that also increase the weight of the flocs and also increase the rate of settling.
4.	Coagulation does not involve physical mixing process.	Flocculation involves physical mixing.

Que 4.16. **Describe briefly the various constituents of a coagulation sedimentation plant.** **AKTU 2015-16, Marks 10**

OR

Elaborate the constituents of a clariflocculator with neat sketch.

AKTU 2016-17, Marks 10

Answer

The Constituents of a Coagulation Sedimentation Tank : The coagulation sedimentation plant sometimes called simply a coagulation plant or a clariflocculant or, contains the following four units :

1. **Feeding Devices :**

i. The chemical coagulant may be fed into the raw water either in a powdered form or in a solution form.

ii. The former is known as dry feeding, and the latter is known as wet feeding.

iii. Wet feeding equipments are generally costlier than the dry feeding equipments, but they have the advantage that they can be easily controlled and adjusted.

iv. The choice between these two types of equipments depends upon the following factors :

   a. The characteristics of the coagulant and the convenience with which it can be applied :

b. The amount of the coagulant to be used.

c. The cost of the coagulant and the size of the plant.

2. **Mixing Devices :**

i. After the addition of the coagulant to the raw water, the mixture is thoroughly and vigorously mixed, so that the coagulant gets fully dispersed into the entire mass of water.

ii. This violent agitation of water can be achieved by means of mixing devices, such as, centrifugal pumps, compressed air, mixing basins, etc.

iii. Out of these devices, mixing basins are most important and normally adopted.

iv. There are two types of mixing basins, viz.

a. Mixing basins with baffle walls, and

b. Mixing basins equipped with mechanical devices.

3. **Flocculation Tank or a Flocculator :**

i. The best floc will form when the mixture of water and coagulant are violently agitated followed by a relatively slow and gentle stirring to permit build up and agglomeration of the floc particles.

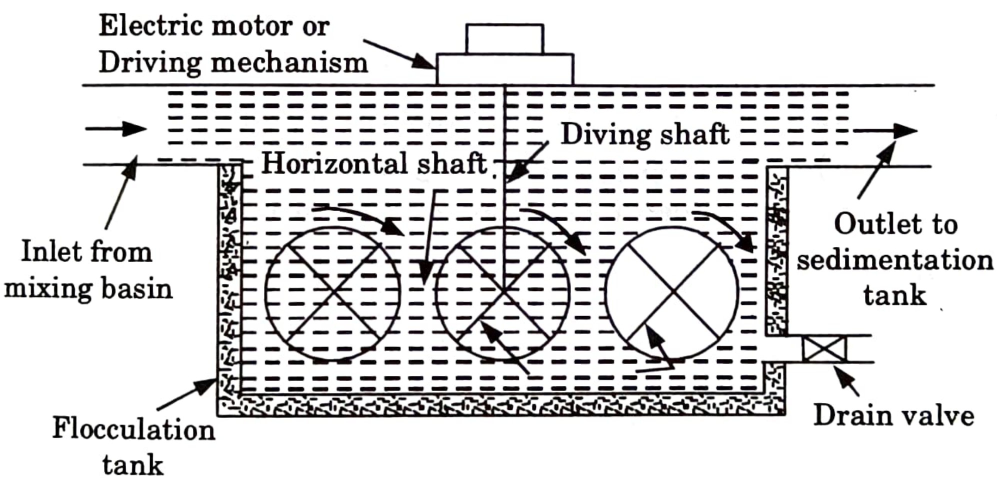


Fig. 4.16.1. Flocculator fitted with slowly movig paddles.

ii. From the mixing basin, the water is, therefore, taken to a flocculation tank called a flocculator, where it is given a slow stirring motion.

iii. Rectangular tanks fitted with paddles operated by electric motors can best serve this purpose, although even plain flocculation chambers with controlled flow velocities are also possible.

iv. The water coming out from the flocculator is taken to the sedimentation tank.

4. **Sedimentation Tank :**

i. Sedimentation basins are generally made of reinforced concrete, and may be rectangular or circular in plan.

ii. Long narrow rectangular tanks with horizontal flow are generally preferred to the circular tanks with horizontal radial or spiral flow.

iii. The capacity and other dimensions of the tank should be properly designed, so as to affect a fairly high percentage of removal of the suspended materials.

iv. A plain sedimentation tank under normal conditions may remove as much as 70 % of the suspended impurities present in water.

Types of Sedimentation Tanks : The sedimentation tanks can basically be divided into two types :

a. Horizontal flow tanks types.

b. Vertical or up flow tanks.

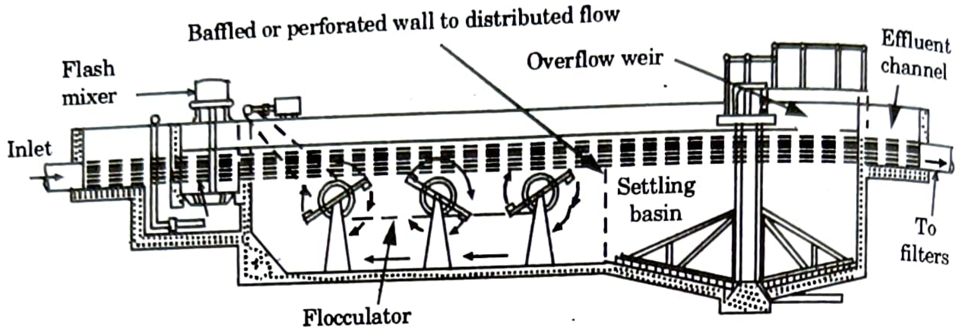


Fig. 4.16.2. Clariflocculator.

Que 4.17. **Design a coagulation-cum-sedimentation tank with continuous flow for a population of 60,000 persons with a daily per capita water allowance of 120 litres. Make suitable assumptions where needed.**

AKTU 2016-17, Marks 10

Answer

Given : Population = 60,000. Daily per capita water allowance = 120 litres.
To Find : Design a coagulation-cum-sedimentation tank.

A. Design of the Settling Tank :

1. Average daily consumption = Population × Per capita demand

$$= 60{,}000 \times 120 = 7.2 \times 10^6 \text{ litres}$$

2. Assuming the maximum daily demand as 1.8 times the average daily demand.

The maximum daily consumption

$$= 1.8 \times 7.2 \times 10^6 \text{ litres} = 12.96 \times 10^6 \text{ litres}$$

3. Quantity of water to be treated during an assumed detention period of 4 hours

$$= \frac{12.96 \times 10^6}{24} \times 4 = 2.16 \times 10^6 \text{ litres} = 2.16 \times 10^3 \text{ m}^3$$

Hence, the capacity of the tank required

$$= 2.16 \times 10^3 \text{ m}^3$$

4. Assuming an overflow rate of 1000 litres/hr/m^2 of plan area, we get

$$Q / (B \times L) = 1000$$

where, $$Q = \frac{2.16 \times 10^6}{4} \text{ litres/hr} = 540 \times 10^3 \text{ litres/hr.}$$

5. Plan area $= B \times L = \frac{Q}{1000} = \frac{540 \times 10^3}{1000} = 540 \text{ m}^2.$

Using the width of the tank (B) as 12 m, we get

The length (L) of the tank = 540 / 12 = 45 m.

6. Hence, use a tank of 45 m × 12 m × 4 m. Provide extra depth for sludge storage, as 4.5 m depth at the starting end, and $4.5 + \frac{45}{50} = 5.4$ m at the d/s end (using 1 in 50 slope). Use a freeboard of 0.5 m above the water level, as shown in Fig. 4.17.1.

B. Design of the Floc-Chamber :

1. Assume the effective depth in the floc-chamber as half of the depth in the tank near the floc-chamber,

i.e., Effective Depth $= \frac{4.5}{2} = 2.25$ m

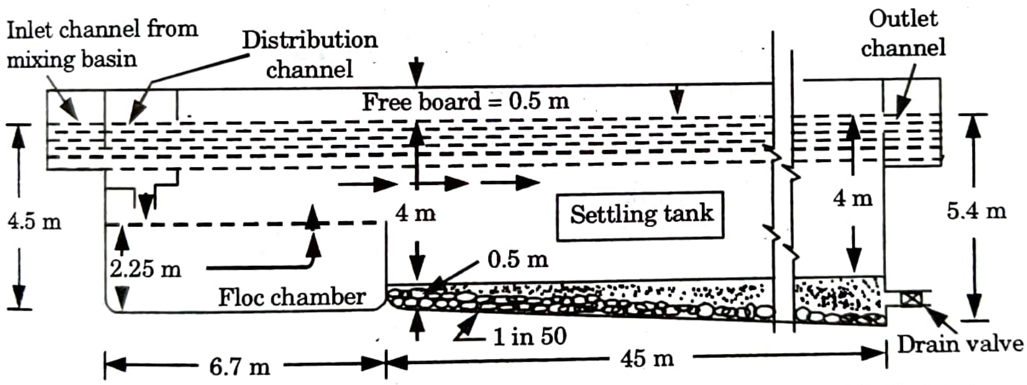


Fig. 4.17.1. Dimensions of the coagulation-cum-sedimentation tank.

2. Assume the period of flocculation or detention period as 20 minutes. (*i.e.*, between 15 to 40 min)

Now, the capacity of the chamber

= Flow required in 20 minutes

$$= \frac{12.96 \times 10^3}{24} \times \frac{20}{60} \text{ m}^3 = 180 \text{ m}^3$$

3. The plan area required

$$= \frac{\text{Capacity}}{\text{Depth}} = \frac{180}{2.25} \text{ m}^2 = 80 \text{ m}^2$$

4. Using the same width as 12 m, we get the length of flocculation chamber

= 80 / 12 = 6.67 m (say 6.7 m)

5. The details and dimensions are shown in Fig. 4.17.1.

Que 4.18. **Design a clariflocculator for an average flow of water 250 m³/hr. Assume any data suitably if required.**

AKTU 2017-18, Marks 10

Answer

Given : Discharge = 250 m³/hr

To Find : Design of clariflocculator

1. **Assume Design Parameters :**

i. Detection period = 20 minutes.

ii. Average value of $G = 40\ s^{-1}$.

iii. Speed of paddles = 4.5 rpm

iv. Area of paddles = 15 % of the cross-sectional area of basin.

v. Velocity ratio, $k = 0.25$

vi. $\mu = 1.0087 \times 10^{-3}$ N-sec/m² at 20°C

vii. $\rho = 998$ kg/m³ at 20°C.

viii. Ratio of length to width of tank = 2

2. **Computation of Volume of Flocculation Tank :**

i. Volume of tank, V = Design flow × Detention time

$$= 250 \times 20/60 = 83.33\ m^3$$

ii. Let the depth of the tank = $0.4\ B$

iii. Let the length of tank = $2B$

$$B \times 2\ B \times 0.4\ B = 83.33$$

$$B = 4.705\ m$$

iv. From which width of tank,

$$B = 4.705 \simeq 5\ m$$

v. Length of tank, $L = 5 \times 2 = 10$ m

vi. Height of tank, $H = 0.4 \times 5 = 2$ m

3. **Computation of Power Required :**

Power, $P = G^2 V \mu$

$$= (40)^2 \times 83.33 \times 1.0087 \times 10^{-3} = 134.5 \text{ watts}$$

4. **Computation of Velocity difference between the Paddle and Water :**

Let us provide revolving paddles attached to three horizontal shafts running parallel to the length. Let each shaft be located at mid-depth of the tank. Let us provide four paddles to each shaft, each running parallel to the shaft.

i. Maximum available outer radial distance of each paddle

$$= \frac{B}{2 \times 3} = \frac{5}{6} = 0.833 \text{ m.}$$

ii. Assume 25 cm width of blade, maximum value of,

$$r = 0.833 - 0.25/2 = 0.7 \text{ m.}$$

iii. Hence keep distance r from the centre line of paddles to the centre of shaft as 0.7 m.

$$v_p = \frac{2\pi\, rn}{60} = \frac{2\pi}{60} \times 0.7 \times 4.5 = 0.33 \text{ m/sec}$$

$$v_r = (1 - k)\, v_p = (1 - 0.25) \times 0.33 = 0.2474 \text{ m/sec}$$

5. Computation of Paddle Size :

i. We know that

$$p = 1/2\, C_D\, \rho A_p\, v_r^3$$

where, $C_D = 1.8$ for flat blades

$$134.5 = 1/2 \times 1.8 \times 998\, A_p \times (0.2474)^3$$

$$A_p = 9.89 \text{ m}^2$$

ii. Number of paddles = 3 × 4 = 12

Area of the each paddle = 9.89/12 = 0.824 m^2.

iii. Let the length of each paddle = 4.8 m.

(Slightly less than half the length of tank)

$$\text{Width of paddle} = \frac{9.89}{4.8} = 2.06 \text{ m.}$$

Hence provide 2.06 m wide paddles, each of length 4.8 m.

PART-8

Theory of Filtration, Hydraulics of Filtration.

CONCEPT OUTLINE

Theory of Filtration : In the filteration, water undergoes four different processes :

i. Mechanical straining.
ii. Flocculation and sedimentation.
iii. Biological metabolism.
iv. Electrolytic changes.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.19. **Describe the filtration and theory of filtration of wastewater.**

Answer

Filtration :

1. The process of passing the water through the beds of granular materials (called filters) is known as filtration.
2. Filtration may help in removing colour, odour, turbidity and pathogenic bacteria from the water.
3. Two types of filters that are commonly used for treating municipal water supplies are :
   i. Slow sand gravity filters,
   ii. Rapid sand gravity filters.

Theory of Filtration : Filtration may be explained on the basis of the following four actions :

1. **Mechanical Straining :**
   i. The particles of suspended matter that are of size larger than the size of the interstices or voids between the sand grains cannot pass through these interstices and are therefore arrested and removed by the action of mechanical straining.
   ii. It cannot remove colloidal matter or bacteria that are too small to be strained out.
2. **Sedimentation and Adsorption :** The interstices between the sand grains act as minute sedimentation tanks in which the particles of the suspended matter settle on the sides of the sand grains.
3. **Biological Metabolism :**
   i. The growth and life processes of the living cells is known as biological metabolism.
   ii. Suspended impurities contain some portion of organic impurities such as algae, plankton etc., which are food of various types of micro-organisms.
   iii. These organisms act on the organic matter and cause chemical and biological change in the water.
   iv. These organic impurities form a layer on the top of sand bed which is known as 'Schmutzdecke' or 'dirty skin'.
   v. Micro-organisms live in this dirty skin and act on the organic impurities of water.
4. **Electrolytic Action :**
   i. The sand particles of filter media and ionized matter in the water carry electrical charges of opposite nature, therefore they attract each other and neutralize the charge of each other.
   ii. While doing so the chemical constituents of the water are altered.
   iii. After long use the electric charge of filter sand is exhausted, which is renewed by washing the filter bed.

Que 4.20. **Write short notes on the following :**

1. **Pressure filter**
2. **Advantages and disadvantages of tube setters/plate settlers**
3. **Sludge blanked clarifier**
4. **Backwashing in filters.**

AKTU 2013-14, Marks 10

Answer

1. **Pressure filter :**

i. Pressure filters are just like small rapid gravity filters placed in closed vessels, and through which water to be treated is passed under pressure. Since water is forced through such filters at a pressure greater than the atmospheric pressure, it is necessary than these filters are located in air tight vessels.

ii. The raw water is pumped into the vessels by means of pumps. The pressure so developed may normally vary between 30 to 70 metre head of water, *i.e.*, 300 to 700 kN/m^2.

2. **Advantages and Disadvantages of Tube Setters/Plate Settlers :**

Advantages of Tube Settlers :

i. They are available in blocks which can easily be fitted into many different sizes and shapes of tanks and are held in place by steel supports.

ii. Most are manufactured from PVC so they are lightweight and economical.

Disadvantages of Tube Settlers :

i. May experience flow distribution issues with their small path for water flow, with possible plugging.

ii. Due to their design, settling zones may interfere with incoming water.

Advantages of Plate Settlers :

i. Constructed of stainless steel they offer years of durability.

ii. Low maintenance.

v. Due to their high efficiency, the size of the basin can be reduced by up to 2 times compared with Tube Settlers

Disadvantages of Plate Settlers :

i. One negative of Plate Settlers is their need for a certain installation height.

ii. The initial investment for plate settlers is greater.

3. **Sludge Blanket Clarifier :**

i. A sludge blanket clarifier is a treatment unit combining flocculation and upward flow sedimentation, which is more efficient compared to the conventional sedimentation tank.

ii. It has the ability to treat water at a faster rate, resulting in less space requirement.

iii. The removal of suspended particles takes place by a combination of flocculation, sedimentation and straining as the water passes upwards through the blanket of sludge formed within the clarifier.

4. **Backwashing in Filters :** Backwashing consists of reversing the flow of water so that it enters from the bottom of the filter bed, lifts and rinses the bed, then exits through the top of the filter tank.

Procedure : Backwashing of granular media filters involves following steps :

i. First, the filter is taken off line and the water is drained to a level that is above the surface of the filter bed.
ii. Next, compressed air is pushed up through the filter material causing the filter bed to expand breaking up the compacted filter bed and forcing the accumulated particles into suspension.
iii. After the air scour cycle, clean backwash water is forced upwards through the filter bed continuing the filter bed expansion and carrying the particles in suspension into backwash troughs suspended above the filter surface.
iv. In some applications, air and water streams are simultaneously pushed upwards through the granular media followed by a rinse water wash.
v. Backwashing continues for a fixed time, or until the turbidity of the backwash water is below an established value.
vi. At the end of the backwash cycle, the upward flow of water is terminated and the filter bed settles by gravity into its initial configuration. Water to be filtered is then applied to the filter surface until the filter clogs and the backwash cycle needs to be repeated.

PART-9

Slow Sand, Rapid Sand and Pressure Filters, Backwashing.

