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ESE – 2019 MAINS
OFFLINE TEST SERIES

CIVIL ENGINEERING

TEST – 6
SOLUTIONS

All Queries related to **ESE – 2019 MAINS Test Series** Solutions are to be sent to the following email address
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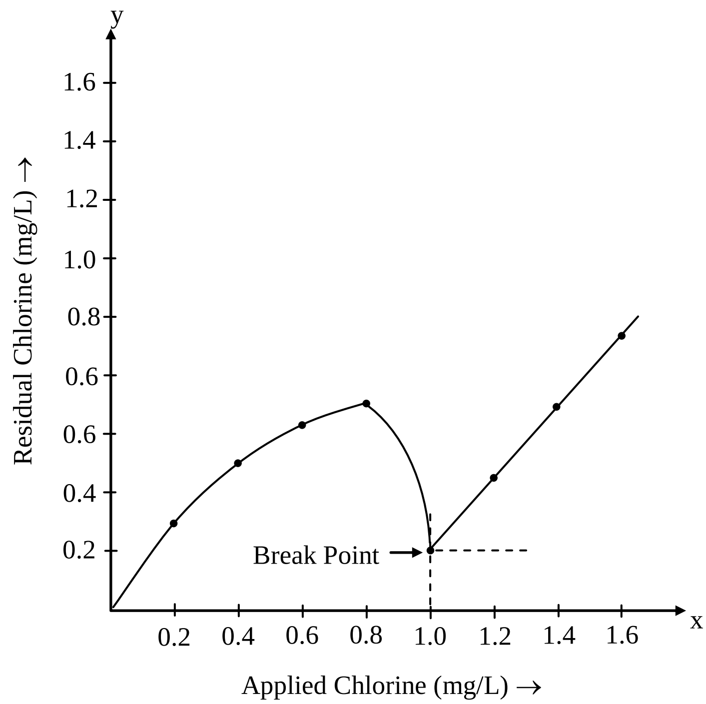
01(a).

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



Break point is presented 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.

01(b).(i)

Sol: **(a) Overflow rate [Surface loading rate] :**

$$= \frac{\text{Discharge per day on each settling tank}}{\text{Surface area of settling tank}}$$

$$= \frac{\left[\dfrac{1.5\times10^6}{2}\right]}{[12\times3.5]} = 17857.14\ l\text{t/day/m}^2 = 17.857\ \text{m}^3\text{/day/m}^2$$

(b) Efficient weir loading rate:

$$= \frac{\text{Discharge per day on each settling tank}}{\text{efficient weir length}}$$

$$= \frac{\left[\frac{1.5\times10^{6}}{2}\right]\times\frac{1}{10^{3}}}{13.5}$$

$= 55.56\ m^3/day/m$

01(b).(ii)

Sol: Discharge (Q) = Population × Per capita sewage flow

$$= \left(\frac{10000\times180}{10^{6}}\right)$$

Q = 1.8 MLD

$$\text{Surface Area of oxidation pond} = \frac{\text{Total BOD applied}}{\text{OLR}}$$

$$= \frac{1.8\times200}{250}$$

= 1.44 hectare

$L \times B = 1.44 \times 10^4\ m^2$

L : B = 4 : 1

$4B^2 = 1.44 \times 10^4$

B = 60 m

L = 240 m

$$\text{Detention Time} = \frac{\text{volume of oxidation pond}}{\text{Discharge}}$$

$$= \frac{60\times240\times1.5}{1.8\times10^{3}}$$

= 12 days

(within the permissible limit, hence ok)

01(c).

Sol:

- **Plume:** The path taken by a continuous discharge of gaseous effluents emitted from a stack or chimney is called as Plume.
- The shape of the path and distribution of gaseous plumes in the atmosphere depends upon localized air stability.
- Different plume behaviors under different temperature variations (lapse rates) are discussed as below:

(i) **Looping plume:** This is common type of plume behavior which occurs under superadiabatic lapse rate (SALR) conditions with sight to moderate wind speeds on a hot summer afternoon when large scale thermal eddies are present. The plume has wavy behaviour since it occurs in a highly unstable atmosphere. The high turbulence helps in rapid dispersion of the plume, but high concentration may occur close to the stack if the plume touches the ground.

(ii) **Coning plume:** Coning plume occurs on cloudy day or nights with strong winds (velocity 32 km/h) when the lapse rate is near neutral (adiabatic condition). The plume shape is vertically symmetrical about the plume line. However, the plume reaches the ground at greater distance than with looping.

(iii) **Fanning plume:** This occurs under extreme inversion conditions, in the presence of light wind. Most of the vertical dispersion is suppressed by extremely stable condition, and the plume fans out in the horizontal direction. Strong concentrations at plume height are exhibited down wind of the stack. A fanning plume is often observed at a height and in the early morning in all seasons.

(iv) **Lofting plume:** Plume is said to be lofting when there exists a strong super adiabatic lapse rate (SALR) above a surface inversion. In such a condition, downward motion and mixing is prevented by surface inversion but the upward mixing will be quite turbulent and rapid. The emission will therefore not reach the ground surface.

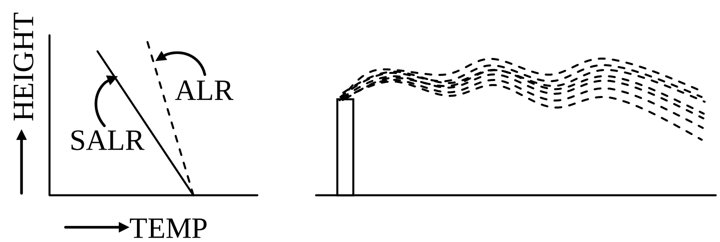
Lofting is the most favourbale plume type as far as ground level concentrations are concerned and is one of the major goals of tall-stack operation.

(v) Fumigating plume: The conditions for fumigation are just the inversion of lofting plume. Fumigation takes place when an inversion layer occurs at a short distance above the top of the stack and super adiabatic conditions prevail below it. Hence the pollutions cannot escape above the top of stack and they are brought down rapidly near ground due to turbulence in the region above the ground and below the inversion, caused by strong lapse rate. Fortunately, this condition is usually of short duration lasting for about 30 minutes. Fumigation is favoured by clean skies and light winds, and is more common in summer season. Fumigation represents quite a bad case of atmospheric dispersion.

(vi) Trapping plume: This condition is achieved when the plume is caught between two inversion layers. Hence the emitted plume can neither go up nor down and will be trapped between the two levels. The diffusion of the effluent will be severely restricted to the unstable layer between the two stable regions. A trapping plume is considered to be a bad condition for dispersion.

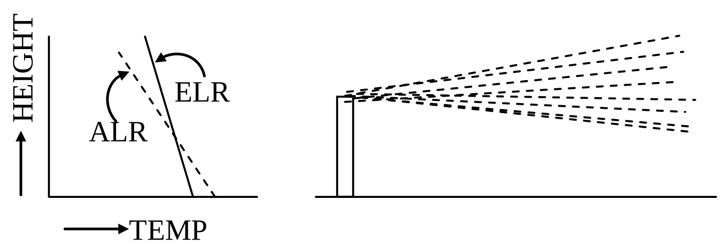
Types of Plume Behaviour:

(i) Strong Lapse Condition
(Strong Instability)



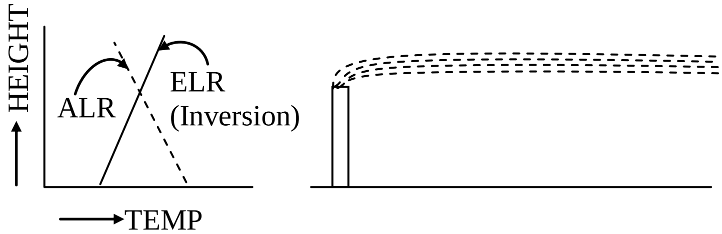
(i) LOOPING PLUME

(ii) Weak Lapse Condition
(Near Neutral Stability)



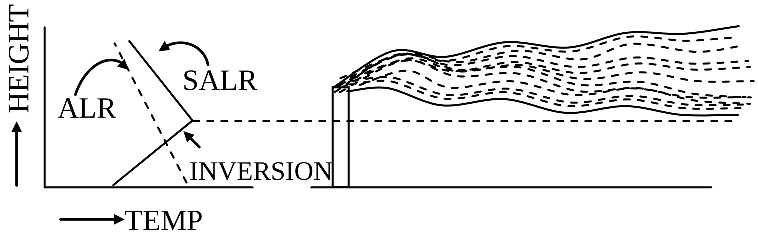
(i) CONING PLUME

(iii) Inversion Condition



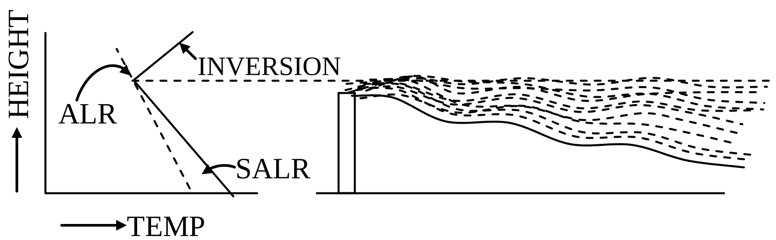
(iii) FANNING PLUME

(iv) Inversion Below Lapse Aloft



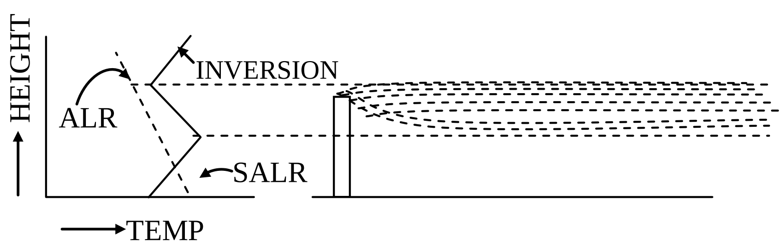
(iv) LOFTING PLUME

(v) Lapse Below Inversion Aloft



(v) FUMIGATING PLUME

(vi) Inversions Below And Above Stack



(vi) TRAPPING PLUME

01(d).

