Q.10 Determine the dimensions of a high rate trickling filter for the following data:

(i) Sewage flow = 3.0 MLD

(ii) Recirculation ratio = 1.5

(iii) *BOD* of raw sewage = 250 mg/L

(iv) *BOD* removed in primary tank = 25%

(v) Final effluent *BOD* desired = 30 mg/L

By what % the diameter of the filter will have to be modified if it is to be designed as a standard r trickling filter for the above requirement.

[25 marks : 19

Solution:

$$\text{Total BOD present in raw sewage} = 3.0 \times 10^6 \times 250 \times 10^{-6} = 750 \text{ kg/day}$$

$$BOD \text{ removed in the primary clarifier} = 25\%$$

$$\therefore\ BOD \text{ entering per day in the filter units} = 0.75 \times 750 = 562.5 \text{ kg}$$

Permissible *BOD* concentration in the effluent = 30 mg/L

$$\therefore\quad \text{BOD allowed to go into the effluent} = 30 \text{ mg/L} \times 3.0 \times 10^6 = 90 \text{ kg}$$

$$\therefore\quad \text{BOD removed by the filter per day} = 562.5 - 90 = 472.5 \text{ kg}$$

$$\text{Efficiency of filter} = \frac{\text{BOD Removed}}{\text{Total BOD Applied}} \times 100 = \frac{472.5}{562.5} \times 100 = 84\%$$

But we know that
$$\eta = \frac{100}{1 + 0.0044\sqrt{\dfrac{Y}{VF}}}$$

where *Y* is Total BOD applied to the filter per day in kg, *V* is filter volume in ha-m and *F* is Recirculation fa

But
$$F = \frac{1 + (R/I)}{[1 + 0.1(R/I)]^2}$$

where *R*/*I* is called recirculation ratio

$$\therefore\quad F = \frac{1 + 1.5}{[1 + 0.1 \times 1.5]^2} = 1.89$$

$$\because\quad \eta = \frac{100}{1 + 0.0044\sqrt{\dfrac{Y}{VF}}}$$

$$\Rightarrow\quad 84 = \frac{100}{1 + 0.0044\sqrt{\dfrac{562.5}{V \times 1.89}}}$$

$$\Rightarrow\quad 1 + 0.0044\sqrt{\frac{297.62}{V}} = \frac{100}{84}$$

$$\Rightarrow\quad \frac{297.62}{V} = \left[\frac{(100/84) - 1}{0.0044}\right]^2$$

$$\Rightarrow\quad V = \frac{297.62}{1874.03} = 0.1588 \text{ ha-m} = 1588 \text{ m}^3$$

Using 1.5 m depth of the filter, we get

$$\text{Area required} = \frac{1588}{1.5} = 1058.67 \text{ m}^2$$

$$\therefore\quad \text{Diameter of filter tank required} = \sqrt{\frac{1058.67 \times 4}{\pi}} = 36.7 \text{ m}$$

For a standard rate trickling filter, recirculation ratio is zero.

$$\therefore\quad F = \frac{1 + (R/I)}{[1 + 0.1(R/I)]^2} = \frac{1 + 0}{[1 + 0]^2} = 1$$

$$\because \quad \eta = \frac{100}{1+0.0044\sqrt{\frac{Y}{VF}}}$$

$$\Rightarrow \quad 84 = \frac{100}{1+0.0044\sqrt{\frac{562.5}{V\times 1}}}$$

$$\Rightarrow \quad 1+0.0044\sqrt{\frac{562.5}{V}} = \frac{100}{84}$$

$$\Rightarrow \quad \sqrt{\frac{562.5}{V}} = \frac{1.19-1}{0.0044}$$

$$\Rightarrow \quad \frac{562.5}{V} = 1874.03$$

$$\Rightarrow \quad V = 0.3 \text{ ha-m} = 3000 \text{ m}^3$$

Again, using depth of filter as 1.5 m, we get

$$\text{Area of filter} = \frac{3000}{1.5} = 2000 \text{ m}^2$$

$$\therefore \quad \text{Diameter of filter tank required} = \sqrt{\frac{2000\times 4}{\pi}} = 50.46 \text{ m}$$

Diameter of high rate trickling filter tank = 36.7 m

Diameter of standard rate trickling filter tank = 50.46 m

$$\text{Percentage change in diameter of high rate trickling filter} = \left(\frac{50.46-36.7}{36.7}\right)\times 100 = 37.5\%$$

Thus, the diameter of filter should be increased by 37.5%.

Q.11 Estimate efficiency of a 30 m diameter and 1 m deep single stage high rate trickling filter for the following data:

(i) Sewage flow = 4.5 MLD (million litres per day) **(ii) Recirculation ratio = 1.4**

(iii) BOD of raw sewage = 250 mg/L **(iv) BOD removed in primary clarifier = 25%.**

[20 marks : 1997]

Solution:

Total BOD present in raw sewage per day = $4.5 \times 10^6 \times 250 \times 10^{-6} = 1125$ kg

BOD removed in primary clarifier = 25%

∴ BOD entering in the filtering unit = 0.75 × 1125 = 843.75 kg per day

We know that
$$\eta = \frac{100}{1+0.0044\sqrt{\frac{Y}{VF}}}$$

where
$$Y = 843.75 \text{ kg per day}$$

$$V = \frac{\pi}{4}\times(30)^2\times 1 = 706.86 \text{ m}^3 = 0.0707 \text{ ha-m}$$

But,
$$F = \frac{1+(R/I)}{[1+0.1(R/I)]^2} = \frac{1+1.4}{[1+0.1\times 1.4]^2} = 1.847$$

$$\because \quad \eta = \frac{100}{1+0.0044\sqrt{\frac{Y}{VF}}}$$

$$\Rightarrow \quad \eta = \frac{100}{1+0.0044\sqrt{\frac{843.75}{0.0707\times 1.847}}} = 73.87\% \text{ (Ans.)}$$

Q.12 Results of chlorine demand test on a raw water are tabulated below:

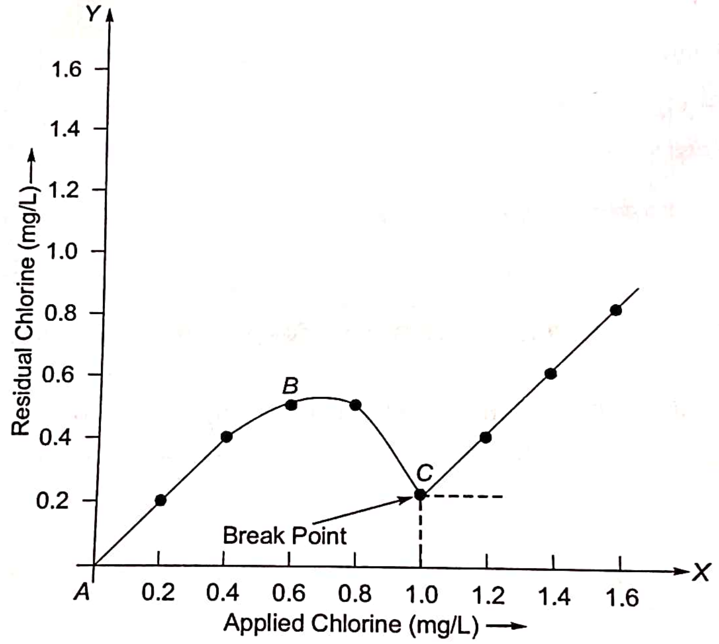
Sample No.	Chlorine dosage (mg/L)	Residual chlorine after 10 min contact (mg/L)
1	0.2	0.19
2	0.4	0.36
3	0.6	0.50
4	0.8	0.48
5	1.0	0.20
6	1.2	0.40
7	1.4	0.60
8	1.6	0.80

By plotting the data, determine 'break point dosage'. What is the 'chlorine demand' at dosage 1.2 mg/L?

[10 marks : 1997]

Solution:

The given data is plotted as shown below with applied chlorine on *X*-axis and residual chlorine on *Y*-axis.



Break point is represented by Point *C*, and hence the break point dosage is 1.0 mg/L.

Chlorine demand is the difference between applied chlorine and residual chlorine and it becomes equal to 1.0 – 0.2 = 0.8 mg/L at break point. This chlorine demand becomes constant thereafter and all added chlorine appears as free chlorine. Thus at any dosage above 1.0 mg/L, the chlorine demand will remain steady and equal to 0.8 mg/L.

Hence, the chlorine demand at a dosage of 1.2 mg/L will be equal to 0.8 mg/L. This tallies with the given data of chlorine residual of 0.4 mg/L with a dose of 1.2 mg/L, giving chlorine demand = 1.2 – 0.4 = 0.8 mg/L.

Q.13 Water has to be supplied to a town with one lakh population at the rate of 150 litre/capita/day from a river 2000 m away. The difference in elevation between the lowest water level in the sump and reservoir is 40 m. If the demand has to be supplied in 8 hrs, determine the size of the main and the brake horse power of the pumps required. Assume maximum demand as 1.5 times the average demand. Assume $f = 0.03$, velocity in the pipe = 2.4 m/s and efficiency of pump = 80%.

[15 marks : 1997]

Solution:

$$\text{Average water demand} = \text{Population} \times \text{daily rate of water supply}$$
$$= 100{,}000 \times 150 = 15 \text{ MLD}$$
$$\therefore \quad \text{Maximum demand} = 1.5 \times \text{Average demand}$$
$$= 1.5 \times 15 = 22.5 \text{ MLD}$$
$$\therefore \quad \text{Maximum discharge required} = \frac{22.5 \times 10^6}{10^3 \times 8 \times 60 \times 60} = 0.7812 \text{ m}^3\text{/s}$$

Now,

$$\text{Area of pipe, } A = \frac{Q}{V} = \frac{0.7812}{2.4} = 0.3255 \text{ m}^2$$
$$\Rightarrow \quad d^2 = \frac{0.3255 \times 4}{\pi}$$
$$\Rightarrow \quad d = 0.644 \text{ m}$$

$$\text{Head loss due to friction,} \quad h_f = \frac{fLV^2}{2gd} = \frac{0.03 \times 2000 \times (2.4)^2}{2 \times 9.81 \times 0.644} = 27.36 \text{ m}$$

Required lift head between sump and reservoir = 40 m

∴ Total head against which pump has to work = Total lift head + Friction head loss

$$= 40 + 27.36$$
$$= 67.36 \text{ m}$$

$$\text{Brake horse power} = \frac{\gamma_w QH}{\eta \times 0.7457} = \frac{9.81 \times 0.7812 \times 67.36}{0.80 \times 0.7457} = 865.38 \text{ BHP}$$

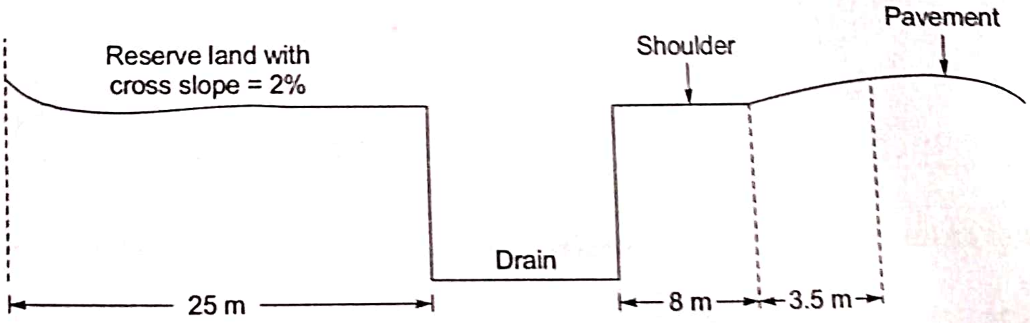
Q.14 The surface water from airport road side is drained to the longitudinal side drain from across one half of a bituminous pavement surface of total width 7.0 m, shoulder and adjoining land of width 8.0 m on one side of the drain. On the other side of the drain, water flows across from reserve land with average turf and 2% cross slope towards the side drain, the widthof this strip of land being 25 m. The inlet time may be assumed to be 10 mm for these conditions. The runoff coefficients of the pavement, shoulder and reserve land with turf are 0.8, 0.25 and 0.35 respectively. The length of the stretch of land parallel to the road from where the water is expected to flow to the side drain is 400 m. Estimate the quantity of runoff flowing in the drain assuming 10 year frequency. The side drain will pass through clayey soil with allowable velocity of flow as 1.33 m/s. Intensity-duration chart for 10 year frequency is:

Duration (minutes)	5	10	15	20	30
Intensity (mm/hr)	160	150	125	110	95

[15 marks : 1997]

Solution:

Let A be the area and K be the runoff coefficient respectively. Let subscripts 1, 2, 3 denote parameters for pavement, shoulder and reserve land respectively.



$$K_1 = 0.80; K_2 = 0.25; K_3 = 0.35$$
$$A_1 = 3.5 \times 400 = 1400 \text{ m}^2$$

$$A_2 = 8 \times 400 = 3200 \text{ m}^2$$

$$A_3 = 25 \times 400 = 10{,}000 \text{ m}^2$$

We know that runoff coefficient (K) for the entire area can be given by

$$K = \frac{K_1A_1 + K_2A_2 + K_3A_3}{A_1 + A_2 + A_3}$$

$$= \frac{(0.80 \times 1400) + (0.25 \times 3200) + (0.35 \times 10{,}000)}{1400 + 3200 + 10{,}000} = 0.3712$$

Given that $T_i = 10$ minutes

Channel flow time, $T_f = \dfrac{\text{Length of drain}}{\text{Velocity of flow in drain}} = \dfrac{400}{1.33} = 300.752 \text{ sec} = 5.013$ minutes

Time of concentration, $T_c = T_i + T_f = 10 + 5.013 = 15.013$ minutes

From the intensity duration chart, intensity of rainfall corresponding to 15 minutes is given by

$$p_c = 125 \text{ mm/hr}$$

∴ Quantity of runoff, $Q = Kp_cA$

$$= 0.3712 \times \frac{125 \times 10^{-3}}{60 \times 60} \times 400 \times (3.5 + 8 + 25) = 0.1882 \text{ m}^3/\text{sec}$$

Q.15 An environmental survey for a town with population of 30000 revealed the following: Domestic sewage produced at the rate of 240 litres per capita per day. The per capita BOD of the domestic sewage being 72 g/day.

Industrial wastes produced were estimated as 4 million litres per day with BOD of 1500 mg/L.