CONCEPT OUTLINE

Types of Filters : Three types of filters are commonly used :

i. Slow sand gravity filters,
ii. Rapid sand gravity filters, and
iii. Pressure filters.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.21. **Differentiate between slow sand and rapid sand filters.**

AKTU 2014-15, Marks 10

OR

Compare the slow sand filter and rapid gravity filter.

AKTU 2016-17, Marks 10

Answer

S.No.	Item	Slow Sand Filter	Rapid Sand Filter
1.	Rate of filtration	100 to 200 litres per hour per m^2.	3000 to 6000 litres per hour per m^2.
2.	Loss of head	15 cm initial to 100 cm final.	30 cm initial to 3 m final.
3.	Size of bed	Requires large area.	Requires small area.
4.	Coagulation	Not required.	Essential.
5.	Filter media of sand	Effective size : 0.2 to 0.3 mm C_u : 2 to 3 Depth : 105 cm, reduced to not less than 30 cm by scrapping.	Effective size : 0.35 to 0.6 mm C_u : 1.2 to 1.7 Depth : 75 cm not reduced by washing.
6.	Base material of gravel	Size : 3 to 65 mm Depth : 30 to 75 cm	Size : 3 to 40 mm Depth : 60 to 90 cm
7.	Method of cleaning	Scrapping of top layer to 15 mm to 25 mm.	Agitation and backwashing with or without compressed air.
8.	Period of cleaning	1 to 2 months.	2 to 3 days.
9.	Efficiency	Very efficient in the removal of bacteria but less efficient in the removal of colour and turbidity.	Less efficient in removal of bacteria, more efficient in the removal of colour and turbidity.
10.	Economy	High initial cost	Cheap and economical

Que 4.22. Explain the under drainage system of a rapid sand filter and mention the general rules of design for such a system.

Answer

A. Under Drainage System :

1. In slow sand filters, the under drainage system was provided only to receive and deliver the filtered water whereas in rapid sand gravity filters, the under drainage system serves for two purposes; viz.

i. To receive and collect the filtered water, and

ii. To allow the back washing for cleaning of filter.

2. Various forms of under drainage systems, such as :

i. Manifold and lateral system,

ii. The wheeler bottom,

iii. The porous plate bottom, etc. have been designed for rapid gravity filters, and are patented by their manufacturers.

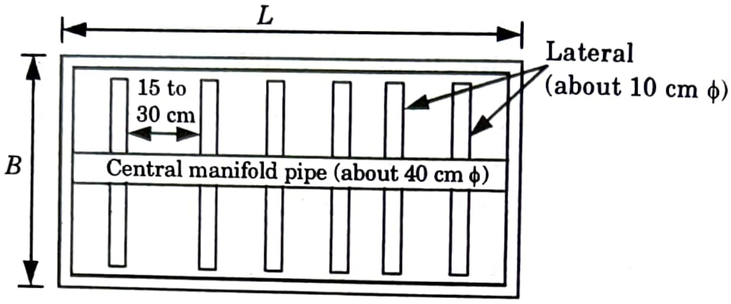


Fig. 4.22.1. Plan of a manifold and lateral under drainage system for a rapid gravity filter.

B. General Design Rules : The following points may also be considered and kept in mind, while designing the sizes of the pipes to be used in the above system :

1. The total cross sectional area of perforations should be about 0.2 percent of the total filter area.

2. The cross sectional area of each lateral should be about 2-4 times the total cross-sectional area of perforations in it, for diameter of perforations 10 mm and 5, mm respectively.

3. The cross sectional area of the manifold should be about twice the cross sectional areas of the lateral drains.

4. $\dfrac{\text{Length of each lateral}}{\text{Diameter of the lateral}} \not> 60$

5. Maximum permissible velocity in the manifold to provide the required amount of wash water is about 1.8 to 2.4 m/sec.

PART-10

Design of Slow and Rapid Sand Filters.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.23. **Design a rapid sand filter, where, Design Discharge = 55, 5 % of filtered water for storage to meet the backwash requirement. Each backwashing period is of 30 minutes. Available surface area configuration of filter unit = 10 m × 4 m. Filter size (total area provided) = 2 × 5 × 4 = 40 m sq. Porosity of bed = 0.50, Specific gravity = 2.5, Average particle size = 0.6 mm. Drag coefficient = 5.02. Expand the bed = 0.66 from its original undisturbed depth = 0.6 m. (Take a standard values wherever required).**

AKTU 2013-14, Marks 10

Answer

Given : Discharge = 55, Backwashing period = 30 min, Area of filter unit = 10 m × 4 m, Filter size = 40 m^2, Porosity of bed = 0.50, Expand of bed = 0.66, Undisturbed depth = 0.6 m, C_o = 5.02, Particle size = 0.6 mm.
To Find : Design the rapid sand filter.

1. Filtered water required for backwashing = 5 %

$$= 5\,\% \times 55 \text{ Mld} = 2.75 \text{ Mld}$$

2. Daily water demand of filtered water

$$= 55 + 2.75 = 57.75 \text{ Mld.}$$

3. Since 30 minutes (*i.e.*, 0.5 hr) is lost daily in backwashing the filters, the effective time left for working of filter units.

$$= 24 - 0.5 = 23.5 \text{ hr.}$$

4. Filtered water required per hour

$$= \frac{57.75}{23.5} = 2.457 \text{ Ml/h}$$

5. Now, filtration rate = 15 m^3/m^2/h

Area of filter required

$$= \frac{\left[\dfrac{2.457 \times 10^6}{10^3}\right]}{15 \text{ m}^3/\text{m}^2/\text{h}} = 163.8 \text{ m}^2$$

6. Size of filter (given) = 10 m × 4 m

Area of one filter unit = 40 m^2

Number of units required = $\dfrac{163.8}{40}$ = 4.095 ; say 4.

i. Using one filter unit as stand by unit, total number of filters required = 5.

For settling velocity (v_s) as

$$v_s = \sqrt{\frac{\frac{4}{3} g d (G-1)}{C_D}}$$

$$= \sqrt{\frac{\frac{4}{3} \times 9.81 \times 0.6 \times 10^{-3}\,(2.5-1)}{5.02}} = 0.048 \text{ m/sec}$$

ii. We know that $\dfrac{D_e}{D} = \left(\dfrac{1-e}{1-e_{fb}}\right)$

$$\frac{0.66 \text{ m}}{0.60 \text{ m}} = \frac{1-0.5}{1-e_{fb}}$$

$$(1-e_{fb}) = \frac{0.5 \times 0.6}{0.66} = 0.455$$

$$e_{fb} = 0.545$$

iii. We know that $e_{fb} = \left(\dfrac{v_b}{v_s}\right)^{0.22}$

$$0.545 = \left(\frac{v_b}{0.048}\right)^{0.22}$$

or $v_b = 3.04 \times 10^{-3}$ m/sec $= 0.304$ cm/sec $= 18.2$ cm/min.

Hence, the backwash upflow velocity = 18.2 cm/min.

Que 4.24. **In a water treatment plant, raw water is passed through a filter bed of uniform sand at a velocity of 5 m/hour. The filter is made of sand grains of diameter = 0.4 mm, shape factor = 0.85 and specific gravity = 2.65. the depth of the bed is 0.67 m and porosity is 0.4. Determine the head loss through the bed. (Take density of water = 968 kg / m³ and dynamic viscosity = 1.0 × 10⁻³ kg/m).**

AKTU 2014-15, Marks 10

Answer

Given : Velocity = 5m/hr, Sand diameter = 0.4 mm, Shape factor = 0.85, Specific gravity = 2.65, Depth of bed = 0.67 m, Porosity = 0.4, Density of water = 968 kg/m³, Dynamic viscosity = 1 × 10^{-3} kg/m

To Find : Head loss

1. The head loss through a clean stratified sand filter with uniform porosity and having representative particle size d, is given by Rose's equation as :

$$h_f = \frac{1.067\,(v)^2 D}{\phi g e^4}\left[\frac{C_D}{d}\right]$$

where, h_f = Head loss through the filter in m.

v = Approach velocity or filtration velocity in m/s.

D = Depth of filter in m.

ϕ = Shape factor for non spherical sand particles.
g = Acceleration due to gravity in m/s^2.
e = Porosity.
C_D = Drag coefficient, given by the equations 9.4 to 9.6.

2. Reynold's number = $\dfrac{\text{v}\, d}{\nu}$

$$\therefore \quad R_e = \frac{\text{v}\,\phi d}{\nu}$$

3. Substituting given values, we get

$$\text{v} = \text{Filtration velocity in m/sec}$$
$$= 5 \text{ m/hr (given)}$$
$$= \frac{5m}{(60 \times 60)\text{ sec}} = 1.389 \times 10^{-3} \text{ m/sec}$$
$$d = \text{Sand grains diameter} = 0.4 \text{ mm} = 0.4 \times 10^{-3}\text{m}$$
$$\phi d = 0.85 \times 0.4 \times 10^{-3} = 0.34 \times 10^{-3} \text{ m}$$
$$\nu = \frac{\mu}{\rho_\omega} = \frac{1.0 \times 10^{-3}}{998 \frac{\text{kg}}{\text{m}^3}} \left(\frac{\text{kg}}{\text{m sec}}\right) = 1.002 \times 10^{-6} \text{ m}^2/\text{sec}$$
$$R_e = 1.389 \times 10^{-3} \times 0.34 \times 10^{-3}/(1.002 \times 10^{-6}) = 0.471$$
$$R_e = 0.471 < 0.5$$

4. when $R_e < 0.5$

$$C_D = \frac{24}{R_e} = \frac{24}{0.471} = 50.92$$

5.
$$h_f = \frac{1.067 \times (1.389 \times 10^{-3})^2 \times 0.67}{0.85 \times 9.81 \times 0.4^4} \left[\frac{50.92}{0.4 \times 10^{-3}}\right]$$
$$= 822.5 \times \frac{10^{-6}}{10^{-3}} = 0.822 \text{ m}$$

Que 4.25. **Design a rapid sand filter to treat 10 million litres of raw water per day allowing 0.5 % of filtered water for back washing. Half hour per day is used for backwashing. Assume necessary data.**

AKTU 2014-15, Marks 10

Answer

Given : Water required per day = 10 Ml, Backwashing required per day = 0.5 % of filtered water, Time = Half hour
To Find : Design rapid sand filter

A. Design of Filter :

1. Total filtered water = 10 / 0.95 = 10.53 Mld
2. Half hour is lost every day in washing the filter, we have filtered water required per hour

$$= \frac{10.53}{23.5} = 0.448 \text{ Ml/hr}$$

3. Assuming the rate of filtration

$$= 5000 \text{ lt/hr/m}^2,$$

4. Area of filter required

$$= \frac{0.448 \times 10^6}{5000} = 89.6 \text{ m}^2$$

5. Assuming, $L/B = 1.5$ and two beds, the total area provided,

$$2 \times (LB) = 89.6 \text{ m}$$
$$LB = 44.8 \text{ m}$$
$$1.5\, B^2 = 44.8 \text{ m}$$
$$\text{Width, } B = 5.47 \text{ m}$$
$$\text{Length, } L = 8.2 \text{ m}$$

6. Hence, adopt 2 filter units, each of dimensions is 8.2 m × 5.47 m

B. Design of Under Drainage System :

1. Total area of the perforations = 0.2 % of filter area

$$= \frac{0.2}{100} \times 5.47 \times 8.2 = 0.09 \text{ m}^2$$

2. Now, assuming the area of each lateral = 2 × Area of perforation

$$= 2 \times 0.09 = 0.18$$

3. Area of mainfold = 2 × 0.18 = 0.36 m^2

Diameter of mainfold,

$$d = \sqrt{\frac{0.36 \times 4}{\pi}} = 0.677 \text{ m}$$

4. Hence use 70 cm diameter manifold pipe laid lengthwise along the centre of the filter bottom.
5. Laterals running perpendicular to the manifold assume manifold may be laid at a spacing of 25 cm.
6. The number of laterals $= \frac{8.2 \times 100}{25} = 32.8 \approx 35$

Hence, use 70 laterals in all, in each unit

7. Length of each lateral

$$= \frac{\text{Width of filter}}{2} - \frac{\text{Diameter of manifold}}{2}$$

$$= \frac{5.47}{2} - \frac{0.70}{2} = 2.39 \text{ m}$$

8. Now adopting 13 mm diameter perforation in the laterals we have

$$0.09 = x \times \pi / 4 \times 0.013^2$$
$$x = 678$$

9. Number of perforation in each lateral = $678 / 70 = 9.68 \approx 10$
10. Area of perforation per lateral = $10 \times \pi / 4 \times 1.3^2 = 13.27\ \text{cm}^2$

Now, area of each lateral = 2 × Area of perforation per lateral

$$= 2 \times 13.27 = 26.54\ \text{cm}^2$$

$$\text{Diameter of each lateral} = \sqrt{26.54 \times \frac{4}{\pi}} = 5.81\ \text{cm}$$

Que 4.26. **The population of a city is 50,000 and the per day capita consumption is 130 lit/day. Calculate the following in respect of the rapid sand filter for the above data.**
i. Total area of filters,
ii. Number and dimension of each filter,
iii. Quantity of air for air wash per filter bed, and
iv. Back wash water per filter bed after air wash.

AKTU 2015-16, Marks 10

Answer

Given : Population = 50,000
Per capita consumption = 130 l/day
To Find : Total yield area, Number and dimension of each filter, Quantity of air and back wash water, Back wash water per filter bed after air wash.

1. Water required per day

$$= 50{,}000 \times 130 = 6.5\ \text{Ml}$$

2. Assuming that 4 % of filtered water is required for washing of the filter every day, we have

Total filtered water required per day

$$= \frac{6.5}{0.960} = 6.770\ \text{Ml/day}$$

3. Now assuming that 0.5 hours is lost every day in washing the filter, we have filtered water required per hour

$$= \frac{6.770}{23.5}\ \text{Ml/hours} = 0.288\ \text{Ml/hr}$$

4. Now, assuming the rate of filtration to be 5000 litres/hr/m^2. We have the area of filter required

$$= \frac{0.288 \times 10^6}{5000} = 57.6\ \text{m}^2$$

5. Now assuming the length of the filter bed (L) as 1.5 times the width of the filter bed (B). Total area of filter units (Adopt 2 filter units)

$$2 \times (L \times B) = 57.6 \text{ m}$$
$$2 \times (1.5\, B)(B) = 57.6 \text{ m}$$
$$B^2 = 19.2 \text{ m}$$

Width, $B = 4.38$ m

Length, $L = 1.5\, B = 1.5 \times 4.38 = 6.57$ m

Hence, adopt 2 filter units, each of dimensions 6.57 m × 4.38 m.

6. Assume supply of compressed air for about 4 minutes at a rate of 600 l/min/m^2 of filter area.

   Quantity of air required $= 6.57 \times 4.38 \times 4 \times 600$
   $= 69063.84$ litres $= 69.06$ m^3

7. Back wash water per filter bed after air wash :

   Assume back washing rate = 200 litres/minutes/m^2

   Quantity of back wash water required
   $= 6.57 \times 4.38 \times 200 \times 30 = 172659.6$ litres

Que 4.27. **A rapid sand filter has a bed depth of 0.7 m. It is composed of sand grains that have a specific gravity of 2.65 and shape factor of 0.82. The porosity of the bed is 0.45 throughout the sieve analysis of the sand is shown below :**

Sieve No.	Mass Retained (%)	Average Particle Size (mm)
1	0.87	1.0
2	8.63	0.71
3	21.30	0.54
4	28.10	0.46
5	23.64	0.38
6	7.09	0.32
7	3.19	0.27
8	2.16	0.23
9	1.02	0.18

Determine the head loss through the bed if the flow rate is 5.0 m/s and water temperature is 17° C. **AKTU 2017-18, Marks 10**

Answer

Given : Depth of filter, $D = 0.7$ m, Specific gravity, $G = 2.65$
Shape factor, $\phi = 0.82$, Porosity, $n = 0.45$
Flow rate, v = 5 m/sec, Temperature, $T = 17$°C
To Find : Head loss.