Sol: Estimation of missing precipitation record

Given the annual precipitation values, P_1, P_2, P_3 …P_m at neighbouring M stations 1, 2, 3, …. M respectively, it is required to find the missing annual precipitation P_x at a station X not included in the above M stations. Further, the normal annual precipitations N_1, N_2 …N_i … at each of the above (M + 1) stations including station X are know.

If the normal annual precipitations at various stations are within about 10% of the normal annual precipitation at station X, then a simple arithmetic average procedure is following toe estimate P_x. Thus

$$P_x = \frac{1}{M}\left[P_1 + P_2 + ... + P_m\right]$$

If the normal precipitations vary considerably, then P_x is estimated by weighing the precipitation at the various stations by the ratios of normal annual precipitations. This method, known as the normal ratio method, gives P_x as

$$P_x = \frac{N_x}{M}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + ... + \frac{P_m}{N_m}\right]$$

Stations	P	Q	R	S
N(cm)	80.5	65.5	75.0	90.5
P(cm)	89.3	68.7	79.5	P_s = ? = P_x

$N_s = 90.5$

–10% +10%

81.45 99.55

N_p, N_Q & N_R are not within 10% of N_s

$$\frac{P_x}{N_x} = \frac{1}{m}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + ... + \frac{P_M}{N_M}\right]$$

$$\frac{P_s}{90.5} = \frac{1}{3}\left[\frac{89.3}{80.5} + \frac{68.7}{65.5} + \frac{79.5}{75}\right]$$

$P_s = 97.08$ cm

01(e).

Sol: Q = 30 cumecs

y =3 m

B=15 m

A= (B+2y) y = (15+2×3)×3

= 63 sq.m

V_a = velocity in the channel = velocity in the approach = Q/A = 30/63

= 0.48 m/s

$$\frac{v_a^2}{2g} = \frac{0.48^2}{2\times 9.81} = 0.0117 \text{ m}$$

$$\text{U/s T.E.L} = \text{U/s FSL} + \frac{v_a^2}{2g} = 115 + 0.00117 = 115.012 \text{ m}$$

$Q = c_d\, LH^{3/2}$

$30 = 1.7 \times 10 \times H^{3/2}$

H=1.462 m

Crest level = U/S TEL - H

= 115.012-1.462

= 113.65 m

02(a). (i)

Sol: Hydrated lime ($Ca(OH)_2$)

= CO_2 + Mg + HCO_3

(in m.eq/lt) = $\frac{10}{22} + \frac{30}{12} + \frac{230}{61}$

= 6.725 m.eq/lt

Dose of hydrated lime = Hydrated lime × Equivalent weight of hydration

$$= 6.725 \times \left[\frac{40 + 2(16+1)}{2}\right]$$

= 248.825 mg/lt

02(a). (ii)

Sol:

a) Q = 1 MLD

$= 1 \times 10^6\ l$/day

Soda ash (Na_2CO_3) required

$$= \frac{100}{(23+2\times35.5)}\times(23\times2+12+3\times16)+\frac{80}{(24+32+4\times16)}\times(23\times2+12+3\times16)$$

$$= \frac{100}{111}\times106+\frac{80}{120}\times106 = 166.16 \text{ mg/lit}$$

Quantity of soda ash required

$= 166.16 \times 10^6 \times 10^{-6} = 166.1$ kg

b) Alkalinity = 200 mg/l

= CH

Hardness = 100 mg/l as $CaCl_2$

Hardness = 80 mg/l as $MgSO_4$

Amount of quick lime (CaO) required

$$= \frac{200}{100}\times56+\frac{80}{120}\times56$$

= 149.33 mg/l

Quantity of quicklime required to treat 1 MLD of water

$= 149.33 \times 10 \times 10^6 = 149.33$ kg

c) $CaO + H_2O \rightarrow Ca(OH)_2$

$56 \rightarrow 74$ mg/l

149.33 kg $\rightarrow$ x

(Slaked lime) $x = \dfrac{149.33\times74}{56}$ = 197.33 mg/l

Slaked lime of 85% purity required instead of quick lime

$$= \frac{197.33}{85}\times100 = 232.15 \text{ mg/}l$$

Quantity of slaked lime required to treat 1 MLD of water

$= 232.15 \times 10^6 \times 10^6 = 232.15$ kg

02(b). (i)

Sol: Average Rate of daily water supplied to town

$$= \frac{120000 \times 180}{10^3 \times 86400}$$

$= 0.25\ m^3/sec$

Assume 80% of water supplied appears as sewage = $0.25 \times 0.8 = 0.2\ m^3/sec$

Maximum sewage discharge = 3×0.2

$= 0.6\ m^3/sec$

V = 0.75 m/sec

Q = A V

$$A = \frac{Q}{V} = \frac{0.6}{0.75} = 0.8\ m^2$$

$$\frac{\pi}{4} d^2 = 0.8 m^2$$

d = 1.01 m

02(b). (ii)

Sol: Assume 5 day BOD as 68% of estimate BOD

$$\therefore BOD_{ultimate} = \frac{BOD_5}{0.68}$$

$= 389.7\ mg/l$

Total oxygen demand/ $\dot{m}$ kg = $\dfrac{BOD_{ultimate} \times \text{Discharge per day}}{10^6}$

$$= \frac{389.7 \times 30 \times 10^6}{10^6}$$

= 11691.17 kg

Population Equivalent = $\dfrac{\text{Total oxygen demand}}{\text{Per capita BOD}}$

$$= \frac{11691.17 \times 10^3}{75} = 1.56 \text{ lakh}$$

02(b). (iii)

Sol: As per the given data

Air temperature $T_a = 13^oC$

Stack gas temperature $T_s = 149^oC$

1. Converting temperature to K

$T_a = 273 + 13 = 286^ok$

$T_s = 273 + 149 = 422^ok$

2. Calculating $\Delta T = T_s - T_a$

$= 422 - 286$

$= 136^o$ k

3. Formula for estimating, Δh is

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

$V_s = 9.14$ m/s

d = 1.07 m

u = 3.56 m/s

p = 1000 milli bar

$$\therefore \ \Delta h = \frac{9.14 \times 1.07}{3.56}\left[1.5 + \left[2.68 \times 10^{-3}\right]\frac{1000 \times 136 \times 1.07}{422}\right]$$

= 6.6 m

4. Calculate effective height, $H = h + \Delta h$

$= 236 + 6.6$

$= 242.6$ m

02(c).

Sol: The storage equation is

$$S = k\,[xI + (1 - x)\,O]$$

$$S_1 = k\,[xI_1 + (1 - x)O_1]$$

$$S_2 = k[xI_2 + (1 - x)\,O_2]$$

Basic routing equation is given by

$$\left(\frac{I_1 + I_2}{2}\right)t - \left(\frac{O_1 + O_2}{2}\right)T = \left(S_2 - S_1\right)$$

$$\left(\frac{I_1+I_2}{2}\right)t-\left(\frac{O_1+O_2}{2}\right)t = k[xI_2+(1-x)O_2]-k[x(I_1)+(1-x)O_1]$$

$$\left(\frac{I_1+I_2}{2}\right)t+k[xI_1+(1-x)O_1]=\left(\frac{O_1+O_2}{2}\right)t+k(xI_2+(1-x)O_2)$$

$$(I_1+I_2)+\frac{2k}{t}(xI_1+(1-x)O_1)=(O_1+O_2)+\frac{2k}{t}[xI_2+(1-x)O_2]$$

$$\left[I_1+\frac{kxI_1}{0.5t}\right]+\left[I_2-\frac{kxI_2}{0.5t}\right]+\left[\frac{k(1-x)O_1}{0.5\Delta t}-O_1\right]=O_2+\frac{k(1-x)}{0.5t}O_2$$

$$\Rightarrow O_2\left[\frac{0.5t+k(1-x)}{0.5t}\right]=I_1\left[\frac{kx+0.5t}{0.5t}\right]+I_2\left[\frac{0.5t-kx}{0.5t}\right]+O_1\,(k-kx-0.5t)$$

$$\Rightarrow O_2\,[k-kx+0.5t] = I_1\,[0.5t+kx]+I_2\,[-kx+0.5t]+O_1\,(k-kx-0.5t)$$

$$\Rightarrow O_2=\left(\frac{kx+0.5t}{k-kx+0.5t}\right)I_1+\left(\frac{-kx+0.5t}{k-kx+0.5t}\right)I_2+\left(\frac{k-kx-0.5t}{k-kx+0.5t}\right)O_1$$

$$\Rightarrow O_2 = C_o\,I_2+C_1\,I_1+C_2O_1$$

It is the required Muskingum equation

Where $C_o=\dfrac{-kx+0.5t}{k-kx+0.5t}$

$$C_1=\frac{kx+0.5t}{k-kx+0.5t}$$

$$C_2=\frac{k-kx-0.5t}{k-kx+0.5t}$$

Sum of coefficient of Muskingum equation

$C_o + C_1 + C_2$

$$=\frac{-kx+0.5t+kx+0.5t+k-kx-0.5t}{k-kx+0.5t}$$

$$=\frac{k-kx+0.5t}{k-kx+0.5t}=1$$

$\therefore\ C_o + C_1 + C_2 = 1$

03(a).

