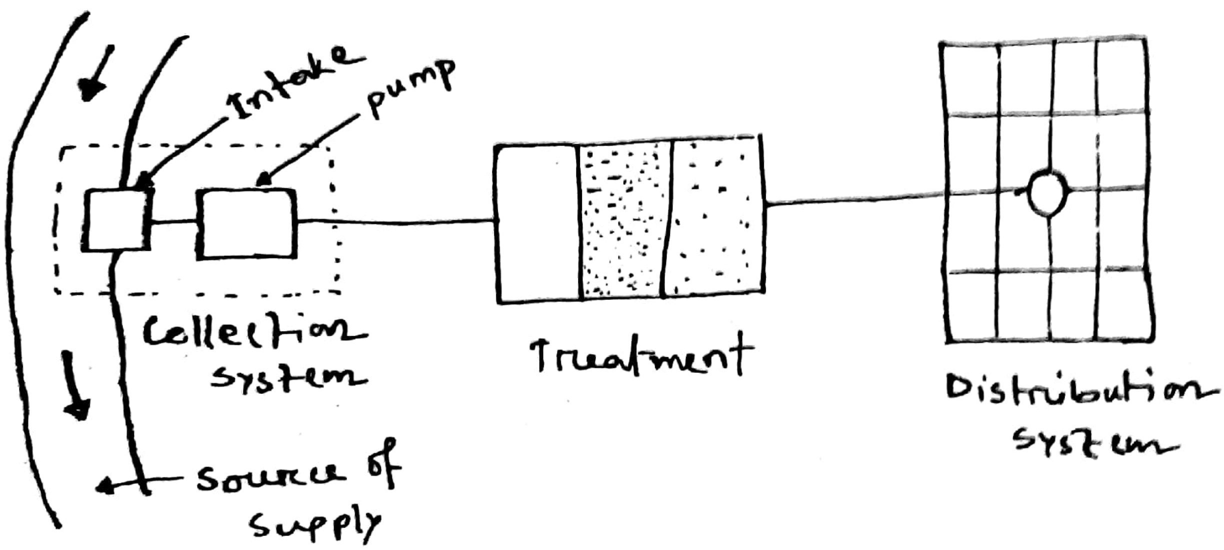
# "Water Supply"

## * Objectives of water supply system:

- Supply water in adequate quantity
- supply safe and wholesome water to the consumers
- make water easily available to the consumers.

## * Elements of water supply:

- Source of supply
- Collection System
- Treatment.
- Distribution system.




## * Choice of source of water supply: (main considerations)

① Quality ② Quantity ③ cost.

provision → প্রস্তুতি

## * Planning a Municipal water supply system:

1. Estimate the future population of the community,
2. Location of a reliable source of water of adequate quality.
3. provision for the necessary storage of water.
4. Determination of the physical, chemical & biological characteristics of water.
5. Design of the various units of Treatment plant.
6. Design of distribution system.
7. provision for the establishment of an organization which will maintain & operate the supply, distribution & treatment facilities.
8. Design a suitable collection system.

*** Design period:** It is the period into the future for which the estimate is to be made. Usually 25~40 Yrs is considered to be sufficient.

## * Factors affecting per capita consumption of water:

18-15

1. Size of the city.
2. Characteristics of people
3. Climatic condition.
4. pressure of water.
5. Quality of water.
6. Sewerage facilities.
7. Nature of supply.
8. Nos of inhabitants.

* The total quantity of water required by a community per day.

$$Q_f = P_f * q$$

where, $P_f$ = estimated population at the end of Design life.

$q$ = per capita water consumption / day.

$$\text{per capital water consumption/day} = \frac{\text{Total consumption in gallon}}{\text{population} * 365}$$

* **prediction of population:**

1. Uniform growth rate method.
2. Uniform percentage growth rate method.
3. Decreasing growth rate method.
4. Graphical extension method.
5. Graphical comparison method.
6. Geometric progression method
7. Least square parabolic method.

$$P_n = P_p (1+r)^n$$

$$r = \sqrt[n]{\frac{P_2}{P_1}} - 1$$

$P_n$ = Future population

$P_p$ = Present "

$n$ = design year

$r$ = rate of annual population growth.

$P_1$ & $P_2$ are population of $n$ years appart.

* The population of a city was 124000 in 1960s and 152000 in 1970s. (a) what was the annual rate of increase (b) what will be the probable population in 1980s.

Soln:

$P_1 = 124000$, $P_2 = 152000$, $n = 10$ (1970 - 1960)

(a) $r = \sqrt[n]{\frac{P_2}{P_1}} - 1 = \sqrt[10]{\frac{152000}{124000}} - 1 = 1.0232 - 1 = 0.0232$ (Ans)

(b) $P_n = P_p \times (1+r)^n = 152000(1+0.0232)^{10} = 246000$ Ans

* The population of a town was 180000 in 1980 & 220000 in 1990s. What will be the population in 2005?

Soln:

$P_n = P_p(1+r)^n \Rightarrow 220000 = 180000(1+r)^n$

$\Rightarrow (1+r)^{10} = 1.22 \Rightarrow r = 0.02$

$r = \sqrt[n]{\frac{P_2}{P_1}} - 1 = 0.02$

$\therefore P_{2005} = P_p(1+r)^n \Rightarrow P_{2005} = 220000 \times (1+.02)^{15}$

$= 296100$ Ans

Scanned by CamScanner

## *Source & significance of selected water quality parameters:

(1) **pH:** pH is a term used to express the intensity of acid and alkaline condition of a solution.

$$pH = -\log[H^+]$$

Source: $CO_2$, $HCO_3$, $CO_3$ in most natural water.

Standard: 6.5 ~ 8.5 (Bd), (WHO)

Significance: pH is important for coagulation, disinfection, water softening & corrosion control.

(2) **Colour:** Suspended matter cause 'apparent colour'
Dissolved matter cause 'True colour'.

Source: Coloured organic substances

Standard: 15 Pt. Co. unit or Hazen unit. (Bd, WHO)

Significance: not accepted due to aesthetic reason.

(3) **Turbidity:** An expression of certain light scattering & light absorbing property of water sample.

Source: Suspended clay, silt, finely divided organic and inorganic matters.

Standard: 10 NTU (Bd), 5 NTU (WHO)

Significance: objectionable to consumers, stimulate the growth of bacteria.
↳ উৎসাহিত করা

(4) Total dissolved solids (TDS):

Source: inorganic salts, organic matters.

Standard: 1,000 mg/L (Bd)

Excellent < 300 mg/L, Good 300~600 mg/L, Fair 600-900 mg/L, poor 900-1200 mg/L, Unacceptable > 1200 mg/L

Significance: Taste, Hardness, corrosion, irrigation problem, laxative & reverse effect on health.

(5) Alkalinity: The alkalinity of water is a measure of its capacity to neutralize acids.

Source: Salts of weak acid & strong base.

Significance: Excessive or insufficient alkalinity interferes with water treatment (coagulation).

(6) Hardness: Hardness is that property of water that requires considerable amount of soap to produce foam.

Source: Multivalent metalic cations: $Ca^{++}$, $Mg^{++}$, $Na^{+}$

Standard: 200~500 mg/L as $CaCO_3$ (Bd), 500 mg/L (WHO)

Significance: - produce scale ~~to~~ in hot water pipe.

- Staining of containers.

(7) **Chlonide ($Cl^-$):** widely distributed in nature in the form of NaCl, KCl, $CaCl_2$.

Source: The solvent power of dissolved chlorides from top soil & depper formations.

Standard: 150 ~ 600* mg/L, coastal Belt → 1000 mg/L (Bd)
250 mg/L (WHO)

Significance: Corrosive to metals. Higher chloride content indicates sewage pollution.

(8) **Nitrate ($NO_3^-$):**

Source: Urine, fertilizers, bacterial decomposition of organics.

Standard: 10 mg/L (Bd), 50 mg/L (WHO)

Significance: toxic when present in excessive amount. Growth of algae, cause methamoglobinaemia.

(9) **Iron (Fe):**

Source: Dissolution of rocks & minerals in ground water, sewage or discharge from iron-related industries.

Standard: 0.3 ~ 1.0 mg/L (Bd), < 0.3 mg/L (WHO)

Significance: Undesirable taste, staining of cloths & plumbing fixtures.
↳ দাগযুক্ত করা

*Ferment = গাঁজিয়ে তোলা, উত্তেজিত করা

(10) Arsenic (As):

Source: Geological formation, industrial discharges, mining operations.

Standard: 0.05 mg/L (Bd), 0.01 mg/L (WHO)

Significance: As(III) is more toxic than As(V). Causes skin cancer, Black-foot diseases, arsenicosis.

(11) Total Coliform & faecal Coliform:

TC → Ferment lactose in culture @ 37°C including E. Coli

FC → Ferment lactose in culture @ 44.5°C.

Source: Normally inhabits the intestinal tract of man/other warm blooded animals and is excreted in large number with the faeces.

Standard: Nil/100 mL.

Significance: water borne diseases.

* prove that, $pH + pOH = 14$

Proof: we know,

$$H_2O \rightleftharpoons H^+ + OH^-$$

at 25°C, $K_w = \frac{[H^+][OH^-]}{[H_2O]} = 10^{-14}$ and $[H_2O] = 1$

$$\Rightarrow [H^+][OH^-] = 10^{-14}$$

$$\Rightarrow \log[H^+] + \log[OH^-] = \log 10^{-14}$$

$$\Rightarrow -\log[H^+] + -\log[OH^-] = -\log 10^{-14}$$

$$\Rightarrow pH + pOH = 14$$

(Proved)

Md Mirraz Gazi
B Sc in CE, KUET

* If a water Sample after analysis found as $H^+$ ions concentration of $10^{-8.5}$ moles. Comments about the alkalinity of water or acidity of water? if $OH^-$ is $10^{-9.5}$. Find pH?

Soln.

$pH = -\log(H^+)$
$= -\log(10^{-8.5})$
$= 8.5$ (alkaline)

$pOH = -\log(OH^-)$
$= -\log(10^{-9.5})$
$= 9.5$
$\therefore pH = 14 - 9.5$
$= 4.5$ (acidic)

Ans

* Calculate pH of 1 mg/L of $Ca(OH)_2$.

Ans:

Molecular weight of $Ca(OH)_2 = 40 + (16+1)*2 = 74$

74 mg/L $Ca(OH)_2$ contain 2 mole $OH^-$

$\therefore$ 1 mg/L " " $\frac{2}{74}$ " "
$= 0.027$ mole $OH^-$

$\therefore [OH^-] = 0.027M$

$\therefore pOH = -\log[OH^-] = 1.57$

$\therefore pH = 14 - 1.57 = 12.43$

Ans.