Head loss, $h_f = \dfrac{1.067\, v^2 D}{\phi g \times n^4} \sum \dfrac{C_D \times x}{d}$

1. For, $d = 1$ mm

Kinetic viscosity, $\nu = 1.002 \times 10^{-6}$ m²/sec

$$R_e = \frac{5 \times 0.82 \times 1 \times 10^{-3}}{1.002 \times 10^{-6}} = 4091.9 \approx 4092$$

$$C_D = \frac{24}{4092} + \frac{3}{\sqrt{4092}} + 0.34$$

$$C_D = 5.86 \times 10^{-3} + 0.047 + 0.34 = 0.39 = 0.4$$

2. For $d = 0.71 \text{ mm} = 0.71 \times 10^{-3}$ m

$$R_e = \frac{5 \times 0.82 \times 0.71 \times 10^{-3}}{1.002 \times 10^{-6}} = 2905$$

$$C_D = \frac{24}{2905} + \frac{3}{\sqrt{2905}} + 0.34$$

$$C_D = 8.26 \times 10^{-3} + 0.056 + 0.34 = 0.404$$

3. For $d = 0.54 \text{ mm} = 0.54 \times 10^{-3}$ m

$$R_e = \frac{5 \times 0.82 \times 0.54 \times 10^{-3}}{1.002 \times 10^{-6}} = 2209.6$$

$$C_D = \frac{24}{2209.6} + \frac{3}{\sqrt{2209.6}} + 0.34$$

$$C_D = 0.01 \times 0.064 + 0.34 = 0.414$$

4. For $d = 0.46 \text{ mm} = 0.46 \times 10^{-3}$ m

$$R_e = \frac{5 \times 0.82 \times 0.46 \times 10^{-3}}{1.002 \times 10^{-6}} = 1882$$

$$C_D = \frac{24}{1882} + \frac{3}{\sqrt{1882}} + 0.34 = 0.422$$

5. For $d = 0.38 \text{ mm} = 0.38 \times 10^{-3}$ m

$$R_e = \frac{5 \times 0.82 \times 0.38 \times 10^{-3}}{1.002 \times 10^{-6}} = 1554.89 \approx 1555$$

$$C_D = \frac{24}{1555} + \frac{3}{\sqrt{1555}} + 0.34 = 0.431$$

6. For $d = 0.32 \text{ mm} = 0.32 \times 10^{-3}$ m

$$R_e = \frac{5 \times 0.82 \times 0.32 \times 10^{-3}}{1.002 \times 10^{-6}} = 1309.4$$

$$C_D = \frac{24}{1309.4} + \frac{3}{\sqrt{1309.4}} + 0.34$$

$$C_D = 0.018 + 0.083 + 0.34 = 0.441$$

7. For $d = 0.27 \text{ mm} = 0.27 \times 10^{-3} \text{ m}$

$$R_e = \frac{5 \times 0.82 \times 0.27 \times 10^{-3}}{1.002 \times 10^{-6}} = 1104.8$$

$$C_D = \frac{24}{1105} + \frac{3}{\sqrt{1105}} + 0.34 = 0.452$$

8. For $d = 0.23 \text{ mm} = 0.23 \times 10^{-3} \text{ m}$

$$R_e = \frac{5 \times 0.82 \times 0.23 \times 10^{-3}}{1.002 \times 10^{-6}} = 941$$

$$C_D = \frac{24}{941} + \frac{3}{\sqrt{941}} + 0.34 = 0.464$$

9. For $d = 0.18 \text{ mm} = 0.18 \times 10^{-3} \text{ m}$

$$R_e = \frac{5 \times 0.82 \times 0.18 \times 10^{-3}}{1.002 \times 10^{-6}} = 736.53 \approx 737$$

$$C_D = \frac{24}{737} + \frac{3}{\sqrt{737}} + 0.34 = 0.483$$

∴ Head loss,

$$h_f = \frac{1.067 v^2 D}{\phi g \times n^4}\left[\frac{0.4 \times 0.87}{1} + \frac{0.404 \times 8.63}{0.71} + \frac{0.414 \times 21.3}{0.54} + \frac{0.422 \times 28.10}{0.46} + \frac{0.431 \times 23.64}{0.38} + \frac{0.441 \times 7.09}{0.32} + \frac{0.452 \times 3.19}{0.27} + \frac{0.464 \times 2.16}{0.23} + \frac{0.483 \times 1.02}{0.18}\right]$$

$$= \frac{1.067 \times (5)^2 \times 0.7}{0.82 \times 9.81 \times (0.45)^4} [0.348 + 4.91 + 16.33 + 25.78 + 26.81 + 9.77 + 5.34 + 4.36 + 2.74]$$

$$h_f = 5450.57 \text{ mm}$$

Que 4.28. **Design a rapid sand filter for producing a net filtered water flow of 300 m³/hr.**

The other relevant data are as follows :

Quantity of backwash water used = 4 % of filter output

Time lost during backwashing = 30 min

Design rate of filtration = 5 m³/m²/hr

Length to width ratio = (1.25 to 1.33): 1

Under drainage system = Central manifold

Size of perforations = 9 mm.

AKTU 2017-18, Marks 10

Answer

A. Calculation for Dimension of Tank :

1. Quantity of water to be filtered = 300 m^3/hr = 300 × 10^3 × 24 l/day
= 7.2 ML/day

2. Quantity of back washwater used
= 4 % of output = 1.04 × 7.2 = 7.488 Ml/day

3. Now, assuming that 0.5 hour is waste everyday in washing the filter, then filtered water required per hour

$$= \frac{7.488}{23.5} = 0.3186 \text{ Ml/hr}$$

4. Rate of filtration = 5 m^3/m^2/hr = 5 × 10^3 l/m^2/hr

5. Area of filter required $= \dfrac{0.3186 \times 10^6}{5 \times 10^3} = 63.72 \text{ m}^2$

6. Now, assuming the length of filter bed (L) as 1.3 times the width of filter bed (B) and two beds, the total area required (Taken 2 bed filter).

$$2 \times (1.3B)(B) = 63.72$$
$$2.6(B)^2 = 63.72$$

Width, $B = 4.9$ m

Length, $L = 1.3\,B = 1.3 \times 4.9 = 6.39$ m

Use 2 filter beds each of dimension 6.5 × 5 m

B. Design of Under Drainage System :

1. Total area of perforation

$$= \frac{0.2}{100} \times \text{Filter area} = \frac{0.2}{100} \times (6.5 \times 5)\,\text{m}^2 = 0.065\,\text{m}^2$$

2. Since, the size of perforation = 9 mm

∴ Area of each lateral

$$= 2 \times \text{Total area of perforation} = 2 \times 0.065 = 0.13\,\text{m}^2$$

3. Now assuming the area of manifold to be about twice the area of lateral,

4. Area of manifold = 2 × 0.13 = 0.26 m^2

Diameter of manifold (d)

$$\pi d^2 / 4 = 0.26$$
$$d = 0.6 \text{ m}$$

5. Hence, use a 60 cm dia. manifold pipe laid lengthwise along the centre of filter bottom. Lateral run perpendicular to the manifold eliminating from the manifold may be laid at a spacing of say 15 cm.

$$\text{No of laterals} = \frac{6.5 \times 100}{15} = 43.33$$

6. Hence, use 87 laterals in all, in each unit.

PART-11

Requirements of an Ideal Disinfectant, Various Disinfectants, Chlorination and Practices of Chlorination.

CONCEPT OUTLINE

Disinfectants : There are various chemicals which used as disinfectant like :

i. Oxidizing chemicals : e.g., Chlorine, bromine, iodine, ozone, etc.
ii. Metal ions : e.g., Silver and copper ions.
iii. Alkalies and acids.
iv. Surface active chemicals. *e.g.*, Cationic detergents.

Chlorination : It is the process, in which chlorine is used as disinfectant to kill the bacteria from filtered water.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.29. What is meant by "disinfection" in treating public water supply ? What is its importance ? What are the chemicals which are used as disinfectants and what are their comparative merits and demerits ? **AKTU 2013-14, Marks 10**

Answer

A. Disinfection :

1. Disinfection is the process employed to inactive the disease producing bacteria (pathogens), by addition of certain chemicals in order to meet the primary objective of providing safe water.
2. Chlorination is used extensively in water treatment plants to disinfect water.

B. Importance of Disinfection :

1. This process of purification is the most important, because the bacterially contaminated water may lead to the spread of various diseases and their epidemics, thus causing disasters to public life.
2. The presence of turbidities, colour, or minerals, etc., may not be dangerous, but the presence of even a single harmful organism will definitely prove dangerous, thereby making 'disinfection' as the most important process.

C. **Disinfectant :** Following are the chemicals used as disinfectants :

Disinfectant	Merits	Demerits
Chlorine	i. Effective for most microorganisms. ii. Can oxidize iron and manganese. iii. Technology well understood.	i. Forms DBPs when organic substances are present. ii. Not effective against Cryptosporidium protozoa. iii. Can cause taste and odour problems.
Chloramines	i. Forms more stable residual than chlorine alone. ii. Forms less taste and odour causing compounds in water. iii. Technology well understood.	i. Less effective than chlorine against microorganisms, especially viruses and protozoa. ii. Poorly oxidizes iron and manganese. iii. Usually requires a more powerful disinfectant for primary disinfection.
Chlorine Dioxide	i. More effective than chlorine or chloramines as disinfectant against microorganisms. ii. Controls taste and odour better than chlorine in some cases.	i. Must be produced on site. ii. Requires daily chlorite and chlorine dioxide monitoring. iii. Costs more for equipment and chemicals than chlorine.
Ozone	i. Most powerful disinfectant used in drinking water treatment. ii. More effective than chlorine dioxide.	i. Must be produced on site. ii. Takes more technical skill to use. iii. Requires bromate monitoring.

Que 4.30. **Describe the methods of disinfection.**

Answer

Following are the various methods of disinfection :

A. **Physical Methods :**

1. **Disinfection by Heat :** Boiling of water.

2. **Disinfection by Light :** Sunlight is a natural disinfectant. Irradiation by ultraviolet rays intensifies disinfection.

B. **Chemical Methods :**

1. **Oxidizing Chemicals :** They comprise :

i. The halogens : Chlorine, bromine and iodine .

ii. Ozone.

iii. Other oxidants such as potassium permanganate and hydrogen peroxide.

2. **Metal Ions :** Such as silver and copper ions. Silver ions are bactericidal, though they are neither virucidal nor cysticidal.

3. **Alkalies and Acids :** It is well known that pathogenic bacteria do not last long in highly alkaline ($pH > 11$) or highly acidic ($pH < 3$) water.

4. **Surface Active Chemicals :** Among surfactants, the cationic detergents are only weakly destructive. The neutral detergents occupy an intermediate position.

C. **Minor Methods of Disinfection :**

1. **Excess Lime Treatment :**

i. It has been found that when pH of water is greater than 9.5, E-coli present in water will die. Hence when enough lime is added to bring the pH to this figure, sterilization of E-coli and other bacteria occurs.

ii. The removal of bacteria is upto 99.93 % or even 100 %. The necessary dose of lime is between 10 to 20 ppm of calcium oxide.

2. **Silver Treatment :** Water can also be disinfected with silver by the electro-katadyn action or oligodynamic action.

3. **Ultra-Violet Ray Treatment :**

i. The ultra-violet ray offers an effective method for sterilization of water, since the light is effective in killing both the active bacteria as well as spores.

ii. Though sun is the most powerful source of ultra-violet rays, it requires a large exposure area and long time.

Que 4.31. **Draw a curve between chlorine added and residual chlorine in a chlorination process. Discuss all important points of this curve.**

OR

Explain the following terms :

1. **Double chlorination.**
2. **Break point Chlorination.**
3. **Super chlorination.**

AKTU 2016-17, Marks 10

OR

c. **Explain briefly the following processes :**

1. **Break point chlorination**
2. **Super chlorination**

AKTU 2013-14, Marks 05

Answer

The different types of chlorination adopted in water treatment are as follows :

1. **Plain Chlorination :**
i. When the raw water contains turbidity less than 10 NTU, obtained from lakes or reservoirs, the water could be supplied to the public without any treatment except chlorination.
ii. Such chlorination is called plain chlorination.
ii. The dosage of chlorine for plain chlorination is about 0.5 mg/l.

2. **Pre-Chlorination :**
i. Pre-chlorination is the process of applying chlorine to the water before coagulation.
ii. It improves the coagulation and reduces load on filters. It also reduces taste, colour, odour, algae and other organisms.
iii. The chlorine dose for pre-chlorination should be 0.1 to 0.5 mg/l.
iv. The pre-chlorination is always followed by post chlorination, so as to ensure final safety of water.

3. **Post Chlorination :**
i. Post chlorination is the normal process of applying chlorine at the end, when all other treatments are completed.
ii. The chlorine dose should be such as to leave a residual-chlorine of about 0.1 to 0.2 mg/l after a contact period of 20 to 30 minutes.
iii. This residual chlorine will ensure the disinfection of water if at all any recontamination occurs in the transmission and distribution system.

4. **Double Chlorination :**
i. The term double chlorination is used to indicate that the water has been chlorinated twice.
ii. The pre-chlorination and post chlorination are generally used in double chlorination.
iii. Post chlorination, however, is generally always used, while the pre-chlorination is also used when the waters are highly turbid and contaminated.

5. **Break Point Chlorination :**
i. Break point chlorination is a term which gives us an idea of the extent of chlorine added to the water.
ii. In fact, it represents, that much dose of chlorination, beyond which any further addition of chlorine will equally appear as free residual chlorine.

6. **Super Chlorination :**
i. Super chlorination is a term, which indicates the addition of excessive amount of chlorine (*i.e.*, 5 to 15 mg/l) to the water.

ii. This may be required in some special cases when the water is highly polluted, or during epidemics of water borne diseases.

iii. The huge quantity of chlorine, which is added in super chlorination, is such as to give about 1 to 2 mg/l of residual beyond the break point in the treated water.

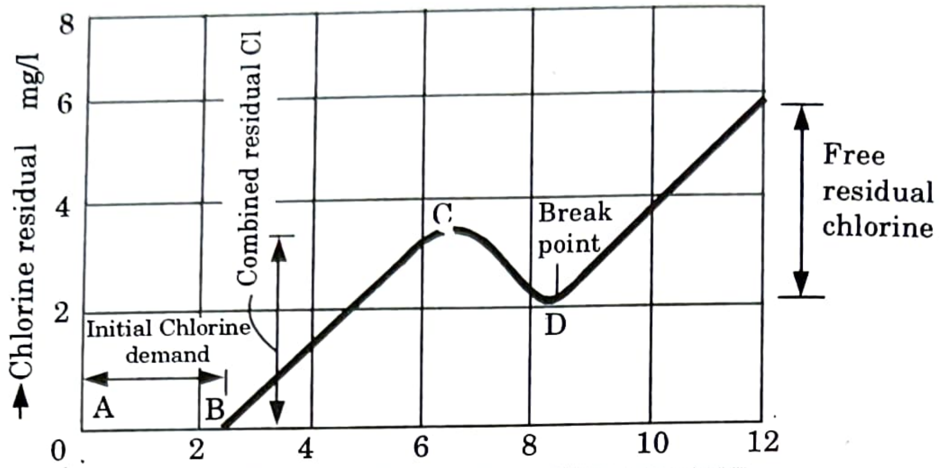


Fig 4.31.1. Break point chlorination.

7. De-chlorination :

i. De-chlorination means removing the chlorine form the water.

ii. This is generally required when super-chlorination has been practiced.

iii. The de-chlorination process may either be carried out to such an extent that sufficient residual chlorine of 0.1 to 0.2 mg/l only remains in water after de-chlorination.

iv. The common de-chlorinating agents are sulphur dioxide gas, activated carbon, sodium thiosulphate, sodium metasulphate and ammonia.

Que 4.32. **Discuss the use of chlorine as disinfecting agent with reference to :**

A. Its disinfecting action.

B. Its doses.

C. Its forms.

D. Testing its residuals.

AKTU 2015-16, Marks 10

Answer

A. Disinfecting Action of Chlorine :

1. When chlorine is added to water, it forms hypochlorous acid or hypochlorite ions, which have an immediate and disastrous effect on most forms of microscopic organisms. The reactions that take place are :

$$Cl_2 + H_2O \xrightarrow{pH > 8} \underset{\text{Hypochlorous acid}}{HOCl} + HCl$$

2. The hypochlorous acid is unstable and may break into hydrogen ions and hypochlorite ions

$$HOCl \underset{pH < 7}{\overset{pH > 8}{\rightleftharpoons}} \underset{\text{Hydrogen ions}}{H^+} + \underset{\text{Hypochlorite ions}}{OCl^-}$$

3. The above reaction is reversible and depends upon the pH value of water. The dissociation of hypochlorous acid into ions is more effective at high pH values.
4. Thus, at pH values greater than 10, only OCl^- ions are found ; while in pH of less than 7 (more than 5), HOCl will generally exist without dissociating into OCl^- ions ; and in the pH range of below 5, chlorine does not react and remains as elemental chlorine.
5. The chlorine will immediately react with ammonia present in water to form various chloramines, as given below :

$$NH_3 + HOCl \rightarrow \underset{\text{Monochloramine}}{NH_2Cl} + H_2O$$

$$NH_2Cl + HOCl \rightarrow \underset{\text{Di-chloramine}}{NHCl_2} + H_2O$$

$$NHCl_2 + HOCl \rightarrow \underset{\text{Nitrogen Trichloramine}}{NCl_3} + H_2O$$

6. The monochloramine (NH_2Cl) predominates at pH value of over 7.5, dichloramine ($NHCl_2$) at pH range of 5 to 6.5, and nitrogen trichloramine (NCl_3) at pH below 4.4.
7. Thus, in the usual chlorine treatment, when pH is kept slightly less than 7, dichloramine formation is the most predominant.

B. Its Doses : Doses of Chlorine :

1. In general, most of the waters are satisfactorily disinfected if the free chlorine residual is about 0.2 mg/l, 10 minutes after the chlorine is applied.
2. The optimum dose of chlorine for given water is, therefore, generally determined experimentally by adding varying amounts of chlorine to a given sample and observing the residual left after a contact period of about 10 minutes.
3. The dose which leaves a residual of about 0.2 mg/l is then selected.
4. The total dose (in mg/l) minus the free residual will automatically represent the chlorine demand of water.

C. Its forms : Chlorine is generally applied in the following forms :

1. In the form of liquid chlorine or as chlorine gas.
2. In the form of hypochlorites or bleaching powder.
3. In the form of chlorine tablets.
4. In the form of chloramines, *i.e.*, a mixture of ammonia and chlorine.
5. In the form of chlorine dioxide.

D. Testing of Chlorine Residuals : Following are the test used :

i. Orthotolidine test, ii. DPD test,
iii. Chlorotex test, and iv. Starch iodide test.

Starch Iodide Test :

i. In this test, one litre of water sample is collected in heat-proof earthen ware vessel (called casserole), to which 10 mL of potassium iodide solution is added.

ii. The contents are thoroughly mixed, and 5 mL of starch solution is added, which produces blue colour.

iii. This blue colour is removed by titrating this water sample against sodium thiosulphate solution of normality N/100.

iv. The amount of chlorine can be calculated as :

Quantity of chlorine (mg / l) = 0.355 × Quantity of thiosulphate used (ml)

PART-12

Water Softening and Ion-exchange Process.

CONCEPT OUTLINE

Water Softening : The reduction or removal of hardness from water is known as water softening.

Types of Hardness : Following are two types.

i. Temporary hardness. ii. Permanent hardness.