Sol: Given Data:

Discharge, $Q = 0.5\ m^3/s = 0.5 \times 3600 \times 24 = 43200\ m^3/d$

Overflow rate = $32.5\ m^3/d/m^2$

Detention time, t = 95 minutes

Range of length to width ratios = 2:1 to 5:1

Let the length, breadth and depth of the tank to be L, B and H respectively

We know that

$$\text{Overflow rate } = \frac{\text{Discharge}}{\text{Surface area of tank}}$$

$$\Rightarrow 32.5 = \frac{43200}{BL} \qquad [\because \text{ Surface area of tank} = BL]$$

$\Rightarrow BL = 1329.23\ m^2$

$\therefore$ Surface area of tank is $1329.23\ m^2$

Capacity of the tank, $V = Q \times t = \frac{43200}{24} \times \frac{95}{60} = 2850\ m^3$

V = BLH

But, $\therefore$ BL × H = 2850

$$\Rightarrow H = \frac{2850}{1329.23} = 2.14\ m$$

$\therefore$ Depth of the clarifier is 2.14 m. it may be noted that this value indicate only the water depth. An allowance for deposition of sludge and slit is provided which can be adopted as 0.5 m.

Let us assume the trial ratio as 2:1 i.e.

L = 2 B

$\therefore$ 2B $\therefore$ B × H = 2850

$$\Rightarrow B = \sqrt{\frac{2850}{2 \times 2.14}} = 25.81\ m$$

$\therefore$ L = 2 × 25.81 = 51.62 m

As per the design recommendations, horizontal flow velocity should lie between 0.15 m/min to 0.9 m/min. Normally it check for horizontal flow velocity V_h.

$V_h \times t = L$

$\Rightarrow V_h = \dfrac{51.62}{95} = 0.543$ m/min < 0.9 m/min (Hence OK)

If the L:B ratio is increased then V_h will increase and exceed the maximum permissible value of 0.9 m/min. Hence the above ratio of 2:1 is adopted which gives the dimension of the tank as 51.56 × 25.78 × (2.14 + 0.5) m

03(b). (i)

Sol: Maximum demand = Population × 1.5 × average demand

= 200000 × 1.5 × 150 = 45 MLD

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

$$Q = \frac{45\times10^6}{10^3\times15\times60\times60} = 0.8333 \text{ m}^3/\text{sec}$$

HP of pump = 300

But, we know that, $HP = \dfrac{\gamma_w QH}{0.7457\times\eta}$

$$\Rightarrow 300 = \frac{9.81\times0.8333\times H}{0.7457\times0.70}$$

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

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

$\Rightarrow 19.16 = 15 + h_f$

$\Rightarrow h_f = 19.16 - 15$

$\Rightarrow h_f = 4.16$ m

Now length of pipe (L) = 2500 m

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

ii) We know that $h_f = \dfrac{fLV^2}{2gd}$

Now, $\dfrac{\pi d^2}{4} = \dfrac{Q}{V} = \dfrac{0.8333}{1.3}$

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

$\Rightarrow$ d = 0.9 m

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

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

03(b). (ii)

Sol: Given area of town, A = 2 km^2 = 200 ha

$$Q_{DWF} = \frac{1{,}00{,}000 \times 200 \times 0.8}{10^3 \times 24 \times 60 \times 60}$$

$= 0.185\ m^3/s$

$t_c = t_e + t_s$

$= 30 + 20$

$= 50$ min

I = 0.5

$$R = \frac{25.4a}{t_c + b}$$

$$= \frac{25.4 \times 40}{50 + 20}$$

= 14.514 mm/hr

$$Q_{WWF} = \frac{AIR}{360}$$

$$= \frac{200 \times 0.5 \times 14.514}{360}$$

$= 4.03\ m^3/s$

$\therefore Q_{com} = Q_{DWF} + Q_{WWF}$

$= 0.185 + 4.03$

$= 4.216\ m^3/s$

Sewer running half full

$Q_{com} = AV$

$$4.216 = \frac{\pi}{8}D^2 \times \frac{1}{n}\left(\frac{D}{4}\right)^{2/3} S^{1/2}$$

$$4.216 = \frac{\pi}{8}D^2 \times \frac{1}{0.012}\left(\frac{D}{4}\right)^{2/3}\left(\frac{1}{500}\right)^{1/2} \Rightarrow D = 2.1\text{ m}$$

03(c).(i)

Sol: 1 Cm D.C. means that 1 cm of water from an area of 6 hactare is entering the tiles per day.

Volume of water passing the drain in 1 day $= \left(\frac{1}{100} \times 6 \times 10^4\right)$ = 600 m^3/day

Volume of water passing the drain in 1 day $= \frac{600}{24 \times 3600} = \frac{1}{144} m^3/s$

$Q = \frac{1}{144}$ m^3/s

For circular drain of Diameter D, $A = \frac{\pi D^2}{4}$, $P = \pi D$

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

$$\frac{1}{144} = \frac{1}{0.011}\left(\frac{\pi D^2}{4}\right)\left(\frac{D}{4}\right)^{2/3}\left(\frac{0.3}{100}\right)^{1/2}$$

D= 0.132 m

D=13.2 cm

$= \frac{1.25}{100} \times 12 \times 10^4$ = 1500

03(c).(ii)

Sol:

a) $$\text{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} = \frac{22}{\sqrt{\frac{3+1.5}{2}}}$$

$$= \frac{22}{\sqrt{2.25}} = 14.67$$

SAR is between 10 and 18, hence it is medium - sodium water(S_2). Since electrical conductivity is between 100 and 250 micro mho per cm at 25^0C. Hence it is low salinity water (C_1). Hence water classified as C_1- S_2 water.

b) In fine textured soils, medium sodium water may create following problems:

- Soil becomes less permeable
- Soil starts crusting when it is dry
- Ph increases and soil becomes alkaline
- Soil becomes plastic and sticky when wet

c) Gypsum ($CaSO_4$) can be added to the soil or to the water to overcome from the problems created by using medium sodium water

04(a). (i)

Sol:

(i) The rate of fire demand as per National Board of Fire Underwriters formula for a central congested city whose population is less than or equal to 2 lakh is given by

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

Where Q is amount of water required in litres per minute and P is population in thousands

$$Q = 4637\sqrt{200}[1 - 0.01\sqrt{200}]$$

= 56303.08 litres per minute

$$= \frac{56303.08 \times 60 \times 24}{10^6} \text{ MLD}$$

= 81.08 MLD

(ii) Kuichling's Formula,

$$Q = 3182\sqrt{P} = 3182\sqrt{200} = 45000.28 \text{ litres/min}$$

= 64.8 MLD

(iii) Freeman Formula,

$$Q = 1136\left[\frac{P}{5} + 10\right] = 1136\left[\frac{200}{5} + D\right] = 56800 \text{ litres/min}$$

= 81.79 MLD

(iv) Buston's Formula,

$$Q = 5663\sqrt{P} = 5663\sqrt{200}$$

= 80086.91 litres per minute

= 115.33 MLD

04(a). (ii)

Sol: Given Q = 1000 m^3/day

η_{PT} = 20%

$$y_i = 200 - 200 \times \frac{20}{100}$$

= 160 mg/*l*

η = 87.5

$$y_e = 160 - 160 \times \frac{87.5}{100}$$

= 20 mg/*l*

$$\frac{F}{M} = \frac{Q(y_i - y_e)}{VX}$$

$$0.2 = \frac{1000(160 - 20)}{V \times 2500}$$

V = 2800 m^3

$$OLR = \frac{Qy_i}{V} = \frac{10 \times 160}{2800}$$

$\Rightarrow$ OLR = 0.571 kg/day/m^3

Mass of solids wasted/day = $\dfrac{VX}{\theta_c} = \dfrac{2.8 \times 2500}{10}$ = 700 kg/day

$$SVI = \frac{10^6}{X_V} = \frac{10^6}{10000}$$

SVI = 100 m*l*/g

$$\frac{Q_r}{Q} = \frac{X}{X_V - X} = \frac{2500}{10000 - 2500}$$

$$\frac{Q_r}{Q} = 0.33$$

04(b).

Ans: Precipitation:

- Denotes all forms of water that reach the earth from atmosphere (rainfall, snowfall, dew, hail etc).
- Rainfall is used syno0nymously with precipitation. The team "rainfall" is used to describe precipitations in the form of water drops of sizes larger than 0.5 mm. The maximum size of a raindrop is about 6 mm/

Type	Intensity
1. Light rain	trace to 2.5 mm/h
2. Moderate rain	2.5 mm/h to 7.5 mm/h
3. Heavy rain	> 7.5 mm/h

Drizzle: Size of drop is less than 0.5 mm and intensity is very small. Drops float in air.

Snow: Ice crystals, combine to form flakes.

Hail: Lumps of ice more than 8mm in size.

Sleet: It is in the form of ice crystals of size 1 mm to 5 mm

Glaze: Freezing of drizzle or rain when they come in contact with cold objects.

Dew: Moisture condensed from the atmosphere in small drops upon cool surfaces. Dew form directly by condensation on the ground mainly during the night when the surface has been cooled by the outgoing radiation.

Frost: Frost is a form of precipitation which occurs in the form of scales, needles, feathers or tank. It is a type of dew in which water vapour in the air is transformed directly into the ice crystals when it falls on the earth.

Types of Precipitations:

(a) Cyclone

(b)Convective

(c) Orographic

(d) Frontal

(a) Cyclone:

- It is a large low pressure region with circular wind motion.
- Isobars are closely spaced and winds are anticlockwise in the northern hemisphere.

- The centre of the storm is called 'eye', which will be relatively quiet.
- Outside the eye, very strong winds with speed decreasing towards outer edge.
- Pressure increases outwards.
- Rainfall will be heavy over larger area.