* Carbonate Hardness: Carbonate hardness (CH) associated with the anions $HCO_3^-$ and $CO_3^{2-}$.

* Non-carbonate Hardness: Non-carbonate hardness (NCH) associated with other anions except $CO_3^{2-}$ and $HCO_3^-$.

* Alkalinity: It is a meaure of buffering capacity of water and is define as the quality of ions in water that will react to neutralize the $H^+$ ions.

Total Alkalinity $= HCO_3^- + CO_3^{2-} + OH^- - H^+$

# Formula:

- Total Hardness (TH) = Conc of $Ca^{2+}$ + conc. of $Mg^{2+}$ + Conc of $Sr^{2+}$
- Equivalent weight = $\frac{\text{Atomic weight}}{\text{valency}}$

For example:

EW of $CaCO_3$ = $(40+12+16\times3)/2$ = 50 g/eq
= 50 mg/Milli eq.

EW of $Ca^{2+}$ = $\frac{40}{2}$ = 20 mg/M.eq

EW of $Mg^{2+}$ = $\frac{24}{2}$ = 12 mg/M.eq ; EW of $Sr^{2+}$ = 43.8 mg/Meq

- Mg/L of 'x' as $CaCO_3$ = $\left(\frac{\text{conc. of 'x' mg/L}}{\text{EW of 'x' mg/Meq}}\right) * 50$ mg/Meq as $CaCO_3$.

* A sample of ground water has 100 mg/L of $Ca^{2+}$ and 10 mg/L of $Mg^{2+}$. Express its hardness in units of Meq/L and mg/L as $CaCO_3$.

Soln: TH = Conc. of $Ca^{2+}$ + Conc. of $Mg^{2+}$

$$= \frac{\text{conc. of } Ca^{2+} \text{ mg/L}}{\text{EW of } Ca^{2+} \text{ mg/Meq}} + \frac{\text{conc. of } Mg^{2+} \text{ mg/L}}{\text{EW of } Mg^{2+} \text{ mg/Meq}}$$

$$= \frac{100}{20} + \frac{10}{12}$$

= 5.82 Meq/L (Ans)

Again,

TH = Conc. of $Ca^{2+}$ + Conc. of $Mg^{2+}$

$$= \left(\frac{\text{Conc. of } Ca^{2+} \text{ mg/L}}{\text{EW of } Ca^{2+} \text{ mg/Meq}} + \frac{\text{conc. of } Mg^{2+} \text{ mg/L}}{\text{EW of } Mg^{2+} \text{ mg/Meq}}\right) * 50 \text{ mg/Meq}$$

$$= \left(\frac{100}{20} + \frac{10}{12}\right) * 50 \text{ as } CaCO_3$$

= 290 mg/L as $CaCO_3$ (Ans)

502

* A sample of water at pH 10 has 32 mg/L of $CO_3^{2-}$ and 56 mg/L of $HCO_3^-$. Find the total alkalinity as $CaCO_3$.

Soln:

$pH = -\log[H^+] \Rightarrow [H^+] = 10^{-10}$ moles/L

$= 10^{-10}$ moles/L * 1 mgm/mole (Molecular wt of $H^+$)

$= 10^{-10}$ gm/L $= 10^{-7}$ mg/L

$[H^+] \times [OH^-] = 10^{-14} \Rightarrow [OH^-] = 10^{-4}$ moles/L

$= 10^{-4}$ moles/L * 17 gm/mole (Molecular wt of $OH^-$)

$= 17 \times 10^{-4}$ gm/L $= 1.7$ mg/L

Total alkalinity $= HCO_3^- + CO_3^{2-} + OH^- - H^+$

$$= \left( \frac{\text{conc. of } HCO_3^- \text{ mg/L}}{\text{EW of } HCO_3^- \text{ mg/Meq}} + \frac{\text{conc. of } CO_3^{2-} \text{ mg/L}}{\text{EW of } CO_3^{2-} \text{ mg/Meq}} + \frac{\text{conc. of } OH^- \text{ mg/L}}{\text{EW of } OH^- \text{ mg/Meq}} - \frac{\text{conc. of } H^+ \text{ mg/L}}{\text{EW of } H^+ \text{ mg/Meq}} \right) * 50 \text{ mg/Meq as } CaCO_3$$

$$= \left( \frac{56}{\frac{1+12+16\times3}{1}} + \frac{32}{\frac{12+16\times3}{2}} + \frac{1.7}{\frac{16+1}{1}} - \frac{10^{-7}}{\frac{1}{1}} \right) * 50$$

$= 104$ mg/L as $CaCO_3$

Ans

* The Ca content of a water sample is 26 mg/L. What is the Ca. hardness as $CaCO_3$.

Soln:

Ca. Hardness $= \frac{26}{20} \times 50$

$= 65$ mg/L as $CaCO_3$

Ans.

* The sample of water contains 24 mg/L magnesium. Express the Mg hardness as $CaCO_3$.

Soln:

Mg. hardness $= \frac{24}{12} \times 50$

$= 99$ mg/L as $CaCO_3$

Ans

*An analysis of a sample of water with pH 7.5 produce the following concentration (mg/L)

BUET

| Cations | Anions |
|---|---|
| $Ca^{2+} = 80$ | $Cl^- = 100$ |
| $Mg^{2+} = 30$ | $SO_4^{2-} = 201$ |
| $Na^+ = 72$ | $HCO_3^- = 165$ |
| $K^+ = 6$ | |

Calculate Total Hardness, Carbonate hardness, Non-carbonate hardness, Total alkalinity as $CaCO_3$ & also find TDS in mg/L

Soln: ① TH = conc. of $Ca^{2+}$ + conc. of $Mg^{2+}$

$$= \left(\frac{\text{conc. of } Ca^{2+} \text{ mg/L}}{\text{EW of } Ca^{2+} \text{ mg/Meq}} + \frac{\text{conc. of } Mg^{2+} \text{ mg/L}}{\text{EW of } Mg^{2+} \text{ mg/Meq}}\right) * 50 \text{ mg/Meq as } CaCO_3$$

$$= \left(\frac{80}{20} + \frac{30}{12}\right) * 50 = 325 \text{ mg/L as } CaCO_3.$$

② CH = conc. of $HCO_3^-$ + conc. of $CO_3^{2-}$

$$= \left(\frac{\text{conc. of } HCO_3^- \text{ mg/L}}{\text{EW of } HCO_3^- \text{ mg/Meq}} + \frac{\text{conc. of } CO_3^{2-} \text{ mg/L}}{\text{EW of } CO_3^{2-} \text{ mg/Meq}}\right) * 50 \text{ mg/Meq as } CaCO_3$$

$$= \left(\frac{165}{\frac{1+12+16\times3}{1}} + \frac{0}{\frac{12+16\times3}{2}}\right) * 50 = 135.24 \text{ mg/L as } CaCO_3.$$

③ TH = CH + NCH

$\Rightarrow$ NCH = TH − CH = 325 − 135.24 = 189.7 mg/L as $CaCO_3$

④ TC = $HCO_3^- + CO_3^{2-} + OH^- - H^+$

= 135.24 + 0 + 0 − 0

= 135.24 mg/L as $CaCO_3$

$\Rightarrow$ pH = $-\log[H^+]$

$\Rightarrow [H^+] = 10^{-7.5} = 3.16\times10^{-8}$ m

$= 3.16\times10^{-8}$ mole/L × 1 g/mole

$= 3.16\times10^{-8}$ gm/L $= 3.16\times10^{-5}$ m

$[OH^-] = 10^{-14}$ mole/L

$= 10^{-14} \times 17$ gm/L

$= 17\times10^{-11}$ mg/L

⑤ TDS = Sum of all cations & anions

= 80 + 30 + 72 + 6 + 100 + 201 + 165

= 654 mg/L

Ans

Md. Miraz Gazi
B. Sc. in CE, KUET

* TDS: The materials which passes through the filter of 2 micro-m or smaller size is known as total dissolved solids. TDS = TS − TSS

* TSS: The materials which retains by the filter is the total suspended solids.

* An analysis of a sample of water produce the following concentration (mg/L). Determine concentration of $Na^+$ ion & TH, CH & NCH as $CaCO_3$?

| Cations | Anions |
| --- | --- |
| $Ca^{2+} = 40$ | $Cl^- = 11$ |
| $Mg^{2+} = 10$ | $SO_4^{2-} = 67.2$ |
| $Na^+ = ?$ | $HCO_3^- = 11$ |
| $K^+ = 7$ | |

**Soln:**

Conc. of $Ca^{2+}$ mg/L as $CaCO_3$ = $\frac{40}{20} * 50 = 100$ mg/L

" " $Mg^{2+}$ " " " = $\frac{10}{12} * 50 = 41.67$ mg/L

" " $Na^+$ " " " = $\frac{x}{23} * 50 = 2.2x$ mg/L

" " $K^+$ " " " = $\frac{7}{39} * 50 = 8.97$ mg/L

" " $Cl^-$ " " " = $\frac{11}{35.5} * 50 = 15.49$ mg/L

" " $SO_4^{2-}$ " " " = $\frac{67.2}{\frac{32+16\times4}{2}} * 50 = 70$ mg/L

" " $HCO_3^{-1}$ " " " = $\frac{11}{\frac{1+12+16\times3}{1}} * 50 = 90.16$ mg/L

Σ Cations = Σ Anions

$\Rightarrow 100 + 41.67 + 2.2x + 8.97 = 15.49 + 70 + 90.16$

$\Rightarrow x = 11.4$ mg/L as $CaCO_3$ **Ans**

$TH = Ca^{2+} + Mg^{2+} = 141.67$ mg/L as $CaCO_3$

$CH = HCO_3^- + CO_3^{2-} = 90.16 + 0 = 90.16$ mg/L as $CaCO_3$

$NCH = TH - CH = 51.51$ mg/L as $CaCO_3$

Ans

* Write down the quality parameter of water or test of water.

Ans: 1. Physical quality parameter
- Temperature, Color, Turbidity, odour test.
2. Chemical quality parameter
- Total solids, Hardness, Chlorine, pH value, Iron, Arsenic, Lead, Copper and Fluorine etc.
3. Biological quality parameter
- BOD (Biochemical oxygen demand)
- COD (Chemical oxygen demand)
4. Bacteriological quality parameter
- TOC (Bacteria coli, Escherichia coli)
- ThoD (Theoritical oxygen demand)

* **BOD**: The amount of oxygen required by bacteria to oxidize the organic matter in aerobic condition is known as BOD. Bd. St: 0.2 mg/L

Aus-14
Meghna-17

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{Bacteria} 6CO_2 + 6H_2O + Energy$$

Energy ↓ New bacterial cell.