The sewage effluents can be discharged into a river with a minimum dry weather flow of 4500 litres/sec and a saturation dissolved oxygen content of 7 mg/L. It is necessary to maintain a dissolved oxygen content of 4 mg/L in the stream. For designing a sewage treatment plant, determine the degree of treatment required to be given to the sewage. Assume

k_D = Deoxygenation coefficient = 0.1

k_R = Reoxygenation coefficient = 0.3

An overall expansion factor of 10% to be provided. [20 marks : 1997]

Solution:

Per capita BOD of the domestic sewage = 72 gm/day = 72×10^3 mg/day

Per capita sewage produced = 240 lit/day

∴ BOD per litre of the domestic sewage = $\dfrac{72 \times 10^3}{240} = 300$ mg/L

Amount of domestic waste water produced per day = $30000 \times 240 = 7.2 \times 10^6$ litres

∴ Net BOD of all waste waters (domestic + industrial) = $\dfrac{7.2 \times 300 + 4 \times 1500}{7.2 + 4} = 728.57$ mg/L

Total waste water discharge = $\dfrac{(7.2 + 4) \times 10^6}{24 \times 60 \times 60} = 129.63$ lit/sec

Total waster water discharge with 10% expansion = $129.63 + \dfrac{10}{100} \times 129.63 = 142.593$ lit/sec

Now, Initial *DO* of saturated stream water = 7 mg/L

Assuming that the *DO* of waste water is nil, at the starting point.

$$DO \text{ of the mixture} = \frac{DO \text{ of river} \times Q_r + DO \text{ of sewage} \times Q_s}{Q_r + Q_s}$$

where $Q_r = 4500$ lit/sec; $Q_s = 142.593$ lit/sec

$$\therefore \quad DO \text{ of mixture} = \frac{7 \times 4500 + 0 \times 142.593}{4500 + 142.593} = 6.785 \text{ mg/L}$$

$$\therefore \quad \text{Initial deficit in } DO = D_o = 7 - 6.785 = 0.215 \text{ mg/L}$$

Given that

$$f = \frac{k_R}{k_D} = \frac{0.3}{0.1} = 3$$

$$D_c = 7 - 4 = 3 \text{ mg/L}$$

$$D_o = 0.215 \text{ mg/L}$$

We know that

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

$$\Rightarrow \quad \left(\frac{L_o}{3 \times 3}\right)^{3-1} = 3\left[1 - (3-1) \times \frac{0.215}{L_o}\right]$$

$$\Rightarrow \quad \frac{L_o^2}{81} = 3\left[1 - \frac{0.43}{L_o}\right]$$

$$\Rightarrow \quad \frac{L_o^2}{3 \times 81} = \frac{L_o - 0.43}{L_o}$$

$$\Rightarrow \quad L_o^3 = 243L_o - 104.49$$

$$\Rightarrow \quad L_o^3 - 243L_o + 104.49 = 0$$

$$\Rightarrow \quad L_o = 15.37 \text{ mg/L}$$

Maximum permissible 5 day BOD of the mix at mix temperature

$$= L_o\left[1 - 10^{-k_D t}\right] = 15.37\,[1 - 10^{-0.1 \times 5}] = 10.51 \text{ mg/L}$$

$$\text{Again BOD}_{\text{mix}} = \frac{C_s \times Q_s + C_r\, Q_r}{Q_s + Q_r}$$

$$\Rightarrow \quad 10.51 = \frac{C_s \times 142.593 + 0 \times 4500}{142.593 + 4500}$$

where C_s = Maximum permissible BOD$_5$ of waste water

$$\Rightarrow \quad C_s = \frac{10.51 \times (142.593 + 4500)}{142.593}$$

$$\Rightarrow \quad C_s = 342.19 \text{ mg/L}$$

∴ Degree of treatment required

$$= \left(\frac{\text{Initial BOD of city waste water} - \text{Max. permissible BOD of waste water}}{\text{Initial BOD of city waste water}}\right) \times 100$$

$$= \frac{728.57 \times 128.57 - 342.19 \times (128.57 \times 1.1)}{728.57 \times 128.57}$$

$$= 48.3\%$$

Q.16 A rectangular settling tank without mechanical equipment is to treat 1 million litres of raw water per day. If the design criteria are that the detention period is 2.5 hours, the velocity of flow is 8 cm/minutes and depth of water and sediment is 4.5 m, then what would be:

(i) The length of the tank?

(ii) The width of the tank if an allowance of 1.5 m is to be made for sediment?

(iii) Overflow rate of the tank?

[15 marks : 1998]

Solution:

Given data:

Discharge, $Q = 10^6$ litres per day

Detention period, $t = 2.5$ hours

Velocity of flow, $v_h = 8$ cm/min

Depth of water and sediment = 4.5 m

(i) We know that

$$v_h \times t = \text{Length of tank}$$

$$\Rightarrow \quad L = 8 \times 10^{-2} \times 2.5 \times 60$$

$$\Rightarrow \quad L = 12 \text{ m}$$

(ii) When an allowance of 1.5 m is made for sediment, then depth of water, $H = 4.5 - 1.5 = 3$ m

But, $$v_h = \frac{Q}{BH}$$

$$\Rightarrow \quad B = \frac{Q}{Hv_h}$$

$$\Rightarrow \quad B = \frac{\dfrac{10^3 \text{ m}^3}{24 \times 60 \text{ min}}}{3 \times 8 \times 10^{-2}} = 2.9 \text{ m}$$

(iii) Overflow rate $= \dfrac{Q}{BL} = \dfrac{10^6 \times (10^{-3}/24)}{2.9 \times 12} = 1.1973 \text{ m}^3/\text{hr}/\text{m}^2$

Q.17 Suggest a suitable disinfection device for water supplies in rural areas with open dug wells as the source of water.

[10 marks : 1998]

Solution:

Potassium Permanganate ($KMnO_4$) is used as a popular disinfectant for disinfecting well water supplies in villages which are generally contaminated with lesser amounts of bacteria. Besides killing bacteria, it also helps in oxidising the taste producing organic matter. It is therefore, sometimes added in small doses (such as 0.05 to 0.10 mg/L) even to filtered and chlorinated water. It has also been used as an algicide and for removing colour and iron from water.

For treating well water supplies, small amount of potassium permanganate is dissolved in a bucket of water and is mixed with well water, thoroughly. The addition of potassium permanganate to water produces pink colour. However, if the pink colour disappears, it shows that organic matter is present in water, and more quantity of $KMnO_4$ should be added, until the pink colour stands. The well should not be used for at least 48 hours after the addition of $KMnO_4$. The normal doses of this disinfectant varies between 1 to 2 mg/L with a contact period of 4 to 6 hours.

$KMnO_4$ though cheap, handy and quite useful, yet cannot guarantee 100% removal of bacteria. It can remove about 98% bacteria. It can possibly remove 100% organisms causing cholera, but is of little use against other disease organisms. Moreover, the water treated with $KMnO_4$, with the passage of time, produces a dark brown precipitate, which is noticeable as a coating on porcelain vessels and is difficult to remove without scouring. This method of disinfection is therefore not satisfactory and not recommended except for rural areas.

Q.18 What will be the maximum upper limit of BOD of a glucose solution of concentration 300 mg/L?

[10 marks : 1998]

Solution:

Since the $\frac{BOD}{COD}$ ratio varies between 0.92 to 1.0, the value of maximum ultimate *BOD*, in absence of BOD test, can be taken equal to *COD*. Moreover, the value of *COD*, can either be determined by the dichromate test for complex waste waters; or may be determined theoretically if the organic compounds and their concentrations present in waste waters are known. Such a theoretical oxygen demand of an organic compound can be calculated by writing the balanced reaction for the compound with oxygen to produce CO_2 and H_2O and other oxidised organic components.

In the given case, water contains only glucose, which is oxidised as follows:

$$\underset{180}{C_6H_{12}O_6} + \underset{192}{6O_2} \longrightarrow \underset{264}{6CO_2} + \underset{108}{6H_2O}$$

From the above equation, it is obvious that

180 mg of glucose require 192 mg of oxygen for complete oxidation

$\therefore$ Theoretical oxygen demand per mg of glucose $= \frac{192}{180} = 1.07$

$\therefore$ Total theoretical oxygen demand of 300 mg/L glucose solution $= 1.07 \times 300 = 321$ mg/L

This demand can be taken as the maximum ultimate *BOD*.

Hence, the maximum *BOD* = 321 mg/L

Q.19 The census record of a particular town shows the population figures as follows:

Years	1960	1970	1980	1990
Population	55,500	63,700	71,300	79,500

Estimate the population for the year 2020 by Decreasing Rate of Growth.

[10 marks : 1999]

Solution:

The decreasing rate of growth method is as follows:

Year	Population	Increase in Population	% Increase in Population (r)	Decrease in% Increase (r′)
1960	55,500			
		8,200	14.77	
1970	63,700			2.84
		7,600	11.93	
1980	71,300			0.43
		8,200	11.50	
1990	79,500			

$$\text{Avg. value of } \quad r' = \frac{2.84 + 0.43}{2} = 1.635$$

$$r = 11.50$$

$$P_{2000} = P_{1990} + \left(\frac{r - r'}{100}\right) \times P_{1990} = 79500 + \left(\frac{11.50 - 1.635}{100}\right) \times 79500 = 87{,}343$$

Q.22 A town of 200,000 population is to be supplied water from a source 2500 m away. The lowest water level in the source is 15 m below the water works of the town. The demand of water is estimated as 150 lit/capita/day. A pump of 300 HP is operated for 15 hours. If the maximum demand is 1.5 times the average demand, the velocity of flow through the rising main is 1.3 m/sec and the pump efficiency is 70%, determine (i) hydraulic gradient and (ii) friction factor for the pipe.

[15 marks : 1999]

Solution:

$$\text{Maximum demand} = \text{Population} \times 1.5 \times \text{average demand}$$
$$= 200{,}000 \times 1.5 \times 150 = 45 \text{ MLD}$$

The pumping is done for 15 hours a day, hence maximum discharge required for pumping,

$$Q = \frac{45 \times 10^6}{10^3 \times 15 \times 60 \times 60} = 0.8333 \text{ m}^3\text{/sec}$$

$$\text{HP of pump} = 300$$

But, we know that

$$HP = \frac{\gamma_w Q H}{0.7457 \times \eta}$$

$$\Rightarrow \quad 300 = \frac{9.81 \times 0.8333 \times H}{0.7457 \times 0.70}$$

$$\Rightarrow \quad H = 19.16 \text{ m}$$

But total head (H) = head difference between source and water works + head loss due to friction in rising main

$$19.16 = 15 + h_f$$

$$\Rightarrow \quad h_f = 19.16 - 15$$

$$\Rightarrow \quad h_f = 4.16 \text{ m}$$

$$\Rightarrow \quad \text{Now length of pipe } (L) = 2500 \text{ m}$$

(i) $\text{Hydraulic gradient} = \dfrac{h_f}{L} = \dfrac{4.16}{2500} = \dfrac{1}{601}$

(ii) We know that

$$h_f = \frac{fLV^2}{2gd}$$

Now

$$\frac{\pi d^2}{4} = \frac{Q}{V} = \frac{0.8333}{1.3}$$

$$\therefore \quad d = \sqrt{\frac{0.8333}{1.3} \times \frac{4}{\pi}}$$

$$\Rightarrow \quad d = 0.9 \text{ m}$$

$$\because \quad h_f = \frac{fLV^2}{2gd}$$

$$\Rightarrow \quad f = \frac{4.16 \times 2 \times 9.81 \times 0.9}{2500 \times (1.3)^2} = 0.0174$$

Q.23 Compare 'Trickling Filter' and 'Recirculation with Bio-filters'.
Describe with a neat sketch the working of a 'Sludge digestion tank with floating cover'.

[7 + 8 = 15 marks : 1999]

Solution:

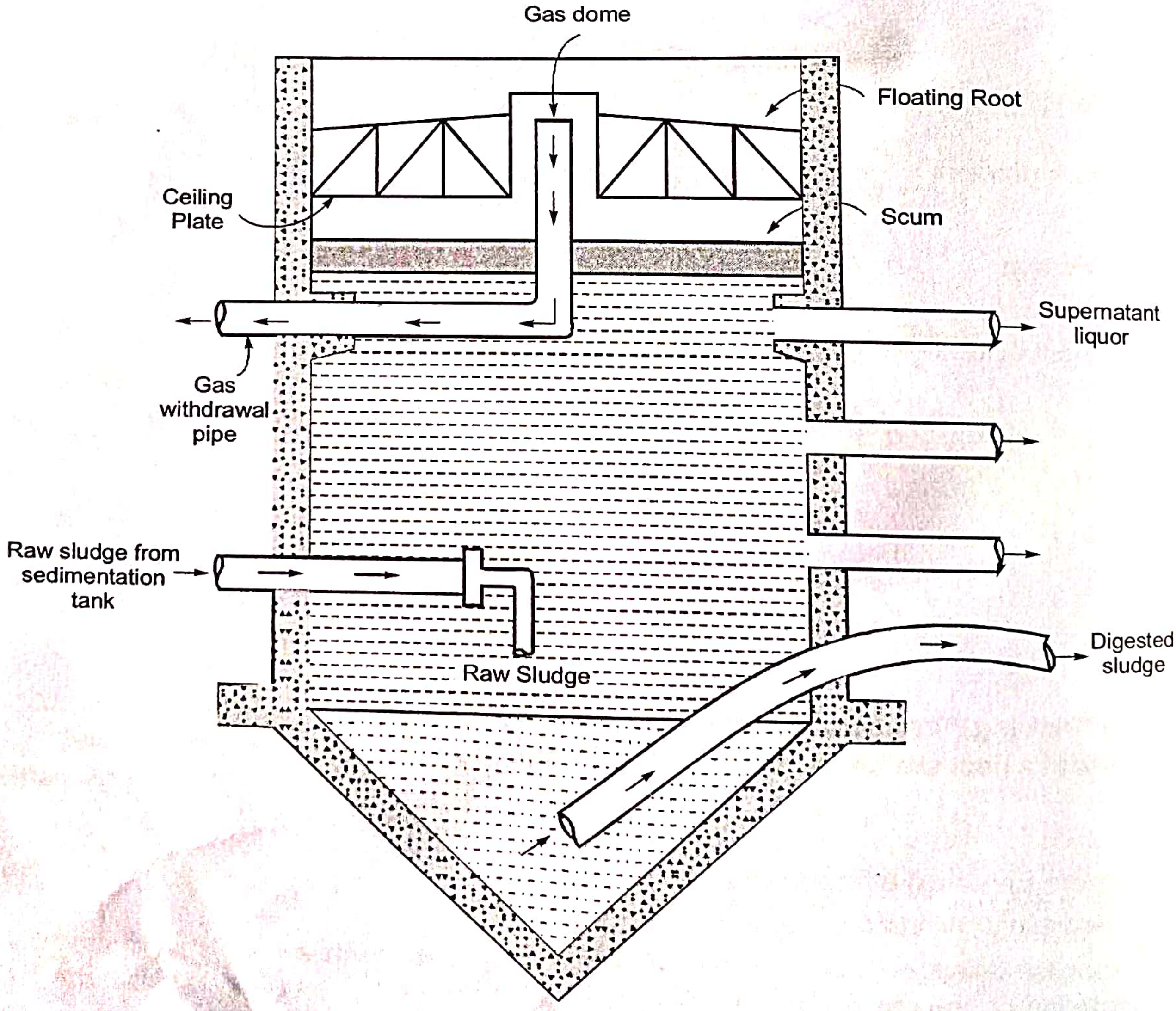
Trickling filters are classified in two types:

(i) Standard rate trickling filter (ii) High rate trickling filter

The construction details of these filters are same, except that provision is made in high rate trickling filters for recirculation of sewage through the filter, by pumping a part of the filtered effluent to the primary sedimentation tank, and repassing through it and the filter. The high rate trickling filters make it possible to pass sewage at greater loadings, thus require lesser space and lesser filter media. The value of hydraulic loading for conventional (standard rate) trickling filters may vary between 22 to 44 M litre/ha/day. The hydraulic loading can still be increased to about 110 to 330 M litre/ha/day in high rate trickling filters. The value of organic loading for conventional filters may vary between 900 to 2200 kg of BOD_5 per ha-m. This organic loading value can be further increased to about 6000 to 18000 kg of BOD_5 per ha-m in high rate trickling filters. The depth of high rate trickling filters varies between 1.2 to 1.8 m.

Bio filters are essentially high rate filters, but comparatively shallower than trickling filters. The depth varies between 1.2 m to 1.5 m (the depth is kept less on the consideration that the main action of treatment is involved in the upper surface layer of the filter). The filter utilizes recirculation of a portion of the filter effluent to the PST for a second passage through the filter. If additional treatment is necessary to lower the BOD content in the effluent, such as in the case of strong sewages, a second stage filter may be provided. Also the quality of the final effluent can also be changed by altering the loading rate and the recirculation ratio. These filters are capable of giving any degree of treatment by appropriate selection of flow diagram and recirculation ratio. Organic loading normally ranges between 9000 to 11000 kg of BOD_5 per ha-m per day. The total hydraulic loading may range between 110 to 330 million litres per day per hectare.