Tropical Cyclone:

A tropical cyclone, also called cyclone in India, hurricane in USA and typhoon in South-East Asia, is a wind system with an intensity strong depression with MSL pressures sometimes below 915 m bars. The normal areal extent of a cyclone is about 100-200 km in diameter. The isobars are closely spaced and the winds are anticlockwise in the northern hemisphere. The centre of the storm, called the eye, which may extend to about 10-50 km in diameter, will be relatively quiet. However, right outside the eye, very strong wind reaching to as much as 200 kmph exist. The wind speed gradually decreases towards the outer edge. The pressure also increases outwards. The rainfall will normally be heavy in the entire area occupied by the cyclone.

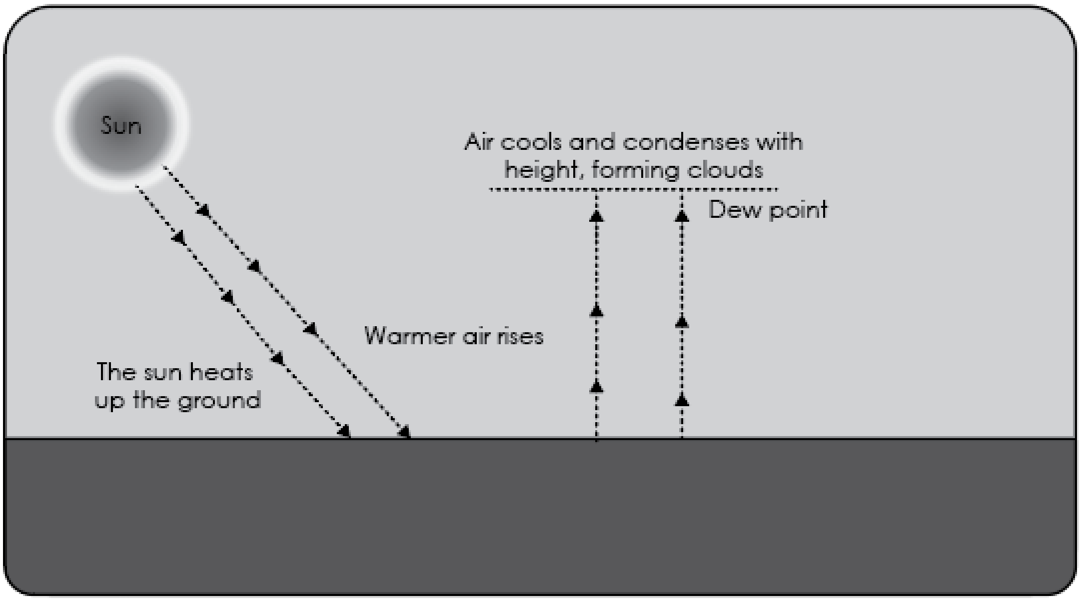
Extratropical cyclone: These are cyclones formed in locations outside the tropical zone. Associated with a frontal system, they possess a strong counter-clockwise wind circulation in the northern hemisphere. The magnitude precipitation and wind velocities are relatively lower than those of a tropical cycle. However, the duration of precipitation is usually longer and the areal extend also is larger.

Anticyclone:

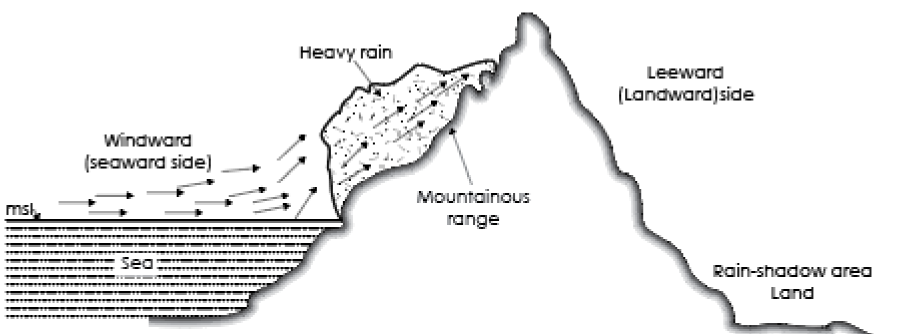
- It is a region of high pressure.
- Cause clockwise wind in the northern hemisphere.
- At outer edges precipitation exists.

(b) Convective Precipitation:

In this type of precipitation a packet of air which is warmer than the surrounding air due to localized heating rises because of its lesser density. Air from cooler surroundings flows to take up its place thus setting up a convective cell. The warm air continues to rise, undergoes cooling and results in precipitation. Depending upon the moisture, thermal and other conditions light showers to thunderstorms can be expected in convective precipitation. Usually the areal extent of such rains is small, being limited to a diameter of about 10 km.



(c) Orographic Precipitation: Moist air mass gets lifted up due to the presence of mountain barriers and consequently undergoes cooling and gives precipitation. This type is called as Orographic precipitation. The wind ward slope gets heavy precipitation and leeward slope gets light rainfall.



Orographic Precipitation

(d) Frontal Precipitation:

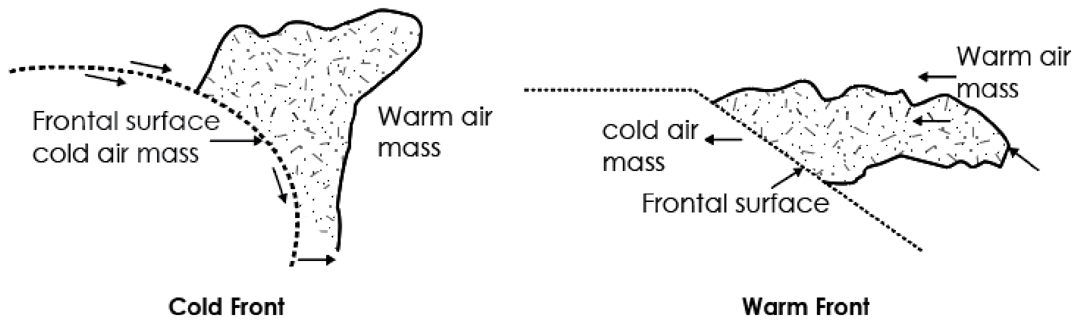
Type of cyclonic precipitation

Frontal surface or a front is a surface which separates a warm air mass and a cold air mass.

Frontal precipitation is further divided into two types

(i) Warm front precipitation

(ii) Cold front precipitation



04(c).

Sol:

(i) The ratio of the total sediment deposited in the reservoir to the total sediment flowing in the river is called <u>trap efficiency.</u>

Trap efficiency is generally 95-10%, even inspite of taking necessary precautions and measures to control like silt excluders and silt ejectors.

It is observed that it is very difficult to bring trap efficiency less than 90%.

(ii) **Capacity-inflow ratio:** The ratio of reservoir capacity to the total inflow of water in it is known as capacity inflow ratio. It is a very important factor. Because trap efficiency (n) has been found to be function of capacity-inflow ratio

$$\eta = f\left[\frac{\text{Capacity}}{\text{Inflow}}\right]$$

The graph shown given relationship between trap efficiency and log $\left[\frac{\text{Capacity}}{\text{Inflow}}\right]$

(iii) $f_u = 160$

$$f = \frac{f_u}{FOS} = \frac{160}{4} = 40 \text{ kg/cm}^2$$

$$= 400 \text{ t/m}^2$$

S = 2.4

C = 0.67

$w = 1000 \text{ kg/m}^3 = 1 \text{ t/m}^3$

$$H_L = \frac{f}{W(S - CH)} = \frac{400}{1(2.4 - 0.67 + 1)} = 146.52 \text{ m}$$

Base width will be

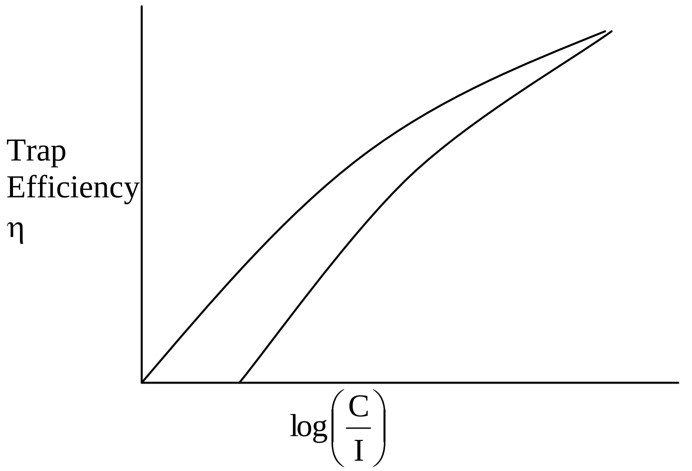
Greater value of $\frac{H}{\mu(S-C)}$ & $\frac{H}{\sqrt{S-C}}$

$\mu = \frac{2}{3}$ (Generally)

$$b_1 = \frac{146.52}{\frac{2}{3}(2.4 - 0.67)} = 127 \text{ m}$$

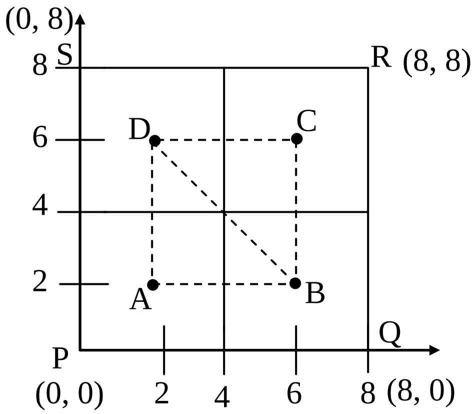
$$b_2 = \frac{146.52}{\sqrt{2.4 - 0.67}} = 111.39 \text{ m}$$

Design base width will be Greater value i.e 127 m



05(a).