* **COD**: The amount of oxygen required by strong chemical oxidizing agent to oxidize the organic matter in acid condition is known as COD. Bd. St: 0.4 mg/L

$$C_6H_{12}O_6 + O_2 \xrightarrow[K_2Cr_2O_7,\ KMnO_4]{} CO_2 + H_2O + Energy$$

* **ThoD**: The amount of oxygen required to oxidize the organic matter to $CO_2$ completely.

* <u>$BOD_5$</u>: The amount of oxygen required by bacteria to oxidize the organic matter in aerobic condition for 5 days at 20°c temperature is called $BOD_5$.

5-days BOD is required because, ultimate $O_2$ demand is considerably higher during this day.

$$BOD_5 = \left[(DO)_{initial} - (DO)_{final}\right] * DF$$

DF → Dilution factor

Why 5-day BOD is measured in laboratory?

Ans: i) Dissolved oxygen (DO) is maximum at 5 days.

ii) 95% decomposition at 5 days.

iii) Measured DO content, be incubated under controlled conditions.

iv) Temperature controlled at 20°c

Md. Minarul Gazi
B.Sc. in CE, KUET

* Write down the formula for BOD determination.

Ans: The rate of decomposition of organic waste is proportional to the amount of waste available.

If $L_t$ represents the amount of oxygen demand left after time t, then assuming a first order reaction

$$\frac{dL_t}{dt} = -K L_t \; ; \; K = \text{BOD rate constant } (time^{-1})$$

$L_t$ = Amount of BOD remaining after time t

$L_o$ = Amount of BOD at t = 0 or ultimate BOD.

$$\Rightarrow \frac{dL_t}{L_t} = -K\,dt$$

$$\Rightarrow \int_{L_o}^{L_t} \frac{dL_t}{L_t} = -K \int_0^t dt$$

$$\Rightarrow \ln \frac{L_t}{L_o} = -Kt \;\Rightarrow L_t = L_o e^{-Kt} \;\ldots\ldots (1)$$

We know,

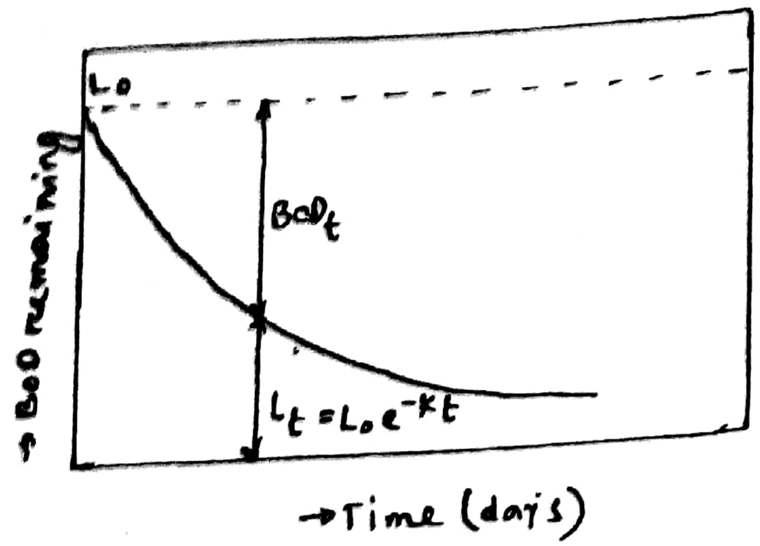
Ultimate BOD = Remaining BOD + Removed BOD

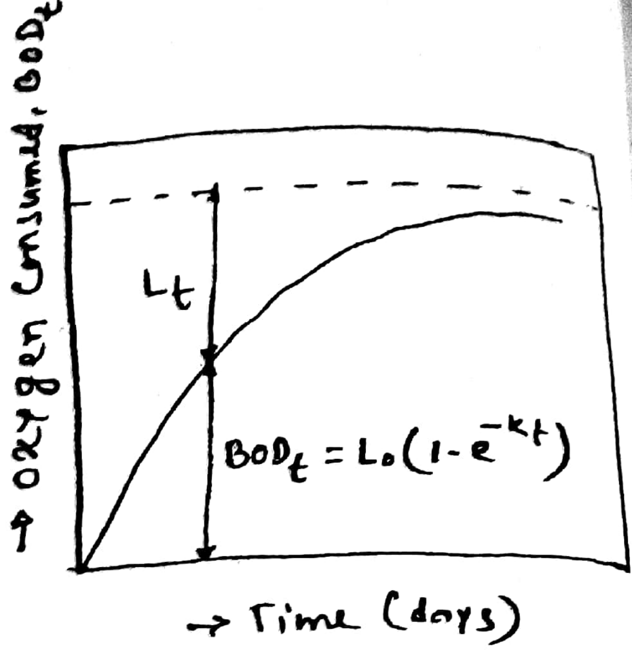
$$\Rightarrow L_o = L_t + BOD_t \Rightarrow BOD_t = L_o - L_t$$

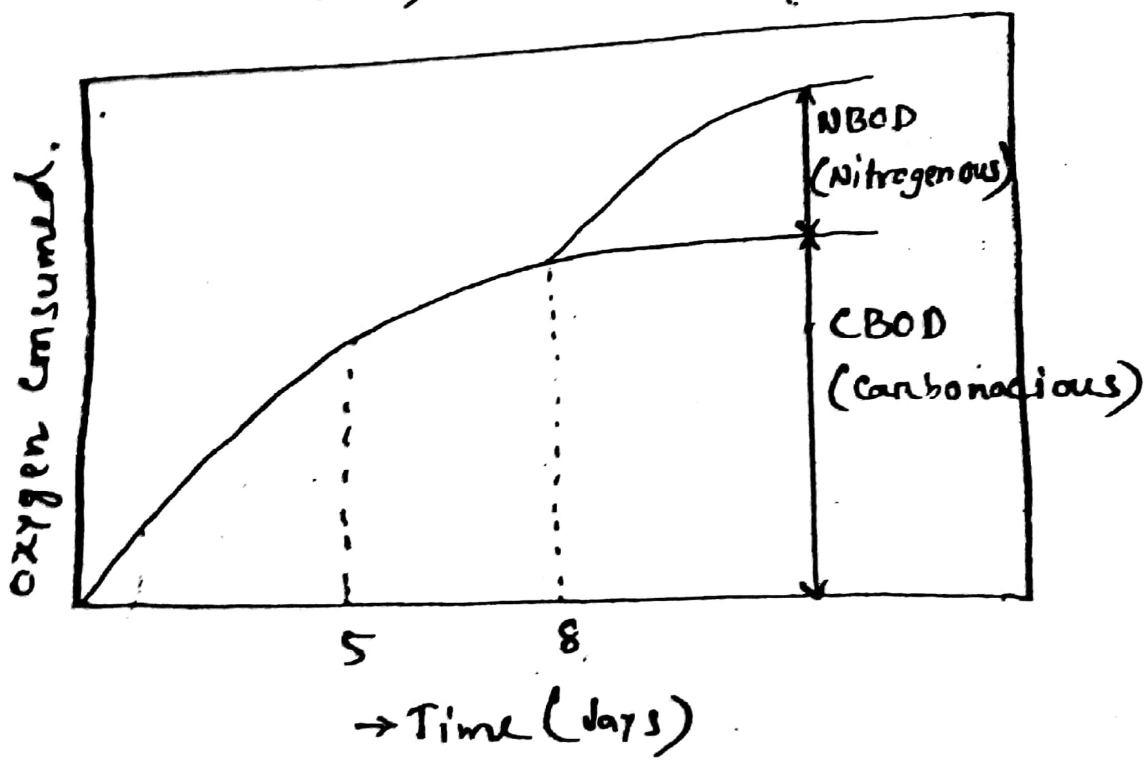
$$\Rightarrow BOD_t = L_o(1 - e^{-Kt})$$

* Why we need to determine BOD?

y-14 Ans: - To determine the polluting strength of sewage and industrial waste in terms of oxygen.




* Equation for find value of K of any temp. from the given temp. is –

(20°C)

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

* **Seeding:**

$$BOD_m V_m = BOD_w V_w + BOD_d V_d \; ; \; V_m = V_w + V_d$$

- $BOD_m$ ↳ mix water
- $BOD_w$ ↳ waste water
- $BOD_d$ ↳ dilution water

* A sample of sewage is mixed with water in the ratio 1:20 (1mL sewage is diluted to 20 mL by adding water) for BOD test. The initial DO is 8.5 mg/L and final DO after 5 day is 3.1 mg/L. Calculate $BOD_5$ of the sewage?

**Soln:**

$$BOD_5 = (DO_i - DO_5) * DF$$

$$= (8.5 - 3.1) * \frac{20}{1} = 108 \text{ mg/L}$$

Ans

* 2.5 mL of raw sewage has been diluted to 250 mL and DO concentration of diluted sample at the begining of BOD test was 8 mg/L and 3mg/L after 5 days incubation at 20°c. Determine BOD of raw sewage?

**Soln:**

$$BOD_5 = (DO_i - DO_5) * DF$$

$$= (8 - 3) * \frac{250}{2.5} = 500 \text{ mg/L}$$

Ans

* A sample of sewage was incubated for 2 days and the BOD of the sample was observed to be 165 ppm at 20°c. Determine 5 day 20°c & 20 days 20°c BOD values.

Assume, $K(20°c) = 0.1/\text{day}$.

**Soln:** We know,

$$BOD_t = L_0(1 - e^{-Kt})$$

$$\Rightarrow 165 = L_0(1 - e^{-0.1*2}) \Rightarrow L_0 = 910 \text{ PPm}$$

$$\therefore BOD_5 = L_0(1 - e^{-Kt}) = 910 * (1 - e^{-.1*5}) = 358 \text{ PPm}$$

$$BOD_{20} = 910(1 - e^{-.1*20}) = 787 \text{ PPm}$$

Ans

Scanned by CamScanner

* The 5 day 20°C BOD of a sewage is 200 mg/L. $K_1 = 0.17 d^{-1}$.
Find the ultimate BOD.

Megha-17

Soln.

$$BOD_t = L_0(1-e^{-Kt})$$

$$\Rightarrow L_0 = \frac{200}{1-e^{-0.17*5}} \Rightarrow L_0 = 232 \text{ mg/L}$$ **Ans**

* The 5 day 20°C BOD of a sewage is 276 mg/L and the ultimate BOD is 380 mg/L. Find the BOD reaction rate constant.