A sludge digestion tank consists of a circular RCC tank with hoppered bottom and having a floating roof over its top. The raw sludge is pumped into the tank, and when the tank is first put into operation, it is seeded with the digested sludge from another tank. A screw pump with an arrangement for circulating the sludge from bottom to top of the tank or vice versa is commonly used for stirring the sludge. Sometimes, power driven mechanical devices may be used for stirring the sludge. A typical sludge digestion tank is shown below.



Q.31 Following mean monthly flows were observed at a site on a stream in a typical year:

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Monthly flow (cumec)	15	10	8	6	5	12	25	40	71	60	40	20

Assuming that the stream flow is to be fully utilised for delivering water to a city to meet its fixed monthly demand by diversion of flow from storage reservoir through a conduit, find the capacity of the conduit in cumec for which it is to be designed. Determine the minimum storage capacity in ha-m of the storage reservoir to ensure that all the available flow is fully utilised to meet the constant monthly demand of the city.

[20 marks : 2001]

Solution:

Since the stream flow is to be fully utilized for delivering water to the city to meet its fixed monthly demand

∴ Average fixed monthly demand = Average monthly Inflow

$$= \frac{821.9232}{12} = 68.4936$$

S.No.	Month Inflow (cumec)	Monthly Inflow (Mm³)	Monthly Outflow (Mm³)	Monthly deficit	Monthly Surplus	Monthly deficit	Cum. Sul.	Cum.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	Jan	15	40.176	68.4936	28.3176	—	—	—
2.	Feb	10	24.192	68.4936	44.3016	—	—	—
3.	March	8	21.4272	68.4936	47.0664	—	—	—
4.	Apr	6	15.552	68.4936	52.9416	—	—	—
5.	May	5	13.392	68.4936	50.1016	—	—	—
6.	June	12	31.104	68.4936	37.3896	—	—	—
7.	July	25	66.960	68.4936	1.5336	—	261.652	
8.	August	40	107.136	68.4936	—	38.6424	—	—
9.	Sep	71	184.032	68.4936	—	115.5384	—	—
10.	Oct	60	160.704	68.4936	—	92.2104	—	—
11.	Nov	40	103.680	68.4936	—	35.1868	—	281.578
12.	Dec	20	53.568	68.4936	14.9256	—	14.9256	—
Total		312	821.9232					

The minimum storage is the maximum of cumulative surplus and cumulative deficit. Thus the minimum storage in storage reservoir = 281.578 Mm³ = 28157.8 ha-m

Design discharge in m³/s for the conduit $= \frac{821.9232 \times 10^6}{24 \times 3600 \times 365} = 26.06$ m³/s

Q.32 A trickling filter plant treats 1500 cum per day of sewage with a BOD_5 of 220 mg/L and a suspended solid concentration of 250 mg/L. Estimate the total solid production assuming that primary clarification removes 30% of BOD and 60% of influent solids. Take the solid production in the trickling filter as a 0.5 kg/kg of the applied BOD.

[10 marks : 2001]

Solution:

Solids removed in primary clarification units of the trickling filter plant

$= 60\%$ of influent suspended solids $= \frac{60}{100} \times 250 = 150$ mg/L

$$= \frac{150 \times 10^{-6}}{10^{-3}} \text{ kg/m}^3 = 150 \times 10^{-3} \text{ kg/m}^3$$

$\therefore$ Solids removed per day $= 150 \times 10^{-3} \times 1500 = 225$ kg

BOD_5 removed in primary clarification = 30%

$\therefore$ BOD applied to filters $= 100 - 30 = 70\%$

$$\therefore \text{Total BOD applied to filters} = 0.70 \times \frac{220 \times 10^{-6}}{10^{-3}} \times 1500 = 231 \text{ kg/day}$$

Solid production in filters = 0.5 kg/kg of BOD applied = $0.5 \times 231 = 115.5$ kg/day

$\therefore$ Total solid production = Solid removed in primary clarification + Solids produced in filters

= $225 + 115.5 = 340.5$ kg/day

Q.33 A waste water plant produces 1000 kg of dry solids per day at a moisture content of 95%. The solids are 70% volatile with a specific gravity of 1.05 and the remaining are non-volatile with a specific gravity of 2.5. Find the sludge volume after digestion, which reduces volatile solids content by 50% and decreases the moisture content to 90%.

[15 marks : 2001]

Solution:

Total solids produced = 1000 kg per day

Volatile solids = 70% of total solids produced

$$= \frac{70}{100} \times 1000 = 700 \text{ kg}$$

$\therefore$ Non-volatile solids $= 1000 - 700 = 300$ kg

Now, volatile solids removed in digestion = 50% of volatile solids $= \frac{50}{100} \times 700 = 350$ kg

$\therefore$ Volatile solids left in the digested sludge $= 700 - 350 = 350$ kg

Non-volatile solids in the digested sludge = 300 kg (as in original sludge)

We know that 90% moisture content of digested sludge indicates that in a 100 kg digested sludge, 90 kg is water and remaining 10 kg are solids.

Total amount of solids in the digested sludge $= 350 + 300 = 650$ kg

$$\therefore \text{Mass of water in the digested sludge} = 650 \times \frac{90}{10} = 5850 \text{ kg}$$

Density of volatile solids $= G_v \times \rho_w = 1.05 \times 1000 = 1050 \text{ kg/m}^3$

Density of non-volatile solids $= G_n \times \rho_w = 2.5 \times 1000 = 2500 \text{ kg/m}^3$

$$\text{Volume of volatile solids in the digested sludge} = \frac{\text{Mass}}{\text{Density}} = \frac{350}{1050} = 0.333 \text{ m}^3$$

$$\text{Volume of non-volatile solids in the digested sludge} = \frac{300}{2500} = 0.12 \text{ m}^3$$

$$\text{Volume of water in digested sludge} = \frac{5850}{1000} = 5.85 \text{ m}^3$$

$\therefore$ Sludge volume after digestion $= 0.333 + 0.12 + 5.85 = 6.303 \text{ m}^3$

therefore commonly used.

Q.37 Population of a town is 20,000 with an assured water supply of 150 litre per head per day. BOD of the waste water is 150 mg/L. Design the most suitable waste water treatment system (without power supply) for the town.

Which symbiotic system is applied in waste water treatment? Explain its principle and under what conditions the process may be found suitable for a community.

[8 + 7 = 15 marks : 2002]

Solution:

For the effective removal of BOD either trickling filter or oxidation pond may be designed. The waster water treatment plant should be without any power supply as given in the problem. Hence, oxidation pond may be designed as given below:

The quantity of water supplied per day = 20000 × 150 = 3×10^6 litres

Assuming 80% of the water supplied is converted in sewage

$\therefore$ Quantity of sewage produced = $0.80 \times 3 \times 10^6 = 2.4 \times 10^6$ litres

BOD content of waste water = $2.4 \times 10^6 \times 150 \times 10^{-6} = 360$ kg/day

Assuming the organic loading in the pond is 150 kg/ha/day.

$$\therefore \text{Surface area required} = \frac{\text{BOD content}}{\text{organic loading}} = \frac{360}{150} = 2.4 \text{ ha} = 24000 \text{ m}^2$$

Assuming length of the pond (L) as twice of its width (B).

$$\begin{aligned}
\therefore \quad L \times B &= 24000 \\
\Rightarrow \quad 2 \times B \times B &= 24000 \\
\Rightarrow \quad B &= 109.5 \text{ m say } 110 \text{ m} \\
\therefore \quad L &= 2 \times B = 220 \text{ m}
\end{aligned}$$

Using a pond with effective depth as 1.8 m, we get

$$\text{Capacity of pond} = 220 \times 110 \times 1.8 = 43560 \text{ m}^3$$

$$\text{But} \quad \text{Capacity} = \text{Sewage flow per day} \times \text{Detention time in days}$$

$$\therefore \quad 43560 = \frac{2.4 \times 10^6}{10^3} \times \text{Detention time in days}$$

$$\Rightarrow \quad \text{Detention time} = \frac{43560 \times 10^3}{2.4 \times 10^6} = 18.15 \text{ days}$$

Hence using an oxidation pond with length = 220 m; width = 110 m and over all depth = 1.8 + 1 = 2.8 m and a detention period of **18.15 days.**

Design of inlet and outlet pipe:

Assuming an average velocity of sewage as 0.9 m/s and daily flow for 8 hrs only

$$\therefore \quad \text{Discharge} = \frac{2.4\times 10^6}{10^3\times 8\times 60\times 60} = 0.0833 \text{ m}^3\text{/sec}$$

$$\therefore \text{ Area of inlet pipe required} = \frac{\text{Discharge}}{\text{Velocity}} = \frac{0.0833}{0.9} = 0.09 \text{ m}^2$$

$$\therefore \quad \text{Diameter of inlet pipe} = \sqrt{\frac{4\times 0.09\times 10^4}{\pi}} = 33.85 \text{ cm} \approx 34 \text{ cm}$$

Diameter of outlet pipe may be takes as 1.5 times that of inlet i.e. 51 cm.

Algal symbiosis or algal photosynthesis is applied in waste water treatment. The principle is that in a total aerobic pond, the stabilization of waste is brought about by aerobic bacteria, which flourish in the presence of oxygen. The oxygen demand of such bacteria in such a pond is met by the combined action of algae and other micro-organisms such as bacteria and protozoa. This is called as algal symbiosis. In this symbiosis, the algae growing in the presence of sunlight produce oxygen by action of photosynthesis and this oxygen is utilized by the bacteria for oxidising the waste organic matter. The end products of the process are carbon dioxide, ammonia and phosphates which are required by algae to grow and continue to produce oxygen. This process can be applied in treating sewage and biodegradable waste waters.

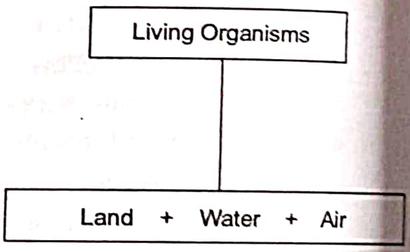
Q.38 Explain the components of an ecosystem. Give a pictorial example of structural components of ecosystem. [10 marks : 2002]

Solution:

The four major elements i.e. land, water, air and living organisms (plants and animals) together constitutes what is known as ecosystem. Ecosystem can be further subdivided into:

1. Physical environment
2. Biological environment

Land, water and air together, in fact, forms one group of environment called physical environment whereas the living organisms form another group of environment called biological environment. While the physical environment (land, water and air) is essential for existence of life in various forms, the biological environment provides the necessary food, so very essential for the sustenance of man on earth. Man as a matter of fact cannot survive on the earth without plant and animal life.



Components of Ecosystem

Q.39 Why is sedimentation considered a necessity for treating raw water? What are the factors that affect sedimentation and how is sedimentation done? What is the purpose of coagulation in treatment of raw water? Give a neat sketch of 'Baffle type of mixing basin' for coagulation. [15 marks : 2003]

Solution:

Most of the suspended impurities present in water do have a specific gravity greater than that of water. In still water, these impurities will therefore tend to settle down under gravity, although in normal raw supplies, they remain in suspension because of the turbulence in water. Hence, as soon as turbulence is retarded by offering storage to the water, these impurities tend to settle down at the bottom of the storage tank. This is the principle behind sedimentation.

The settlement of a particle in water brought to rest, is opposed by the following factors:

(i) The velocity of flow which carries the particle horizontally. The greater the flow area, the lesser is the velocity and hence more easily the particle will settle down.

(ii) The viscosity of water in which the particle is travelling. The viscosity varies inversely with temperature. Warm water is less viscous and therefore offer less resistance to settlement. However, the temperature of water cannot be controlled to any appreciable extent in water purification processes and hence this factor is generally ignored.

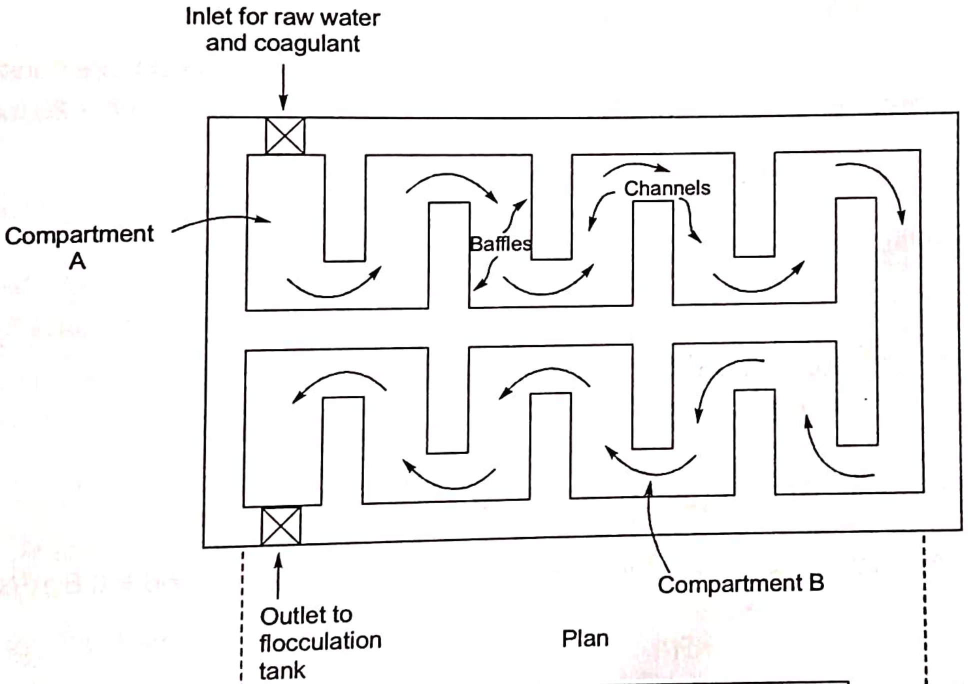
(iii) The size, shape and specific gravity of particle. The greater is the specific gravity more readily the particle will settle. The size and shape of the particle also affect the settling rate.

The clarification of water by the process of sedimentation can be effected by providing conditions under which the suspended material present in water can settle out. The most important parameter among the above mentioned factors the velocity of flow and the shape and size of the particles are tried to be controlled in special basins called sedimentation basins. The viscosity is left uncontrolled as the same is not practically possible. The velocity of flow can be reduced by increasing the length of travel and by detaining the particles for a longer time in the sedimentation basin.