Sol:



Arithmetic mean method

$$P_a = \frac{P_1 + P_2 + \ldots. + P_m}{m} = \frac{8 + 6 + 9 + 11}{4} = 8.5 \text{cm}$$

Thiessen polygon method

$$P_a = \frac{P_1A_1 + P_2A_2 + \ldots. + P_mA_m}{A_1 + A_2 + \ldots + A_m}$$

$$= \frac{(8\times16) + (6\times16) + (9\times16) + (11\times16)}{16 + 16 + 16 + 16} = 8.5 \text{ cm}$$

$A_A = A_B = A_C = A_D = 4 \times 4 = 16$

05(b).

Sol: Most of the suspended impurities present in water to 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 extend in water purification processes and hence this factor is generally ignored.

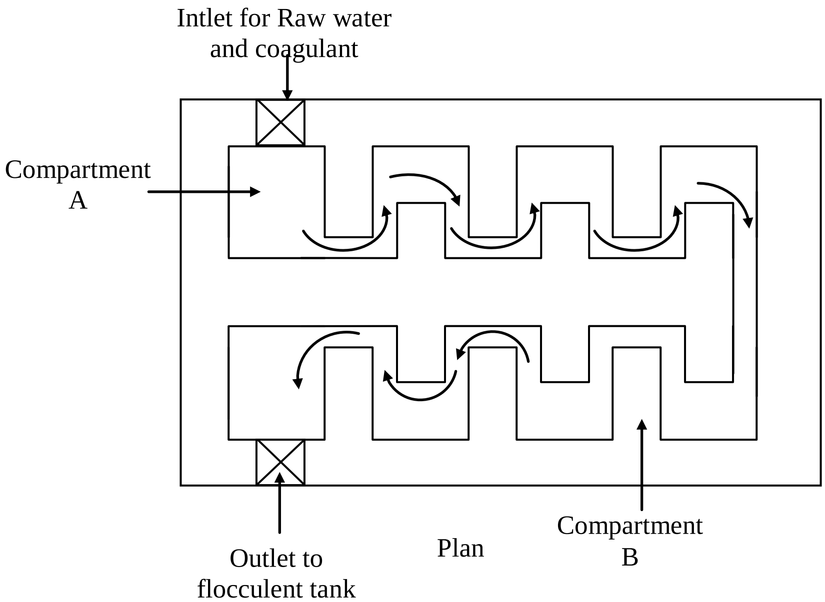
(iii) The size shape and specific gravity of particle. The greater is the specific gravity more readily the particle will settle. The size and shape of the particle also affect the settling rate.

The clarification of water by the process of sedimentation can be affected 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 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.

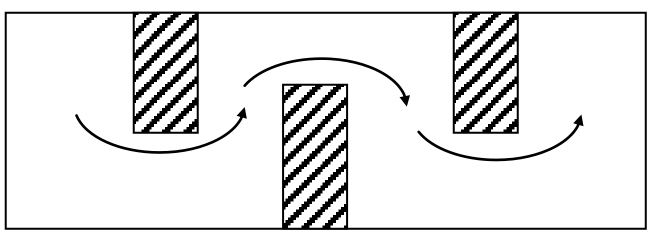
The size and shape of the particles can be altered by adding certain chemicals in water. These chemicals are called coagulants and they make the sedimentation quite effective by leading to the settlement of even very fine and colloidal particles. This is known as sedimentation aided with coagulants.

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 provisions 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

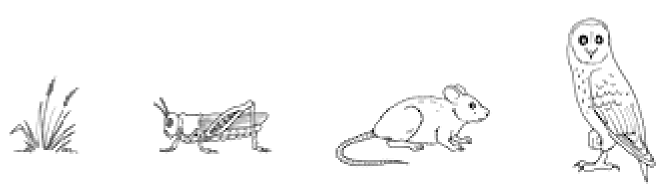
05(c).

Ans:

Ecology: A scientific study of the interactions of organisms with their physical environment and with each other is called as Ecology.

Ecosystem: A functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment is called as Ecosystem.

Food Chain: The chain of transformation and transfer of food energy in the ecosystem from one group of organism to another group through a series of steps or levels is called food chain.



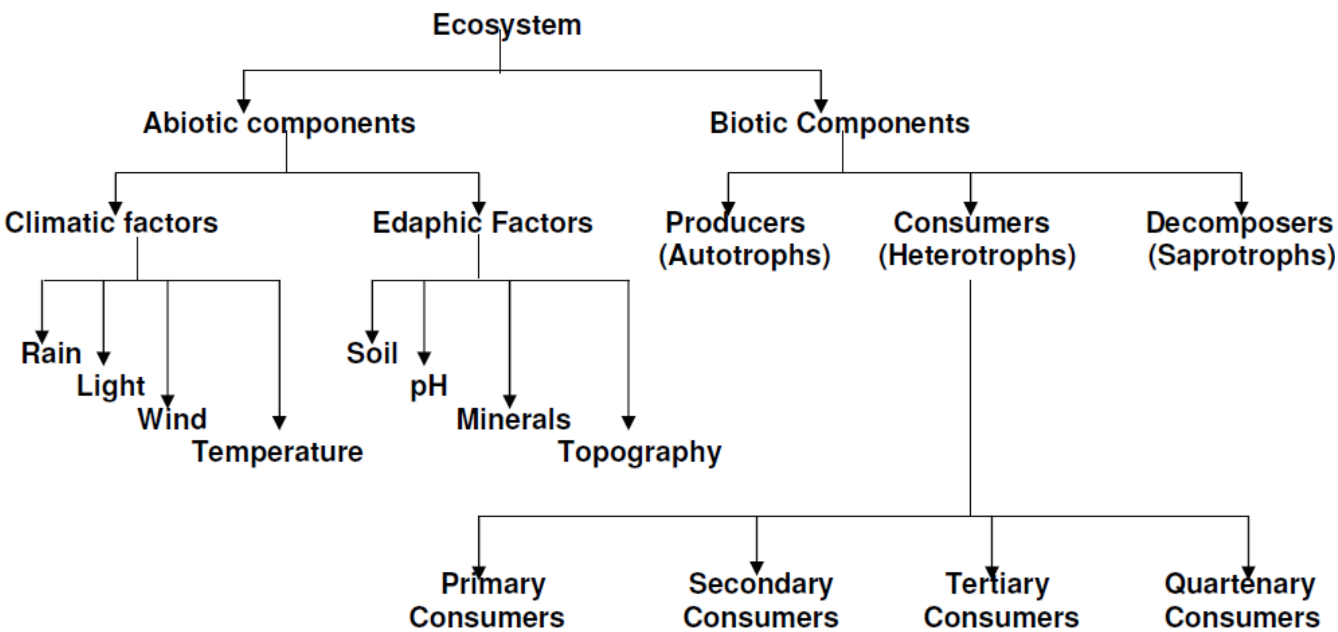
Components of Ecosystem:

They are broadly grouped into:-

(a) Abiotic and (b) Biotic components

(a) Abiotic components (Nonliving): The abiotic component can be grouped into following three categories:-

(i) **Physical factors:** Sun light, temperature, rainfall, humidity and pressure. They sustain and limit the growth of organisms in an ecosystem.



(ii) Inorganic substances: Carbon dioxide, nitrogen, oxygen, phosphorus, sulphur, water, rock, soil and other minerals.

(iii) Organic compounds: Carbohydrates, proteins, lipids and humic substances. They are the building blocks of living systems and therefore, make a link between the biotic and abiotic components.

(b) Biotic components (Living)

(i) Producers: The green plants manufacture food for the entire ecosystem through the process of photosynthesis. Green plants are called autotrophs, as they absorb water and nutrients from the soil, carbon dioxide from the air, and capture solar energy for this process.

(ii) Consumers: They are called heterotrophs and they consume food synthesized by the autotrophs. Based on food preferences they can be grouped into three broad categories.

Herbivores (e.g. cow, deer and rabbit etc.) feed directly on plants,
carnivores are animals which eat other animals (eg. lion, cat, dog etc.)

(iii) Decomposers: Also called **saprotrophs.** These are mostly bacteria and fungi that feed on dead decomposed and the dead organic matter of plants and animals by secreting enzymes outside their body on the decaying matter. They play a very important role in recycling of nutrients. They are also called **detrivores or detritus feeders**.

Functions of ecosystem

Ecosystems are complex dynamic system. They perform certain functions. These are:-

(i) Energy flow through food chain

(ii) Nutrient cycling (biogeochemical cycles)

(iii) Ecological succession or ecosystem development

(iv) Homeostasis (or cybernetic) or feedback control mechanisms.

Types of ecosystems

Ecosystem varies greatly in size from a small pond to a large forest or a sea. Many ecologists regard the entire biosphere as a global ecosystem, as a composite of all local ecosystems on Earth.

Ecosystems are classified as follows:

(i) Natural ecosystems

(ii) Man made ecosystems

(i) Natural ecosystems

(a) Totally dependent on solar radiation e.g. forests, grasslands, oceans, lakes, rivers and deserts. They provide food, fuel, fodder and medicines.

(b) Ecosystems dependent on solar radiation and energy subsidies (alternative sources) such as wind, rain and tides. e.g tropical rain forests, tidal estuaries and coral reefs.

(ii) Man made ecosystems

(a) Dependent on solar energy-e.g. Agricultural fields and aquaculture ponds.

(b) Dependent on fossil fuel e.g. urban and industrial ecosystems.

Man made ecosystems are again classified into two basic categories, namely the terrestrial and the aquatic.

- **Terrestrial Ecosystem**
- ➢ The ecosystem which is found only on landforms is known as the terrestrial ecosystem.
- ➢ The main factor which differentiates the terrestrial ecosystems from the aquatic ecosystems is the relative shortage of water in the terrestrial ecosystems and as a result the importance that water attains in these ecosystems due to its limited availability.
- ➢ Another factor is the better availability of light in these ecosystems as the environment is a lot cleaner in land than it is in water.
- ➢ The main types of terrestrial ecosystems are the forest ecosystems, the desert ecosystems, the grassland ecosystems and the mountain ecosystems.
- **Aquatic Ecosystem:**
- ➢ An ecosystem which exists in a body of water is known as an aquatic ecosystem.
- ➢ The aquatic ecosystems are mainly of two types, the freshwater ecosystems (Lentic) and the marine ecosystems (Lotic).