Soln.

$$BOD_5 = L_0(1-e^{-Kt})$$

$$\Rightarrow 276 = 380(1-e^{-K*5}) \Rightarrow K = 0.1124 \text{ day}^{-1}$$ **Ans**

* If the $BOD_5$ at 20°C of a sewage sample is 320 mg/L calculate its 10 day BOD at 30°C?

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

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

$$\Rightarrow K_{30} = 0.1(1.047)^{10}$$

$$= 0.163/\text{day}.$$

| $K_{20} = 0.1/\text{day}$ (धरावना)

Again, $BOD_5 = L_0(1-e^{-Kt})$

$$\Rightarrow L_0 = \frac{320}{1-e^{-0.1*5}} \Rightarrow L_0 = 468 \text{ mg/L}$$

$\therefore$

$$BOD_{10} = L_0(1-e^{-K_{30}t})$$

$$= 468(1-e^{-0.163*10})$$

$$= 375.02 \text{ mg/L}$$ **Ans**

* For a waste water of a sample 5 day BOD at 20°C is 250 mg/L & is of the 70% of ultimate BOD. What will be the 4 day BOD at 30°C?

Soln:

$$L_o = \frac{250}{0.7} = 357.14 \ mg/L$$

Again, $BOD_5 = L_o(1 - e^{-K_{20} t})$

$$\Rightarrow 250 = 357.14(1 - e^{-K_{20} * 5}) \Rightarrow K_{20} = 0.105 /day.$$

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

$$\Rightarrow K_{30} = 0.105(1.047)^{30-20} \Rightarrow K_{30} = 0.166/day.$$

$$\therefore BOD_4 = L_o(1 - e^{-K_{30} t})$$

$$= 357.14(1 - e^{-0.166 * 4})$$

$$= 280 \ mg/L$$ Ans

* 1 mL of sewage is diluted to 20 ml by adding water for BOD test. If $DO_i = 8.4$ mg/L, $DO_5 = 4.2$ mg/L, reaction rate constant, $K = 0.22 \ day^{-1}$. calculate
i) $BOD_5$ ii) Ultimate carbonacious BOD, $L_o$ iii) Remaining oxygen demand after 5 days?

Soln:

i) $BOD_5 = (DO_i - DO_5) * DF$

$$= (8.4 - 4.2) * \frac{20}{1}$$

$$= 84 \ mg/L$$

ii) $BOD_5 = L_o(1 - e^{-Kt})$

$$\Rightarrow L_o = \frac{84}{1 - e^{-0.22*5}}$$

$$= 126 \ mg/L$$

iii) Remaining oxygen demand, $L_5 = L_o - BOD_5$

$$= 126 - 84$$

$$= 42 \ mg/L$$

OR

$$L_t = L_o e^{-Kt}$$

$$= 126 * e^{-0.22*5} = 42 \ mg/L.$$ Ans

* The $BOD_5$ of wastewater is determined to be 150 mg/L at 20°C ($K = 0.23\ day^{-1}$). What is ultimate BOD & $BOD_8$ if the test was run at 15°C? What portion of ultimate BOD would be remaining unoxidized after 20 days at 20°C?

Soln.

$BOD_5 = L_0(1-e^{-Kt})$

$\Rightarrow L_0 = \dfrac{150}{1-e^{-0.23*5}}$

$= 220$ mg/L

Again,

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

$\Rightarrow K_{15} = 0.23*(1.047)^{15-20}$

$= 0.1829\ day^{-1}$

$\therefore BOD_8 = L_0(1-e^{-K_{15}*t})$

$= 220(1-e^{-0.1829*8})$

$= 169$ mg/L

Again:

$L_t = L_0 e^{-Kt}$

$\Rightarrow \dfrac{L_t}{L_0} = e^{-0.23*20}$

$= 0.01 = 1\%$

Ans

* A test bottle containing seeded dilution water has it's DO level drop by 0.8 mg/L in a 5 day test. A 300 ml BOD bottle filled with 30 ml of waste water and the rest are seeded with dilution water experiences a drop of 7.3 mg/L DO in the same 5-day period. Calculate the $BOD_5$ of waste water.

Soln:

$V_w = 30$ ml.

$V_m = 300$ ml

$V_d = 270$ ml

$BOD_m V_m = BOD_w V_w + BOD_d V_d$

$\Rightarrow 7.3*300 = BOD_w*30 + 0.8*270$

$\Rightarrow BOD_w = 65.8$ mg/L

Ans

* What is NBOD?

Ans: The amount of oxygen required to oxidize the nitrogenous matter of waste water is called nitrogenous BOD.

$$NH_3 + 2O_2 \rightarrow NO_3^- + H_2O + H^+$$

($NH_3$ ↳ 14, $2O_2$ ↳ 64)

Theoretical NBOD = $\frac{64}{14}$ = 4.57 mg/L of $O_2$/mg/L of N

* Why COD is greater than BOD?

Ans: BOD of any water represents the biodegradible organic content only but COD covers total organic content. That means, BOD is a fraction of COD. So, COD is greater than BOD.

Mas-14

* Data obtained from a wastewater sample:

$BOD_5$ = 400 mg/L; K = 0.29 $day^{-1}$, $NH_3$-N = 800 mg/L ($NH_3$ = 80 mg N/L)

Estimate the total quantity of DO (mg/L) that will be required for complete stabilization of this wastewater?

Soln:

$$BOD_5 = L_0(1-e^{-kt}) \Rightarrow L_0 = \frac{400}{1-e^{-.29\times5}} = 522.58\ mg/L$$

$L_0$ (CBOD)

NBOD = 80 * 4.57 = 365.6 mg/L

∴ Total DO required = CBOD + NBOD = 888.2 mg/L

Ans

* A canal exerted waste water in a river at 55000 $m^3$/day. BOD of waste water is 130 mg/L. What is the total amount of BOD exerted in the river?

Soln:

L-16

Total BOD = 55000 * 1000 * 130 [1 $m^3$ = 1000 L]

= 7150000000 mg/day

= 7150 kg/day

Ans.

* A municipal waste water treatment plant discharge 1.2 m³/s of effluent having BOD of 60 mg/L that has a flow of 9.3 and BOD is 6 mg/L. Estimate the mixing BOD of the river just downstream of the flow.

DB-15

Soln:

$Q_w = 1.2\ m^3/s$

$BOD_w = 60\ mg/L$

$Q_d = 9.3\ m^3/s$

$BOD_d = 6\ mg/L$

$Q_m = 1.2 + 9.3 = 10.5\ m^3/s$

$$BOD_m Q_m = BOD_w Q_w + BOD_d Q_d$$

$$\Rightarrow BOD_m = \frac{60 \times 1.2 + 6 \times 9.3}{10.5}$$

$$= 12.171\ mg/L$$

Ans

* A waste water of 5 m³/s is discharged into a river flow of 50 m³/s. The ultimate BOD of wastewater is 200 mg/L. The river has BOD of 3 mg/L.

Soln:

$$BOD_m Q_m = BOD_w Q_w + BOD_d Q_d$$

$$\Rightarrow BOD_m = \frac{200 \times 5 + 3 \times 50}{50 + 5} = 20.91\ mg/L$$

Ans.

* If a treatment plant is treating the waste water to remove 70% BOD, what is the amount of BOD exerted now?

Soln: 30% Ans.

Scanned by CamScanner

# Water Treatment/purification

# Objectives of water treatment.

- To make water
  1) safe to drink 2) pleasant to taste and 3) suitable for domestic uses.

# Write down the methods of water purification/Treatment.

Ans:

① Plain sedimentation
② Sedimentation with coagulation
③ Filtration
④ Disinfection
⑤ Water softening
⑥ Aeration
⑦ Activated carbon application
⑧ Demineralization
⑨ Desalinization.

# **Plain Sedimentation**: This is a process causing the organic or inorganic particles heavier than water to settle by retaining water in a tank or basin.

# **Settling velocity**: A particle having specific gravity of more
than 1, i.e. heavier than water, tends to move downward in
water by the force of gravity, accelerating until the frictional
resistance of the water equals the gravitational force
acting upon the particle. Thereafter, the particle travels
with a constant vertical velocity called terminal/settling
velocity.

For particle size 0.1cm and $Re \leq 1$:

Stoke's formula, $V_s = \frac{g}{18\mu}(\rho_s - \rho_w) d^2$

5

Scanned by CamScanner

where, $V_s$ = settling velocity, g = acceleration due to gravity

~~$\rho_s$ = Mass density of fluid, $\rho_w$ = Mass~~

$\rho_s$ = Mass density of particle, $\rho_w$ = Mass density of fluid.

$\mu$ = Kinematic viscosity of water

d = Diameter of the particle

The above equation can also write as —

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

S – sp. gr. of particle; 1 – sp. gr. of fluid.

## For particle size > 1 cm, Re > 2000:

Newtons Law,

$$V_s = \sqrt{\frac{4g}{3C_D}(S-1)d}$$

$C_D$ → Newtons drag co-efficient.

## * Factors affecting settling velocity:

- Horizontal flow velocity of water
- Shape & size of the particle
- Sp. gr. of the particle
- viscosity of water
- Temperature of water.

# Design of sedimentation tank:

**Rectangular:**

Surface overflow rate/

Surface loading, $SOR = \frac{Q}{BL}$ → (0.20 to 1 m/hr)

Detention time, $T = \frac{\text{Volume of tank}}{\text{Flow per unit time}}$ → (1 to 3 hrs)

$$= \frac{BLH}{Q}$$

Height, H = 1.5 ~ 2.0 m

∴ volume of tank, V = QT

**Circular:**

$V = D^2[0.011D + 0.786H]$

where,

V = volume of circular tank in $ft^3$

D = Dia of the tank, ft.

H = vertical depth, ft.

* Find the dimension of a settling (sedimentation) tank to treat 45 $m^3$ of raw water per hour when the overflow rate is 0.5 m/hr and the detention time is 3 hours.

**Soln:**

$SOR = \frac{Q}{BL} \Rightarrow BL = \frac{45}{0.5} = 90\ m^2$ —— (i)

Detention time, $T = \frac{V}{Q} = \frac{BLH}{45} \Rightarrow BLH = 135\ m^3$ —— (ii)

From (i) & (ii), $H = 1.5\ m$,

Let, $L/B = 4 \Rightarrow L = 4B$.

$\therefore 4B^2 = 90$ | $L = \frac{90}{B} = 18.97\ m$

$\Rightarrow B = 4.74\ m$

$\therefore$ size: = 4.75 m × 18.97 m × 1.5 m

Ans

* One million gallons of water per day (1mgd) passes through a sedimentation tank which is 20ft wide, 50 ft long and 10 ft deep. Find a) Detention time for the basin b) Average velocity of flow through the basin c) If the suspended solids content of the water averages 40 ppm, what weight of dry solids will be deposited every 24 hours assuming 75% removal in the basin b) surface over flow rate.