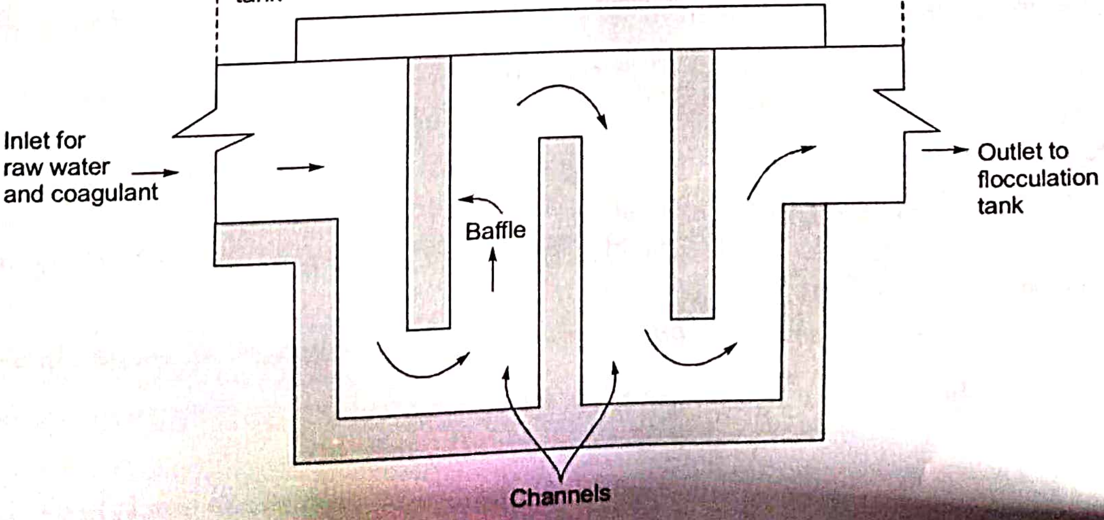
The size and shape of the particles can be altered by adding certain chemicals in water. These chemicals are called coagulants and they make the sedimentation quite effective by leading to the settlement of even very fine and colloidal particles. This is known as sedimentation aided with coagulation.

Mixing basin with baffle walls: The baffle type mixing basins are rectangular tanks which are divided by baffle walls. The baffles may either be provided in such a way as the water flows horizontally around their ends or they may be provided as to make the water move vertically over and under the baffles. The hindrances and the disturbances created by the provision of baffles in the path of flow, give it sufficient agitation, as to cause necessary mixing to develop the floc.

The brief sketch of a baffle type mixing basin is given below.



Plan



Sectional View

Q.40 A combined sewer of circular section is to be laid to serve an area of 100 ha with a population of 90000 supplied with water at 200 *LPCD*. Assuming an impermeability factor of 0.50 and time of concentration of rainfall '*t*' as 20 minutes, calculate the size of the sewer when it has to run full with a velocity of 0.3 m/s. Assume suitable coefficients for '*a*' and '*b*' in the equation for '*R*', the intensity of rainfall relating to '*t*', the time of concentration.

[10 marks : 2003]

Solution:

Given data:

Population = 90000

Daily water supply per capita = 200 litres

Area, $A = 100 \text{ ha} = 100 \times 10^4 \text{ m}^2 = 10^6 \text{ m}^2$

Impermeability factor or runoff coefficient = 0.50

Time of concentration, t = 20 minutes

∴ The intensity of a rain is inversely proportional to the duration of the rain, an intensity duration curve can be represented by a generalised equation, of the form

$$R = \frac{a}{t+b}$$

where R = intensity of rainfall in cm/hr

t = time of concentration in minutes and a and b are constant.

When the value of t is between 5 to 20 minutes, $a = 75$ and b = 10 and $a = 100$ and $b = 20$ for $20 < t < 100$.

$$\therefore \quad R = \frac{75}{20+10} = 2.5 \text{ cm/hr}$$

Now average water supply = Population × average per capita water supply

$= 90000 \times 200$

= 18 MLD

Assuming 80% of the water is converted into sewage

Volume of sewage = $0.80 \times 18 = 14.4$ MLD

$$\text{Average dry weather flow} = \frac{14.4 \times 10^6}{10^3 \times 24 \times 60 \times 60} = 0.1666 \text{ m}^3/\text{s}$$

∴ Maximum dry weather flow, $Q = 3 \times \text{Average dry weather flow} = 3 \times 0.1666 = 0.5 \text{ m}^3/\text{s}$

Now, By Kuichling formula, we know that

$$Q_P = KRA$$

where Q_P is the peak rate of runoff in m³/s

$$\therefore \quad Q_P = 0.50 \times \frac{2.5 \times 10^{-2}}{60 \times 60} \times 10^6$$

$$\Rightarrow \quad Q_P = 3.47 \text{ m}^3/\text{s}$$

Thus, for the combined sewer, the discharge

$$= Q + Q_P = 0.5 + 3.47 = 3.97 \text{ m}^3/\text{sec}$$

We know that

Discharge in the sewer = Area of sewer × Velocity in sewer

$$3.97 = \frac{\pi}{4} \times D^2 \times 0.3$$

$$\Rightarrow \quad D^2 = \frac{3.97 \times 4}{0.3 \times \pi}$$

$$\Rightarrow \quad D = 4.10 \text{ m}$$

41 Design an oxidation pond with inlet and outlet pipes for treating sewage from a residential colony with 500 persons contributing sewage at 120 litres/capita/day. The 5-day BOD of sewage is 300 ppm. Assume velocity of sewage flow as 0.9 m/s, specific gravity of organic load as 1, and daily flow for 8 hrs organic loading in the pond at 300 kg/ha/day.

[15 marks : 2003]

olution:

Quantity of sewage to be treated per day = 500 × 120 = 0.06×10^6 litres

$$\text{BOD content} = 0.06 \times 10^6 \times 300 \times 10^{-6} = 18 \text{ kg/day}$$

$$\text{Organic loading in the pond} = 300 \text{ kg/ha/day (given)}$$

$$\therefore \quad \text{Surface area required} = \frac{\text{BOD content}}{\text{Organic loading}} = \frac{18}{300} = 0.06 \text{ ha} = 600 \text{ m}^2$$

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

$$L \times B = 600$$

$$2B^2 = 600$$

$$\Rightarrow \quad B = 17.32 \text{ m say } 17.5 \text{ m}$$

$$\Rightarrow \quad L = 2B = 2 \times 17.5 = 35 \text{ m}$$

$\therefore$ Using a tank with effective depth as 1.5 m, we get

$$\text{Capacity of tank} = 35 \times 17.5 \times 1.5 = 918.75 \text{ m}^3$$

$$\therefore \quad \text{Detention time in days} = \frac{\text{Capacity of tank}}{\text{Sewage flow per day}} = \frac{918.75 \times 10^3}{0.06 \times 10^6}$$

$$= 15.31 \text{ days}$$

Hence, using a oxidation pond with length = 35 m, width = 17.5 m

Overall depth = 1.5 + 1 = 2.5 m and a detention period of 15.31 days.

Design of inlet pipe and outlet pipe

$$\text{Velocity of sewage flow} = 0.9 \text{ m/s (given)}$$

$$\text{Time of daily flow} = 8 \text{ hrs (given)}$$

$$\therefore \quad \text{Discharge} = \frac{0.06 \times 10^6}{10^3 \times 8 \times 60 \times 60} = 2.083 \times 10^{-3} \text{ m}^3\text{/sec}$$

$$\therefore \quad \text{Area of inlet pipe required} = \frac{2.083 \times 10^{-3}}{0.9} = 2.3144 \times 10^{-3} \text{ m}^2 = 23.14 \text{ cm}^2 \simeq 23.15 \text{ cm}^2$$

$$\therefore \quad \text{Diameter of inlet pipe} = \sqrt{\frac{23.15 \times 4}{\pi}} = 5.43 \approx 6 \text{ cm}$$

Diameter of outlet pipe may be assumed as 1.5 times that of inlet pipe i.e. 9 cm.

Q.42 Compute the effective stack height of a coal burning power plant with physical stack height of 200 m and stack diameter of 0.8 m, stack gas exit velocity of 18.3 m/sec, temperature of gas 140°C, when the ambient air temperature is 8°C, atmospheric pressure is 1000 millibars and average wind speed is 4.5 m/sec. Also compute the emission rate of sulphur dioxide of the plant assuming burning of 24,000 tonnes of coal per day with a sulphur content of 4.2%. **[15 marks : 2003]**

Solution:

As per Holland's equation, the plume height can be given as

$$\Delta h = \frac{V_s D}{u}\left[1.5 + 2.68 \times 10^{-3} \, P.D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

where Δh is rise of plume above stack height in m, V_s is stack gas velocity in m/s, D is exit diameter of stack in m, u is wind speed in m/s, P is atmospheric pressure in millibars, T_s is stack gas temperature in °K and T_a is ambient air temperature in °K

Given

$$V_s = 18.3 \text{ m/s};\ D = 0.8 \text{ m};\ u = 4.5 \text{ m/s};\ P = 1000 \text{ millibars};\ h = 200\text{m}$$

$$T_s = 140 + 273 = 413\ ^\circ\text{K}$$

$$T_a = 8 + 273 = 281\ ^\circ\text{K}$$

$\therefore$

$$\Delta h = \frac{V_s D}{u}\left[1.5 + 2.68 \times 10^{-3}\ P.D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

$$= \frac{18.3 \times 0.8}{4.5}\left[1.5 + 2.68 \times 10^{-3} \times 10^3 \times 0.8\left(\frac{413 - 281}{413}\right)\right]$$

$$= 7.11 \text{ m}$$

Effective height of stack = Physical stack height (h) + $\Delta h = h + \Delta h = 200 + 7.11 = 207.11$m

Now, Sulphur content of coal = 4.2%

Coal burnt per day = 24000 t

$\therefore$ Sulphur produced per day $= \frac{4.2}{100} \times 24000 = 1008$ tonnes

Now, this sulphur will combined with oxygen to produce SO_2

$$\underset{32}{S} + \underset{32}{O_2} \longrightarrow \underset{64}{SO_2}$$

32 t of sulphur produce 64 t of sulphur dioxide

$\therefore$ 1008 t of sulphur will produce $= 1008 \times \frac{64}{32} = 2016$ tonnes of SO_2 per day

$\therefore$ Emission rate of SO_2 $= \frac{2016 \times 1000}{24 \times 60 \times 60} = 23.33$ kg/sec

Q.43 A Rapid Sand Filter is to be provided in a water treatment plant, to process the water for a town with a population of 275000. The water demand is 200 litre/capita/day. The rate of filtration is 15 m³/m²/hr. Allow 5% of filtered water for storage to meet the backwash requirements. Each backwashing period is of 30 min. Determine the number of filters required allowing one as a standby unit. The available surface area configuration of filter unit is 10 m × 4 m. Also compute the up-flow velocity and head-loss to expand the bed to 0.66 m The porosity of the bed is 0.50. Specific gravity is 2.5. The average particle size is 0.6 mm. The drag coefficient is 25.02 and the kinematic viscosity is 0.10136 × 10-5 m²/s The flow is assume to be transitional flow.

[15 marks : 2004]

Solution:

Maximum water demand per day

= Population × maximum daily rate of water supply

= 275000 × 1.8 × Average daily rate of water supply

= 275000 × 1.8 × 200 = 99 MLD

5% of the filtered water is stored to meet the backwash requirements.

$\therefore$ Total filtered water required per day $= 99 + \frac{5}{100} \times 99 = 103.95$ MLD

It is given that 30 min (0.5 hour) are required for backwashing.

$\therefore$ filter water required per hour $= \frac{103.95}{23.5} = 4.4234 \times 10^6$ litres per hour $= 4423.4\ \text{m}^3$ per hour

$$\text{Area of filter} = \frac{\text{Filtered water required per hour}}{\text{Rate of filtration}} = \frac{4423.40}{15} = 294.89\ \text{m}^2$$

The available surface area configuration of filter unit is 10 m × 4 m

Given

$$V_s = 18.3 \text{ m/s}; D = 0.8 \text{ m}; u = 4.5 \text{ m/s}; P = 1000 \text{ millibars}; h = 200\text{m}$$

$$T_s = 140 + 273 = 413\ °\text{K}$$

$$T_a = 8 + 273 = 281\ °\text{K}$$

$$\therefore \quad \Delta h = \frac{V_s D}{u}\left[1.5 + 2.68 \times 10^{-3}\ P.D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

$$= \frac{18.3 \times 0.8}{4.5}\left[1.5 + 2.68 \times 10^{-3} \times 10^3 \times 0.8\left(\frac{413 - 281}{413}\right)\right]$$

$$= 7.11 \text{ m}$$

Effective height of stack = Physical stack height (h) + $\Delta h = h + \Delta h = 200 + 7.11 = 207.11$m

Now, Sulphur content of coal = 4.2%

Coal burnt per day = 24000 t

$$\therefore \quad \text{Sulphur produced per day} = \frac{4.2}{100} \times 24000 = 1008 \text{ tonnes}$$

Now, this sulphur will combined with oxygen to produce SO_2

$$\underset{32}{S} + \underset{32}{O_2} \longrightarrow \underset{64}{SO_2}$$

32 t of sulphur produce 64 t of sulphur dioxide

$$\therefore 1008 \text{ t of sulphur will produce} = 1008 \times \frac{64}{32} = 2016 \text{ tonnes of } SO_2 \text{ per day}$$

$$\therefore \quad \text{Emission rate of } SO_2 = \frac{2016 \times 1000}{24 \times 60 \times 60} = 23.33 \text{ kg/sec}$$

Q.43 A Rapid Sand Filter is to be provided in a water treatment plant, to process the water for a town with a population of 275000. The water demand is 200 litre/capita/day. The rate of filtration is 15 m³/m²/hr. Allow 5% of filtered water for storage to meet the backwash requirements. Each backwashing period is of 30 min. Determine the number of filters required allowing one as a standby unit. The available surface area configuration of filter unit is 10 m × 4 m. Also compute the up-flow velocity and head-loss to expand the bed to 0.66 m The porosity of the bed is 0.50. Specific gravity is 2.5. The average particle size is 0.6 mm. The drag coefficient is 25.02 and the kinematic viscosity is 0.10136 × 10-5 m²/s The flow is assume to be transitional flow.

[15 marks : 2004

Solution:

Maximum water demand per day

= Population × maximum daily rate of water supply

= 275000 × 1.8 × Average daily rate of water supply

= 275000 × 1.8 × 200 = 99 MLD

5% of the filtered water is stored to meet the backwash requirements.

$$\therefore \text{ Total filtered water required per day} = 99 + \frac{5}{100} \times 99 = 103.95 \text{ MLD}$$

It is given that 30 min (0.5 hour) are required for backwashing.

$$\therefore \text{ filter water required per hour} = \frac{103.95}{23.5} = 4.4234 \times 10^6 \text{ litres per hour} = 4423.4 \text{ m}^3 \text{ per hour}$$

$$\text{Area of filter} = \frac{\text{Filtered water required per hour}}{\text{Rate of filtration}} = \frac{4423.40}{15} = 294.89 \text{ m}^2$$

The available surface area configuration of filter unit is 10 m × 4 m

Number of filter units required $= \dfrac{294.89}{10 \times 4} = 7.37$ units

Hence, providing 8 units and 1 unit as a standby unit respectively.

Backwashing of granular medium filters is accomplished by reversing the flow and forcing clean water upward through the media. To clean the interior of the bed, it is necessary to expand it so that the granules are no longer in contact with each other, thus exposing all surfaces for cleaning. To hydraulically expand a porous bed, the head loss must be at least equal to the buoyant weight of the particles in the fluid. For a unit area of filter this is expressed by

$$h_{fb} = L(1-e)\frac{\rho_m - \rho_w}{\rho_w}$$

where h_{fb} is head loss required to initiate expansion in m, L is depth of bed in m, e is porosity of the medium, ρ_m is density of medium in kg/m³ and ρ_w is density of water in kg/m³

Assuming, depth of bed, $L = 0.60$ m

$$\rho_m = G\rho_w = 2.5 \times 1000 = 2500 \text{ kg/m}^3$$

$$\rho_w = 1000 \text{ kg/m}^3$$

$$e = 0.5$$

$$\therefore \quad h_{fb} = \frac{0.6\,(1-0.5) \times (2500-1000)}{1000}$$

$$\Rightarrow \quad h_{fb} = 0.45 \text{ m}$$

Now, the head loss through an expanded bed is essentially unchanged because the total buoyant weight of the bed is constant.