Methods of Removing Temporary Hardness : There are two methods for removing temporary hardness.

i. Boiling of hard water, and ii. Addition of lime.

Methods of Removing Permanent Hardness : There are three methods which are commonly adopted for removing permanent hardness.

i. Lime-soda process, ii. Zeolite process, and

iii. Demineralization process.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.33. What do you understand by hard water ? Why is it necessary to remove the hardness of water ?

Answer

Hard Water :

1. Water is said to be hard when it contain relatively large amounts of bicarbonates, carbonates, sulphates and chlorides of calcium and magnesium dissolved in it.

2. Water is classified with regard to its hardness, as given below :

i. **Soft :** 50 (Total hardness as mg/l of $CaCO_3$)

ii. **Moderately Hard :** 50 – 150 (Total hardness as mg/l of $CaCO_3$)

iii. **Hard :** 150 – 300 (Total hardness as mg/l of $CaCO_3$)

iv. **Very Hard :** 300 (Total hardness as mg/l of $CaCO_3$)

Necessaries to Remove the Hardness of Water :

1. It causes more consumption of soap in laundry work. This proves to be uneconomical for washing processes in the textile industries.
2. It leads to the modification of some of the colours, and thus affects the working of the dyeing system.
3. It causes serious difficulties in the manufacturing process, such as paper making, canning, ice manufacturing, rayon industry etc.
4. It causes formation of scales on the boilers and other hot water heating system.
5. It causes choking and clogging troubles of house plumbing due to precipitation of salts causing hardness.

vi. It makes food tasteless, tough or rubbery.

Que 4.34. Differentiate between permanent and temporary hardness. How would you remove temporary hardness ?

Answer

A.

S. No.	Permanent Hardness	Temporary Hardness
1.	It is due to the presence of chlorides or sulfates of calcium and magnesium.	Temporary hardness is due to the presence of bi-carbonates of calcium and magnesium.
2.	Can't be removed by boiling.	Can be removed by boiling.
3.	Hardness removal is expensive.	Hardness removal is cheap.
4.	This is known as alkaline hardness.	This is known as non-alkaline hardness.

B. **Removal of Temporary Hardness :** Temporary hardness or bicarbonate hardness can be removed by the following methods :

1. **By boiling :** The following reaction takes place during boiling :

$$Ca(HCO_3)_2 + \text{Heat} \longrightarrow CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

$$Mg(HCO_3)_2 + \text{Heat} \longrightarrow MgCO_3 \downarrow + H_2O + CO_2 \uparrow$$

However, the first method has practical limitations on large scale. Hence, the second method is adopted.

2. **By adding lime :** The following reactions take place when lime is added :

$Ca(HCO_3)_2 + Ca(OH)_2 = 2\,CaCO_3 \downarrow + 2H_2O$

$Mg(HCO_3)_2 + Ca(OH)_2 = CaCO_3 \downarrow + MgCO_3 \downarrow + 2H_2O$

The calcium carbonate and magnesium carbonate so formed can be removed in the sedimentation tanks, since these are insoluble.

Que 4.35. **Explain any one method of softening water.**

AKTU 2013-14, Marks 05

OR

Elaborate the base exchange process for hardness removal.

AKTU 2016-17, Marks 05

Answer

Base Exchange Process :

1. Zeolites are the natural salts or clays, which are hydrated silicates of sodium and aluminium. ($Na_2O\ Al_2O_3 x.SiO_2 y.H_2O$).
2. The zeolites or Resins have the excellent property of exchanging their cations and hence, during softening operation, the sodium ions of the zeolite get replaced by the calcium and magnesium ions present in hard waters.
3. The chemical reactions which may be involved are given in the following equation, where Z stands for the complex zeolite radical.

$$\underset{\substack{\text{Sod. zeolite}\\\text{or active zeolite}}}{Na_2Z} + \underset{\substack{\text{Cal. or Mg.}\\\text{salt}}}{\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}\left\{\begin{matrix}(HCO_3)_2\\SO_4\\Cl_2\end{matrix}\right.} \longrightarrow \underset{\substack{\text{Sod. salts}\\\text{which don't}\\\text{cause hardness}}}{Na_2\left\{\begin{matrix}(HCO_3)_2\\SO_4\\Cl_2\end{matrix}\right.} + \underset{\substack{\text{Ca or Mg zeolite}\\\text{i.e. exchanged}\\\text{or used zeolite}}}{\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Z}$$

4. The calcium and magnesium zeolite can be regenerated into active sodium zeolite by treating it with 5–10 percent solution of sodium chloride.
5. The exchange reactions that take place during regeneration can be represented as :

$$\underset{\text{Used zeolite}}{\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Z} + \underset{\substack{\text{Sod. chloride}\\\text{solution}}}{2NaCl} \longrightarrow \underset{\substack{\text{Regenerated}\\\text{zeolite}}}{Na_2Z} + \left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Cl_2$$

6. The hard water enters through the top, and is evenly distributed on the entire zeolite bed. The softened water is collected through the strainers at the base.

7. When a significant portion of the sodium in the zeolite has been replaced by calcium and magnesium, it is regenerated by first washing it with water by reversing the flow, and then treating it with 10 percent solution of brine (NaCl).
8. The excess brine solution retained in the zeolite after the treatment is removed by again washing it with good water. The regenerated zeolite can be used afresh for softening.

Que 4.36. Discuss advantage and disadvantage of soda lime process and ion exchange methods of water softening.

AKTU 2017-18, Marks 10

Answer

1. **Advantages of Lime Soda Process :**

i. This process is suitable for turbid, chalybeate and acidic water where zeolite process cannot be used.

ii. This method removes iron and manganese also to some extent.

iii. This method is better for excessively hard water, particularly those high in magnesium hardness and for water high in sodium.

iv. The process can be easily added to an existing filter plant of any water supply scheme.

v. The process increases the pH value of water, which results in decrease in corrosion of the distribution system.

2. **Disadvantage of Lime Soda Process :**

i. A large quantity of sludge is formed in this process and hence, there are problems of its disposal.

ii. The method requires recarbonation. In the absence of recarbonation, a thick layer of calcium carbonate will be deposited in the filtering media and distribution system.

iii. The process requires skilled supervision.

iv. It is not possible to produce zero hardness by this process. However, zero hardness is seldom required.

3. **Advantages of Zeolite Process :**

i. No sludge is formed, and hence there are no problems of sludge disposal.

ii. The zeolite unit is compact, and hence small space is required.

iii. The unit can be easily operated. Highly skilled labour is not required.

iv. The first cost of the unit and the operating cost are low.

v. This process is free from danger of excess chemicals in the effluent, since no chemicals are added to water.

vi. This process is independent of the change in the quality of raw water.

vii. There is no problem of deposition of layer of calcium carbonate or any other chemical in the distribution system.

4. Disadvantages of Zeolite Process :

i. This method is not suitable for highly turbid water, since suspended particles get deposited around the zeolite particles.

ii. This process is not suitable for water containing iron and manganese.

iii. This process is not suitable for acidic waters which irreversibly substitute hydrogen for sodium in the zeolite.

Que 4.37. **At a water treatment plant, 12 million litres of water is treated daily, using alum dosage of 16 mg per litre. Find total quantity of alum used daily.**

AKTU 2014-15, Marks 10

Answer

Given : Quantity of water = 12 Mld = 12×10^6 litre/day
Alum dose = 16 mg/l
To Find : Total quantity of alum

1. 1 litre of water requires = 16 mg of alum
2. Hence, 12 Ml water requires

$$= \frac{16 \times 12 \times 10^6}{10^3 \times 10^3} = 192 \text{ kg/day}$$

$$= 1.92 \text{ quintals/day}$$

☺☺☺

5

UNIT

Secondary and Tertiary Treatment

CONTENTS

PART-1

Secondary Sedimentation and Theory of Organic Matter Removed, Working of Activated Sludge Process.

CONCEPT OUTLINE

Secondary Sedimentation : The effluent of the filter is passed through a sedimentation called the secondary sedimentation.

Activated Sludge : Activated sludge is the active biological material produced by activated sludge plant.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. **What is meant by activated sludge ? Describe the treatment of sewage by activated sludge process. Mention the advantages and disadvantages of this system.**

Answer

Activated Sludge : The activated sludge is the sludge which is obtained by settling sewage in presence of abundant oxygen so as to be super charge with favourable aerobic microorganism.

Process :

1. The activated sludge process is the biological process by which non-settleable substances occurring in dissolved and colloidal forms are converted into settleable sludge which is removed from the liquid carrier (water).
2. At a plant the activated sludge is settled out along with the suspended solids present in the wastewater.

Advantages following are the advantages of ASP :

1. Clear sparkling 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. Relatively low cost of installation as compared to the total cost of trickling filter.
6. Smaller area required, as compared to trickling filters.

Disadvantages : Following are the disadvantages of ASP :

1. High cost of operation.
2. Necessity of constant skilled attendance.
3. Uncertainly of the expected results under all conditions.
4. Large quantity of sludge is produced which is difficult to dewater, digest and dispose of.

Que 5.2. **Write short note on :**

1. **Aeration period (*i.e.*, HRT).** 2. **Volumetric loading.**
3. **Food to micro-organism ratio (F/m).**
4. **Sludge age.**
5. **Sludge volume index.**
6. **Sludge recycle and rate of return sludge.**

OR

Explain the term sludge volume index. **AKTU 2015-16, Marks 10**

Answer

1. **Aeration Period (*i.e.*, HRT) :**

i. The aeration period (t) empiric decides the loading rate at which the sewage is applied to the aeration tank.

ii. Detention or aeration period

$$(t) = \frac{\text{Volume of the tank}}{\text{Rate of sewage flow in the tank}}$$

2. **Volumetric Loading :** It is defined as the BOD_5 load applied per unit volume of aeration tank. This loading is also called organic loading.

$\therefore$ Volumetric BOD loading or Organic loading

$$= \frac{\text{Tank through influent sewage in gm}}{\text{Volume of the aeration tank in m}^3} = \frac{Q\,Y_0}{V}$$

where, Q = Sewage flow into the aeration tank in m³/sec.

Y_0 = BOD_5 in (mg/l or gm/m³) of the influent sewage.

V = Volume of aeration tank in m³.

3. **Food to Micro-organism Ratio (F/M) :** It is a manner of expressing BOD loading with regard to the microbial mass in the system. The BOD load applied to the system in kg or gm is represented as food (F), and the total microbial suspended solid in the mixed liquor of the aeration tank is represented by M.

$$\therefore \text{ F/M ratio} = \frac{\text{DailyBOD load applied to the aerator system in gm}}{\text{Total microbial mass in the system in gm}}$$

4. **Sludge Age :** It may be defined as the average time for which particles of suspended solids remain under aeration. It thus, indicates the residence time of biological solids in the system.

$$\therefore \quad \text{Sludge age } (\theta_c) = \frac{\text{Mass of suspended solid in the system}}{\text{Mass of solids leaving the system per day}}$$

5. Sludge Volume Index (SVI) :

i. 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.

ii. SVI 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.

iii. SVI is given by,

$$\text{SVI} = \frac{V_{ab}\,(\text{ml/ l})}{X_{ab}\,(\text{mg/ l})} = \frac{V_{ab}}{X_{ab}} \text{ ml/mg}$$

iv. The usual adopted range of SVI is between 50-150 ml/gm and such a value indicates good settling sludge.

6. Sludge Recycle and Rate of Return Sludge :

i. The MLSS concentration in the aeration tank is controlled by the sludge recirculation rate and the sludge settleability and thickening in the secondary sedimentation tank.

ii. The relationship between sludge recirculation ratio $\left(\frac{Q_R}{Q}\right)$ with X_T and X_R is given by,

$$\frac{Q_R}{Q} = \frac{X_T}{X_R - X_T} = \frac{X_T}{(10^6 / \text{SVI}) - X_T}$$

where,
Q_R = Sludge recirculation rate in m³/d.
X_T = MLSS in the aeration tank in mg/l.
X_R = MLSS in the returned or wasted sludge in mg/l.

Que 5.3. **Calculate the volume and number of aeration tanks and the rate of air supply for the following data of the activated sludge unit;**

Population = 35,000
Average sewage flow = 180 lpcd
BOD of raw sewage = 220 mg/l
BOD removed in primary treatment = 30 %
Overall BOD reduction desired = 85 %

AKTU 2015-16, Marks 10

Answer

To Find : Volume and number of aeration tank, rate of air supply.

1. **Daily Sewage Flow :**
i. Quantity of sewage, $Q = 180 \times 35000$ l/day $= 6300$ m³/day.
ii. BOD of sewage coming to aeration,

$$Y_0 = 70\,\% \times 220\text{ mg/l} = 154\text{ mg/l}$$

($\because$ 30 % BOD is removed in primary settling)

iii. BOD left in effluent, $Y_E = 15\,\% \times 220$ mg/l $= 33$ mg/l

($\because$ Overall 85 % BOD removal is desired)

iv. BOD removed in activated plant $= 154 - 33 = 121$ mg/l
v. Efficiency required in activated plant $= 121 / 154 = 0.79 = 79$ %
vi Assume F/M $= 0.33$ and MLSS (X_T) $= 2000$ mg/l
vii. Volume of aeration tank is given by,

$$\frac{F}{M} = \frac{QY_0}{VX_T}$$

$$0.33 = \frac{6300 \times 154}{V \times 2000}$$

$$V = 1470\text{ m}^3$$

2. **Check for Aeration Period or HRT (t) :**

We know that, $t = \dfrac{V}{Q} \times 24\text{ h} = \dfrac{1470}{6300} \times 24\text{ h}$

$= 5.6$ h (within the limits of 4 h to 6 h)

3. **Check for SRT (θ_C) :**

i. We know that, $VX_T = \dfrac{\alpha_y\, Q(Y_0 - Y_E)\theta_c}{1 + K_e\,\theta_c}$

where, α_y = Yield coefficient = 1.0

K_e = Endogenous respiration rate constant $= 0.06\text{ d}^{-1}$.

ii. Substituting the values, we get

$$1470 \times 2000 = \frac{1 \times 6300(154 - 33)\,\theta_c}{(1 + 0.06 \times \theta_c)}$$

$$\theta_c = 1 / 0.2 = 5\text{ days}$$

iii. It lie between 5 to 8 days.

4. **Check for Volumetric Loading :**

i. Volumetric loading $= \dfrac{Q\,Y_0}{V}$ gm/m³.

$= \dfrac{6300 \times 154}{1470}$ gm/m³ $= 660$ gm/m³ $= 0.66$ kg/m³

(Within the permissible range of 0.3 – 0.7 kg/m³)

5. **Check for Return Sludge Ratio :**
i. We know that;

$$\frac{Q_R}{Q} = \frac{X_T \text{ (i. e. MLSS)}}{(10^6/\text{SVI}) - X_T}$$

where, SVI = 125 ml/gm (this value should be in the range of 50 –150).

$$\frac{Q_R}{Q} = \frac{2000}{\left(\frac{10^6}{125} - 2000\right)} = 0.33$$

(*i.e.*, within the prescribed range of 25 to 50 %)

ii. The sludge pumps for bringing recirculated sludge from the secondary sedimentation tank will have a capacity

$$= 33\ \% \times Q$$

$$= 33\ \% \times 6300 \text{ m}^3/\text{d} = 2079 \simeq 2100 \text{ m}^3/\text{d}$$

6. Tank Dimensions :

i. Adopt aeration tank of depth 3 m and width 4.5 m. The total length of the aeration channel required.

$$= \frac{\text{Total volume required}}{B \times D} = \frac{1470}{4.5 \times 3} = 108.9 \text{ m ; say } 111 \text{ m.}$$

ii. Provide a continuous channel, with 3 aeration chambers, each of 37 m length.

iii. Total width of the unit, including 2 baffles each of 0.25 m thickness $= 3 \times 4.5 + 2 \times 0.25 = 14$ m.

iv. Total depth provided including free-board of 0.6 m will be $3 + 0.6 = 3.6$ m.

v. Overall dimensions of the aeration tank will be 37 m × 14 m × 3.6 m.

7. Rate of Air Supply :

i. Assuming the air requirement of the aeration tank to be 100 m³ of air per kg of BOD removed, we have air required *i.e.*, blower capacity

$$= 100 \times \frac{121 \times 6300}{1000} \text{ m}^3/\text{day} = 121 \times 630 \times \frac{1}{24 \times 60} \text{ m}^3/\text{min} = 53 \text{ m}^3/\text{min.}$$

PART-2

Trickling Filters.

CONCEPT OUTLINE

Trickling Filters : These filters are also known as percolating filters or sprinkling filters. It consists 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.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.4. **Discuss in brief the conventional trickling filters with neat sketch.**

AKTU 2013-14, Marks 05

Answer

Trickling Filters :

1. It consists of (i) A water tight holding tank, (ii) Distribution system, (iii) Filter media, and (iv) Under drainage system.
2. The tank is either square or rectangular in shape if fixed nozzles are used and circular if rotary distributors are used.
3. As rotary distributors are more reliable and easy to maintain and operate, circular shape is most commonly used.
4. The tank walls of either masonry or concrete are made water tight.
5. The distribution system spreads primary sedimentation tank effluent over a bed of filter media supported by a tile under-drain system which also provides adequate ventilation.
6. The walls of the tank are designed to withstand the pressure of sewage from inside.
7. The under drain system is supported by a floor which slopes to a collection channels.