BPBD-16

Sol$^n$:

a) Detention time = $\frac{\text{volume}}{\text{Flow per unit time}}$

$$= \frac{20\times50\times10}{\frac{1\times10^6}{7.48}} \times 24$$

1 gallon $= \frac{1}{7.48}$ $ft^3$

= 1.8 hrs.

b) velocity, $V_s = \frac{Q}{A} = \frac{(1\times10^6)/7.48}{20\times10\times24\times60\times60}$

= 0.0077 ft/s

c) Total solid deposited $= \frac{40\times10^6}{10^6} \times 8.34 \times 0.75$ [1 gallon = 8.34 lb

= 250 lb/day

d) Over flow rate $= \frac{Q}{BL} = \frac{1\times10^6}{50\times20}$ = 1000 gpd/sft.

Ans

* If the flow for water supply is 1000 m³/day. Design the size of plain sedimentation tank for a detention time of 2hrs. Assume B:L = 2:3, tank depth 2m.

Sol$^n$: We know,

$T = \frac{V}{Q} = \frac{BLH}{Q} \Rightarrow BLH = QT$

$\Rightarrow BL = \frac{QT}{H} \Rightarrow BL = \frac{1000\times2}{24\times2}$

$\frac{B}{L} = \frac{2}{3}$

$\Rightarrow B = \frac{2}{3}L$

H = 2m, T = 2hrs.

$\Rightarrow \frac{2}{3}L\times L = 41.67 \Rightarrow L^2 = 62.5$

$\therefore L = 8m$

$\therefore B = \frac{2}{3}\times8 = 5.33\ m$

Ans

* A rectangular sedimentation tank is to treat 400000 gpd of raw water. The detention period is 4 hrs, the velocity of flow 3 inch/minute and the depth of water and sediment is 14 ft. If an allowance of 4 ft for sediment is made, what should be the length and width of sedimentation tank?

Sol$^n$:

$Q = 400000$ gpd $= \frac{400000}{24 \times 7.48} = 2228.16$ cft$^3$/hr

$H = 14 - 4 = 10$ ft.

let, $L = 1.5B$

$T = \frac{V}{Q}$

$\Rightarrow 4 = \frac{BLH}{2228.16}$

$\Rightarrow BL = \frac{2228.16 \times 4}{10}$

$\Rightarrow 1.5B^2 = 897$

$\therefore B \simeq 24.5$ ft.

$\therefore L = 1.5 \times 24.5 \simeq 36.5$ ft

Ans

* A circular sedimentation tank with standard mechanical sludge removal equipment is to handle 750000 gpd of raw water. If the detention period is 4 hrs and the depth of the tank is to be 10 ft. What should be the diameter of the tank?

Sol$^n$:

$Q = 750000$ gpd $= \frac{750000}{24 \times 7.48} = 4177.81$ ft$^3$/hr

$H = 10$ ft

$T = \frac{V}{Q}$

$\Rightarrow V = QT = 4177.81 \times 4 = 16710$ cft.

$\therefore V = D^2(0.011D + 0.785H)$

$\Rightarrow 16710 = D^2(0.011D + 0.785 \times 10)$

By trail & error

$D = 45$ ft Ans

* A settling tank 3m deep, 60m long. What is the flow velocity of the particle having size 0.025m at 25°c sp. gr. 2.65 & kinematic viscosity of water, $\nu = 0.01 m^2/sec$

Soln:

$$V_s = \frac{g}{18\mu}(s-1)d^2 = \frac{9.81}{18 \times .01}(2.65-1) \times (.025)^2$$

$\therefore V_s = 0.056$ m/sec

| $g = 9.81 m/s^2$
| $s = 2.65$, $\mu = 0.01 m^2/sec$
| $L = 60m$
| $h = 3 - 0.5 \rightarrow$ (freeboard)
| $= 2.5m$

Now, $\frac{V}{V_s} = \frac{L}{h}$

$\Rightarrow V = \frac{60}{2.5} \times .056$

$= 1.35$ m/sec **Ans**

* Design a circular flow of radial circular sedimentation tank for a flow of 15000 m³/day in waste stabilization pond.

Soln: Let, SOR = 25 m/day, Retention time, T = 2hrs.

We know, $SOR = \frac{Q}{A} \Rightarrow A = \frac{15000}{25} = 600m^2$

$\therefore \frac{\pi}{4}d^2 = 600 \Rightarrow d = 27.64m$

[SOR = 20~40 m/d for waste stabilization]

Again, $T = \frac{V}{Q} = \frac{AH}{Q}$

$\Rightarrow H = \frac{QT}{A} = \frac{15000 \times 2}{24 \times 600} = 2.08m$ **Ans.**

* One million gallon (mgd) per day water passes through a sedimentation tank of 50' x 20' x 10'. Find detention time.

Soln:

$T = \frac{V}{Q}$

$= \frac{50 \times 20 \times 10}{133.69 \times 10^3}$

$= 0.0748$ days

$= 1.8$ hr. **Ans**

| Q = 1 mgd
| $= \frac{1 \times 10^6}{7.48}$
| $= 133.69 \times 10^3$ ft³/day

**# Coagulation:** This process is applied for the removal of the colloids and very fine particles having very low or no settling velocity. The stability of the colloids in water is derived from the zeta potential, which is the sum of van der waal's and electrostatic forces on the surface of the particles. The surface changes are negative and require neutralization by the addition of positive ions for destabilization of these particles. Coagulation is the process of addition of salt that produces positive ions in water and leading to destabilization of colloids.

**Common coagulants:**

- Aluminium sulphate — $Al_2(SO_4)_3 \cdot nH_2O$
- Ferric sulphate — $Fe_2(SO_4)_3 \cdot 9H_2O$
- Ferric chloride — $FeCl_3 \cdot 6H_2O$
- Ferrous sulphate — $FeSO_4$
- Sodium Aluminate

**# Draw the graph for coagulant dose Vs pH:**

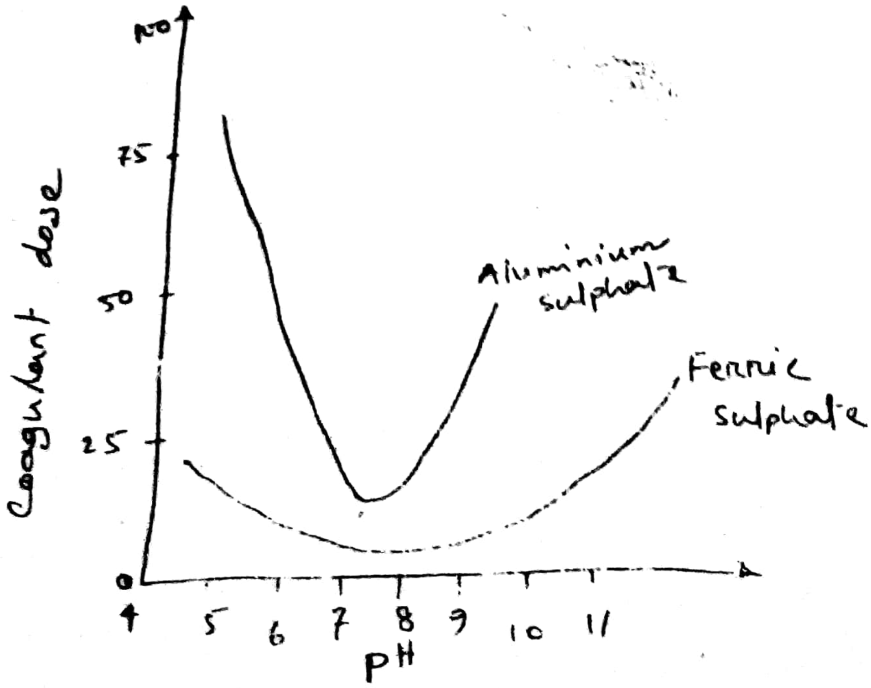



Fig: pH zones of coagulation of ferric sulphate and alluminium sulphate.

# Flocculation: Flocculation is a slow mixing technique which greatly increases the probability of particle collisions & promotes agglomeration of the destabilized particles to form large flocculant particles (flocs).

Tikas-14

# Jar test: This is a laboratory method to determine the optimum dosage of a particular coagulant which is required to be added to the raw water for coagulation and sedimentation in a treatment plant.

# Filtration: Filtration is a process of water purification in which water is allowed to pass through a bed of filtering media, usually sand and gravel and purified water is collected through an underdrain system.

# Types of Filters:

① Slow Sand Filter → usually gravity type.
② Rapid Sand Filter → both gravity & pressure type.

# Slow Sand Filter: In slow sand filter, the water is allowed to pass through a bed of fine sand which retains most of the impurities present in water. It is suitable for the development of a surface water based water supply system in developing countries. The main purposes of slow sand filters are —

- reduce the number of micro-organisms
- retain the organic & inorganic solid matters
- oxidize organic compounds dissolved in water.

The no. of rectangular filter units required —

$$n = 0.5\sqrt[3]{A}$$

→ total surface area ...

Characteristics:

- Rate of filtration is low, 0.1~0.3 $m^3/m^2/hr$.
- No pretreatment is required.
- Low cost of operation & maintenance.
- Cleaning of filter bed by scraping.
- Not suitable for water having turbidity > 30 NTU.

# Rapid Sand Filter: In rapid sand filter, the filtration rate is higher as compared to SSF due to the use of larger and relatively uniform size sand particles as filter medium. The filter beds usually include a coarse sand layer about 1m thick.

Characteristics:

- Rate of filtration is high, 5~15 $m^3/m^2/hr$.
- pretreatment (coagulation, flocculation, sedimentation) are required.
- High cost of operation & maintenance.
- Cleaning of filter bed by backwashing.
- High removal of turbidity and colour (80~85%) and bacteria (85~95%)

- The number of filter units required,

$$N = 0.04\sqrt{Q}$$ ← plant capacity $m^3/day$.

$$N = 2.7\sqrt{Q}$$ ← plant capacity in mgd (mega gallon/day)

# Operational difficulties of RSF:

- Negative head & air binding.
- Cracking of filter bed.
- Formation of mud balls.
- Jetting & sand boils.
- Sand leakage into the underdrain system.

# Mud balls: It consists of grain of sand and chemical ~~flocks~~ flocs carried over from the coagulating basin.

* A Rapid sand filter is to be designed for a capacity of 27,000 $m^3/day$. What should be the number and size of the units. Calculate the percentage of filt... water required to wash the filter bed and the capacity of wash water tank.