$\therefore$ Weight of packed bed = Weight of bed fluidized

$$L(1-e)\frac{(\rho_m - \rho_w)}{\rho_w} = L_{fb}(1-e_{fb})\frac{(\rho_m - \rho_w)}{\rho_w}$$

$$\therefore \quad L_{fb} = L\frac{(1-e)}{(1-e_{fb})}$$

where L_{fb} is depth of expanded bed and e_{fb} = porosity of expanded bed

$$\therefore \quad 0.66 = 0.6\frac{(1-0.5)}{(1-e_{fb})}$$

$$\Rightarrow \quad e_{fb} = 1 - \frac{0.6 \times 0.5}{0.66}$$

$$\Rightarrow \quad e_{fb} = 0.5454$$

Now this quantity e_{fb} is a function of the terminal settling velocity of the particles and the backwash velocity (up-flow velocity). An increase in the backwash velocity will result in a greater expansion of the bed. The expression commonly used to relate the bed expansion to backwash velocity and particle settling velocity is

$$e_{fb} = \left(\frac{v_b}{v_t}\right)^{0.22}$$

where v_b is the backwash velocity and v_t is terminal settling velocity.

Assuming flow to be transitional, then

$$C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$$

$$\Rightarrow \quad 25.02 - 0.34 = \frac{24}{Re} + \frac{3}{\sqrt{Re}}$$

$$\Rightarrow \quad 24.68 = \frac{24}{Re} + \frac{3}{\sqrt{Re}}$$

Solving by hit and trial method, we get Re = 1.1 > 1 (Transitional)

$$\therefore \quad v_t^2 = \frac{4}{3}\frac{(\rho_m - \rho_w)gd}{C_D\rho_w}$$

$$\Rightarrow \quad v_t^2 = \frac{4 \times 9.81 \times (2500 - 1000) \times 0.6 \times 10^{-3}}{3 \times 25.02 \times 1000}$$

$$\Rightarrow \quad v_t^2 = 4.705 \times 10^{-4} \text{ m/s}$$

$$\Rightarrow \quad v_t = 0.022 \text{ m/s}$$

Now, we know that $e_{fb} = \left(\frac{v_b}{v_t}\right)^{0.22}$

$$(e_{fb})^{1/0.22} = \frac{v_b}{v_t}$$

$$\Rightarrow \quad v_b = 0.022 \times (0.5454)^{1/0.22}$$

$$\Rightarrow \quad v_b = 1.39 \times 10^{-3} \text{ m/s}$$

Q.44 A combined sewer of circular section is to be designed in a sewage system for a city with a popul of 100000 in an area of 100 hectares. The mean flow of sewage from the city is 250 litre/capita The rainfall intensity in the area is 4 cm/hr. The coefficient of runoff of the area is 0.48. The ra peak to average sewage flow is 2.0. The Manning's roughness coefficient is 0.012 and the Ha William's coefficient is 85. Using Manning's equation and Hazen William's expression, determin gradient of the sewer to carry the peak flow with a velocity of 1.2 m/s.

[15 marks : 2

Solution:

$$\therefore \quad \text{Average sewage flow} = \text{Population} \times \text{Mean flow of sewage}$$

$$= 100000 \times \frac{250 \times 10^{-3}}{24 \times 60 \times 60} = 0.289 \text{ m}^3\text{/s}$$

$$\therefore \quad \text{Peak sewage flow, } Q = 2.0 \times 0.289 = 0.579 \text{ m}^3\text{/s}$$

$$\text{Area, } A = 100 \text{ ha} = 100 \times 10^4 \text{ m}^2 = 10^6 \text{ m}^2$$

$$\text{Coefficient of runoff, } K = 0.48$$

$$\text{Rainfall intensity, } p = 4 \text{ cm/hr}$$

$$\therefore \quad \text{Peak rate of runoff, } Q_P = KpA = 0.48 \times \frac{4 \times 10^{-2}}{60 \times 60} \times 10^6 = 5.33 \text{ m}^3\text{/s}$$

$$\therefore \quad \text{Total flow through the sewer} = Q + Q_P = 0.579 + 5.33 = 5.909 \text{ m}^3\text{/s}$$

If the diameter of the combined sewer is D, then

$$\frac{\pi}{4} \times D^2 = \frac{5.909}{1.2} \qquad [\because Q = AV]$$

$$\Rightarrow \quad D^2 = \frac{5.909 \times 4}{1.2 \times \pi}$$

$$\Rightarrow \quad D = 2.5 \text{ m}$$

(i) As per Manning's equation

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

Given $V = 1.2$ m/s

$$R = \frac{D}{4} = \frac{2.5}{4} = 0.625 \text{ m}$$

$$n = 0.012$$

$$1.2 = \frac{1}{0.012} \times (0.625)^{2/3} \times S^{1/2}$$

$\therefore$ $$S^{1/2} = \frac{1.2 \times 0.012}{(0.625)^{2/3}}$$

$\Rightarrow$ $$S = \frac{1}{2577}$$

$\Rightarrow$

(ii) As per Hazen-William's formula

$$V = C R^{0.63} S^{0.54}$$

where

$$V = 1.2 \text{ m/sec}$$

$$C = 85$$

$$R = 0.625 \text{ m}$$

$$1.2 = 85 \times (0.625)^{0.63} (S)^{0.54}$$

$\therefore$ $$(S)^{0.54} = \frac{1.2}{85 \times (0.625)^{0.63}}$$

$\Rightarrow$ $$S = \frac{1}{1542.5}$$

$\Rightarrow$

45 **Classify the solid wastes, giving suitable example for each of them. Also explain the different methods of disposal of solid wastes.**

[10 marks : 2004]

lution:

Refuse represents the dry wastes or solid wastes of the society except human excreta and sullage. It includes garbage, ashes, rubbish, dust, etc.

(i) Garbage includes all sorts of putrescible organic wastes obtained from kitchens, hotels, restaurants, etc. All waste food articles, vegetable peelings, fruit peelings, etc., are thus included in this term.

(ii) Ashes denote the incombustible waste products from hearths and furnaces, and houses or industries.

(iii) Rubbish includes all non-putrescible wastes except ashes. It, thus includes all combustible and non-combustible wastes such as rags, paper pieces, broken pieces of glass and furniture, card boards, broken crockery, etc.

Besides the technical classification based on the type of wastes, the refuse may also be classified, depending on its source, as: (i) House refuse; (ii) Street refuse and (iii) Trade refuse.

Collection of refuse:

The refuse is generally collected in individual houses in small containers and from there, it is collected by sweepers in small hand driven lorries/carts and then dumped into the masonry chambers constructed along roadsides by municipalities. The refuse is finally carted away by municipal trucks, for further disposal during some day time.

Disposal of refuse:

The refuse can be disposed of by various methods, such as

(a) **Sanitary land filling:** In this method of refuse disposal, refuse is carried and dumped into the low lying area under an engineered operation, designed and operated according to the acceptable standards, as not to cause any nuisance or hazards to public health or safety. Area method and trench method are two methods of land filling which are usually adopted.

SOLVED NUMERICAL EXAMPLES

EXAMPLE 1. Define MPN of E.coli. Also write the genral equation adopted in standard methods for the probability curve of the E.coli distribution. (GATE 2009)

Solution : Definition : M.P.N. of E.coli is based on a statistical analysis of the number of positive and negative results obtained when testing multiple portions of equal volume and in portions constituting a geometric series for the presauce of coliform.

It may also be defined as that bacterial density which if it had been actually present in the sample under examination, would more frequently than any other, have given the observed analytical results.

General equation adopted in standard methods for the probability curve of the E.coli distribution is

$$Y = \frac{1}{a}[(1-e^{-N_1\lambda})^p (e^{-N_1\lambda})^q][(1-e^{-N_2\lambda})^r (e^{-N_2\lambda})^s]$$

$$\times[(1-e^{-N_3\lambda})^b (e^{-N_3\lambda})^u]$$

where N_1, N_2 and N_3 = size of portions examined in mm.

p, r, b = number of portions of respective sizes giving positive tests for coliforms

q, s, u = number of portions of respective sizes giving negative tests for coliforms

λ = concentration of coliform per ml.

Y = probability of occurrence of a particular result

e = base of Naperian logarithm

a = a constant for a particular set of conditions and thus may be omitted in computation of λ.

EXAMPLE 2. Calculate the population equivalent of a city given (*i*) the average sewage from the city is 95 × 10⁶ l/day and (*ii*) the average 5-day BOD is 300 mg/1. (Engg. Services Exam., 2007)

Solution: The population equivalent of a sewage is the number of the persons who could be responsible for the sewage which would have the same characteristics of B.O.D. at the standard sewage.

$$\text{Average sewage} = 95 \times 10^6 \text{ l/day}$$

$$\text{5-day B.O.D.} = 300 \text{ mg/1}$$

$$\therefore \quad \text{Total 5-day B.O.D. per day} = 95 \times 10^6 \times 300 \text{ mg}$$

$$= \frac{95 \times 10^6 \times 300}{10^6} \text{ kg}$$

As per IS code per capita/day B.O.D. of domestic sewage = 0.08 kg/capita/day

$$\therefore \quad \text{Population equivalent} = \frac{95 \times 10^6 \times 300}{10^6 \times 0.08} = 356250$$

Ans. Population equivalent 3,56,250.

EXAMPLE 3. If the period of incubation is 10 days at 20°C in the relative conductivity test on sewage, calculate the percentage of relative stability. *(Engg. Services Exam., 2005)*

Solution: The ratio of oxygen available in the effulent (as D.O., nitrite or nitrate) to the total oxygen required to satisfy its first stage B.O.D. demand, is called *relative stability*.

Its value is given by $S = 100\,[1-(0.794)^{t(20)}]$ ...(*i*)

where relative stability is S and

$t\,(20)$ is the time in days for sewage sample when incubated at 20 °C.

Substituting the values in Eqn. (*i*), we get

$$S = 100\,[1-(0.794)^{10}] = 100\,[1-0.09958]$$

$$= 100 \times 0.90042 = 90.042\%$$

Ans. Relative stability is 90.042%.

EXAMPLE 4. 2.5 ml of raw sewage has been diluted to 250 ml & the D.O. concentration of the diluted sample at the beginning of the BOD test was 8 mg/l and 5 mg/l after 5 days incubation at 20°C. Determine the BOD of raw sewage? (Engg. Services Exam., 2006)

Solution: $\text{Dilution Factor} = \dfrac{250}{2.5} = 100$

$$\text{D.O. consumed} = 8 - 5 = 3 \text{ mg/l}$$

$$\text{B.O.D. of raw sewage} = \text{D.O. consumed} \times \text{D.F.}$$

$$= 3 \times 100 = 300 \text{ mg/l}$$

Ans. B.O.D. of raw sewage is 300 mg/l

EXAMPLE 5. If a 3 day B.O.D. of sewage at 20°C is 400 mg/l. Find its 5 day B.O.D. at 20°C? Assume value of K_{20} = 0. 1/day. (Civil Services Main Exam., 2008)

Solution: $y_t = L\left[1-(10)^{-K_D t}\right]$

$$400 = L\left[1-(10)^{-0.1\times3}\right]$$

$$L = 801.9 \text{ mg/l}$$

$$\text{5 day B.O.D. at 20°C} = y_t = L\left[1-(10)^{-K_D t}\right]$$

$$y_5 = 801.9\left[1-(10)^{-.1\times5}\right]$$

$$= \mathbf{548.31 \text{ mg/l}}$$

Ans. 5 day B.O.D. is 548.31 mg/l

EXAMPLE 6. Determine the ultimate BOD of a waste water sample which was subjected to the BOD determination as follows:

6 ml of waste water containing no dissolved oxygen (D.O.) was mixed with 294 ml of dilution water containing 8.6 mg/l of D.O. After incubation at 20°C for 5 days, the D.O. of the mixture was 5.4 mg/l. The BOD rate constant, *k* to the base *e* is 0.25/day.

(GATE 2009)

Solution:

Volume of sewage sample = 6 ml

D.O. of sewage sample = 0

Volume of dilution water = 294 ml

D.O. of dilution water = 8.6 mg/l

5 days D.O. of mixture = 5.4 mg/l

Volume of diluted sample = 6 + 294 = 300 ml

$$\text{D.O. of diluted sample} = \frac{6\times0+294\times8.6}{300}$$

$$= 8.428 \text{ mg/l}$$

$$\text{D.O. consumed in B.O.D. test} = 8.428-5.40$$

$$= 3.028 \text{ mg/l}$$

B.O.D. of 5 days y_5 = D.O. consumed × Dilution factor

$$= 3.028 \times (300/6) = 151.4$$

Let L be the ultimate B.O.D.

$$y_5 = L[1-(10)^{-kd\times t}]$$

or

$$151.40 = L[1-10^{-0.25\times5}] = \left[1-\frac{1}{(10)^{1.25}}\right]$$

$$= L \times 0.94376$$

$$\therefore \quad L = \frac{151.40}{0.94376} = 160.42 \text{ mg/l}$$

Ans. Ultimate B.O.D. is 160.42 mg/l.

EXAMPLE 7. The following observations were made on a 4% dilution of waste water

Dissolved oxygen (D.O.) of aerated water used for dilution = 3 mg/l

Dissolved oxygen (D.O.) of diluted sample after 5 days incubation = 0.8 mg/l

Dissolved oxygen (D.O.) of original sample = 0.6 mg/l

Calculate the BOD of 5 days and ultimate BOD of the sample assuming that the deoxygenation coefficient at test temperature is 0%. **(Engg. Services Exam., 2010)**

Solution: The 100% content of sample consists of 4% of waste water and 96% of the aerated water used for dilution

$$D.O. = 0.6 \times 0.04 + 3 \times 0.96 = 2.904 \text{ mg/l}$$

D.O. of diluted sample after 5 days of incubation = 0.8 mg/l

D.O. consumed = 2.904 − 0.8 = 2.104 mg/l

B.O.D. of 5 days = D.O. consumed × Dilution factors

$$= 2.104 \times \frac{100}{4} = 52.6 \text{ mg/l} \qquad \ldots(i)$$

Let ultimate B.O.D. is denoted by L

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

$$52.6 = L\left[1-10^{-0.1\times5}\right]$$

$$52.6 = 0.684\ L$$

$$L = 76.9 \text{ mg/l} \qquad \ldots(ii)$$

Ans. (*i*) and (*ii*) above.

EXAMPLE 8. 125 cumecs of sewage of a city is discharged in a perennial river which is fully saturated with oxygen & flows at a minimum rate of 1600 cumecs with a minimum velocity of 0.12 m/sec. If the 5 day BOD of sewage is 300 mg/l. Find out

Assume:

(*i*) Co-efficient of purification of river as 4.0

(*ii*) Co-efficient of DO is 0.11

(*iii*) The ultimate BOD is 125% of the 5-day BOD of the mixutre of sewage & river water.

(Engg. Services Exam 2012)

Solution : Initial D.O. of the river = 9.2 mg/l (at 20°C)

D.O. of mixture at $t = 0$

Initial D.O. deficit D_0 = 9.2 − 8.53 = 0.67 mg/l

5-day BOD of mixture of sewage & river water

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

$$= \frac{125\times300+0\times1600}{1725}$$

$$= 21.74 \text{ mg/l}$$

Ultimate BOD of mixture $L = 21.74 \times 1.25 = 27.17$ mg/l

Now

$$\left(\frac{L}{fD_c}\right)^{f-1} = f\left[1-\frac{D_0}{L}(f-1)\right]$$

$$\left(\frac{27.17}{4\times D_c}\right)^3 = 4\left[1-\frac{0.67}{27.17}(3)\right]$$

$$\therefore \quad D_C = 4.39 \text{ mg/l}$$

$$t_c = \frac{1}{k_D(f-1)}\log_{10}\left[f\left\{1-(f-1)\frac{D_0}{L}\right\}\right]$$

$$= \frac{1}{0.11\times3}\log_{10}\left[4\left\{1-3\times\frac{0.67}{27.17}\right\}\right]$$

Now $t_c = 3.96$ days

$$\text{Distance} = V \times t_c = \frac{0.12}{1000}\times3.96\times24\times60\times60$$

$$= 41.06 \text{ km}$$

Ans. Critical D.O. deficit will occur at 41.06 km.