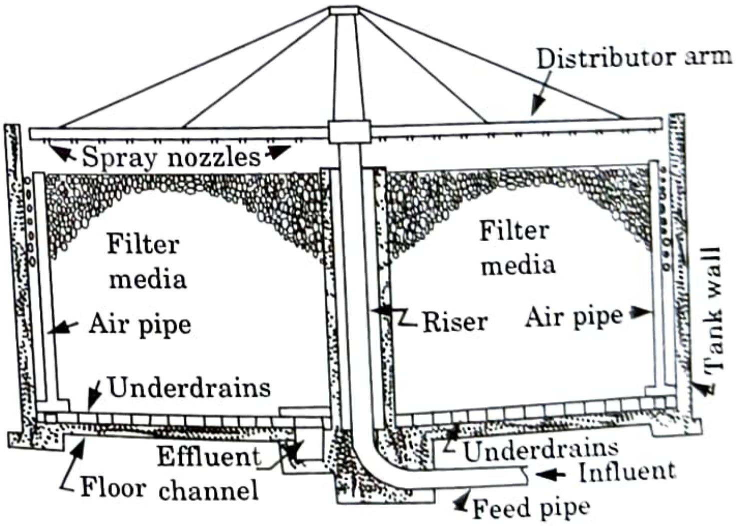


Fig. 5.4.1. Typical cross-section of tricking filter.

Que 5.5. **Briefly describe the classification of trickling filters. Explain the mechanism of biofilm formation and mass transfer in a trickling filter process with a neat sketch.**

AKTU 2017-18, Marks 10

Answer

A. Classification : Trickling filters have been classified in two ways :

1. According to Organic or Hydraulic Loadings :

	Hydraulic loading $m^3/d/m^2$	**Organic loading $g/d/m^3$**
Low rate filter	1-4	80 to 320
High rate filter	10 to 30 (with recirculation)	500 to 1000 (without recirculation)

2. According to the Number of Units used in Series :

i. Single-Stage Trickling Filter :

a. Only one (single) filter is adopted for the system.

b. When two or more filters are required to use, they will be provided in parallel. Effluent flow is usually not recirculated.

ii. Two-Stage Trickling Filter :

a. This system consists of two filters in series. Recirculation of effluent from each stage is normally adopted.

b. In certain cases, an intermediate clarifier is used between the two filters.

B. Removal Mechanism :

1. As the wastewater trickles through the filter media growth of micro-organisms takes place on the surface of the media or packing material in the form of a layer, known as biofilm or slime layer.

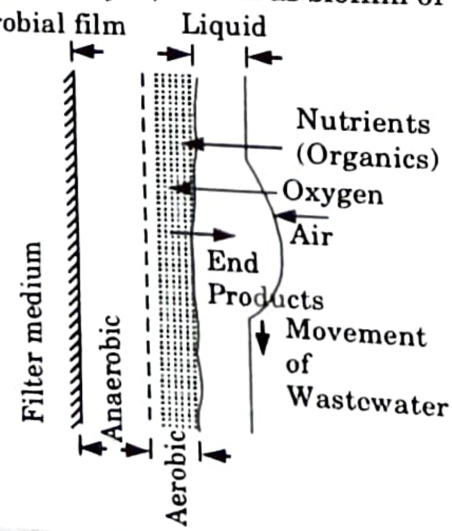


Fig. 5.5.1. Schematic diagram of removal mechanism in a trickling filter.

2. When wastewater passes over this stationary microbial film, contact between the substrates (food) and micro-organisms is established and the substrate is decomposed or degraded aerobically by the attached biomass.

3. Fig. 5.5.1 shows a schematic diagram of organics removal mechanism in a trickling filter. A stage comes when anaerobic conditions are developed nearer to the media surface and the micro-organisms cannot remain attached or fixed to the media.
4. Eventually, there is scouring of the slime layer due to flowing liquid and a fresh slime layer begins to grow on the media.

Que 5.6. What do you understand by the efficiency of a trickling filter ? How do you determine the efficiency, using :

A. NRC formulae.

B. Eckenfelder equation.

AKTU 2013-14, Marks 10

Answer

Efficiency of a Trickling Filter : It is the ratio of removable BOD to total BOD entering.

A. **NRC Formulae :** Following are the two types of NRC formulae :

1. **National Research Council (NRC) Equation :** The following NRC equations are normally used to determine the efficiency of single stage and two stage filter. They are also applicable to both low and high rate trickling filters.

i. For a low rate or single stage TF,

$$E_1 = \frac{100}{1 + 0.443\sqrt{\dfrac{W_1}{V_1 F_1}}}$$

ii. For a high rate or two stage TF,

$$E_2 = \frac{100}{1 + \dfrac{0.443}{(1 - E_1)} \times \sqrt{\dfrac{W_2}{V_2 F_2}}}$$

where, E_1 = BOD removal efficiency of the filter of a single stage TF system or first filter of two stage TF system.

E_2 = BOD removal efficiency of the second filter or two stage TF system.

W_1 = BOD loading to the filter of a single stage TF system or first filter of a two stage TF system, in kg BOD_5/d.

W_2 = BOD loading to second filter of a two stage TF system, kg $BOD_5/d = W_1 (1 - E_1)$

V_1 = Volume of the filter of a single stage TF system or first filter of a two stage TF system, in m^3.

V_2 = Volume of second filter of a two stage TF system, m^3.

F_1 = Recirculation factor for first stage filter is given by,

$$\frac{1 + R_1}{[1 + (1 - f) R_1]^2}$$

F_2 = Recirculation factor for second stage filter is given by,

$$\frac{1 + R_2}{[1 + (1 - f) R_2]^2}$$

R_1 = Recirculation ratio of the filter of a single stage TF system or first filter of a two stage TF system.

R_2 = Recirculation ratio of second filter of a two stage TF system

f = Treatability factor (0.9 for domestic wastewater).

2. **Modified National Research Council (NRC) Equation :** For the first filter of a two stage TF or single stage TF, the equation is given by,

$$V_1 F_1 = \frac{W_1}{5.08}\left[\frac{E_1}{1 - E_1}\right]^2$$

and for the second filter of a two stage TF,

$$V_2 F_2 = \frac{W_2}{5.08}\left[\frac{E_2}{(1 - E_1)(1 - E_2)}\right]^2$$

where, all the terms are as defined earlier in National Research council equation.

B. Eckenfelder Equation :

i. Without recirculation, $\dfrac{S_e}{S_0} = e^{-kD/Q_L^n}$

ii. With recirculation, $\dfrac{S_e}{S_0} = \dfrac{e^{-kD/Q_L^n}}{(1 + R) - R\, e^{-kD/Q_L^n}}$

where, S_e = Effluent substrate concentration, BOD_5, mg/l (g/m^3).

S_0 = Influent substrate concentration, BOD_5, mg/l (g/m^3).

S_a = Substrate concentration of influent and recycled flow BOD_5

$$\text{mg/l} = \frac{S_0 + RS_e}{1 + R}$$

K = Treatability or waste removal constant (usually varies from 0.01 to 0.1 min^{-1}).

D = Depth of filter media, in m.

n = Empirical or filter media constant (usually assumed as 0.5).

Q_L = Hydraulic loading rate, m^3/m^2 min.

R = Recirculation ratio.

Que 5.7. **The sewage flows from a primary settling tank to a standard rate trickling filter at a rate of 5 million litres per day having a 5 day BOD of 150 mg/l. Determine the depth and the volume of the filter, adopting a surface loading of 2500 l/m^2/day and an organic loading of 165 g/m^3 day. Also determine the efficiency of the filter unit, using NCR formula. (Take standard values wherever required).**

AKTU 2013-14, Marks 10

Answer

Given : Rate of trickling filter = 5 Mld, BOD_5 = 150 mg/l
Surface loading = 2500 l/m²/day, Organic loading = 165 g/m³ day
To Find : Efficiency of filter unit.

1. Total 5-day BOD present in sewage,

$$= \frac{150 \times 5 \times 10^6}{10^3} = 750000 \text{ gm/day}$$

2. Volume of the filter media required,

$$= \frac{\text{Total BOD}}{\text{Organic loading}}$$

$$= \frac{750000}{165} = 4545.45 \text{ m}^3$$

3. Surface area required for the filter,

$$= \frac{\text{Total flow}}{\text{Hydraulic loading}}$$

$$= \frac{5 \times 10^6}{2500} = 2000 \text{ m}^2$$

4. Depth of the bed required,

$$= \frac{4545.45}{2000} = 2.27 \text{ m}$$

5. Efficiency of the filter is given by,

$$E = \frac{100}{1 + 0.0044\sqrt{u}}$$

where, u = Unit organic loading in kg/ha = m/day
= 165 gm/m³/day (given)
u = 1650 kg/ha = m/day

$$E = \frac{100}{1 + 0.00443\sqrt{1650}} = 84.84 \%$$

Que 5.8. **Determine the size of high rate trickling filter for the following data :**
Flow – 4 Mld, Recirculation ratio = 1.4, BOD of raw sewage = 250 mg/l, BOD removed in primary clarifier = 25 %, Final effluent BOD desired = 50 mg/l.

AKTU 2014-15, Marks 10

Answer

Given : Discharge = 4 Mld, Recirculation ratio, $R = 1.4$,
Initial BOD = 250 mg/l, Final BOD = 50 mg/l
To Find : Size of high rate trickling filter

1. Total BOD present in raw sewage per day = 4.5 ML × 250 mg/l = 1125 kg,
2. BOD removed in the primary clarifier = 25 %.
   BOD entering per day in the filter units = 0.75 × 1125 kg = 843.75 kg
3. Permissible BOD concentration in the effluent = 50 mg/l
   BOD allowed to go into the effluent = 50 mg/l × 4.5 ML = 225 kg
4. BOD removed by the filter per day = 843.75 – 225 = 618.75 kg.
5. Efficiency of the filter = $\dfrac{\text{BOD removed}}{\text{Total BOD entering}} \times 100$
   $$= \frac{618.75}{843.75} \times 100 = 73.3\ \%$$
6. Efficiency of the filter is given by NRC equation as, $E = \dfrac{100}{1 + 0.443\sqrt{\dfrac{W}{VF}}}$
7. $$F = \frac{1 + \dfrac{R}{I}}{\left[1 + 0.1\dfrac{R}{I}\right]^2} \qquad \left[\because R_1 = \frac{R}{I} = 1.4\right]$$
   $$= \frac{1 + 1.4}{(1 + 0.1 \times 1.4)^2} = \frac{2.4}{(1.14)^2} = \frac{2.4}{1.3} = 1.85$$
8. $$73.3 = \frac{100}{1 + 0.443\sqrt{\dfrac{843.75}{V \times 1.85}}}$$
   $$= 674.6\ \text{m}^3$$
9. Using 1.5 m depth the filter, we have
   Area required = $\dfrac{674.6}{1.5} = 450\ \text{m}^2$
10. Diameter of the filter tank required = $\sqrt{\dfrac{450 \times 4}{\pi}} = 23.94\ \text{m} \approx 24\ \text{m}$

Que 5.9. **Differentiate between activated sludge process and trickling filter process.**

AKTU 2014-15, Marks 10

Answer

S. No.	Trickling Filter Process	Activated Sludge Process
1.	In case of trickling filter process, the bacterial film coating contact material is stationary and likely to become clogged after sometime.	In activated sludge process, the fine suspended matter of sewage itself contains the bacterial film, which is kept moving because of the constant agitation.
2.	Less efficient than activated sludge process.	More efficient than trickling filter.
3.	Large area required.	Less area required.
4.	Operating head is more.	Operating head is less.
5.	Low cost of operation.	High cost of operation.
6.	No skilled labour required.	Skilled labour required.
7.	Problems occur from odour or nuisance.	No problem as process is under water.

Que 5.10. **Distinguish between low rate trickling filters and high rate trickling filters.**

AKTU 2015-16, Marks 05

Answer

S. No.	Characteristics	Low Rate Filters	High Rate Filter
i.	Depth of filter media	Varies between 1.6 to 2.4 m.	Varies between 1.2 to 1.8 m.
ii.	Size of filter media	25 to 75 mm.	25 to 60 mm.
iii.	Land required	More land area is required as the filter loading is less.	Less land area is required as the filter loading is more.
vi.	Cost of operation	It is more for treating equal quantity of sewage.	It is less for treating equal quantity of sewage.
v.	Type of effluent produced	The effluent is highly nitrified and stabilized, with BOD in effluent $\leq$ 20 ppm or so.	The effluent is nitrified upto nitrite stage only and is thus less stable, and hence it is of slightly inferior quality. BOD in effluent $\geq$ 30 ppm or so.

PART-3

Aerated Lagoon.

CONCEPT OUTLINE

Aerated Lagoons : It is a deeper oxidation pond, with oxygen introduced by mechanical aerators rather than relying on the photosynthetic oxygen production alone.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.11. What is aerated lagoon and what are their design considerations and design criteria ?

Answer

A. **Aerated Lagoons :**

1. It consists of an earthen basin in which the wastewater is treated on a flow through basis.
2. Oxygen is supplied by means of surface or diffused aerators.
3. It operates at low MLSS concentrations but with long retention time as compared to ASP.
4. In aerated lagoons sludge recycling is not employed.

Types : Following the various types of aerated lagoons :

1. **Aerobic System :**
   i. The aerobic condition prevails in the lagoon. It is normally designed at a high F/M ratio.
   ii. The system assumes complete mixing and wastewater flow is continuous.
   iii. All solids are kept in suspension and they pass out with effluent as no separate secondary settling is provided.
   iv. Therefore, BOD removal efficiency is low.
2. **Facultative System :**
   i. The aerobic and anaerobic conditions prevail in the lagoon.
   ii. It is normally designed at a low F/M ratio.
   iii. The power supplied is just sufficient to supply the required oxygen and therefore, all the solids in the influent do not remain suspended.
   iv. The particulate solids are degraded aerobically while settled solids are decomposed anaerobically at the bottom of the tank.

B. **Design Consideration :** Following are the points considered while designing aerated lagoons :

1. In plan, the lagoons are normally rectangular.
2. The capacity of the lagoon is provided about 30 m^3 per 2 kg to 3.5 kg of BOD.
3. Detection period is 3-4 day.
4. Depth 2.5 to 4 m.
5. The oxygen capacity varies from 1.5 to 2.5 kg/HP/hr at 20 °C.
6. The efficiency of the aerated lagoon is 70 to 95 % BOD removal.

Que 5.12. **Design a facultative aerated lagoon to serve 50,000 people. For sewage flow @ 180 lpcd = 7200 cum/day. Raw BOD_5 = 275 mg/l and final BOD_5 is not exceed 30 mg/l in winter. Ambient air temperature in January is 20 °C and in summer 37 °C.**

AKTU 2014-15, Marks 10

Answer

Given : Population = 50,000, Sewage flow = 180 lpcd
Raw BOD_5 = 275 mg/l, Final BOD_5 = 30 mg/l
Ambient temperature in January and summer = 20 °C and 37 °C
To Find : Design facultative aerated lagoon.

1. **Assume Data :**

Detention time, t = 5 days

Temperature of influent, T_i = 23 °C

K at 20 °C = 0.7/day

2. **Lagoon Size :**

Total sewage flow = 180 × 50,000 = 90,00,000 l/day 9000 m^3/day

Detention time = 5 days

Lagoon volume = 9000 × 5 = 45000 m^3

Let lagoon dimension be (90 × 130 × 4) m^3

3. **Lagoon Winter Temperature :**

$$\frac{t}{h} = \frac{T_i - T_L}{f(T_L - T_a)}$$

where,
t = 5 days
h = 4 m
T_i = 23 °C
f = 0.5 m/d
T_a = 20 °C

$$\frac{5}{4} = \frac{23 - T_L}{0.5(T_L - 20)}$$

$$1.25 \times 0.5\,(T_L - 20) = 23 - T_L$$

$$T_L + 0.625\,T_L = 23 + 12.5$$

$$T_L = 21.84\,°C \approx 22\,°C$$

4. **Estimation of K at 22 °C :**

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

$$K_{20} = 0.7/\text{day}$$

$$T = 22\,°C$$

$$K_{22} = 0.7\,(1.047)^{22-20} = 0.77/\text{day}$$

5. **D/UL estimation :** Keep lagoon geometry such that flow conditions are plug-flow type (*i.e.*, $D/UL = 0.2$ approximately). This will be possible if a long and narrow lagoon is provided or baffles are provided within the rectangular lagoon of (90 m × 130) m to give a winding flow with the same effect.

6. **BOD_5 Removal Efficiency (in Winter) :**

i. $$K \times t = 0.77 \times 5 = 3.85$$

At $$K \times t = 3.85$$

$$D/UL = 0.2,$$

Soluble BOD removal efficiency = 92 %

$$\text{Soluble BOD in effluent} = 275\left(1 - \frac{92}{100}\right) = 22 \text{ mg/l}$$

ii. Let the concentration of suspended solid passing out in the effluent be 3 mg/l.

BOD of VSS = 0.77 (0.6 × 35) = 16.17 mg/l

Hence, BOD of effluent = 22 + 16 = 38 mg/l

iii. $$\text{Overall efficiency in winter} = \frac{275 - 38}{275} \times 100 = 86.18\% \approx 86\,\%$$

7. **Power Requirement :**

i. When efficiency = 86 % and all BOD is removed aerobically

$$O_2 \text{ required} = 0.86\left[\frac{1.42 \times 50 \times 50{,}000}{1000}\right] \text{kg/d}$$

$$= 3053 \text{ kg/d} = 127.2 \text{ kg/hr}$$

ii. Assuming the oxygenation capacity of aerators to be 2 kg O_2/kWh and efficiency of the set up as 80 %.

$$\text{Power needed} = \frac{127}{0.8 \times 2} = 79.375 \text{ kW}$$

iii. $$\text{Power level in lagoon} = \frac{79.375 \times 1000}{45000} = 1.76 \text{ W/m}^3$$

which is acceptable.

9. **Land Requirement :**

i. Net lagoon area = $\frac{45000}{4}$ = 11,250 m^2

ii. Area including embankments and slopes
= 15000 m^2 (approximately)

iii. Area/person = $\frac{15000}{50000}$ = 0.3 m^2/person

PART-4

Waste Stabilization Pond.