Energy Flow in Ecosystem:

Sun is the primary source of energy for all ecosystems on Earth. Of the incident solar radiation less than 50 per cent of it is photosynthetically active radiation (PAR). Photosynthetically active radiation, often abbreviated PAR, designates the spectral range (wave band) of solar radiation from 400 to 700 nanometers that photosynthetic organisms are able to use in the process of photosynthesis.

Plants capture only 2-10 per cent of the PAR and this small amount of energy sustains the entire living world. The energy of sunlight fixed in food production by green plants is passed through the ecosystem by food chains and webs from one trophic level to the next. In this way, energy flows through the ecosystem.

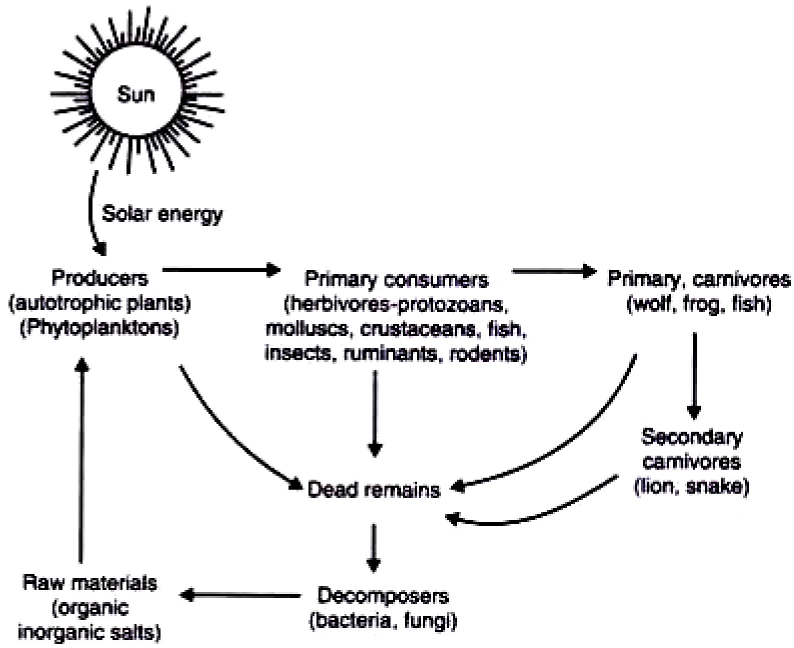


Fig: Energy Flow Through an Ecosystem

05(d).

Sol: $T = \frac{1}{P} \Rightarrow$ Probability of occurrence of the event $= \frac{1}{T} = \frac{1}{40}$

By means of Binomial theorem,

Probability of occurrence of event 'r' times in 'n' successive years is given by

$P(x = r) = {}^{n}c_r p^r q^{n-r}$

p = probability of each occurrence

q = probability of each non-occurrence

= 1 – P

(a) r = 2 n = 25

$P(X = 2) = {}^{25}c_2 \left(\frac{1}{40}\right)^2 \left(\frac{39}{40}\right)^{23} = 0.1047$

(b) at least one occurrence

$= 1 - P$ (not even one occurrence)

$P[X > 0] = 1 - q^n$

$$= 1 - (1 - \frac{1}{40})^{20}$$

$= 0.3973$

(c) once in 20 successive years

$P[X = 1] = {}^n c_r p^r q^{n-r}$

$$= {}^{20} c_1 \left(\frac{1}{40}\right)^1 \left(\frac{39}{40}\right)^{19}$$

$= 0.3091$

05(e).

Sol:

i) **Non-Modular Outlets :** These outlets operate in such a way that the flow passing through them is a function of the difference in water levels of the distributing channel and the watercourse. Hence, a variation in either affects the discharge. These outlets consist of regulator or circular openings and pavement. The effect of downstream water level is more with short pavement.

ii) **Semi-Modular outlets :** The discharge through these outlets depend on the water level of the distributing channel but is independent of the water level in the watercourse so long as the minimum working head required for their working is available.

iii) **Rigid Modules :** The discharge through modular outlets is independent of the water levels in the distributing channel and the watercourse, within reasonable working limits. This type of outlets may or may not be equipped with moving parts. Though modular outlets, like the Gibb's module, have been designed and implemented earlier, they are not very common in the present Indian irrigation engineering scenario

06 (a). (i)

Sol: Given population = 10,000

Q = Population × Percapita × factor water supply

= 10,000 × 200 × 0.8

= 1.6 MLD

$$= \frac{1.6 \times 10^6}{10^3}$$

= 1600 m^3/day

At 20^o N, OLR = 250 kg/ha/day

$$\text{Surface area of oxidation pond } = \frac{Q y_i}{OLR}$$

$$= \frac{1.6 \times 300}{250}$$

= 1.92 ha

L × B = 1.92 × 10^4 m^2

Assume L : B = 4 : 1

⇒ L = 4 B

⇒ 4 B × B = 1.92 × 10^4

$$B = \sqrt{\frac{1.92 \times 10^4}{4}} = 69.282 \text{ m}$$

⇒ L = 4 B = 277.128 m

Assume depth, H = 1 m

$$DT = \frac{V}{Q} = \frac{L \times B \times H}{Q} = \frac{1.92 \times 10^4 \times 1}{1600}$$

= 12 days

Design is ok.

06(a). (ii)

Sol:

Air Pollution control Devices

Suspended Particulate matter removal devices

Wet Collectors (or) Scrubbers

Devices for Removal of Gaseous contaminants

(1) → **Gravity setting chambers:**

Min Particle size of Removal : >50 m

Efficiency [%] : <50%

(2) → **Centrifugal Setting Chambers:**

Min Particle size of Removal : 5-25 μm

Efficiency [%] : 50-90%

(3) → **Electrostatic Precipitator:**

Min Particle size of Removal : > 1 μm

Efficiency [%] : 95-99%

(4) → **Fabric Filtration [Cotton Boy House Filters]:**

Min Particle size of Removal : > 1 μm

Efficiency [%] : 99%

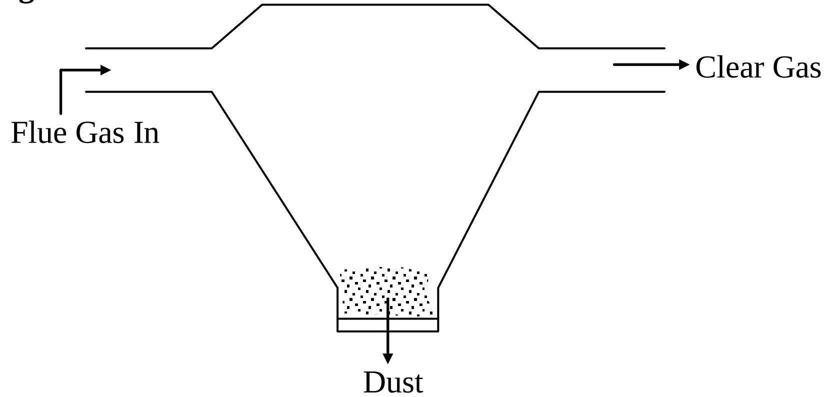
Type	Min-Particle size	Efficiency
1. Syray Towers	> 10 μm	< 80%
2. Cyclonic Scrubbers	> 2.5 μm	< 80%
3. Venturi Scrubbers	> 0.5 μm	< 99%

1. **Adsorption:**
Used for removal of SO_2, SO_3, H_2S, F and Oxides of Nitrates

2. **Adsorption:**
Used primarily for control of gases lik SO_2, NO_x, H_2S, Cl_2 NH_3 and some light Hydro carbons

3. **Combustion:**
Pollutions like hydrocarbons, carbon monoxide etc., are easily burned, oxidized and removed from combustion equipment

Gravity setting chambers:



The physical treatment unit for separation of particles of diameter more than 50 μm under the influence of gravitational force based on their size, weight and density is considered to be Gravity Settling Chamber.

It is similar to settling basins in water and waste water treatment units.

Principle:

Provide enlarged areas to minimize horizontal velocities and allow time for the vertical velocities and allow time for the vertical velocity to carry the particle to the floor.

- Usual velocity of air [Horizontal Flow Through velocity] : 0.5 – 2.5 m/s
- Optimum for best results $V_h \leq 0.3$ m/sec
- If, theoretical removal efficiency of particle is considered as 100% [Partially, efficiency is always less than 100%] in a chamber of length L,

Time to travel air [Gas] from inlet to outlet = Time to settle down the particle

$$\frac{V_t}{H} = \frac{V_h}{L}$$

Where,

V_t = Terminal settling velocity of particle [in m/s]

V_h = Horizontal flow through velocity [in m/s]

L = Length of chamber [in m]

H = Height of chamber [in m]

Solving $V_t = \frac{V_h - H}{L}$

If we consider, Stoke's law applied to get diameter of particle $V_t = \frac{gd^2[\rho_p - \rho_a]}{18\mu}$

$$\therefore \frac{V_h.H}{L} = \frac{gd^2[\rho_P - \rho_a]}{18\mu}$$

ρa is insignificant compared to ρp

Then solving for diameter of particle

$$d = \left[\frac{18\mu V_H.H}{g.L.\rho_p}\right]^{1/2}$$

Advantages of Gravitational settling chambers:

1. Simple in design and operation
2. Low pressure loss

Disadvantages:

1. Low collection efficiency [<50%]
2. Required large space for Installation

06(b).