EXAMPLE 9. A waste water treatment plant disposes off its effluents into a stream at a point *A*. Characteristic of stream at a location fairly upstream of *A* of the effluent are as below:

Item	Unit	Effluent	Stream
Flow	m³/sec	0.20	0.50
D.O.	mg/l	2.00	8.00
Temperature	0°C	26	22
BOD$_5$ at 20°C	mg/l	40	3

Assume that the de-oxygenation constant k_1 at 20°C (base *e*) = 0.20, the re-aeration constant k_2 at 20°C (base *e*) = 0.40 for the mixture. The velocity of the stream downstream of the point *A* is 0.2 m/sec. Determine the critical oxygen deficit & its location?

(Civil Services Main Exam., 2008)

Solution :

$$k_D = 0.434k = 0.434 \times 0.2 = 0.087 \text{ per day}$$

$$k_R = 0.434 \times 0.4 = 0.174 \text{ per day}$$

$$\text{D.O. of mixture} = \frac{2.0\times0.2+8.0\times0.5}{0.70} = 5.77 \text{ mg/l}$$

$$\text{BOD}_5 \text{ of mixture} = \frac{40\times0.2+3\times0.5}{0.7} = 13.57 \text{ mg/l}$$

$$\text{Temp. of mix.} = \frac{26\times0.2+22\times0.5}{0.7} = 23.14°\text{C}$$

$$\text{Ultimate BOD of mixture } y_t = L[1-(10)^{-k_Dt}]$$

$$13.57 = L[1-(10)^{-.087\times 5}]$$

$$L = 21.45 \text{ mg/l}$$

$$\text{Temp, of mix.} = 23.14°\text{C}$$

$$\text{Saturation D.O. at } 23.14°\text{C} = 8.79 \text{ mg/l}$$

$$\text{D.O. of mix.} = 6.29 \text{ mg/l}$$

$$\text{Initial D.O. deficit } D_0 = 8.79-6.29 = 2.50 \text{ mg/l}$$

$$k_D(23.14°\text{C}) = k_{D(20)}[1.04]^{T-20}$$
$$= 0.087[1.04]^{3.14} = 0.098$$

$$k_R(23.14°\text{C}) = k_{R(20)}[1.02]^{T-20}$$
$$= 0.174[1.02]^{3.14} = 0.185$$

$$\therefore f = \frac{0.185}{0.098} = 1.88$$

Critical Oxygen Deficit D_c

$$\left[\frac{L}{fD_c}\right]^{f-1} = f\left[1-(f-1)\frac{D_0}{L}\right]$$

$$\left(\frac{21.45}{1.88\times D_c}\right)^{0.88} = 1.88\left[1-0.88\times\frac{2.5}{21.45}\right]$$

$$D_c = 6.28 \text{ mg/l} \qquad ...(i)$$

Time of Critical D.O. deficit t_c:

$$t_c = \frac{1}{k_D(f-1)}\log_{10} f\left[1-(f-1)\frac{D_0}{L}\right]$$

$$= \frac{1}{0.098\times 0.88}\log_{10} 1.88\left[1-(1-0.88)\times\frac{2.5}{21.45}\right]$$

$$= 2.625 \text{ days}$$

$$\text{Distance} = 0.2\times 60\times 60\times 24\times 2.625\times 10^{-3}$$
$$= 45.36 \text{ km} \qquad ...(ii)$$

Ans. (*i*) and (*ii*) above.

EXAMPLE 10. The treated domestic sewage of a town is to be discharged in a natural stream. Calculate the percentage purification reqd. in the treatment plant with the following data:

Population = 50,000

BOD contribution per capita = 0.07 kg/day

BOD of stream on u/s side = 3 mg/l

Permissible max. BOD of stream on D/s side = 5 mg/l

DWF of sewage = 140 litres/capita/day

Minimum flow of stream = 0.13 m³/sec **(IES 2011)**

Solution : Total BOD/day = 0.07 × 50,000 = 3500 kg/day

Total flow of sewage/day = 140 × 50,000 = 7 × 10^6 litres

$$\text{BOD of sewage} = \frac{3500\times 1000\times 1000}{7\times 10^6} = 500 \text{ mg/l}$$

$$\text{Flow of sewage} = \frac{7\times 10^6}{10^3\times 24\times 60\times 60}$$
$$= 0.081 \text{ cumec}$$

Now resultant B.O.D. of mix. reqd. = 5 mg/l

Let B.O.D. of treated sewage = C_s mg/l

$$5 = \frac{Q_S C_S + Q_R C_R}{Q_S + Q_R}$$

$$5 = \frac{0.081\times C_S + 0.13\times 3}{0.081+0.13}$$

On solving, C_s = 8.21 mg/l

$$\% \text{ treatment required} = \frac{500-8.21}{500}\times 100 = 98.36\%$$

Ans. Treatment of sewage required is 98.36%.

EXAMPLE 11. An environmental survey for a town with population of 30,000 revealed the following :

Domestic sewage produced at the rate of 240 litres per capita per day. The per capita BOD of the domestic sewage being 72 g/day.

Industrial wastes produced were estimated as 4 million litres per day with BOD of 1500 mg/l.

The sewage effluents can be discharged into a river with a minimum dry weather flow of 4500 litres/s and a saturation dissolved oxygen content of 7 mg/1. It is necessary to maintain a dissolved oxygen content of 4 mg/1 in the stream. For designing a sewage treatment plant, determine the degree of treatment required to be given to the sewage. Assume

K_D = Deoxygenation coefficient = 0.1, and

K_R = Reoxygenation coefficient = 0.3

An overall expansion factor of 10% be provided.

(IES 2007)

Solution : Per capita sewage produced = 240 litres per day

Per capita BOD of domestic sewage = 72 gm/day

$$\text{BOD per litre of domestic sewage} = \frac{72\times 1000}{240}$$
$$= 300 \text{ mg/litres}$$

Amount of domestic waste produced per day

= population × 240 = 30,000 × 240

= 7.2 × 10^6 litres per day

Amount of Industrial waste produced = 4 × 10^6 litres/day

B.O.D. of industrial waste = 1500 mg/l

Net B.O.D. of domestic + industrial waste

$$= \frac{[7.2\times 300 + 4\times 1500]\times 10^6}{(7.2+4)\times 10^6} = 728.6 \text{ mg/l}$$

$$K_D = 0.1$$
$$K_R = 0.3$$

Initial D.O. deficit D_0 = 0

Allowable D.O. deficit D_c = 7 – 4 = 3 mg/l

$$\frac{L}{D_c} = (f)^{f/f-1} \quad \text{where, } f = \frac{K_R}{K_D} = \frac{0.3}{0.1} = 3$$

$$\frac{L}{3} = (3)^{3/2}$$

$$L = 15.6 \text{ mg/l}$$

Q_R = discharge of river = 4500 litres/s

Q_S = discharge of sewage (domestic + industrial) including 10% of expansion

$$= (7.2+4)\times 1.1\times 10^6 \text{ litres/day}$$

$$= \frac{12.32\times 10^6}{24\times 3600} = 142.60 \text{ litres/s}$$

C = Permissible concentration. (*i.e.*, B.O.D.) of mixture

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

$$15.6 = \frac{C_s\times 142.6 + 0\times 4500}{142.6+4500}$$

1. The waste water from bath rooms, kitchen, etc. is called
   (*a*) refuse (*b*) sullage
   (*c*) sewage (*d*) garbage

2. The liquid waste conveyed by a sewer is known as
   (*a*) sewer (*b*) sewerage
   (*c*) sewage (*d*) all the above are correct

3. The underground conduit constructed for removal of liquid waste of a community is known as
   (*a*) canals (*b*) tunnels
   (*c*) sewer (*d*) sewerage

4. Fresh sewage is usually
   (*a*) alkaline (*b*) neutral
   (*c*) acidic (*d*) has pH value of 7

5. Stale sewage is usually
   (*a*) neutral (*b*) acidic
   (*c*) alkaline (*d*) of pH value 7

6. The solid content of sewage is usually
   (*a*) 99% (*b*) 80 – 85%
   (*c*) 10 – 15% (*d*) 0.1%

7. The minimum diameter of manhole opening is
   (*a*) 50 cm (*b*) 100 cm
   (*c*) 150 cm (*d*) 200 cm

8. The self cleaning velocity normally adopted for sewers is
   (*a*) 0.1 m/sec (*b*) 0.2 m/sec
   (*c*) 0.4 m/sec (*d*) 0.85 m/sec

9. When a sewer gets discharged from two or more main sewers, it is called
   (*a*) leading sewer (*b*) trunk sewer
   (*c*) combining sewer (*d*) intercepting sewer

10. The shape of a sewer suitable to carry combined flow is
   (*a*) circular (*b*) elliptical
   (*c*) horse-shoe shaped (*d*) egg shaped

11. The colour of fresh sewage is
   (*a*) blue (*b*) green
   (*c*) pink (*d*) grey

12. The colour of septic sewage is
   (*a*) black (*b*) green
   (*c*) grey (*d*) blue

13. Stoneware pipes are used for the house drainage system mainly because
   (*a*) they are strongest
   (*b*) they are cheapest
   (*c*) their interior surface is smooth and impervious
   (*d*) their life is 100 years

14. The minimum diameter of sewer pipe is
   (*a*) 1 cm (*b*) 5 cm
   (*c*) 10 cm (*d*) 15 cm

15. Water carriage system is preferred to dry system because
   (*a*) sewage is carried in covered conduits without having any nuisance value
   (*b*) treatment is given to sewage prior to its final disposal thus reducing chances of outbreak of epidemic
   (*c*) there is no dearth of water
   (*d*) (*a*) and (*b*) above are correct

16. In a combined sewer when only the industrial or sanitary sewage are flowing, then it is termed as
(*a*) storm water flow (*b*) industrial flow
(*c*) ordinary flow (*d*) dry weather flow

17. In a combined system, the same sewer is intended to carry both
(*a*) domestic sewage and industrial wastes
(*b*) domestic sewage and storm water flow
(*c*) industrial waste and storm water flow
(*d*) dry weather flow and storm water flow

18. The wash water from stables which contains animal wastes is called
(*a*) barn sludge (*b*) animal sludge
(*c*) live sludge (*d*) horse sludge

19. Partly or completely treated sewage flowing out of a sewage treatment tank, is called
(*a*) treated sewage (*b*) sewage water
(*c*) discharged sewage (*d*) effluent

20. A fresh sewage becomes stale in
(*a*) 1 hour (*b*) 3 hours
(*c*) 6 – 8 hours (*d*) 24 – 36 hours.

21. Waste water is said to be septic when
(*a*) it is known to contain disease producing bacteria
(*b*) it is undergoing decomposition
(*c*) it kills fish and plant life in streams receiving it
(*d*) the chief form of bacterial action in it is of the anaerobic type

22. The process of removing suspended and colloidal matter from sewage is called
(*a*) purification (*b*) clarification
(*c*) suspension (*d*) dewatering

23. Sewage that has received no purification treatment is called
(*a*) raw sewage (*b*) untreated sewage
(*c*) crude sewage (*d*) fresh sewage

24. The minimum infilteration of water in one km. length of sewer pipe per day is
(*a*) 0 litre (*b*) 500 litres
(*c*) 2800 litres (*d*) 1,40,000 litres

25. A branch drain of which the last length of piping of the incoming drain before connection to the sewer is vertical, is called
(*a*) branch pipe (*b*) drain pipe
(*c*) drop connection (*d*) Y-connection

26. In combined sewers the velocity of flow of sewage should not be less than
(*a*) 0.6 m/sec (*b*) 0.75 m/sec
(*c*) 1 m/sec (*d*) 6 m/sec

27. The non-scouring velocity for cement concrete sewers is usually taken as
(*a*) 0.02 m/sec (*b*) 0.10 m/sec
(*c*) 0.12 m/sec (*d*) 0.25 m/sec

28. In separate sewers the minimum velocity of flow should not be less than
(*a*) 0.6 m/sec (*b*) 0.75 m/sec
(*c*) 1 m/sec (*d*) 6 m/sec

29. The maximum velocity of flow is limited to about 3 m/sec, though in practice it should preferably not exceed
(*a*) 2 m/sec (*b*) 2.25 m/sec
(*c*) 2.5 m/sec (*d*) 3 m/sec

30. A sewer of 400 mm diameter and slope 1 in 400, running half-full, has a flow velocity of 0.82 m/sec. What velocity of flow will be obtained if the slope is made 1 in 100?
(*a*) 3.28 m/s (*b*) 1.64 m/s
(*c*) 0.82 m/s (*d*) 0.41 m/s **(IES 2012)**

31. A sewer has a diameter of 300 mm and slope of 1 in 400. While running full it has a mean velocity of 0.7 m/s. If both the diameter and slope are doubled (to respectively be 600 mm and 1 in 200), what will be the changed mean velocity when running half-full? Use Manning's formula.
(*a*) 1.59 m/s (*b*) 2.80 m/s
(*c*) 0.90 m/s (*d*) 1.00 m/s **(IES 2012)**

32. The circular section of a sewer is best suitable when diameter is upto
(*a*) 0.75 m (*b*) 1.25 m
(*c*) 1.5 m (*d*) 3 m

33. While designing a sewerage system, the span of design period is generally taken as
(*a*) one year (*b*) 5 years
(*c*) 10 years (*d*) 20 years

34. Where it is not possible to obtain self-cleansing velocities for sewers, flush tanks are installed with minimum available head of
(*a*) 1 – 2 m (*b*) 2 – 3 m
(*c*) 5 – 7 m (*d*) 10 – 15 m

35. pH value of fresh sewage is expected to be
(*a*) 1 (*b*) 3.5
(*c*) 7 (*d*) 8 to 11

36. The quantity of storm water from an area depends upon
(*a*) shape of the area (*b*) slope of the area
(*c*) nature of soil (*d*) all the above are correct

37. The ratio in between length of the sewer and velocity of flow when running full is known as
(*a*) inlet time (*b*) time of flow
(*c*) time of concentration (*d*) time intensity

38. The average annual rainfall at any station is the mean average of annual rainfall over a period of
(*a*) 10 years (*b*) 25 years
(*c*) 35 years (*d*) 50 years
(*e*) 100 years

39. Industrial sewage is generally expressed in
(*a*) litres per capita per day
(*b*) litres per day per sq. metre
(*c*) litres per hour per sq. metre
(*d*) litres per working (working in the industry) per day

40. The minimum infiltration of water in one km. length of water pipe per day is
(a) zero litres (b) 500 litres
(c) 2800 litres (d) 1,40,000 litres

41. A street sewer into which sewer from house connections is poured is called
(a) street sewer (b) main sewer
(c) lateral sewer (d) head sewer

42. A sewer which receives its flow from a number of transverse sewers or outlets is called
(a) head sewer (b) sewer reservoir
(c) connecting sewer (d) interceptor

43. The gas that is mainly responsible for explosion in sewers is
(a) ammonia (b) methane
(c) oxygen (d) carbon monoxide

44. The velocity of flow in sewers should be
(a) at least 30 cm/sec
(b) not more than 50 cm/sec
(c) less than cleansing velocity
(d) more than cleansing velocity