CONCEPT OUTLINE

Waste Stabilization Ponds : These are also known as oxidation ponds. These are open flow through earthen basins, specifically designed and constructed to treat sewage and biodegradable industrial wastewater.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.13. **What do you understand by 'stabilization ponds' ? Give classification, advantages and disadvantages of stabilization ponds.**

Answer

Stabilization Ponds (Oxidation Ponds) :

1. A stabilization pond is an open, flow-through earthen basin of controlled shape, specifically designed and constructed to treat sewage and biodegradable industrial wastes.
2. These ponds may be considered to be completely mixed biological reactors without solids return.
3. The mixing is usually provided by natural processes (such as wind, heat, fermentation), but may be augmented by mechanical or diffused aeration.
4. Stabilization ponds provide comparatively long detention periods extending from a few to several days.
5. It is a relatively low-cost treatment system which has been widely used, particularly in rural areas.

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).

Advantages of Stabilization Ponds :

i. Lower initial and operating cost.

ii. Regulation of effluent discharge possible.

Disadvantages of stabilization ponds :

i. Requires extensive land area.

ii. Odour problems.

iii. Assimilative capacity of certain industrial waster is poor.

PART-5

Oxidation Ditches.

CONCEPT OUTLINE

Oxidation Ditch : An oxidation ditch is basically an extended aeration system of a modified activated sludge process. It is design and operated on the same principle of the activated sludge process.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.14. **Describe the oxidation ditch and its types.**

Answer

Oxidation Ditch :

1. An oxidation ditch is basically an extended aeration system of a modified activated sludge process. It is design and operated on the same principle of the activated sludge process.

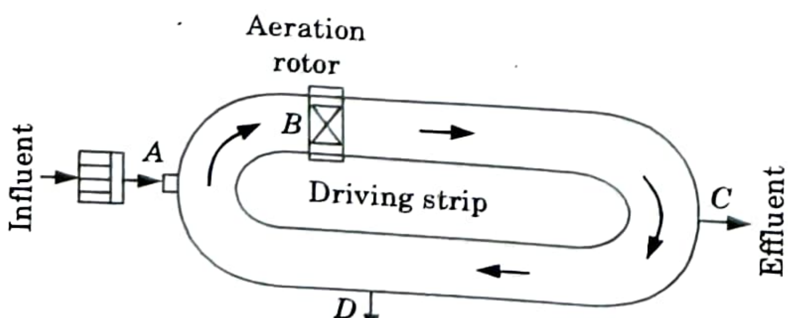


Fig. 5.14.1. Intermittent flow type.

2. An oxidation ditch consists of an endless ditch for the aeration tank and a rotor for aeration mechanism.

3. The ditch consists of a long continuous channel, usually oval in plan.
4. The channel may be earthen with lined sloping sides and lined floor or it may be built in concrete or brick with vertical walls.
5. There is normally no primary tank used in the oxidation ditch process. Raw sewage passes directly through a bar screen to the ditch.

Type of Oxidation Ditches : Following are the type of oxidation ditches :

1. **Intermittent Flow Type :**
   i. In the intermittent flow type oxidation ditch, shown in Fig. 5.14.1, the no separate settling tank is used.
   ii. The flow in the ditch remains suspended during a predetermined period, by stopping the rotor, and the ditch itself is used for settling.
   iii. The supernatant, is withdrawn through the outlet. The surplus sludge, settled in the ditch, is removed with the aid of a sludge trap.
2. **Continuous Flow Type :**
   i. The operation is kept continuous by allowing the mixed liquor to settle in a separate settling tank.
   ii. Quiescent conditions in the clarified liquid passes over the effluent weir for final disposal.
   iii. The settled sludge is removed from the bottom of the clarifier by an air lift or pump and is returned to the ditch.

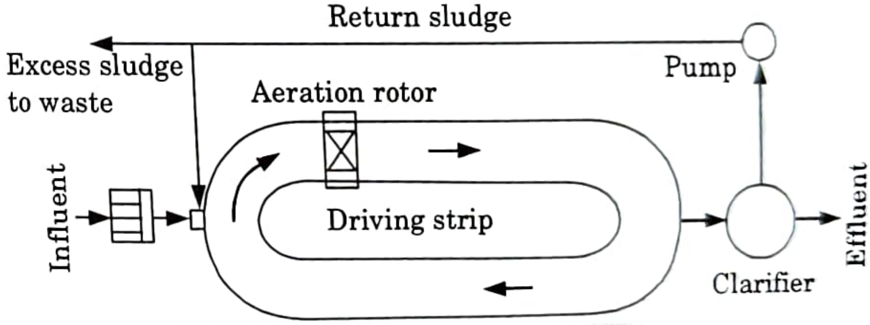


Fig. 5.14.2. Continous flow type.

Que 5.15. **Design an oxidation ditch for a community with the following data.**

i. **Population of the community : 6000 persons.**
ii. **Organic load of sewage : 40 g BOD per capita per day.**
iii. **Sewage flow : 160 litre/capita/day.**
iv. **Permissible BOD of effluent : 20 mg/litre.**

AKTU 2016-17, Marks 10

Answer

Given : Population = 6000
Organic load of sewage = 40g BOD per capita per day.
Sewage flow = 160 litre /capita/day
BOD remaining = 20 mg/l
To Find : Design of oxidation ditch.

1. **Inflow Rate and Influent BOD :**

i. Total sewage flow = 6000 × 160 = 960 × 10^3 l/day (0.96 Mld)

$$Q = 960 \text{ m}^3/\text{day}$$

ii. Total BOD applied = (6000 × 40) × 10^{-3} = 240 kg/day

iii. $$\text{Influent BOD, } L_a = \frac{240 \times 10^6}{960 \times 10^3} = 250 \text{ mg/l}$$

iv. $$\text{BOD removal required} = \frac{250 - 20}{250} \times 100 = 92\ \%$$

2. **Volume of Ditch :**

i. Volume of the ditch can be found from the formula :

$$\text{F/M} = \frac{Q\,L_a}{(V/1000)X_T}, \text{ (where } Q \text{ is in Mld)}$$

Choosing F/M = 0.1 and keeping, X_T = 3000 mg/l, we get

$$V = \frac{1000 \times 0.96 \times 250}{0.1 \times 3000} = 800 \text{ m}^3$$

3. **Volumetric Loading Rate :**

$$\text{Volumetric loading} = \frac{Q\,L_a}{V} = \frac{0.96 \times 250}{800}$$

$$= 0.3 \text{ kg BOD}_5/\text{m}^3$$

(which is within the prescribed range of 0.2 to 0.4)

4. **Hydraulic Retention Time :**

$$\text{HRT} = \frac{V}{Q} = \frac{800}{960} \times 24 = 20 \text{ hours.}$$

(which is within the prescribed range of 20 to 30 hours)

5. **Return Sludge Ratio :**

$$\frac{Q_R}{Q} = \frac{X_T}{\dfrac{10^6}{\text{SVI}} - X_T}$$

Adopting value of SVI = 100

$$\frac{Q_R}{Q} = \frac{3000}{\dfrac{10^6}{100} - 3000} \approx 0.43$$

(which is within the prescribed range of 0.35 to 1.5)

6. **Oxygen Requirement and Number of Rotors :**

i. O_2 required = 1.2 kg/kg of BOD removed

$$= 1.2\,(250 - 20) \times 0.96 \approx 265 \text{ kg/day}$$

$$= 11.04 \text{ kg/hour}$$

ii. Oxygenation capacity of cage rotor of diameter 70 cm, @ 75 rpm, at immersion depth of 16 cm = 2.8 kg of O_2/hr/m length.

∴ Length of rotor needed on the basis of oxygenation capacity

$$= 11.04/2.8 = 3.94 \text{ m (or say 4 m)}$$

iii. Length of rotor needed from velocity consideration of 0.3 m/sec (assuming 150 m^3 of ditch volume per m length of rotor for adequate circulation) = 800/150 = 5.33 m. Hence adopt 2 rotors of 2.7 m length each.

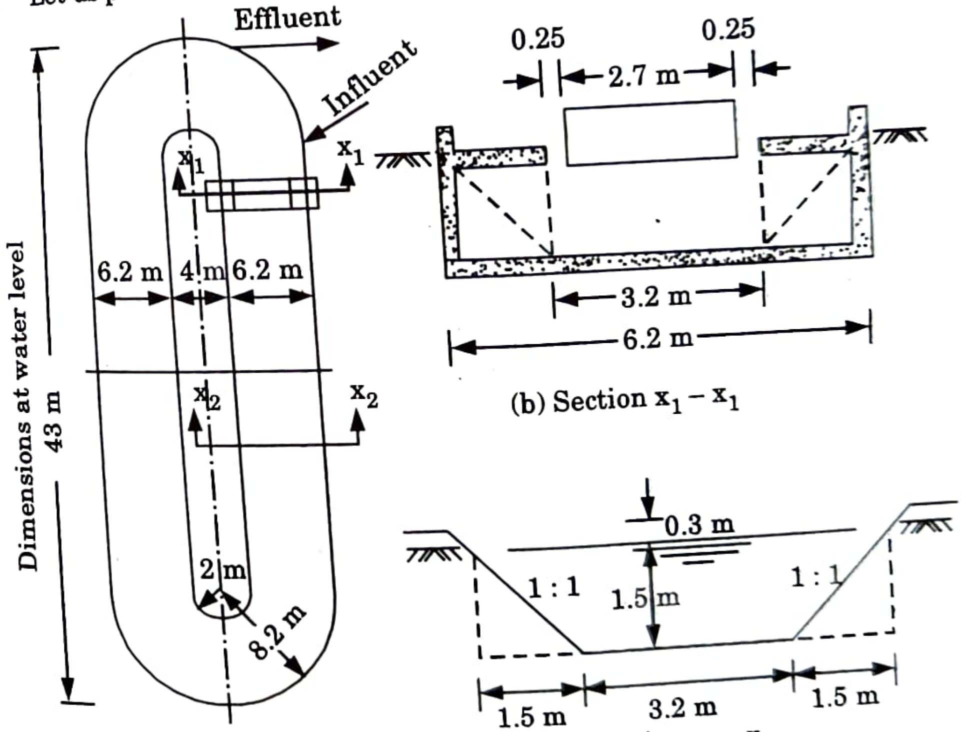
iv. Giving a clearance of 0.25 m on either side, width of ditch = 2.7 + 2 × 0.25 = 3.2 m. Let us keep a depth of 1.5 m.

v. $\therefore$ Surface area required $= \dfrac{800}{1.5} = 533.3\ m^2$

Adopting 2 ditches, surface area of each ditch = 266.7 m^2

$\therefore$ Length of ditch $= \dfrac{266.7}{3.2} = 83.3$ m or say 85 m.

7. **Power Required :**
   i. Power required for each rotor @ 1.35 kW/m length = 1.35 × 2.7 ≈ 3.7 kW.
   ii. Total power required for both ditches = 2 × 3.7 = 7.4 kW.
8. **Design of Settling Tank :**
   i. Let us provide SOR of 20 m^3/m^2/day and a detention time of 2 hours.



(a) Plan (b) Section $x_1 - x_1$ (c) Section $x_2 - x_2$

Fig. 5.15.1. Details of oxidation ditch.

$\therefore$ Surface area, $A = \dfrac{Q}{SOR} = \dfrac{960}{20} = 48\ m^2$

ii. Volume, $V = \dfrac{960}{24} \times 2 = 80\ m^3$

$\therefore$ Depth of tank $= \dfrac{80}{48} = 1.67\ m \approx 1.7\ m$

iii. Diameter of tank = $\sqrt{\frac{48 \times 4}{\pi}} = 7.8$ m.

iv. Hence provide 8 m diameter tank of 1.7 m depth, with hopper bottom.

$$\text{Actual area} = \frac{\pi}{4}(8)^2 = 50.27 \text{ m}^2$$

$$\text{Actual SOR} = 960 / 50.27 = 19.1 \text{ m}^3/\text{m/day}.$$

v. The details of the oxidation ditch (one unit) are shown in Fig. 5.15.1.

Que 5.16. **Explain the mechanism of purification in facultative ponds.**

Answer

Mechanism of Purification :

1. 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.
2. In the facultative zone facultative bacteria oxidize the incoming organics as well as the products of anaerobic decomposition of the bottom anaerobic zone.
3. When sewage enters the pond, the suspended organic matter in the influent as well as the bioflocculated colloidal organic matter settles to the bottom of the pond.
4. In the absence of dissolved oxygen at pond bottom, the settled sludge undergoes anaerobic fermentation with the liberation of methane which represents a BOD removal from the system–0.25 g of methane being literated for every of ultimate BOD utilized.
5. In the liquid layers of the pond, algae begins to grow under favourable conditions.

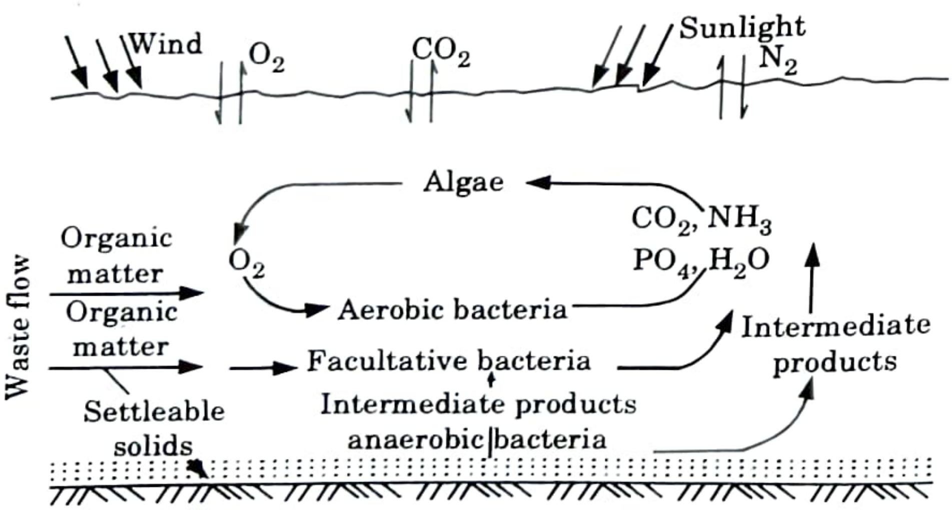


Fig. 5.16.1. Operational lagoon as a facultative system.

6. The algae utilize the carbon dioxide in the sewage for photosynthesis during day light hours, liberating oxygen which maintains aerobic conditions in upper layers of the pond.
7. The aerobic conditions promote the oxidation of organic waste matter by aerobic bacteria.
8. Thus it is seen that there is 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.

PART-6

Rotating Biological Contactors (RBC).

CONCEPT OUTLINE

Rotating Biological Contactor : It is a simple and reliable biological method of treatment for both domestic and industrial wastewater and normally employed for the secondary treatment.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.17. Discuss in brief the rotating biological contactors with neat sketch.

AKTU 2013-14, Marks 05

Answer

1. A rotating biological contactor (RBC) is a cylindrical media made of closely mounted thin flat circular plastic sheets or discs of 3 to 3.5 m in diameter, 10 mm thick, and placed at 30 to 40 mm spacing mounted on a common shaft.
2. The RBC's are usually made in up to 8 m length, and may be placed in series or parallel in a specially constructed tank(s), through which the wastewater is allowed to pass.
3. The RBC's are rotated around their central horizontal shaft, at a speed of 1-2 rpm by means of power supplied to the shaft.
4. In the Rotating Biological Contactor, wastewater is purified using microorganism membranes which are attached to disks.
5. By absorbing oxygen from the air and pollutants from the wastewater, the pollutants are decomposed aerobically.

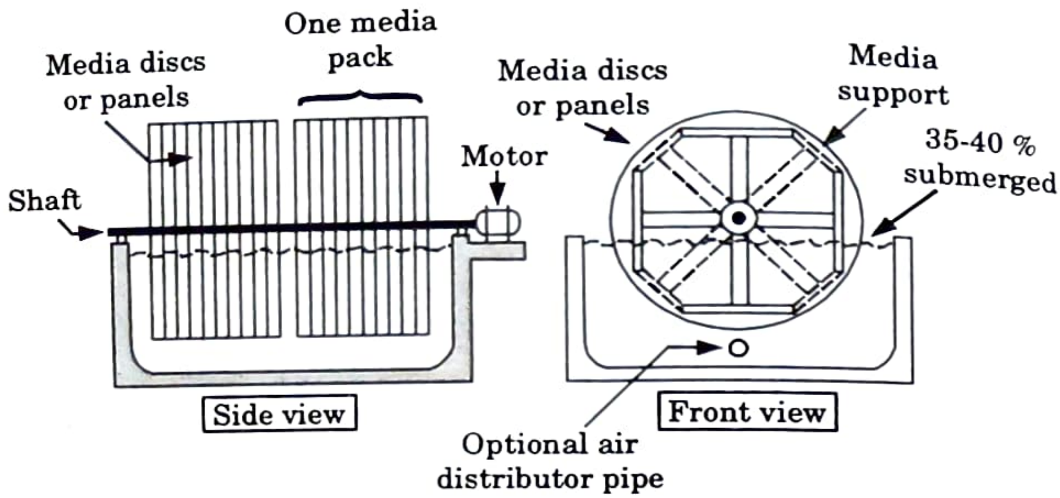


Fig. 5.17.1.

Advantages of Rotating Biological Contactor Unit :

i. Sludge has good settling characteristics.

ii. Low power required.

iii. Simple in operation and maintenance

Disadvantages :

i. Requirement for covering RBC unit to prevent algae growth and freezing in northern part of India.

ii. Continuous supply of electricity required.

PART-7

Design of Low and High Rate Anaerobic Digestion.

CONCEPT OUTLINE

Anaerobic Sludge Digestion : It is the most common process adopted for dealing with wastewater sludge containing primary sludge.