Sol: 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 $= \frac{103.95}{23.5}$

= 4.4234×10^6 litres per hour

= $4423.4\ m^3$ per hour

Area of filter $= \frac{\text{Filtered water required per hour}}{\text{Rate of filtration}}$

$= \frac{4423.40}{15}$ = $294.89\ m^2$

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

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

Hence, providing 8 units and 1 units 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, if 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 kg/m^3

Assuming, depth of bed, L = 0.60 m

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

$\rho_w = 1000$ kg/m^3

e = 0.5

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

$\Rightarrow h_{fb} = 0.45$ 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

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

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

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

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

$$\Rightarrow e_{fb} = 1-\left(\frac{0.6\times 0.5}{0.66}\right)$$

$\Rightarrow e_{fb} = 0.5454$

Now this quantity e_{fb} is a function of the termine 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

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

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

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

Solving by hit and trail method, we get Re = 1.1 > 1 (transitional)

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

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

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

Now we know that $e_{fb} = \left(\frac{V_b}{V_t}\right)^{0.22}$

$$(e_{fb})^{1/0.22} = \frac{V_b}{V_t}$$

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

$\Rightarrow V_b = 1.39 \times 10^3$ m/s

06(c).

Sol: H_1= 80 m, H_2 = 6 m H = 84 m

Free board = 4m

Calculation of forces:

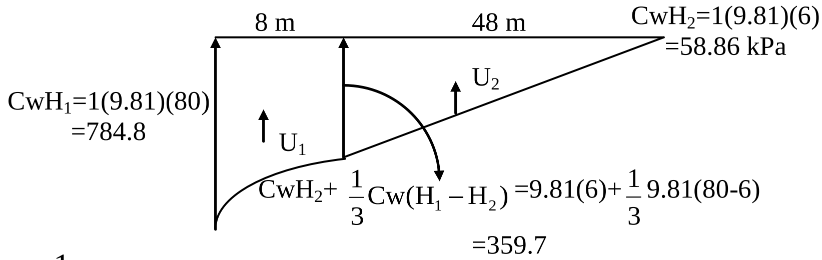
$W_1 = 6 \times 84 \times 1 \times 23.5 = 11844$ kN acting at $56 - \frac{6}{2} = 53$ m from toe

$W_2 = \frac{1}{2} 50 \times 75 \times 23.5 = 44062.5$ kN acting at $50 \times \frac{2}{3} = 33.33$ m from toe

$$P_1 = \frac{WH_1^2}{2} = \frac{9.81(80)^2}{2} = 31392 \text{ kN at } \frac{80}{3} = 26.66 \text{ m from toe}$$

$$P_2 = \frac{WH_2^2}{2} = \frac{9.81(6)^2}{2} = 176.58 \text{ kN at } \frac{6}{3} = 2 \text{ m from toe}$$

$$W_W = \frac{1}{2} 4 \times 6 \times 9.81 = 117.72 \text{ kN at } \frac{4}{3} \text{m from toe}$$



$$U_1 = \frac{1}{2} 8(784.8 + 359.7) = 4578$$

Acting at $48 + \frac{8}{3}\left(\frac{2(784.8+359.7)}{784.8+359.7}\right)$

= 52.59 m

$U_2 = (359.7 + 58.86)\ \frac{48}{2} = 10045$ kN

Acting at $\left(\frac{2(359.7)+58.86}{359.7+58.86}\right)\frac{48}{3} = 29.38$ m

$\Sigma M_R = 2096992.12$ kN-m

$\Sigma M_o = 1319126$ kN-m

$\Sigma H = 31215.42$ kN

$\Sigma V = 43048.86$ kN

Lever arm $\bar{x} = \frac{\Sigma M}{\Sigma V} = \frac{\Sigma M_R - \Sigma M_o}{\Sigma V}$

$$= \frac{2096992.12 - 1319126}{43048.86}$$

= 18.07 m

Eccentricity $e = \frac{b}{2} - \bar{x} = \frac{56}{2} - 18.07 = 9.93\text{m}$

$P_{n\,max}$ at toe :

$$\frac{\Sigma V}{b}\left(1+\frac{6e}{b}\right)=\frac{43048.86}{56}\left(1+\frac{6(9.93)}{56}\right)$$

$$= 1586.66 \text{ kPa}$$

$P_{n\,min}$ at heel

$$\frac{\Sigma V}{b}\left[1-\frac{6e}{b}\right]=\frac{43048.86}{56}(-0.064)$$

$$= -49.2 \text{ kPa}$$

07(a). (i)

Sol: Potassium permanganate (KM_nO_4) is used as a popular disinfection 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 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 the 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 disappear, it shows that organic matter is present in water, and more quantity of KM_nO_4 should be used for at least 48 hours after the addition of KM_nO_4. The normal doses of this disinfection varies between 1 to 2 mg/L with a contact period of 4 to 6 hours.

KM_nO_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 KM_nO_4, with the passage 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.

07(a). (ii)

Sol: Cl_2 dose = 1 mg/L

pH = 7

Ionization constant, $k_i = 2.7 \times 10^{-8}$ mol/lit

$$\%\text{HOC}\ell = \frac{1}{1+\frac{k}{[H^+]}}\times 100 = \frac{1}{1+\frac{2.7\times10^{-8}}{10^{-7}}}\times 100 = 78.7\%$$

Concentration of HOCl = 1 × 78.7 = 78.7 mg/L

at pH = 8

$$\%\text{HOC}\ell = \frac{1}{1+\frac{k_i}{[H^+]}}\times 100$$

$H^+ = 10^{-8}$

$$\%\text{HOC}\ell = \frac{1}{1+\frac{2.7\times10^{-8}}{10^{-8}}}\times 100 = 27.2$$

(Cl_2 dose × HOCl) @ 8 = (Cl_2 dose × HOCl) @ 8

1 × 78.7 = Cl_2 dose @ 8 × 27.02

Cl_2 dose = 2.91 mg/L

07(a). (iii)

Sol: Taking pH as constant

$c^{1.5}t = \mu$

$c_1^{1.5}\times t_1 = c_2^{1.5}\times t_2$

$c_1^{1.5}\times 15 = (1)^{1.5}\times t_2$

$(2.92)^{1.5}\times 15 = (1)^{1.5}\times t_2$

∴ Contact time = 74.845

07(b). (i)

Sol: Population = 2×10^5

Per capita daily demand = 150 litres

Discharge required for the pump will be

$$Q = \frac{2\times10^5\times150\times10^{-3}}{24\times60\times60} = 0.3472\ \text{m}^3/\text{s}$$

Delivery head, H_D = 140 – 120 = 20 m

Loss of head due to friction, h_f = 2 m

Total head against which the pump has to work will be, $H = H_d + h_f = 20 + 2 = 22$ m

Water horse power of the pump is given by

$$WHP = \frac{\gamma_w QH}{0.7457} \qquad [\gamma_w = 9.81\ kN/m^3]$$

$$[\because\ 1\ HP = 745.7\ w = 0.7457\ kW]$$

$$= \frac{9.81 \times 0.3472 \times 22}{0.7457} = 100.486 \simeq 100.5\ HP$$

If η is the efficiency of pump, then Brake horse power is given as

$$BHP = \frac{wHP}{\eta} = \frac{100.5}{0.70} = 143.57\ HP$$

07(b). (ii)

Sol: Given High Rate trickling filter with Q = 10 MLD, $y_i = 200$ mg/*l*, $y_e = 20$ mg/*l*

$$\frac{R}{I} = 1.5$$

$$F = \frac{1 + \frac{R}{I}}{\left(1 + 0.1\frac{R}{I}\right)^2} = \frac{1 + 1.5}{(1 + 0.15)^2} = 1.89$$

$$\eta = \frac{y_i - y_e}{y_i} \times 100 = \frac{100}{1 + 0.0044\sqrt{\frac{Qy_i}{VF}}}$$

$$\Rightarrow \frac{200 - 20}{200} \times 100 = \frac{100}{1 + 0.0044\sqrt{\frac{10 \times 200}{V \times 1.89}}}$$

$\Rightarrow V = 1.66\ m^3$

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

$$1.66 = \frac{\pi}{4} D^2 \times 2m \qquad (\therefore\ H = 2\ m)$$

$\Rightarrow D = 1.03$ m

If there is no recirculation in the same trickling filter

$$F = \frac{1+0}{(1+0.1\times 0)^2} = 1$$

$$\therefore \eta = \frac{100}{1+0.0044\sqrt{\frac{Qy_i}{VF}}}$$

$$= \frac{100}{1+0.0044\sqrt{\frac{10\times 2}{}}}$$

$\therefore$ η = 86.75 %

$$\Rightarrow \frac{y_i - y_e}{y_i}\times 100 = 86.75$$

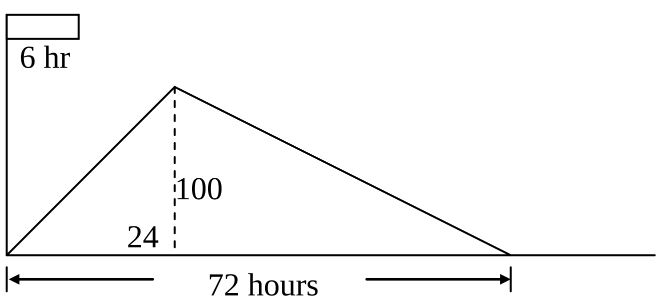
$$\Rightarrow \frac{200 - y_e}{200}\times 100 = 86.75$$

$\Rightarrow y_e = 26.5$ mg/l

$\therefore$ Effluent BOD of no recirculation is taking place = 26.5 mg/l

07(c).