~~soln~~: Length of the filter run → 24 hrs including 5 min for filter washing and 10 min for resettlement of sand bed.

Soln: Let, Rate of filtration $= 5\ m^3/m^2/hr$

Rate of washing $= 35\ m^3/m^2/hr$.

$\therefore$ Filtration period $= 24\text{ hrs} - 15\text{ mins}$

$= 23.75\text{ hrs}$

Filtration rate $= 5 * 23.75 = 118.75\ m^3/m^2/day$

$\therefore$ Filter Area, $A = \frac{27000}{118.75} = 227.37\ m^2$

∴ No. of filter units required, $N = 0.04\sqrt{Q}$
$= 0.04\sqrt{27,000}$
$= 6.57 \simeq 7$ Nos. Ans

∴ Area of each unit $= \frac{227.37}{7} = 32.42\ m^2$

Let,
$L = 1.5W$

∴ $L*W = 32.42$

$\Rightarrow 1.5W^2 = 32.42 \Rightarrow W = 4.66\ m.$

∴ $L = 1.5*4.66 \simeq 7m$ Ans

∴ Area provided $= (7*4.66)*7 = 228.34\ m^2 > 227.37\ m^2$ OK

Wash water required $= 35*\frac{5}{60}*228.34$
$= 666\ m^3/day$ Ans

Minimum capacity of waste water tank $= 666\ m^3$ Ans

percentage of filtered water required for washing
$= \frac{666}{27000}*1000 = 2.47\%$
Ans

* A rapid sand filterplant is to be designed for a capacity of 6 mgd (mega gallon/day). What should be the number and size of filter units? What should be the percentage of filtered water required to wash the filter beds? What should be the capacity of wash water tank?

(1) Rate of filtration $= 2\ gpm/ft^2$ (gallon/min/ft²)

(2) Rate of washing $= 15\ gpm/ft^2$

Length of filter run → 24 hrs including 5 min for washing & 10 min for resettlement of sands.

Sol$^n$: Filtration period = 24 hr − (10+5) min
= 23.75 hrs

Filtration rate = 2 * 23.75 * 60 ~~= gallon/day/ft²~~
= 2850 gallon/day/ft²

Filter Area required = $\frac{6*10^6}{2850}$ = 2100 ft²

No. of unit = $2.7\sqrt{Q}$ = $2.7\sqrt{6}$ = 7 Nos. <u>Ans</u>

∴ Area of each unit = $\frac{2100}{7}$ = 300 ft².

∴ Size of each unit = 20′ × 15′ <u>Ans</u>

Wash water required = 15 * 5 * 2100
= 157500 gallon/day

∴ Capacity of waste wash water tank = 157500 galli
<u>Ans</u>

percentage of filtered water required

= $\frac{157500}{6*10^6}$ * 100 = 2.63 % <u>Ans</u>

* A filter bed has an area of 360 sq. ft. If the washing for 5 min at the rate 24 inch per min is contemplated, how much wash water will be requ

<u>Sol$^n$:</u> Rate of washing = 15 gpm / ft² [ 24 in/m = 2 ft³/ft = (2×7.48 ]

∴ Wash water required = 15 * 5 * 360
= 27,000 gallons.

<u>Ans</u>

[illegible]
B.Sc in CE, KUET

* A rapid sand filter operating at 2 $gpm/ft^2$ needs washing after 24 hr of operation. The filter has an area of 350 $ft^2$ and it needs washing at the rate of 15 $gpm/ft^2$ for 5 min. The time required for resettlement of sand is 10 minutes. What percent of the water that is filtered will be required for wash water?

<u>Soln:</u>

Filtration period = 24 hrs − (10 + 5) min

= 23.75 hrs.

Filtration rate = 2 * 23.75 * 60 = 2850 gallon/day/$ft^2$

Capacity of plant = 2850 * 350 = 997500 gallon/day

Wash water reqd = 15 * 5 * 350 = 26250 gallon/day

Percent of filtered water required

$$= \frac{26250}{997500} * 100 = 2.63\%$$

<u>Ans</u>

* A filter bed has sand depth of 2.5 ft and gravel depth of 1.5 ft. It is to be washed at the rate of 15 $gpm/ft^2$ or a rise rate of 2 ft/min. It is assumed that the sp. gr. of sand is 2.65, its porosity is 40% and all of its is lifted or supported by the rising water. Calculate the total head loss in the filter bed.

<u>Soln:</u>

Head loss in sand = (2.65 − 1) * (1 − .40) * 2.5

= 2.48 ft.

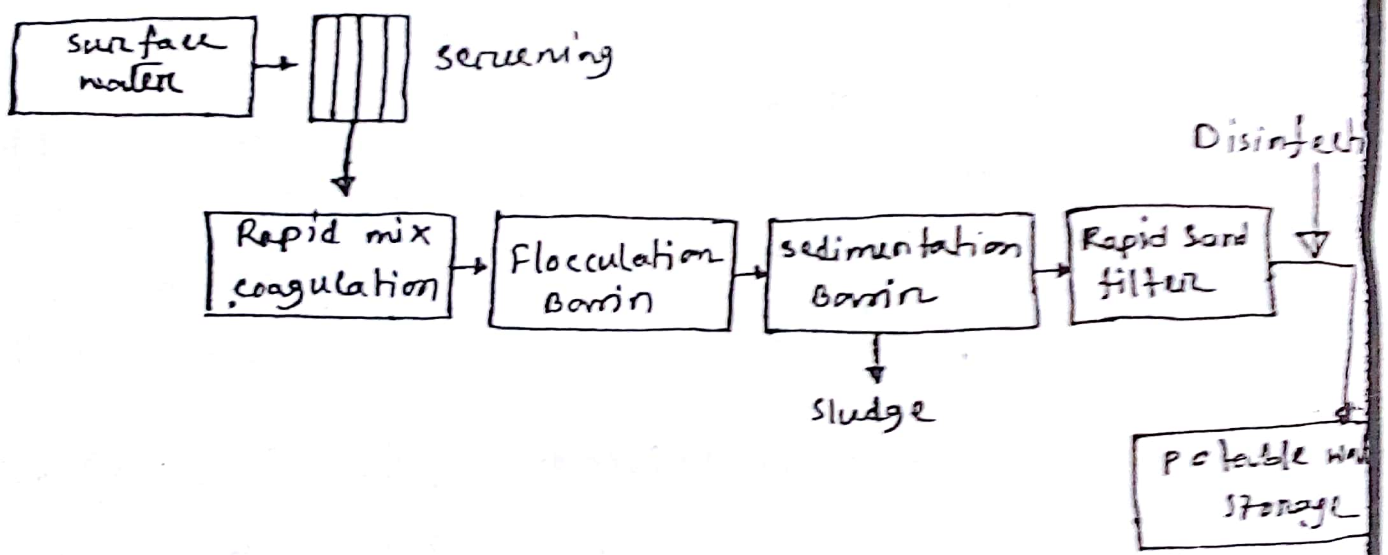
...d is
...t depth of
...when washing
12 inch/min

Head loss in gravel = 0.1 * 2 * 1.5 = 0.3 ft.

Total Head Loss = 2.48 + 0.3 = 2.78 ft

<u>Ans</u>

# Flow chart of conventional water treatment system:



Trough – নালা, ঢাকনিহীন – লম্বা এবং পাত্র-বিশেষ।

# Wash water Troughs:

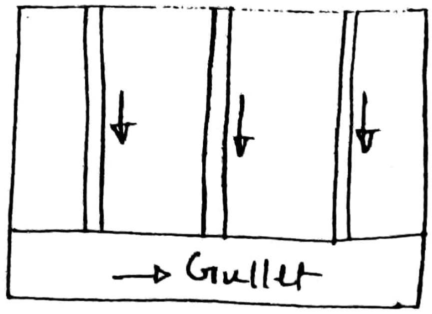



Fig: Arrangement of washwater trough (single unit)

A flat-bottom rectangular trough may be designed as →

$$Q = 1.72\, b y^{3/2}$$

where, $Q$ = total water received by trough in gpm
$b$ = width of trough in inch.
$Y$ = Depth of water at the upper end of the trough in inch.

* An additional 2 inch depth should be provided to allow freeboard.

* A flat-bottom trough is to receive wash water from a section of the filter which is 6 ft wide & 8 ft long. The wash water rate is 15 gpm/ft². If the water is to have a depth of 10 inch at the upper end of the trough, what should be the dimensions of rectangular trough?

**Soln.**

$Q = 6 * 8 * 15 = 720$ gpm ; $Y = 10$ inch.

$Q = 1.72 * b y^{3/2}$ ⇒ $720 = 1.72 * b * 10^{3/2}$

∴ $b = 15$ inch (width)

∴ Depth $= (10 + 2) = 12$ inch (2″ freeboard) Ans

# A v-bottom trough (with sides vertical) is to receive the wash water from a section of a filter bed 6.5 ft wide & 8 ft long. The wash water rate is 15 gpm/ft². Determine the dimension of the trough. Assume the depth of water in the trough as 12 inch (effective).

soln:  $Q = 6.5 * 8 * 15 = 780$ gpm ; $y = 12$ inch

$Q = 1.72\, b y^{3/2}$  $\Rightarrow 780 = 1.72 * b * 12^{3/2}$

$\Rightarrow b = 11$ inch

If v-bottom is a triangle & have the same area of a rectangle with depth 1.5 inch - Free board = 2″

∴ Total depth = 12 + 1.5 + 2 = 15.5 ft.

# Why $Cl_2$ is used for disinfection?  Am

Ans: 1) It is readily available.
2) It is cheap.
3) It is easy to apply.
4) It is easy to transport & not harmful to man.
5) It is very toxic to organism.

**# Disinfection:** The term disinfection is used in practice to describe treatment processes that have the sole objectives of killing the pathogenic organisms.

**# Sterilization:** It is the total destruction and removal of all micro-organisms.

**# Types of disinfection:**

① **physical disinfection:**

i) Boiling – remove pathogenic organisms.
ii) Ultraviolet ray – kill all types of bacteria.
iii) Sunlight – Combination of Boiling & ultraviolet ray.

② **chemical disinfection:** (characteristics)

- Quick and effective in killing pathogenic micro-organisms.
- Not imparting taste, odour, colour & turbidity.
- Not toxic to human & animal life.
- Readily available at moderate cost.

M.Sc.