Types of Anaerobic Sludge Digester : Following types of digesters are used for anaerobic sludge digestion :

i. Conventional or standard rate digester.

ii. High rate completely mixed single and two stage digester.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.18. What is sludge digestion ? What are the different types of anaerobic sludge digesters ?

OR

What is anaerobic digestion ? Explain in detail.

AKTU 2014-15, Marks 05

Answer

Anaerobic Sludge Digestion :

1. The sludge digestion breaks the organic matter of the sludge into liquid and simple compounds which are stable and unfoul in nature.
2. A portion of the solids is converted into liquid and gases due to which the volume of the sludge is reduced by 60-75 percent.
3. The moisture content of the sludge cannot be reduced easily, but after its digestion it can be removed without any difficulty.
4. The gases produced can be used as fuel and the digested sludge has very good fertilizing value.
5. Sludge digestion process removes coliforms by 99.8 % by digestion for 30 days at 95-100 °F temperature.
6. Mostly sludge digestion takes place under anaerobic conditions which result from the activities of two groups of bacteria's.
   i. One group of bacteria's attacks the organic substance such a fats, carbohydrates and proteins and converts them into organic acids and alcohols.
   ii. The second group of bacterial acts under anaerobic conditions and forms methane and carbon dioxide gases using the acids and other products formed by the first group of bacterial.
7. Stages in the sludge digestion process :
   i. Acid fermentation, ii. Acid regression, and iii. Alkaline fermentation.

Types of Digesters : Sludge digesters can be of two types :

1. **Conventional or Low Rate Digester :**
   i. The conventional sludge digestion is carried out in a single stage where digestion, sludge thickening and supernatant formation takes place simultaneously in the same unit.
   ii. A conventional digestion unit may be single stage or in two stages. In two stage process, two tanks are provided- first tank meant for digestion and the second tank is used for storage, thickening and supernatant formation.
2. **High Rate Digester :** The high rate digestion process differs from the conventional single-stage process in that the solids loading rate is much greater, the sludge is intimately mixed and it is heated to achieve optimum digestion rates.

Que 5.19. **What is sludge thickening ? Give detail of gravity thickening.**

AKTU 2014-15, Marks 05

Answer

A. Sludge Thickening :

1. Thickening is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction.
2. This volume reduction, obtained by sludge thickening or sludge concentration, is done for the following purposes :

i. To permit increased loadings to sludge digesters

ii. To increase feed solids concentration to vacuum filters,

iii. To economise on transport cost as in ocean barging in case of a raw sludge,

iv. To minimise the land requirements as well as handling costs when digested sludge has to be transported to disposal site.

B. Gravity Thickening :

1. Gravity thickening is the most common practice for concentration of sludges. Gravity thickening is the simplest and the least expensive.
2. This is adopted for primary sludge or combined primary and activated sludge but is not successful in dealing with activated sludge independently.
3. Fig. 5.19.1 shows a typical waste sludge thickener. The tank resembles a circular clarifier except that the depth/diameter ratio is greater and the hopper bottom has a steeper slope.

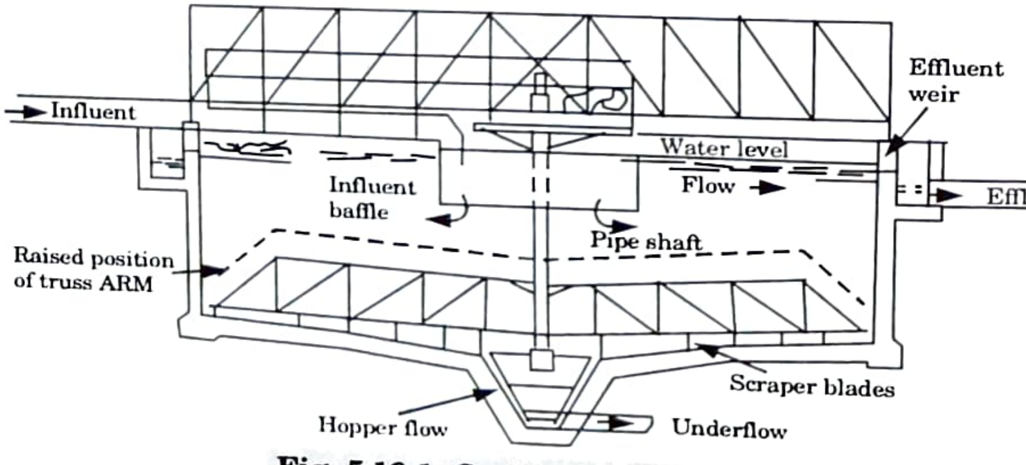


Fig. 5.19.1. Gravity sludge thickener.

5. Dilute sludge is fed to a center feed well. The feed sludge is allowed to settle and compact, and the thickened sludge is withdrawn from the bottom of the tank.
6. A bridge fastened to the tank walls supports a truss-type scraper arm mounted on a pipe shaft equipped with a power lift device thereby opening up channels for water to escape and promoting densification.

7. Also, the slow motion of the scraper dislodges gas bubbles, prevents bridging of solids and moves the sludge towards a central is returned to the primary settling tank.

Que 5.20. **The thickened sludge of 100 m^3/d is processed in a standard rate anaerobic digester. The moisture content of thickened sludge is 95 %. The digestion period is 25 days and the sludge must be stored for 3 months between final disposal events during monsoon period. Organic content of the sludge is 70 percent and 60 percent of the organics are converted into gaseous and liquid end products. The solid content of the digested sludge is 4.5 %. Determine the required reactor volume. Assuming 100 $kg/m^2/yr$ solids loading rate, design the number of sludge drying beds required for dewatering operation.** **AKTU 2017-18, Marks 10**

Answer

Given : Quantity of sludge = 100 m^3/day, Moisture content = 95 % Digestion period, t = 25 day, Monsoon period, T = 3 month, Organic content = 70 % of sludge, Organics convert into gaseous and liquid = 60 %, Solid content of digested sludge = 4.5 %, Solid loading rate = 100 $kg/m^2/yr$.

To Find : Required reactor volume, Design the number of drying beds.

1. Volume of solids removed in the primary settling tank

$$= \frac{70}{100} \times 100 = 70 \text{ m}^3/\text{day}$$

2. Given that 95 % moisture content,
5 kg of dry solid will make = 100 m^3 of wet sludge,
∴ 70 m^3 of dry solid will make

$$V_1 = \frac{100}{5} \times 70 = 1400 \text{ m}^3/\text{day}$$

3. 60 % of organic sludge is changed into liquid and gas, means that 60% of solids are consumed (digested).
Mass of dry solids left in the digested sludge

$$= (100 - 60)\ \%\ \text{of organic solid}$$

$$= 40 \times \frac{70}{100} = 28 \text{ m}^3/\text{day}$$

4. Since digested sludge contains (100 – 4.5) 95.5 % moisture content.

$$V_2 = 28 \times \frac{95.5}{100} = 26.74 \text{ m}^3/\text{day}$$

5. Volume of digester tank is given by,

$$V = \frac{(V_1 + V_2)}{2} t + V_2\, T = \left(\frac{1400 + 26.74}{2}\right) \times 25 + 26.74 \times 3$$

$$= 17914.47 \text{ m}^3/\text{day}$$

6. Let height of digester tank = 8 m

$$\text{Area of digester tank} = \frac{17914.97}{8} = 2239.4 \text{ m}^2$$

7. Using 15 m × 30 m sized bed

$$\text{Number of beds required} = \frac{2239.4}{15 \times 30} = 4.91 \approx 5$$

$$\text{Area of each bed} = \frac{2239.4}{5} = 447.88 \text{ m}^2$$

Using 15 m width of each bed,

Length of bed = 447.88 / 15 = 29.86 ≈ 30 m

9. Hence, 5 beds of size 15 m × 30 m in plan are used.

Que 5.21. **What is sludge digestion ? What are two basic types of sludge digestion units ? Also name and describe methods of sludge disposal.**

AKTU 2017-18, Marks 10

Answer

A. Sludge Digestion and types of Sludge Digestion Units : Refer Q. 5.18, Page 5–25B, Unit-5.

B. Sludge Disposal : Sludge (either wet, dry or incinerated) can be finally disposed off by the following methods :

1. Spreading on Farm Land :

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

ii. Wet dewatered sludge can be incorporated into soil directly by injection into a number of shallow trenches.

iii. After a sludge cake is formed due to evaporation of water, it is covered with dry earth.

iv. After about a month, the whole land is ploughed and used for cultivation.

2. Dumping :

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

ii. This method can be safely adopted for digested sludge, clean grit and incinerator residue.

3. Disposal by Land Filling :

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

ii. The sanitary land fill method is most suitable if it is also used for disposal of other solids wastes of the community.

4. **Sludge Lagooning Method :**
   i. A lagoon is a shallow earth basin into which untreated or digested sludge is deposited.
   ii. Untreated-sludge lagoons stabilize the organic solids by anaerobic and aerobic decomposition, which may give rise to objectionable odours.
5. **Disposal in Water Bodies or Sea :** At some sea coast sites, the sludge either raw or digested may be barged to sea far enough to make available the required dilution and dispersion.

PART-8

Design of Septic Tank.

CONCEPT OUTLINE

Septic Tank : 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.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.22. Discuss septic tank and its design criteria. Also mention the problems and the solutions related to septic tank.

AKTU 2013-14, Marks 10

Answer

A. Septic Tank :

i. 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.

ii. This tank has larger capacity than ordinary primary sedimentation tank, so as to accommodate and hold the settled sludge for its subsequent digestion.

iii. The digestion of settled sludge is carried out by anaerobic decomposition process, giving rise to septicity or septic condition, that is why this unit is known as septic tank.

iv. The foul gases (H_2S, CO_2) 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.

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

1. **Capacity of Septic Tank :** 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.
2. **Free-Board :** A free-board of about 0.3-0.5 m may be provided above the top sewage line in the tank. This will help accommodate the scum in the tank.
3. **Inlet and Outlet Baffles :** The inlet should penetrate by about 30 cm below the top sewage line, and the outlet should penetrate to about 40 % of the depth of sewage. Further, the outlet invert level should be kept 5 to 7.5 cm below the inlet invert level.
4. **Detention Period :** The detention period for a septic tank generally varies between 12 to 36 hours, but is commonly adopted as 24 hours.
5. **Length to Width Ratio :**

i. Septic tanks are usually rectangular with their length at about 2 to 3 times the width.

ii. The width should not be less than 90 cm.

iii. The depth of the tank generally ranges between 1.2 to 1.8 m.

C. Septic Tank Problems :

1. Inlet drains become blocked due to excessive use of cooking oil, fats and grease.
2. Non-Bio degradable products such as diaper and wipes will quickly block the pipe and gives bad smell after some days.
3. Septic tank becomes overflow due to irregular maintenance of tank.
4. Inadequate bacteria in septic tank.

D. Solutions to Septic Tank Problems :

1. To treat the odour in septic tank and execute the bacteria, use various types of neutraliser.
2. Pumping septic tank system regularly.
3. For septic tanks to function satisfactorily, a fairly adequate water supply is a prerequisite.

Que 5.23. **What is septic tank ? Discuss advantages and disadvantages of centralized and decentralized wastewater treatment.**

AKTU 2014-15, Marks 05

Answer

Septic Tank : Refer Q. 5.22, Page 5–29B, Unit-5.

Advantages of Centralized Wastewater Treatment :

i. High treatment efficiency of aspects conventional treatment systems.
ii. Located far away from human aspects settlements.
iii. Possibility of staged development.
iv. Small number of treatment plants easier to manage.
v. Management conducted by organizations with high capacity.

Disadvantages of Centralized Wastewater Treatment :

i. High energy consumption.
ii. Less flexible.
iii. Large investment required.

Advantages of Decentralized Wastewater Treatment :

i. Small (natural) treatment systems use less energy and less energy for pumping.
ii. Reuse of wastewater and sludge easier to manage.
iii. Easier to pilot new technologies.

Disadvantages of Decentralized Wastewater Treatment :

i. Newly developed technologies may be less reliable.
ii. Sludge handling more difficult in many small systems.
iii. Many small treatment plants difficult to manage.

Que 5.24. **Design a septic tank for 300 users. Water allowance is 120 litres per head per day. Detention period may be taken as 8 hours. Draw a neat sketch of a septic tank.**

AKTU 2014-15, Marks 05

Answer

Given : Population = 300, Allowance = 120 l/ capita /day
Detention period = 8 hr
To Find : Design septic tank.

1. Quantity of water supplied

$$= \text{Per capita rate} \times \text{Population}$$
$$= 120 \times 300 = 36000 \text{ l/day}$$

2. Assuming that 80 % of water supplied becomes sewage, we have, The quantity of sewage produced

$$= \frac{80}{100} \times 36000 = 28{,}800 \text{ l/day}$$

3. As given, the detention time is 8 hours.
Quantity of sewage produced during detention period

$$= 28,800 \times \frac{8}{24} = 9600 \text{ litre}$$

4. Now, assuming the rate of deposited sludge as 30 l/capita/year; and also assuming the period of cleaning as 1 year, we have

   Volume of sludge deposited

$$= 30 \times 300 \times 1 = 9000 \text{ litre.}$$

5. Total required capacity of the tank

$$= \text{Capacity for sewage} + \text{Capacity for sludge}$$

$$= 9600 + 9,000 = 18600 \text{ l} = 18.6 \text{ m}^3$$

6. Assuming 1.5 m as depth of the tank, and 0.3 m as free board depth then

$$\text{Surface area} = \frac{18.6}{1.5} = 12.4 \text{ m}^2$$

7. If the ratio of $\frac{L}{B} = \frac{4}{1}$, we get

$$4B^2 = 12.4$$

   Width of tank, $B = 1.76 \simeq 1.8$ m

   Length of tank, $L = 7.2$ m

8. Area of cross-section provided

$$= 1.8 \times 7.2 = 12.96 \text{ m}^2$$

9. Tank size = 7.2 m × 1.8 m × 1.8 m

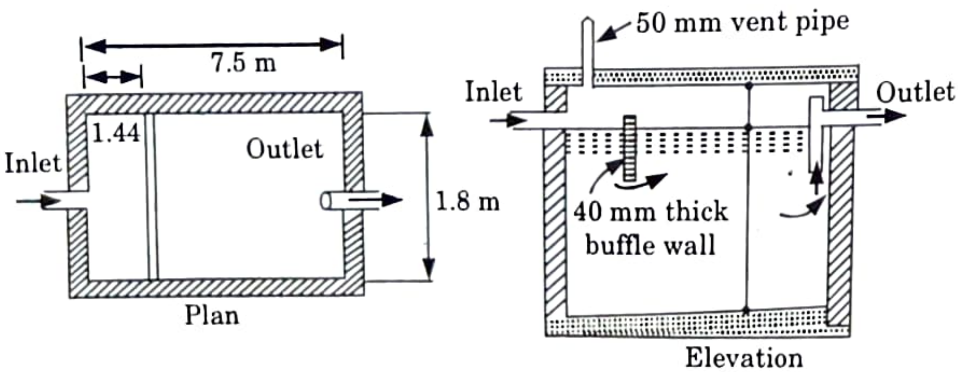


Fig. 5.24.1. Septic tank.

Que 5.25. **Design the septic tank for the following data :**

Number of people = 100

Sewage/capita/day = 120 litres

Desludging period = 1 year

Length : Width = 4 : 1

AKTU 2015-16, Marks 05

Answer

Given : Population = 100, Per capita demand = 120 l

Desludging period = 1 yr, $L : B = 4 : 1$

To Find : Design of septic tank

1. The quantity of water supplied

$$= \text{Per capita rate} \times \text{Population}$$
$$= 120 \times 100 \text{ litres/day} = 12000 \text{ litres/day}$$

2. Assuming that 80 % of water supplied becomes sewage, we have the quantity of sewage produced,

$$= 12000 \times 0.8 = 9600 \text{ litres/day}$$

3. Assuming the detention time to be 24 hours, we have quantity of sewage produced

$$= 9600 \times \frac{24}{24} = 9600 \text{ liters}$$

4. Now assuming the rate of deposited sludge 30 litres/capita/year; and also assuming period of cleaning of 1 year, we have
The volume of sludge deposited

$$= 30 \times 100 \times 1 = 3000 \text{ litres}$$

5. Total required capacity of the tank

$$= \text{Capacity for sewage} + \text{Capacity for sludge}$$
$$= 9600 + 3000 = 12600 \text{ litres} = 12.6 \text{ m}^3$$

6. Assuming 1.5 m as the depth of the tank, we have the surface area of the tank,

$$A = \frac{12.6}{1.5} \text{m}^2 = 8.4 \text{ m}^2$$

8. Ratio of length to width is 4:1, we get

$$4B^2 = 8.4$$
$$B = 1.44 \text{ m}$$
$$\text{Provide width} = 1.5 \text{ m and}$$
$$\text{Provide length} = 4 \times 1.5 = 6 \text{ m}$$

Area of cross-section provided

$$= 6 \times 1.5 = 9 \text{ m}^2$$

9. Thus, the dimension of the septic tank will be 6 m × 1.5 m × (1.5 + 0.3) m. (Free board = 0.3 m).

Que 5.26. **Design a septic tank with neat sketch for a hostel having 175 students. Design sewage flow is 70 lpcd. Desludging period is one year. What would be the size of the dispersion trench, if the effluent from the septic tank is to be discharged in it ?**

AKTU 2017-18, Marks 10

Answer

Given : Population = 175, Sewage flow = 70 lpcd
Desludging period = 1 yr.
To Find : Design septic tank and size of dispersion trench.
Assume : Detention period = 8 hr

1. Quantity of water supplied

$$= \text{Per capita rate} \times \text{Population}$$
$$= 70 \times 175 = 12250 \text{ l/day}$$