Sol:



$$\frac{\text{Area of DRH}}{\text{Area of catchment}} = \text{R cm}$$

$$\frac{\text{Area of UH}}{\text{Area of catchment}} = 1\text{cm}$$

$$\frac{1}{2}72\times 3600\times 100 = A\times 10^6\,\frac{1}{100}$$

$\Rightarrow$ A = 1296 km^2

ii. Estimates of 6 hr 0 sec occur statement in linear proportions?

Time (hr)	6 hr UH ordinate (m^3/s)	DRH due to R		Base flow (m^3/s)	FHG ordinate (m^3/s)
		2 cm	4 cm		
0	0	0	-	25	25
6	25	50	0	25	75
12	50	100	100	25	225
18	75	150	200	25	375
24	100	200	300	25	525
30	87.5	175	400	25	600 M_C
36	75	150	350	25	525
42	62.5	125	300	25	450
48	50	100	250	25	375
54	37.5	75	200	25	300
60	25	50	150	25	225
66	12.5	25	100	25	150
72	0	0	50	25	75
78			0	25	25

iii. As seen from the table above,
Peak discharge of FHG = 600 cumec
It occurs at 30 hour from the start of the storm

08(a). (i)

Sol: Nitrate:

- Nitrate is not harmful because it is fully oxidised. But too much of nitrate affects infants. The reasons behind this is it causes blue baby disease or Mathemoglobinemia. Nitrate concentration should not be more than 45 mg/l.
- Nitrate concentration is measured by colour matching technique. Colour is formed by phenol-di-sulphonic + Potassium hydroxide.
- Free Ammonia + Organic Ammonia = Kjeldahl Ammonia.

Fluoride:

- Fluorides occur sometimes naturally in water. If not, it should be added in controlled quantity during treatment process.
- Fluoridation of water supplies to a level of a 1 mg/l is safe and effective in reducing dental cavities.
- The greatest advantage against teeth decay is when water is drunk in childhood during the period of tooth formation.
- However, optimum concentration of fluoride has to be controlled because excessive amount leads to fluorosis, which causes decolouration or mottling of teeth and sometime bone damage both in children and adults.
- Grater than 5 mg/l cause deformation of bones called bone fluorosis and other skeleton abnormalities.

Permissible Limit:

Acceptable limit is upto 1 mg/l and greater than 1.5 mg/l is cause for rejection.

Total Coliform:

- Testing and counting of pathogenic bacteria can be done but only with great difficulty. Hence these tests are not performed generally in routine.
- The usual routine test are generally conducted to detect and count the presence of coliforms, which themselves are harmless aerobic lacteal fermentery organisms but their presence or absence indicates the presence and absence of pathogenic bacteria.
- Coliforms also known as bacteria Coli [B-coli] or Escherichia Coli [E-coli] are important harmless aerobic microorganisms, which are found residing in the intestine of all warm blooded animals including human beings therefore, are excreted with their faces.
- Since they are harmless organisms to coliform group line longer in water than the pathogenic bacteria. It is generally presumed that the water will be safe and free from pathogenic bacteria if no coliform bacteria are present in it.

The tests for coliforms are:

1. Membrance filter technique
2. MPN test (most probable number)
3. Coliform index

Iron:

- Iron is concentration greater than 0.3 ppm is undesirable as they may cause colouration of clothes washed in such matters.
- They may cause incrustation in water mains due to deposition of ferric hydroxides (Fe $(OH)_3$).
- Some bacteria use iron compound for an energy source and results in lime formation which may produce taste and colour.

$$Fe(HCO_3)_2 \xrightarrow{\text{Oxidation}} Fe(OH_3)\downarrow$$

$$Fecl_e \xrightarrow{\text{Oxidation}} Fe(OH_3)\downarrow$$

$$FeSO_4 \xrightarrow{\text{Oxidation}} Fe(OH_3)\downarrow$$

- Iron posses problems in ground water and bottom layer of lakes but not in surface water. Because surface water has sufficient O_2 and hence precipitate of $Fe(OH)_3$ will occur.

Permissible Limit: Acceptable limit for Fe is 0.1 - 1.0 mg/L

08(a). (ii)

Sol: Cyclonic separators (or) Centrifugal settling chambers:

The physical units for separation of particles of diameter between 5-25 μm by employing centrifugal force on the particle is considered to be cyclonic separator.

- It is a structure, without moving parts where velocity of an inlet gas stream is transformed into a vertex form which centrifugal forces tend to drive the suspended particles to the wall of cyclone body.
- The separating efficiency of a cyclone depending upon magnitude of the centrifugal force exerted on the particles.
- Greater the magnitude of a cyclone depending upon magnitude of the centrifugal force exerted on the particles.
- Greater the magnitude of centrifugal force, greater the efficiency of separator

- $F_c = M_P \times \frac{r^2}{R}$

  F_c = Centrifugal force N

  M_P = Particulate mass, kg

  V_i^2 = Particle velocity m/s

  R = Radius of cyclone

  $\frac{V_i^2}{R}$ = centrifugal acceleration

  L_1 = Length of cylinder = 2D

  L_2 = Length of cone = 2D

  D_e = Diameter of exit = $\frac{1}{2}D$

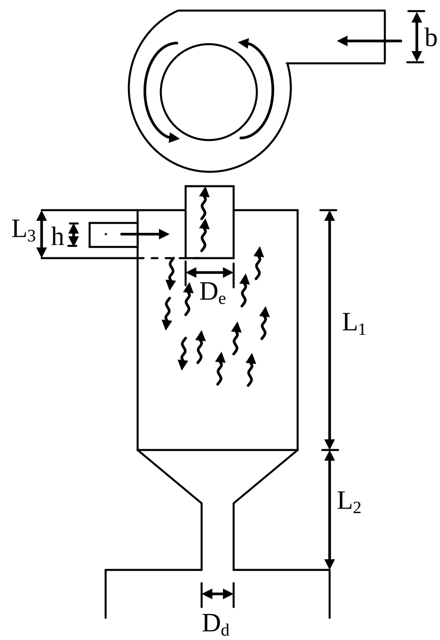
  h = Height of entrance = $\frac{1}{2}D$

  b = Width of entrance = $\frac{1}{4}D$

  D_d = Diameter of Dust exit = $\frac{1}{4}D$

  L_3 = Length of exit dust = $\frac{1}{8}D$

  D = Diameter of cyclone



Dust Hopper

Advantages:

1. Simple in design &n operation
2. Low to moderate pressure
3. Requirement of little floor space
4. Handles high dust loads

Disadvantages:

1. Much head room requirement
2. Low collection efficiency of small particles
3. Sensitivity to variable dust leads & flow rates

08(b).

Sol: $P_1 = 95.5$ cm $\quad P_2 = 42.4$ cm $\quad P_3 = 82.7$ cm

$P_4 = 53.6$ cm $\quad P_5 = 78.5$ cm $\quad P_6 = 67.8$ cm $\quad m = 6$

$$P_a = \frac{P_1 + P_2 + ...+ P_m}{m} = 70.083 \text{ cm}$$

$$\sigma = \sqrt{\frac{\Sigma(P_i - P_a)^2}{m-1}} = 19.59$$

$$C_v = \frac{\sigma}{P_a} \times 100 = 27.96$$

$$n = \left(\frac{C_v}{e}\right)^2$$

$$6 = \left(\frac{27.96}{e}\right)^2 \qquad e = 11.415\%$$

$$\text{If } e = \frac{5}{70.083} \times 100 = 7.13\%$$

$$n = \left(\frac{27.96}{7.13}\right)^2 = 15.36 \approx 16$$

Additional no. of raingauge required = n – m = 16 – 6 = 10

08(c).

Sol: (a) $P_1 = 7$ cm $\qquad P_2 = 9.5$ cm

$R_1 = P_1 - \phi t_1 = 7 - 0.25 \times 8 = 5$ cm $\qquad R_2 = P_2 - \phi t_2 = 9.5 - 0.25 \times 8 = 7.5$ cm/hr

Q_{max} of DRH = Q_{max} of FHG – BF = 100 – 20 = 80

$$Q_{max} \text{ of UH} = \frac{Q_{max} \text{of DRH}}{R_1} = 16 \text{ cm}$$

With $R_2 = 7.5$ cm/hr, $\quad Q_{max}$ of DRH = 16 × 7.5 = 120 m^3/s

Q_{max} of FHG = 120 + 20 = 140 m^3/s

% Increase of peak flood = $\frac{140-100}{100}\times 100 = 40\%$

	Ordinates of 8 hr UH (m^3/s)			DRH of 3 cm in 24 hr (m^3/s) (D) = A + B + C	UH of 24 hr D/3 = E
	A	Lagged by (8 hr) B	Lagged by (16 hr) C		
0	0	-	-	0	0
4	5.5	-	-	5.5	1.83
8	13.5	0	-	13.5	4.5
12	26.5	5.5	-	32.0	10.67
16	45	13.5	0	58.50	19.5
20	82	26.5	5.5	114	38
24	162	45	13.5	220.50	73.5
28	240	82	26.5	348.50	116.17
32	231	162	45	438	146
36	165	240	82	467	162.33
40	112	231	162	505	168.33
44	79	165	240	484	161.33
48	57	112	231	400	133.33
52	42	79	165	286	95.33
56	31	57	112	200	66.66
60	22	42	79	143	47.66
64	14	31	57	102	34
68	9.5	22	42	73.5	24.50
72	6.6	14	31	51.6	17.2
76	4.0	9.5	22	33.5	11.53
80	2.0	6.6	14	22.6	7.53
84	1.0	4.0	9.5	14.5	4.83
88	0.0	2.0	6.0	8.6	2.87
92	-	1.0	4.0	5	1.67
96	-	0	2.0	2	0.67
100	-	-	1.0	1	0.33
104	-	-	0	0	0
		Q_{max} of 24 hr UH = 168.33 m^3/s			