**# Chemicals used in disinfection:**

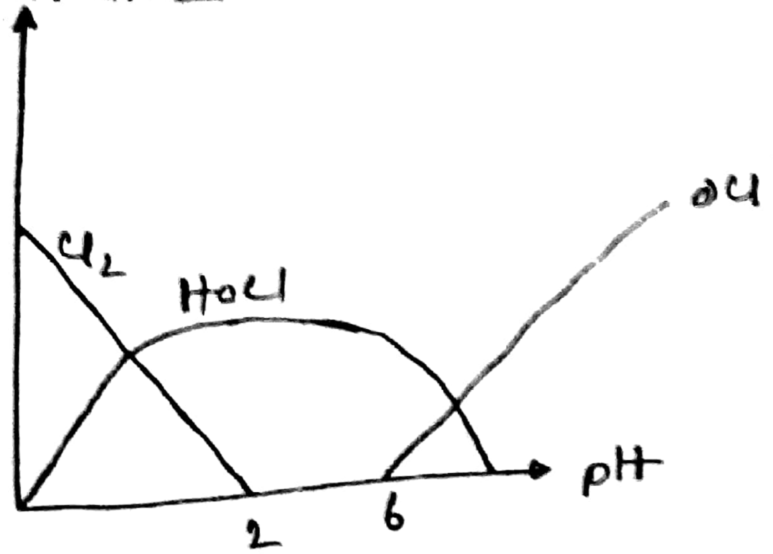
Chlorine ($Cl_2$), Ozone ($O_3$), Iodine (I), $KMnO_4$, $H_2O_2$.

**# Chlorination:** When chlorine is added to water, it reacts according to the following equation –

$$Cl_2 + H_2O \longleftrightarrow HOCl + HCl$$

$$HOCl \longleftrightarrow H^+ + OCl^-$$

The forms of chlorine present in water depend on pH of water. Chlorine in molecular form ($Cl_2$), Hypochlorous acid form ($HOCl$), hypochlorite ion form ($OCl^-$) are present in water at low, moderate and high pH values respectively. The chlorine available in water in any of the above forms is defined as "free available chlorine", which accomplishes the task of disinfection.




# Combined available chlorine:

If ammonia is present in water, monochloramine, dichloramine & nitrogen trichloride are formed as follows:-

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$$

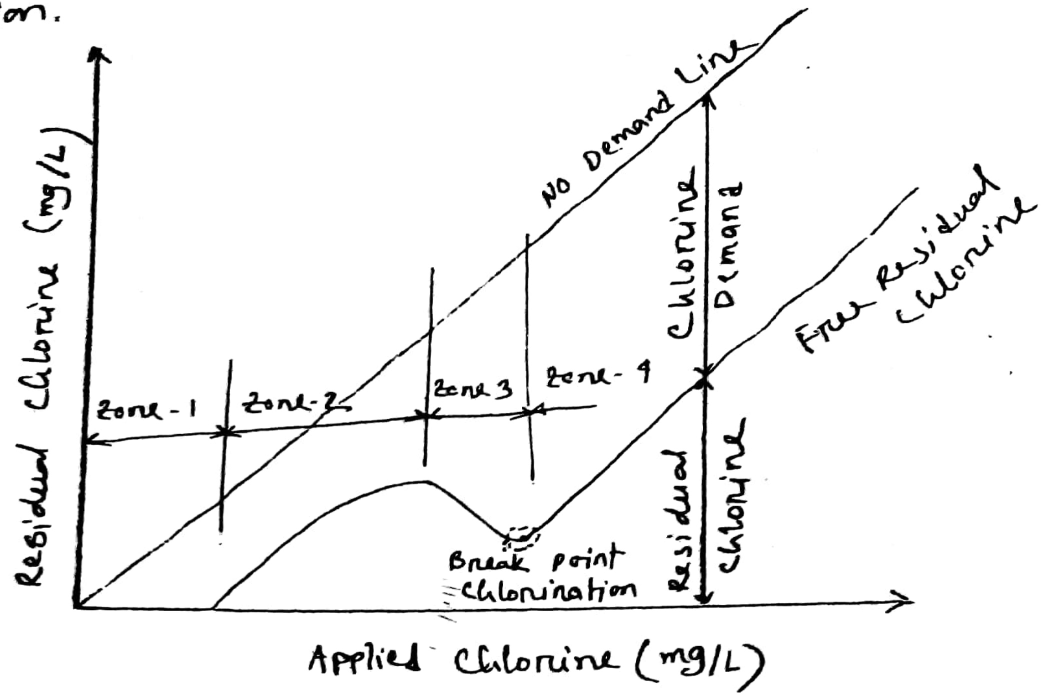
$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$$

The chlorine present in water in chemical combination with ammonia or nitrogenous compounds is known as combined available chlorine.

* Free available chlorine is more effective than combined available chlorine.

# Draw a typical chlorination curve on break point chlorination

Ans: The addition of chlorine at the break is termed as break point chlorination. It is also termed as free residual chlorination.




Zone-1 : Consumption of chlorine by reducing compounds.

Zone-2 : Formation of chloro-organic compound & chloramines.

Zone-3 : Destruction of chloro-organic compound & chloramines.

Zone-4 : Formation of free available chlorine

# Chlorine Demand: The chlorine demand of water is the difference between the amount of chlorine added and the amount of chlorine present as a residual either free or combined after a designated time.

# Pre-chlorination: It is the application of chlorine before any other treatment. This is done frequently for the purpose of controlling algae, taste and odour.

# post Chlorination: post-Chlorination refers to the application of chlorine after other treatment processes, particularly after filtration.

# Super Chlorination; Super chlorination is the application of an excess amount of chlorine to water. The method is effective in destroying high concentrations of taste odour or organic pollutants in water.

# Break point Chlorination: The addition of chlorine at break point is called break point chlorination. It is also termed as free residual chlorination. Its purpose is to oxidize all the organic matter.

* It is required to disinfect 5,00,000 gpd of water with 0.3 mg/l of Chlorine. If bleaching powder is used (which contains $33\frac{1}{3}$ percent of available chlorine), how many pounds of bleaching powder are needed to treat the daily flow of water?

**Soln:** Available Chlorine in the bleaching powder is 33.33%.

So, 1 lb of Chlorine is available in 3 lbs of bleaching powder

We know,

1 mg/l of Chlorine = 8.34 lbs of chlorine per million gallons of water

∴ Amount of bleaching powder required per million gallon = 3 × 8.34 = 25.02 lbs

∴ Amount of bleaching powder $= 25.02 \times \frac{500000}{1000000} \times 0.3$

= 3.75 lbs (1.71 kg)

Md. Mirаz Gazi
B.Sc. in CE, KUET

2 process is correct but answer is wrong.

# Water to be disinfection by bleaching powder Ca(OCl)Cl having $Cl_2$ of 2.3 mg/L. If the 5000 m³/day Ca(OCl)Cl powder is required 25% of $Cl_2$ per kg. Find the amount of Ca(OCl)Cl required per day?

Assume, residual chlorine = 0.2 mg/L, Total $Cl_2$ demand = 2.3 + .2 = 2.5 mg/L

Soln: Available chlorine in bleaching powder is 25%.

so, 1 kg of chlorine is available in 4 kg of bleaching powder

we know,

1 mg/L of chlorine = 3.79 kg of chlorine per million gallon of water

∴ Amount of bleaching powder per million gallon = 3.79 * 4
= 15.16 kg

∴ Amount of bleaching powder = $15.16 * \frac{5000}{\frac{1*10^6 * 3.78}{1000}} * 2.5$

~~= 46.12 kg/day~~

= 50.13 kg/day Ans.

[1 gallon = 3.78 litre]

Soln: Here, 1 kg of chlorine is available in 3.33 kg of bleaching powder.

we know,

1 mg/L of chlorine = 8.34 lbs of chlorine per million gallons of water

= 3.79 kg of chlorine per million gallons of water

∴ Amount of bleaching powder required per million gallon = 3.33 * 3.79 = 12.62 kg

[1 Litre = 0.264 gallon]

Amount of bleaching powder = 12.62 * (4 × 0.264) × 0.5
= 6.66 kg Ans

537

* The population of 2005 and 2015 are 124000 and 158000. What is the water demand of 2025 if water demand is 90 Lpcd. chlorine content of 0.5 mg/L is to be added in the water, how much bleaching powder is needed? (20% chlorine in bleaching powder).

Soln: $r = \sqrt[n]{\frac{P_2}{P_1}} - 1 = \sqrt[10]{\frac{158000}{124000}} - 1 = 0.0232$

$P_n = P_p(1+r)^n = 158000(1+.0232)^{10} = 246000$

GTCL-16

∴ water demand in 2025 = 90 × 246000
= 22140000 L/day
= 22.14 million litre/day.

Here, 1 kg of chlorine available is 5 kg bleaching powder

we know,
1 mg/L of chlorine = 3.79 kg of chlorine per million gallon of water

∴ Amount of bleaching powder required per million gallon = 3.79 × 5 = 18.95 kg

∴ Amount of bleaching powder = 18.95 × (22.14 × .264) × .5
= 55.38 kg/day

* A total of 60 kg Ca(OCl)Cl is used one day Ans. ~~to disinfect~~ volume of 50 million litre (ML) of water. Find the $Cl_2$ dose. Assume 33% available chlorine in Ca(OCl)Cl.

Soln: Here, 1 kg of $Cl_2$ available in 3.33 kg bleaching

we know,
1 mg/L of chlorine = 3.79 kg of chlorine per million gallon of water

∴ Amount of bleaching powder required per million gallon = 3.79 × 3.33 = 12.62 kg

∴ Amount of bleaching powder = $12.62 \times (50 \times .264) \times Cl_2$ dose

⇒ $60 = 12.62 \times (50 \times .264) \times Cl_2$ dose

⇒ $Cl_2$ dose = 0.36 mg/L

Assume, residual $Cl_2$ = 0.2 mg/L

∴ Total $Cl_2$ demand = 0.36 + 0.2

= 0.56 mg/L Ans.

* A slow sand filter produces 1 million Litre of water per day. How much bleaching powder with 28% available chlorine will be required per week to treat this water with chlorine of 0.5 mg/L.

Soln: Here, 1 kg $Cl_2$ is available in 3.57 kg of bleaching powder.

1 mg/L of $Cl_2$ = 3.79 kg of $Cl_2$/million gallon of water.

∴ Amount of bleaching powder required/ million gallon

= 3.57 * 3.79 = 13.54 kg.

∴ Amount of bleaching powder = 13.54 (1 × .264) × .5

= 1.78 kg /day.

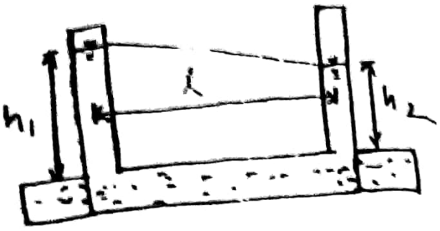
∴ For 1 week = (7 × 1.78) = 12.5 kg /week

Ans.