2. Assuming that 80 % of water supplied becomes sewage, we have,
The quantity of sewage produced

$$= \frac{80}{100} \times 12250 = 9800 \text{ l/day}$$

3. As given, the detention time is 8 hours, we have
Quantity of sewage produced during detention period

$$= 9{,}800 \times \frac{8}{24} = 3266.67 \text{ litre}$$

4. Now, assuming the rate of deposited sludge as 30 l/capita/year; and also assuming the period of cleaning as 1 year, we have
Volume of sludge deposited

$$= 30 \times 175 \times 1 = 5250 \text{ l.}$$

5. Total required capacity of the tank

$$= \text{Capacity for sewage} + \text{Capacity for sludge}$$
$$= 3266.67 + 5250 = 8516.67 \text{ l} = 8.52 \text{ m}^3$$

6. Assuming 1.0 m as depth of the tank, we have (1.0 + 0.3) free board depth

$$\text{Surface area} = \frac{8.52}{1.0} = 8.52 \text{ m}^2$$

7. If the ratio of $\frac{L}{B} = \frac{3}{1}$, we have

$$3B^2 = 8.52$$
$$\text{Width of tank, } B = 1.685 = 1.7 \text{ m}$$
$$\text{Length of tank, } L = 3 \times B = 3 \times 1.7 = 5.1 \text{ m}$$

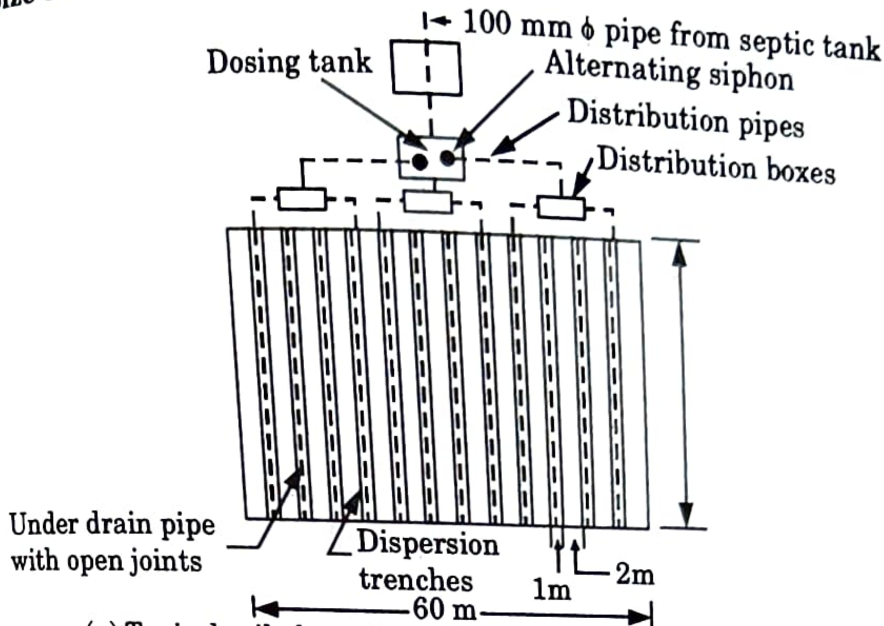
8. Area of cross-section provided

$$= 1.7 \times 5.1 = 8.67 \text{ m}^2$$

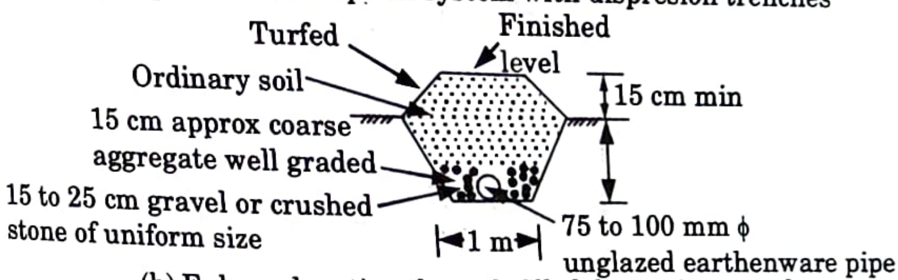
9. Tank size = 5.1 m × 1.7 m × 1.3 m

10. **Sketch of Septic tank :** Refer Q. 5.24, Page 5–31B, Unit-5.

11. **Size of the Dispersion Trench :**



(a) Typical soil absorption system with dispresion trenches



(b) Enlarged section through filled dispersion trench

Fig. 5.26.1. Dispersion trench system.

Que 5.27. **Design a septic tank for a colony of population 150 persons. And draw a neat sketch with details. (Assume data wherever necessary)**

AKTU 2016-17, Marks 10

Answer

Given : Population of colony = 150 persons
To Find : Design a septic tank

Assume the per capita water demand is 120 litres.

1. The quantity of water supplied

$$= \text{Population} \times \text{Per capita rate}$$
$$= 150 \times 120 \text{ litres/day} = 18{,}000 \text{ l/day}$$

2. Assuming that 80 % of water supplied becomes sewage,

The quantity of sewage produced

$$= 18{,}000 \times 0.8 = 14{,}400 \text{ l/day}$$

3. 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)

$$= 14,400 \times 24/24 = 14,400 \text{ litres.}$$

4. Now assuming the rate of deposited sludge as 30 litres/capita/year; and also assuming the period of cleaning as 1 year,

The volume of sludge deposited

$$= 30 \times 150 \times 1 = 4,500 \text{ litres}$$

5. Total required capacity of the tank

$$= \text{Capacity for sewage} + \text{Capacity for sludge}$$
$$= 14,400 + 4,500 = 18,900 \text{ litres} = 18.9 \text{ m}^3$$

6. Assuming 1.5 m as the depth of the tank, we have

The surface area of the tank

$$= \frac{18.9}{1.5} \text{ m}^2 = 12.6 \text{ m}^2$$

7. If the ratio of the length to width is kept as 3 : 1, we have

$$3 \times B^2 = 12.6$$

or $$B = \sqrt{\frac{12.6}{3}} = 2.05 \text{ m (say 2.1 m)}$$

Provide width = 2.1 m, and

Provide length of the tank = 6 m.

8. Area of cross-section provided

$$= 6 \times 2.1 = 12.6 \text{ m}^2$$

9. Thus, the dimensions of the septic tank will be 6 m × 2.1 m × (1.5 + 0.3) m overall depth.

[0.3 m used as free-board]

Hence, use a size of tank 6.3 m × 2.1 m × 1.8 m.

Sketch : Refer Q. 5.24, Page 5–31B, Unit-5.

Que 5.28. **Discuss in brief Imhoff tanks. Design Imhoff tank for a town having population 17000 persons. The rate of sewage is 150 l/day. Assume suitably, any data not given.**

AKTU 2013-14, Marks 10

Answer

A. Imhoff Tank :

1. An Imhoff tank is an improvement over septic tank, in which the incoming sewage is not allowed to get mixed up with the sludge produced, and the outgoing effluent is not allowed to carry with it large amount of organic load, as in the case of a septic tank.

2. They are sometimes also known as two-storey digestion tanks.

B. **Numerical :**

Given : Population = 17000, Rate of sewage = 150 l/day

To Find : Size of Imhoff tank

Design of Sedimentation Chamber :

1. The sewage discharge per day

$$= 17,000 \times 150 = 25,50,000 \text{ l/d}$$
$$= 2550 \text{ m}^3\text{/day}$$

2. Assuming the detention period = 2 hours

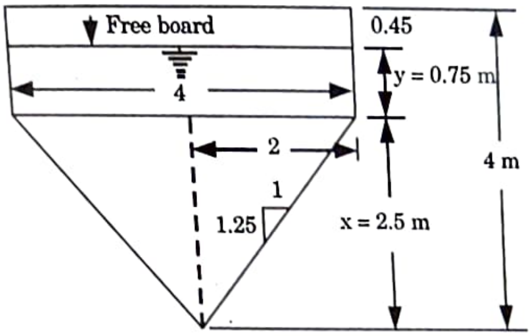


Fig. 5.28.1.

3. Volume of sewage entering in two hours, *i.e.*, the capacity of the chamber

$$= 150 \times 17000 \times \frac{2}{24}$$
$$= 212500 \text{ l} = 212.5 \text{ m}^3$$

4. Assume an effective depth of 2.m (effective depth includes part of the bottom sloping walls of the chamber) and a width of 4 m (say).

5. Length of chamber = $\dfrac{212.5}{2 \times 4}$ = 26.5 = 28 m

6. This length is too large for a single tank. So, let us adopt two tank units, each of length 14 m and width 4 m then

$$\frac{L}{B} = \frac{14}{4} = 3.5 \text{ m}$$

Which is between 3 to 5 and, therefore satisfactory.

7. Chamber dimensions = 14 m × 4 m × 2 m

8. Now, discharge passing each unit = $\dfrac{1}{2}$ × Total discharge = $\dfrac{1}{2}$ × 2.55

= 1.275 Mld

9. **Check for Velocity :** Length of tank = velocity × detention time

$$14 = v \times 2 \times 60$$

$$v = 0.12 \text{ m/min} < 0.3 \text{ m/minute, safe}$$

10. **Check for Surface Loading :**

$$\text{Surface loading} = \frac{Q}{BL} = \frac{1.275 \times 10^6}{4 \times 14}$$

$$= 22767.85 \text{ l/m}^2\text{/day} < 3000 \text{ l/m}^2\text{/day}$$

11. Depth of the rectangular and sloping portions of the sedimentation chamber :

i. Bottom side slope = 1H : 1.25 V

Height of sloping bottom, $n = 1.25 \times \frac{4}{2} = 2.5$ m

ii. Effective depth = 2 m

iii. Height of vertical portion below liquid surface,

$$y = 2 - \frac{1}{2} \times 2.5 = 0.75 \text{ m}$$

iv. Total depth = 0.45 (Freeboard) + 0.75 + 2.5 = 3.7 = 4 m

PART-9

Working of UASBR.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.29. **What is UASBR ? Discuss its features.**

AKTU 2014-15, Marks 05

Answer

Upflow Anaerobic Sludge Blanket Reactor (UASBR) :

i. This is also an up-flow type reactor as shown in Fig. 5.29.1 in which a blanket of biologically formed granules works as packing material.

ii. When uniformly distributed wastewater is fed from the bottom of the tank, liquid passes through the digestion zone of the reactor where solid-liquid separation takes place.

iii. The separated settling solids return to the active blanket zone while the liquid passes over the weir as effluent.

iv. The waste solids get attached to the media (biomass) and are stabilized, and the gas produced due to stabilization of waste is collected in the gas dome.

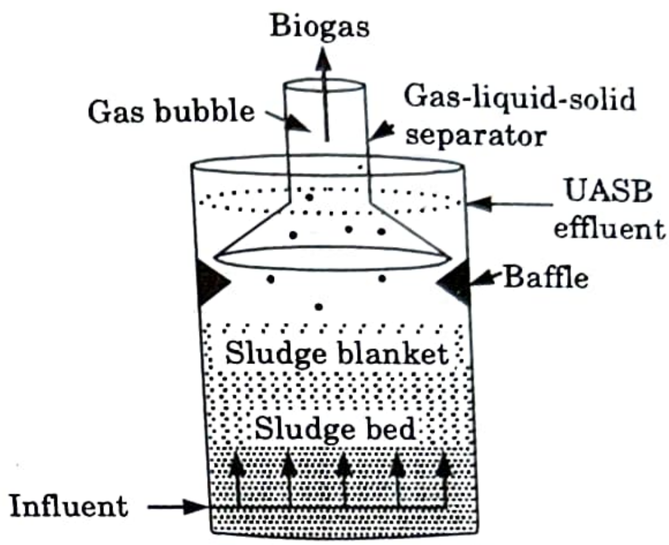


Fig 5.29.1. UASBR.

Features :

1. The slope of the settler (*i.e.*, the inclined wall of the gas collector) should be between 45-60°.
2. The surface area of the apertures between the gas collators should be 15-20 % of the reactor surface area.
3. The height of the gas collector should be between 1.5-2 m at reactor heights of 5.6 m.
4. Scum layer baffles should be installed in front of the effluent weirs.
5. Good removal efficiencies.
6. Low sludge production.
7. Generation of methane gas and N, P, K concentration are retained.

Que 5.30. **With the help of neat sketch explain the functions and operations of UASB. And also state its advantages.**

AKTU 2016-17, Marks 15

Answer

A. Functions of UASB :

1. The upflow anaerobic sludge blanket (UASB) reactor maintains a high concentration of biomass through the formation of highly settleable microbial sludge aggregates.
2. Retention of the bacteria containing sludge in the reactor is one of the most important features of the UASB process.

B. Operation :

1. The wastewater enters the tank from the bottom, and flows upward through the sludge bed, which gets formed during the process itself.

2. The sludge bed develops micro-organisms capable of flourishing in an oxygen deficient environment. The sludge bed (blanket) traps the suspended organics of the upmoving wastewater.

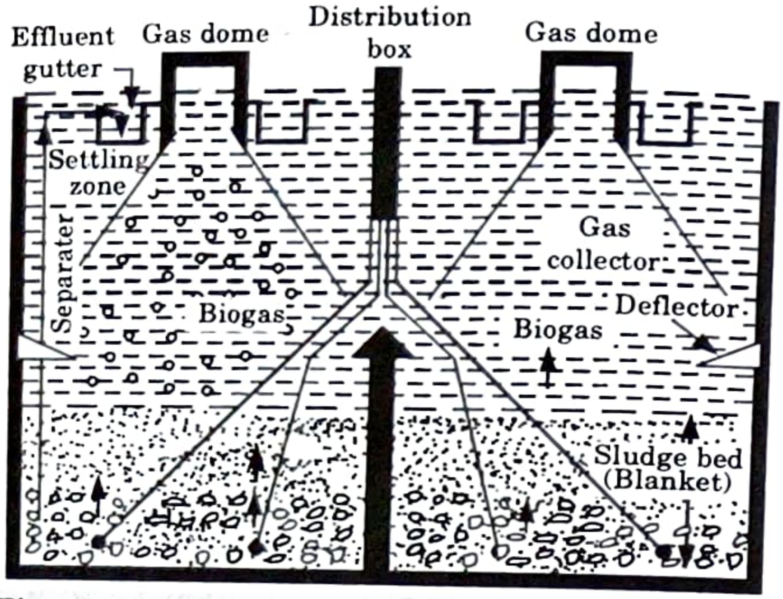


Fig. 5.31.1. Cross-section of a typical UASB reactor.

3. The suspended solid trapped in the sludge bed are degraded by the anaerobic and anaerobically working facultative bacteria, producing methane and carbon dioxide.

4. The biogas produced during the anaerobic decomposition helps in providing gentle mixing and stirring of the biomass, thereby increasing the efficiency of decomposition, reducing the BOD and suspended solids of the wastewater.

5. The methane or biogas is collected at the top of the tank in a gas collector, from where it can be withdrawn for use as a by-product, while the water sludge mixture is made to enter a settling tank where the sludge settles down and flows back into the bottom of the reactor.

6. The sludge will show good settling properties after an initial start up period, followed by granulation, forming a sludge blanket or sludge bed in the lower part of the reactor.

7. The UASB evidently operates as a suspended growth system, with no packing material in the reactor.

C. Advantages : Following are the advantages of UASB :

i. Low energy consumption.

ii. Absence of noise and odour nuisance.

iii. Low initial investment and maintenance cost.

iv. Methane rich biogas production.

v. Production of enriched nutrients sludge.

PART-10

Other Emerging Technologies for Wastewater Treatment.

CONCEPT OUTLINE

Duckweed Pond : It is the pond which consists of duckweed plant. Duckweed plants are the world's smallest and simplest flowering plant.

Vermiculture : It is organic process of using worms, usually red worms, to decompose yard, food and paper waste into rich bi-product including worm castings, vermicompost and worm tea which are in turn used to fertilize organically and safely all type of plant and as a soil amendment.

Root Zone Technology : The root zone treatment system also known as the reed bed system or constructed wetland system is a selected filter bed consisting of a sand/gravel/soil system occasionally with a cohesive element, planted with vegetation that can grow in wetlands.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.31. **Write short notes on duckweed pond, vermiculture and root zone technologies.** **AKTU 2017-18, Marks 10**

Answer

1. **Duckweed Pond :**
   i. Duckweed is a small free-floating and fast growth aquatic plant-has great ability to reduce the BOD, COD, suspended solids, bacterial and other pathogens from waste water.
   ii. It is a complete feed for fish, and due to the high content of proteins and vitamins A and C, it is also a highly nutritious feed for to 3 times when fed with duckweed, than with other conventional feeds in ponds.
   iii. Reduction of BOD, COD in effluents varies from 80-90 % at the retention time of 7-8 days.
2. **Vermiculture :**
   i. Vermiculture is the process of using worms to decompose organic food waste, turning the waste into a nutrient-rich material capable of supplying necessary nutrients to help sustain plant growth.

ii. The goal is to continually increase the number of worms so that you can have a sustainable harvest.

3. Root Zone Technologies :

i. Root zone systems are artificially prepared wetlands comprising of clay or plastic lined excavation and emergent vegetation growing on gravel/ sand mixtures and is also known as constructed wetland.

ii. This method combines mechanical filtration, chemical precipitation and biological degradation in one step for the treatment of wastewater.

iii. The process in a root zone system to treat the sewage begins with passing the raw effluent (after removing grit or floating material) horizontally or vertically through a bed of soil having impervious bottom.

iv. The effluent percolates through the bed that has all the roots of the wetland plants spread very thickly and aerobically oxidize the organic matter of the effluent.

v. The characteristics of plants of absorbing oxygen through their leaves and passing it down to roots through their stems which are hollow, is utilized as a bio-pump.

vi. Away from the roots, anaerobic digestion also takes place. The filtering action of the soil bed, the action with fungi etc. and chemical action with certain existing or added inorganic chemicals help in finally obtaining very clear and clean water.

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