45. The lowest point of the interior of a sewer or drain at any cross-section is called
(a) bottom point (b) negative head point
(c) revetral point (d) invert

46. A street sewer, into which sewer from house connections pours, is called
(a) main sewer (b) street sewer
(c) head sewer (d) lateral sewer

47. Ventillation shafts are provided at the upper end of every branch sewer and they are generally spaced at a distance of
(a) 500 m (b) 300 m
(c) 100 m (d) 50 m

48. Generally salt glazed stone ware pipes are manufactured in size 600 to 750 mm in diameter and their length is upto
(a) 60 to 90 cm (b) 3 m
(c) 5 m (d) 6 m

49. For large sewers, the maximum distance between sewers is usually limited to
(a) 50 metres (b) 300 metres
(c) 1000 metres (d) 1500 metres

50. The quantity of storm water from an area depends upon
(a) shape of the area
(b) slope of the area
(c) nature of the soil
(d) all the above are correct

51. The time that would be required for a drop of water to flow from the upper limit of the drainage area to the point where concentration or the maximum effect of flood is considered is called
(a) inlet time (b) time of flow
(c) time of concentration (d) time intensity

52. Sewer lines are usually laid with the help of a
(a) plain table (b) compass
(c) theodolite (d) sight rails
(e) time intensity

53. Alignment of sewer lines is started from
(a) the outfall (b) the high point
(c) the tail end (d) the last point

54. The proper gradient of sewer lines is ensured by
(a) compass (b) plane labelling
(c) dumpy level (d) telescope

55. Hydraulically the economical section of drains for large flow is
(a) circular (b) V-shaped
(c) rectangular (d) oval shaped

56. Hydraulically for dry weather flow, the best section is
(a) circular
(b) V-shaped with circular invert
(c) rectangular shaped
(d) oval shaped

57. The opening constructed on sewers or drains in order to enable men enter or leave the sewers is called
(a) lamp hole (b) manhole
(c) inspection chamber (d) street inlet

58. Manholes on sewer lines are provided for
(a) periodic cleaning
(b) providing air for oxidation
(c) removal of part of sewerage
(d) all of the above

59. A manhole is generally provided at each
(a) bend
(b) junction and change of sewer dia
(c) change of gradient
(d) all of the above

60. The minimum diameter of working chamber of a circular man hole should be
(a) 0.5 m (b) 0.9 m
(c) 1.2 m (d) 2 m

61. The inlet with a basin which makes grit, sand or debris to settle and thus prevents it from entering into the sewer is called
(a) manhole (b) catch basin
(c) street inlet (d) inspection hole

62. A manhole of such depth that an access shaft is required in addition to the working chamber is called
(a) tube manhole (b) deep manhole
(c) well manhole (d) earth manhole

63. A manhole incorporating a vertical shaft or pipe in which sewage falls from a sewer at a higher level to a sewer at a lower level is called
(a) deep manhole (b) bottom manhole
(c) pit manhole (d) drop manhole

Which of the following statements are correct?
(*a*) 1, 2 and 3
(*b*) 1 and 2 only
(*c*) 2 and 3 only
(*d*) 1 and 3 only
(IES 2012)

111. A detritus tank is provided in the primary treatment of sewage to remove
(*a*) suspended solids
(*b*) grit
(*c*) stones
(*d*) oils and greases

112. Before discharging the foul sewage into rivers, it is treated by
(*a*) screening
(*b*) sedimentation
(*c*) oxidation
(*d*) sludge digestion and disinfection

112 A. Operation generally done during preliminary treatment of sewage is
(*a*) chlorination of sewage
(*b*) oil and grease removal from skimming tanks
(*c*) removal of grit and also floating material through screens
(*d*) (*b*) & (*c*) above

113. The spacing of steel bars in coarse screens used for the treatment of sewage is
(*a*) 10 mm
(*b*) 20 mm
(*c*) 30 mm
(*d*) 50 mm

114. The chlorination in sewage treatment plant is done to
(*a*) accelerate the sludge digestion process
(*b*) disinfect the sewage
(*c*) remove objectionable odour
(*d*) accelerate settlement of suspended matter

115. Grit is composed mostly of
(*a*) grease
(*b*) paper
(*c*) wood
(*d*) sand

116. The spacing of bars of perforation of fine screens used for the treatment of sewage is
(*a*) 2 – 3 mm
(*b*) 8 – 10 mm
(*c*) 15 – 20 mm
(*d*) 25 – 30 mm
(*e*) 50 mm

117. Grit chambers are designed for particles with specific gravity of
(*a*) 2.56
(*b*) 2.65
(*c*) 2.67
(*d*) 1.00

118. The bulking of sludge in activated sludge process can be remedied to some extent by
(*a*) chlorination
(*b*) reducing the aeration period
(*c*) reducing the pH value of the sewage
(*d*) addition of fresh water

119. An activated sludge is **(GATE 2002)**
(*a*) the sludge that is obtained by settling of sewage in presence of abundant oxygen
(*b*) the sludge that has been subjected to 50% anaerobic action
(*c*) the sludge that is discharged from primary settling tanks
(*d*) the sludge that is obtained from the sludge digestion tank

120. In a sludge digestion tank the process of sludge digestion is rapid when the pH value is in the range of
(*a*) 4 – 7
(*b*) 10 – 14
(*c*) 6.8 – 7.2
(*d*) 7 – 9

121. The gas produced during sludge digestion is
(*a*) nitrogen
(*b*) methane
(*c*) carbon monoxide
(*d*) carbon dioxide

122. A tank in which raw or partly treated sewage is collected, allowed to stay and discharged at such a rate as may be necessary for subsequent treatment, is known as
(*a*) surge tank
(*b*) dosing tank
(*c*) sludge tank
(*d*) sedimentation tank

123. Elutrition is the process of
(*a*) adding oxygen to the sludge
(*b*) washing digested sludge
(*c*) sludge digestion
(*d*) disposing off the sludge

124. Oil and grease can be removed by
(*a*) floatation tanks
(*b*) rocks and screens
(*c*) biological growth
(*d*) disinfection

125. Screening or skimming cannot remove
(*a*) large suspended matter
(*b*) oil and fat
(*c*) grease
(*d*) fine suspended matter

126. Fine suspended matter is removed by
(*a*) screening
(*b*) skimming
(*c*) sedimentation
(*d*) filteration

127. The settling velocity does not depend on
(*a*) specific gravity of particles
(*b*) depth of tank
(*c*) size of particles
(*d*) temperature of liquid

128. The settling velocity depends on
(*a*) length of the tank
(*b*) width of the tank
(*c*) depth of the tank
(*d*) length and width of tank

129. The coagulant widely used for sewage treatment is
(*a*) ferric chloride
(*b*) lime
(*c*) alum
(*d*) ferric sulphate

130. The allowable detention period in sedimentation tank is
(*a*) 1 to 3 hours
(*b*) 3 to 5 hours
(*c*) 5 to 10 hours
(*d*) 12 to 24 hours

131. In case the surface area of a sedimentation tank is increased, it will remove more
(*a*) fine particles
(*b*) large particles
(*c*) particles of all sizes
(*d*) water

132. Humus tanks are provided for
(*a*) primary sedimentation
(*b*) secondary sedimentation
(*c*) filteration
(*d*) sludge disinfection

133. The reduction of B.O.D. in a sedimentation tank for sewage treatment may be expected in the range

(a) 10% (b) 10% to 25%
(c) 30% to 40% (d) 60% to 76%

134. The B.O.D. is satisfied in biological treatment by
(a) screening (b) sedimentation
(c) filtration (d) disinfection

135. The normal trickling filter removes
(a) 50% of B.O.D. (b) 80-90% of B.O.D.
(c) 95% of B.O.D. (d) 95-99% of B.O.D.

135A. The sewage filter used in modern sewage treatment works is
(a) intermittent sand filter (b) the contact beds
(c) the trickling filter (d) none of (a), (b), (c)

136. Vacuum filters are used for
(a) slowing down bacterial activity
(b) dewatering of sludge
(c) filteration of sludge
(d) filteration of released water

137. In a high rate trickling filter, high rate of loading is achieved by
(a) better filter media (b) recirculation of sewage
(c) dunbar filters (d) any of the above

138. Which of the following processes takes place in trickling filters?
(a) Filteration (b) Oxidation
(c) Disinfection (d) Biological action

139. Organisms used by both trickling filters and activated sludge system for the bulk of their purification capacity are :
(a) anaerobic (b) parasitic
(c) aerobic (d) none of the above

140. Solids that cannot be removed by filtering are
(a) suspended solids (b) settleable solids
(c) dissolved solids (d) coarse solids

141. The main disadvantage of intermittent sand filters is
(a) requirement of large area
(b) less depth
(c) use of costly chemicals
(d) their suitability for acidic sludges only

142. Lagooning is
(a) method of sludge disinfection
(b) method of sludge dilution
(c) method of rapid sludge digestion
(d) method of sludge disposal

143. The normal rate for the disposal of sewage by irrigation on a sandy soil, in litres per hectare per day, is of the order of
(a) 2,500 (b) 25,000
(c) 250,000 (d) 2,500,000

144. Pumps commonly used for sewage disposal are :
(a) reciprocating pumps (b) turbine pumps
(c) vane pumps (d) mud pumps

145. The impeller for sewage pump is
(a) shrouded on one side only
(c) open type (d) vane type

146. In distribution pipes, drain valves are located
(a) at junctions (b) at summit
(c) at lower joint (d) anywhere

147. Priming of a centrifugal pump may not be necessary, in case the pump is located
(a) at less than 10 m height above the reservoir level
(b) at less than 5 m height above the reservoir level
(c) immediately above the reservoir level
(d) below the reservoir level

148. A device used to measure the flow of waste water is
(a) comparator (b) weir
(c) sluice gate (d) comminutor

149. Which of the following disease is not considered as water borne?
(a) Typhoid (b) Jaundice
(c) Bacillary dysentry (d) Malaria

150. Fish life in receiving streams is most seriously affected by
(a) high coliform counts
(b) drop in dissolved oxygen level
(c) increase in dissolved mineral concentrations
(d) all of the above

151. Carbon dioxide, one of the gases given off by the decomposition of sludge, is not poisonous, but it may cause
(a) combustion (b) corrosion
(c) burns (d) asphyxiation

152. Raw waste water sludge should not be used as a garden fertilizer because it contains
(a) injurious acids (b) pathogenic bacteria
(c) thermophilic organisms
(d) high sodium concentrations

153. A water closet is commonly made of
(a) stone ware (b) terracota
(c) porcelain (d) glazed earthenware

154. Normally the capacity of flushing cisterns for water closets is
(a) 1 to 2 litres (b) 2 to 5 litres
(c) 10 to 15 litres (d) 25 to 40 litres

155. The minimum height of a flushing cistern is
(a) 1 m (b) 3 m
(c) 5 m (d) 7.5 m

156. The system of collecting night soil in pots or pits for periodical removal outside the town area for burial, is known as
(a) potting (b) night washing
(c) conservancy (d) cleansing

157. From septic tank the effluents are discharged into
(a) soak pit (b) drainage
(c) oxidation pond (d) sewer

158. Traps are provided to
(*a*) stop flow of sewage
(*b*) separate the flow of liquids and solids
(*c*) avoid back flow of sewage
(*d*) prevent the escape of foul gases inside and outside the house

159. A trap provided to prevent the foul gases from going in the house, is
(*a*) Greavak trap (*b*) Anti-D trap
(*c*) Guilty trap (*d*) Intercepting trap

160. For a boarding house the standard number of W.Cs. required is
(*a*) 1% (*b*) 2%
(*c*) 5% (*d*) 10%

161. For a cinema hall the number of W.Cs. required for females is
(*a*) 1% (*b*) 2%
(*c*) 2% upto 200 and 1% thereafter
(*d*) 1 % upto 200 and 2% thereafter

162. The minimum depth of water seal in a good trap is
(*a*) 2.5 to 7.5 cm (*b*) 10 to 15 cm
(*c*) 15 to 25 cm (*d*) 30 to 35 cm

163. The average spacing of urinal stalls in public places is kept as
(*a*) 30 cm (*b*) 60 cm
(*c*) 100 cm (*d*) 125 cm

164. For a cinema hall with seating capacity of 1000, the number of urinals to be provided is
(*a*) 5 (*b*) 10
(*c*) 25 (*d*) 40

165. The height of a porcelain urinal stall bowl type, above the foot level is usually
(*a*) 30 cm (*b*) 50 cm
(*c*) 75 cm (*d*) 100 cm

166. The capacity of flushing cisterns for urinals is generally
(*a*) 1 litre (*b*) 5 litres
(*c*) 15 litres (*d*) 40 litres

167. A trickling filter is primarily a
(*a*) straining process to remove suspended solids from sewage
(*b*) biological oxidation process to remove BOD from sewage
(*c*) straining process to remove turbidity from water
(*d*) straining process to remove bacteria from water

168. A combined sewage is one which transports
(*a*) domestic sewage and storm water
(*b*) domestic sewage and industrial wastes
(*c*) domestic sewage and overhead flow
(*d*) domestic sewage industrial wastes and storm water

169. A septic tank is
(*a*) an aerobic method of on-site sewage treatment
(*b*) an anaerobic method of on-site treatment
(*c*) a physical method of water treatment
(*d*) a physicochemical method of water treatment

170. Biochemical oxygen demand (BOD) of wastewater is a measure of
(*a*) total concentration of biochemicals
(*b*) total concentration of organic matter
(*c*) concentration of biodegradable organic matter
(*d*) concentration of chemically oxidisable matter

171. In an atmosphere under super-adiabatic lapse rate conditions, the emission from a chimney produces a plume describable as
(*a*) coning (*b*) loffing
(*c*) looping (*d*) fumigation

172. Chemical oxygen Demand (COD) of a sampls is always greater than Biochemical Oxygen Demand (BOD) since it represents
(*a*) biodegradable organic matter only
(*b*) biodegradable and non-biodegradable organic matter
(*c*) non-biodegradable organic matter
(*d*) inogranic matter

173. A waste water sample diluted to 100 times with aeration water had and initial dissolved oxygen (DO) of 7.0 mg/L and after 5 days of incubation at 20°C, the DO was zero. The BOD of waste water is
(*a*) 700 mg/L (*b*) 100 mg/L
(*c*) cannot be determined (*d*) 7 mg/L

174. High COD to BOD ratio of an organic pollutant represents
(*a*) high biodegradability of the pollutant
(*b*) low biodegradability of the pollutant
(*c*) presence of free oxygen for aerobic decomposition
(*d*) presence of toxic material in the pollutant

175. Activated sludge is the
(*a*) aerated sludge in the aeration unit
(*b*) sludge settled in the humaus tank
(*c*) sludge in the secondary tank after aeration and rich in microbial masses
(*d*) sludge in the secondary tank after aeration and rich in nutrients

176. During temperature inversion in atmosphere, air pollutants tend to
(*a*) accumulate above inversion layer
(*b*) accumulate below inversion layer
(*c*) disperse laterally
(*d*) disperse vertically

177. Symbiosis, the beneficial association between algae and bacteria is used for treatment of waste water in the following unit
(*a*) Activated sludge (*b*) Rotating Biological Disc
(*c*) Anaerobic Digester (*d*) Oxidation Pond

178. The ultimate BOD of the waste water whose 5 days BOD $(BOD)_5$ and rate constant (base) are respectively 150 mg/l and 0.23 is
(*a*) 80 mg/l (*b*) 150 mg/l
(*c*) 180 mg/l (*d*) 220 mg/l

179. The drop manholes are provided in a sewerage system when there is
(a) change in alignment of sewer line
(b) change in size of sewers
(c) change in the elevation of ground level
(d) change from gravity system to pressure system

180. The main constituents of gas generated during the anaerobic digestion of sewage sludge are
(a) carbon dioxide and methane
(b) methane and ethane
(c) carbon dioxide and carbon monoxide
(d) carbon monoxide and nitrogen

181. A single rapid test to determine the pollutional status of river water is
(a) biochemical oxygen demand
(b) chemical oxygen demand
(c) total organic solids
(d) dissolved oxygen

182. Presence of excess nitrates in river water indicates
(a) recent pollution of water with sewage
(b) past pollution of water with sewage
(c) immediate pollution of water with sewage
(d) no pollution of water with sewage

183. The clariflocculator is the unit in which the following things will occur
(a) floc formation and its subsequent removal by filtration
(b) floc formation and its subsequent removal by sedimentation
(c) floc formation and its subsequent removal by decantation
(d) removal of bacteria by filtration and chlorination

184. A rapid test to indicate the intensity of pollution in river water is
(a) biochemical oxygen demand
(b) dissolved oxygen
(c) MPN (d) total dissolved solids

185. Tricking filters are used to remove
(a) suspended solids (b) collidal solids
(c) organic matter (d) pathogenic bacteria

186. Under Indian conditions, the average per capita contribution of BOD is
(a) 10 to 20 gm/d (b) 20 to 35 gm/d
(c) 35 to 50 gm/d (d) 50 to 70 gm/d

187. Sewage sickness relates to
(a) toxicity of sewage interfering with response to treatment
(b) destruction of aquatic flora and fauna due to gross pollution of receiving bodies of water by sewage
(c) reduction is the waste purifying capacity of the soil
(d) clogging of pores in soil due to excessive application of sewage of land, obstructing aeration and leading of septic conditions

188. The slope of a 1.0 m diameter concrete sewer laid at a slope of 1 in 1000, develops a velocity of 1 m/s when flowing full, when it is flowing half full, the velocity of flow through the sewer will be
(a) 0.5 m/s (b) 1.0 m/s
(c) $\sqrt{2}$ m/s (d) 2.0 m/s

189. One litre of sewage when allowed to settle for 30 minutes gives a sludge volume of 27 cm^3. If the dry weight of this sludge is 3.0 gms then its sludge volume index will be
(a) 9 (b) 24
(c) 30 (d) 81

190. An aeration basin with a volume of 400 m^3 contains mixed liquor with suspended solid concentration of 1000 mg/l. The amount of mixed liquor suspended solids in the tank is
(a) 500 kg (b) 250 kg
(c) 6600 kg (d) 400 kg

191. Which one of the following statement is true of trickling filter sludge?
(a) It has a comparatively low sludge volume index
(b) It is more difficult to dewater than activated sludge
(c) It has a comparatively low concentration of sludge solids
(d) It is bulky

192. An industrial waste water enters a stream having a BOD concentration of 10 mg/l and a flow of 20 m^3/s and its BOD concentration is 250 mg/l then the BOD concentration in the stream at a point downstream of the point of confluence of waste water with the stream will be **(GATE 2006)**
(a) 2.67 mg/l (b) 12.09 mg/l
(c) 13.00 mg/l (d) 2.74 mg/l

193. The following reactions take place during anaerobic digestion of organics
1. Methane production 2. Alkaline fermentation
3. Acid fermentation 4. Acid regression
The correct sequence of these reactions is
(a) 3, 4, 2, 1 (b) 4, 3, 2, 1
(c) 3, 4, 1, 2 (d) 4, 3, 1, 2

194. Coal based thermal power stations pollute the atmosphere by adding
(a) NO_x and SO_2 (b) NO_x, SO_2 and SPM
(c) NO_x, SO_2, SPM and CO
(d) NO_x, SPM and CO **(GATE 2005)**

195. Traps are used in household drainage systems to
(a) prevent entry of fond gases in the houses
(b) restrict the flow of water
(c) provide partial vacuum
(d) trap the solid wastes

196. For the combined sewage system egg-shaped sewers are preferred because
(a) their construction is economical
(b) they are structurally more stable
(c) the maintenance is easier
(d) they offer good flow velocity during the dry-weather-flow condition

197. Various unit operations exist in a sewage treatment plant these would include

1. Screening 2. Grit removal
3. Secondary sedimentation
4. Aeration
5. Primary sedimentation

The correct sequence of these operations is

(*a*) 1, 2, 3, 4, 5 (*b*) 1, 2, 5, 4, 3
(c) 2, 1, 4, 5, 3 (*d*) 2, 1, 4, 3, 5

198. In transition of sewers from smaller diameter sewers to larger diameter sewers, the continuity of sewers is maintained at the

(*a*) bottom of the concrete bed of sewers
(*b*) inverts of the sewers
(c) crowns of the sewers
(*d*) hydraulic gradients of the sewers

199. The correct relationship between theoritical oxygen demand (TOD), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) is given by

(*a*) TOD > BOD > COD (*b*) TOD > COD > BOD
(c) COD > BOD > TOD (*d*) BOD > COD > TOD

200. Corrosion of concrete sewers occur due to

(*a*) high velocity of flow of sewage
(*b*) aerobic decomposition of sewage solids
(*c*) Anaerobic decomposition of sewage solids
(*d*) high pH value of sewage

201. The growth of algae is useful in

(*a*) sedimentation tank (*b*) slow sand filter
(*c*) oxidation pond (*d*) sludge digestion tank

202. A polluted stress undergoes self purification is four distinct zones.

1. Zone of clear water
2. Zone of active decomposition
3. Zone of degradation
4. Zone of recovery

The correct sequence of these zones is

(*a*) 4, 3, 2, 1 (*b*) 2, 3, 4, 1
(c) 2, 4, 3, 1 (*d*) 3, 2, 4, 1

203. Under natural condition of flow on polluted river would contain

(*a*) more dissolved oxygen in summer than in winter
(*b*) less dissolved oxygen in summer than in winter
(*c*) more or less the same amount of dissolved oxygen in winter and summer
(*d*) the least amount of dissolved oxygen during the floods

204. Area method of land filling is most suitable when

(*a*) area is unsuitable for excavation of trenches
(*b*) adequate depth of cover material is available at site
(*c*) the water table is near the surface
(*d*) natural or artificial depressions exist in the vicinity

205. Consider the following statements. Excessive growth of water-weeds in a water body is attributed to the

1. increase in the benthic organisms including bacteria
2. imbalance in the aquatic eco system
3. excessive inflow of nutrients

Of these statements

(*a*) 1, 2 and 3 are correct
(*b*) 1 and 2 are correct
(*c*) 1 and 3 are correct
(*d*) 2 and 3 are correct

206. Which one of the following solid waste disposal methods is ecologically most acceptable?

(*a*) sanitary land fill (*b*) incineration
(*c*) composition (*d*) pyrolysis

207. The atmosphere extends up to height of 10,000 km. It is divided into the following four thermal layers.

1. Mesosphere 2. Thermosphere
3. Stratosphere 4. Troposphere

(*a*) 2, 4, 1, 3 (*b*) 4, 2, 1, 3
(*c*) 4, 2, 3, 1 (*d*) 2, 4, 3, 1

208. The waste stabilisation ponds can be

(*a*) aerobic (*b*) anaerobic
(*c*) faculative (*d*) any of the above

209. Which of the following pairs is not correctly matched?

(*a*) BOD — Strength of sewage
(*b*) Methane — Product of anaerobic decomposition
(*c*) COD — Biodegradability of waste-water
(*d*) Nitrate — Mathemoglobinemia

210. The following are the sewage treatment processes

1. Primary sedimentation
2. Screening
3. Grit removal
4. Secondary sedimentation

When only preliminary treatment is to be given for sewage, select the required treatment processes including their correct sequence from the codes given below

Codes:

(*a*) 2, 3 (*b*) 2, 3, 1
(*c*) 1, 2, 3, 4 (*d*) 3, 1, 2, 4

211. Ringlemann's scale is used to

(*a*) measure CO (*b*) measure SO_2
(*c*) grade density of smoke
(*d*) grade of automobile exhaust gas

212. Eutrophication of water bodies is caused by the

(*a*) discharge of toxic substances
(*b*) excessive discharge from nutrients
(*c*) excessive discharge from suspended solids
(*d*) excessive discharge of chlorides

213. Non disposal of solid waste may cause the spread of

(*a*) Malaria (*b*) rodents related plague
(*c*) Typhoid (*d*) dysentery

214. Which of the following is not a major indoor pollutant in a developing country like India, in the rural areas?

(*a*) cooking and heating activities
(*b*) burning of cow dung
(*c*) burning of crop waste
(*d*) building material

ANSWERS

1. (*b*)	**2.** (*c*)	**3.** (*c*)	**4.** (*a*)	**5.** (*b*).	**6.** (*d*)	**7.** (*a*)	**8.** (*d*)	**9.** (*b*)	**10.** (*d*)
11. (*d*)	**12.** (*d*)	**13.** (*c*)	**14.** (*d*)	**15.** (*d*)	**16.** (*d*)	**17.** (*d*)	**18.** (*a*)	**19.** (*d*)	**20.** (*c*)
21. (*d*)	**22.** (*b*)	**23.** (*c*)	**24.** (*c*)	**25.** (*c*)	**26.** (*b*)	**27.** (*d*)	**28.** (*a*)	**29.** (*b*)	**30.** (*b*)
31. (*a*)	**32.** (*c*)	**33.** (*d*)	**34.** (*c*)	**35.** (*d*)	**36.** (*d*)	**37.** (*b*)	**38.** (*c*)	**39.** (*b*)	**40.** (*c*)
41. (*c*)	**42.** (*d*)	**43.** (*b*)	**44.** (*d*)	**45.** (*d*)	**46.** (*d*)	**47.** (*b*)	**48.** (*a*)	**49.** (*b*)	**50.** (*d*)
51. (*c*)	**52.** (*d*)	**53.** (*b*)	**54.** (*c*)	**55.** (*a*)	**56.** (*b*)	**57.** (*b*)	**58.** (*a*)	**59.** (*d*)	**60.** (*c*)
61. (*b*)	**62.** (*b*)	**63.** (*d*)	**64.** (*a*)	**65.** (*c*)	**66.** (*b*)	**67.** (*a*)	**68.** (*c*)	**69.** (*b*)	**70.** (*a*)
71. (*b*)	**72.** (*c*)	**73.** (*a*)	**74.** (*d*)	**75.** (*a*)	**76.** (*d*)	**77.** (*a*)	**78.** (*d*)	**79.** (*b*)	**80.** (*a*)
81. (*c*)	**82.** (*d*)	**83.** (*a*).	**84.** (*b*)	**85.** (*a*)	**86.** (*c*)	**87.** (*a*)	**88.** (*c*)	**89.** (*a*)	**90.** (*a*)
91. (*d*)	**92.** (*c*)	**93.** (*a*)	**94.** (*d*)	**95.** (*a*)	**96.** (*c*)	**97.** (*a*)	**98.** (*b*)	**99.** (*a*)	**100.** (*c*)
101. (*d*)	**102.** (*b*)	**103.** (*d*)	**104.** (*a*)	**105.** (*b*)	**106.** (*b*)	**107.** (*a*)	**108.** (*c*)	**109.** (*c*)	**110.** (*c*)
111. (*b*)	**112.** (*d*)	**112A.** (*d*)	**113.** (*d*)	**114.** (*b*)	**115.** (*d*)	**116.** (*a*)	**117.** (*b*)	**118.** (*a*)	**119.** (*a*)
120. (*c*)	**121.** (*d*)	**122.** (*b*)	**123.** (*b*)	**124.** (*a*)	**125.** (*d*)	**126.** (*c*)	**127.** (*b*)	**128.** (*d*)	**129.** (*a*)
130. (*a*)	**131.** (*c*)	**132.** (*b*)	**133.** (*c*)	**134.** (*c*)	**135.** (*b*)	**135A.** (*c*)	**136.** (*b*)	**137.** (*b*)	**138.** (*d*)
139. (*c*)	**140.** (*c*)	**141.** (*a*)	**142.** (*d*)	**143.** (*c*)	**144.** (*d*)	**145.** (*c*)	**146.** (*c*)	**147.** (*d*)	**148.** (*b*)
149. (*d*)	**150.** (*b*)	**151.** (*d*)	**152.** (*a*)	**153.** (*c*)	**154.** (*c*)	**155.** (*b*)	**156.** (*c*)	**157.** (*a*)	**158.** (*d*)
159. (*d*)	**160.** (*d*)	**161.** (*c*)	**162.** (*a*)	**163.** (*b*)	**164.** (*c*)	**165.** (*c*)	**166.** (*b*)	**167.** (*b*)	**168.** (*a*)

169. (*b*) **170.** (*c*) **171.** (*c*) **172.** (*b*) **173.** (*a*) **174.** (*d*) **175.** (*d*) **176.** (*d*) **177.** (*d*) **178.** (*c*)
179. (*c*) **180.** (*a*) **181.** (*a*) **182.** (*b*) **183.** (*b*) **184.** (*d*) **185.** (*c*) **186.** (*b*) **187.** (*b*) **188.** (*b*)
189. (*a*) **190.** (*d*) **191.** (*b*) **192.** (*d*) **193.** (*a*) **194.** (*c*) **195.** (*a*) **196.** (*d*) **197.** (*b*) **198.** (*b*)
199. (*b*) **200.** (*c*) **201.** (*c*) **202.** (*d*) **203.** (*c*) **204.** (*d*) **205.** (*a*) **206.** (*d*) **207.** (*c*) **208.** (*d*)
209. (*c*) **210.** (*b*) **211.** (*c*) **212.** (*b*) **213.** (*b*) **214.** (*d*) **215.** (*a*) **216.** (*d*) **217.** (*d*) **218.** (*c*)
219. (*d*) **220.** (*c*) **221.** (*d*) **222.** (*d*) **223.** (*d*) **224.** (*b*) **225.** (*d*) **226.** (*a*) **227.** (*d*) **228.** (*a*)
229. (*c*) **230.** (*d*) **231.** (*a*) **232.** (*c*) **233.** (*c*) **234.** (*b*) **235.** (*a*) **236.** (*c*) **237.** (*c*) **238.** (*c*)
239. (*d*) **240.** (*b*) **241.** (*d*) **242.** (*b*) **243.** (*c*) **244.** (*b*) **245.** (*d*) **246.** (*c*) **247.** (*d*) **248.** (*d*)
249. (*d*) **250.** (*a*) **251.** (*a*) **252.** (*a*) **253.** (*d*) **254.** (*c*) **255.** (*a*) **256.** (*d*) **257.** (*c*) **258.** (*d*)
259. (*d*) **260.** (*c*) **261.** (*c*) **262.** (*d*) **263.** (*d*) **264.** (*d*) **265.** (*b*) **266.** (*b*) **267.** (*b*) **268.** (*d*)
269. (*b*) **270.** (*d*) **271.** (*c*) **272.** (*b*) **273.** (*a*). **274.** (*d*) **275.** (*c*) **276.** (*d*) **277.** (*d*) **278.** (*a*)
279. (*d*) **280.** (*a*) **281.** (*c*) **282.** (*d*) **283.** (*c*) **284.** (*b*) **285.** (*d*) **286.** (*c*) **287.** (*c*) **288.** (*c*)
289. (*b*) **290.** (*c*) **291.** (*d*) **292.** (*c*) **293.** (*c*) **294.** (*d*) **295.** (*d*) **296.** (*b*)