# 'Ground Water'

**# Conduit Function:** The property of water related to the conduit function is known as permeability. Permeability is the measure of the capacity of an aquifer to transmit water. According to Darcy's law –

$$V = Ki = K\frac{(h_1 - h_2)}{l}$$




Where,
- $V$ = velocity of flow
- $i$ = hydraulic gradient
- $K$ = Co-efficient of permeability
- $l$ = length of the section of pipe
- $h_1$ = pressure head at entrance 2.
- $h_2$ = pressure head at exit.

**# Types of aquifer:**

1) **Unconfined aquifer/water table aquifer:** not confined by an upper impermeable layer and water is under atmospheric pressure. Upper surface of the zone of saturation is called the watertable.

2) **Confined aquifer/artesian aquifer:** Confined by an overlying impermeable layer. Water is under pressure greater than atmospheric pressure.

For unconfined aquifer,

$$Q = \frac{\pi K (D^2 - d^2)}{\ln(R/r)}$$

where
- $Q$ = well discharge, $m^3/day$
- $K$ = Co-efficient of permeability, m/d
- 540 $D$ = Depth of aquifer, m
- $d$ = Static head, m
- $R$ = Radius of circle of influence, m
- $r$ = radius of the well, m

For Confined aquifer:

$$Q = \frac{2\pi K m (D-d)}{\ln\left(\frac{R}{r}\right)}$$

where,

D−d = Drawdown

m = Difference between confined & impervious layer.

* A 100 mm diameter tubewell is sunk 35 m below static groundwater level. The depth of water in the tubewell while pumping is 33 m. The radius of drawdown is 30 m and the co-efficient of permeability of the aquifer is 0.5 L/s/m². Calculate the probable discharge of the well.

Soln: $K = 0.5\ L/s/m^2$, $D = 35 m$, $d = 33 m$, $R = 30 m$, $r = \frac{100}{2} \times 10^{-3}$
$= 0.05 m$

$$\therefore Q = \frac{\pi K (D^2 - d^2)}{\ln\left(\frac{R}{r}\right)} = \frac{\pi \times 0.5 \times (35^2 - 33^2)}{\ln\left(\frac{30}{0.05}\right)} = 33.4 \text{ lps}$$

Ans

* A 100 mm diameter tubewell is sunk to withdraw water from a 10 m thick Confined aquifer having co-efficient of permeability equal to 0.75 lps/m². The depth of water below the piezometric level is 30 m and it falls 2 m in the tubewell while pumping. Calculate the discharge of the tubewell when the radius of the circle of influence is 30 m.

Ans: $K = 0.75\ lps/m^2$, $m = 10 m$, $R = 30 m$, $r = \frac{1000}{2} \times 10^{-3} = 0.05 m$.

$D - d = 2 m$

$$\therefore Q = \frac{2\pi K m (D-d)}{\ln\left(\frac{R}{r}\right)} = \frac{2\pi \times 0.75 \times 10 \times (2)}{\ln\left(\frac{30}{.05}\right)} = 14.73 \text{ lps}$$

Ans

* A 150 mm dia tubewell produces 100 lps with a drawdown of 3m and a circle of influence of 120m in diameter. The static depth of water in the well is 40m. Calculate the co-efficient of permeability of the aquifer.

Soln: $Q = 100$ lps, $R = \frac{120}{2} = 60m$, $r = \frac{150}{2} \times 10^{-3} = 0.075m$

$D = 40m$, $D - d = 3 \Rightarrow d = 40 - 3 = 37m$

$$Q = \frac{\pi K (D^2 - d^2)}{\ln(R/r)} \Rightarrow K = \frac{100 \times \ln\left(\frac{60}{0.075}\right)}{\pi (40^2 - 37^2)} = 0.92 \text{ lps}/m^2$$

Ans

* With a well of 12 inch diameter having a depth of 100 ft below the level of water table, the depth of water when the well is being pumped is 80 ft. As indicated by the test on a sample the effective size of the soil in the water bearing stratum is 0.30mm and the porosity is 30% and the corresponding co-efficient of permeability is 1260 gpd/sft. The radius of drawdown is assumed to be 1000 ft. What is the probable state of discharge of the well in gpm?

Soln: $D = 100$ ft, $d = 80$ ft, $K = 1260$ gpd/ft$^2$, $R = 1000$ ft, $r = \frac{12}{2} = 6$ inch $= 0.5$ ft

$$\therefore Q = \frac{\pi K (D^2 - d^2)}{\ln(R/r)} = \frac{\pi \times 1260 \times (100^2 - 80^2)}{\ln\left(\frac{1000}{0.5}\right)} = 1875 \text{ gpd}$$

$$= \frac{1875}{24 \times 60} = 1300 \text{gpm}$$

Ans

# Formula for two wells drawing water from a aquifer.

For two similar wells drawing water from the same aquifer situated at well apart, their rate of discharge shall be

$$Q_1 = Q_2 = \frac{K(D^2 - d^2)}{\ln\left(\frac{R^2}{r w}\right)} \quad ; w = \text{spacing of two well}$$

* At what rate could water be pumped from two wells 24 inch diameter each, static depth of water, 200 ft and draw down 30 ft. if both wells are being pumped together at a distance of 24 ft?

**Soln:** Assume, $R = 1025$ ft, $K = 0.999$ gpm/ft$^2$, $r = \frac{24}{2} = 12'' = 1$ ft

$D = 200$ ft, $d = 200 - 30 = 170$ ft, $w = 24$ ft.

$$\therefore Q_1 = Q_2 = \frac{K(D^2 - d^2)}{\ln\left(\frac{R^2}{r w}\right)} = \frac{0.999\,(200^2 - 170^2)}{\ln\left(\frac{1025^2}{1 \times 24}\right)} = 240 \text{ gpm}.$$

$\therefore$ Combined rate of flow from two well

$= 2 \times 240 = 480$ gpm **Ans**

# Well / Tubewell Design: For design a well screen, the following considerations are necessary –

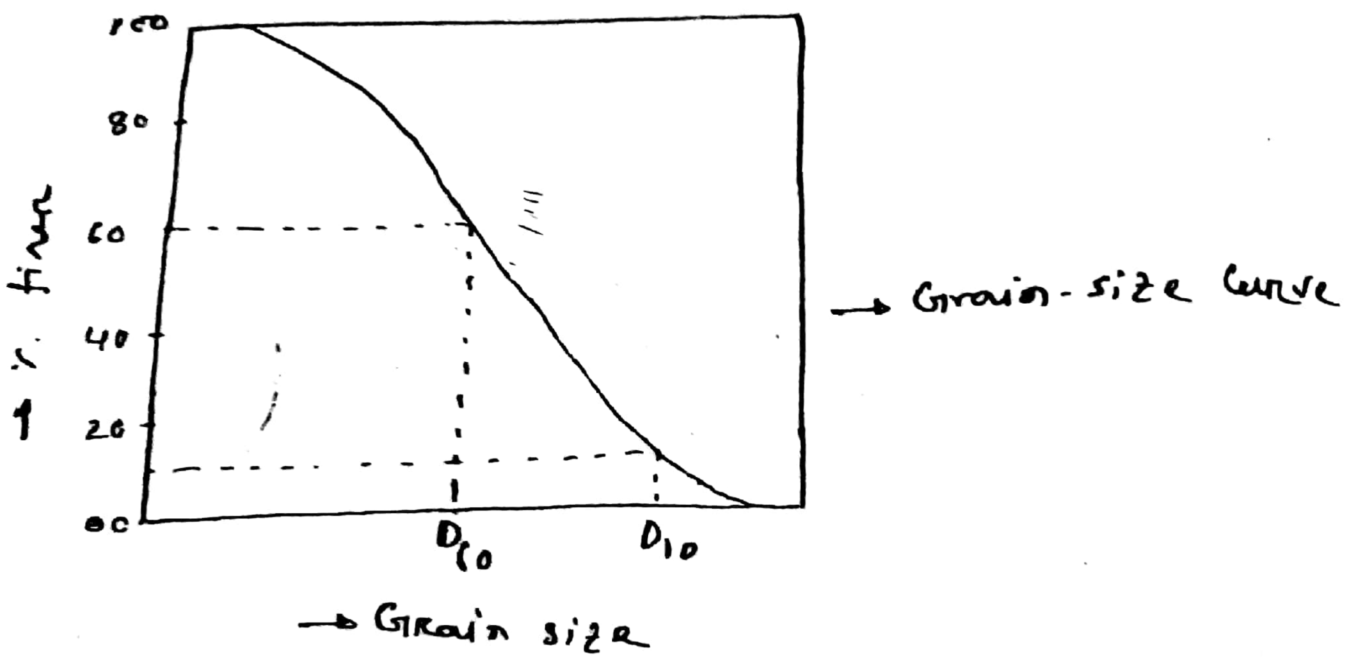
i) Geological formation of the underground strata.

ii) Grain size analysis results of the aquifer.

- The size corresponds to 10% finer is called the effective size, which governs the permeability of the aquifer.

The co-efficient of uniformity, $U = \frac{D_{60}}{D_{10}}$

- The aquifer material having 2 times the effective size and a similar uniformity co-efficient have 4 times higer permeability.




The length and diameter of the strainer may calculated as –

$$Q = \pi D L (0.01P) V_e$$

where, Q = Design discharge of tubewell

D = Diameter of the screen.

L = Length of the screen = 0.7 ~ 0.9 times of aquifer thickness

P = percent opening of the screen, (10%)

$V_e$ = permissible entrance velocity, < 0.03 m/s (0.03 ~ 0.01)

# Rainwater Availability:

The available rainwater can be estimated by—

$$Q = CIA$$

where,
$Q$ = total quantity of rainwater, $m^3/yr$
$C$ = Co-efficient of run off
$I$ = Intensity of rainfall, m/yr
$A$ = Catchment Area, $m^2$

# Catchment Area:

$$A = 0.365 qN / CI = 0.203 qN$$

where, $A$ = Min$^m$ catchment Area.
$q$ = Supplied water, lpcd (per capita water consumption)
$N$ = No. of people
$c$ = co-efficient of run off = 0.75
$I$ = Intensity of rainfall = 2.4 m/yr.

# Storage tank:

volume of storage rainwater tank,

$$V = 0.365 fqN = 0.146 qN$$

where, $f$ = fraction of total available rainwater required to be stored = 0.4

# Time of Concentration: It is the maximum time taken by water to travel from the extreme catchment boundary to the catchment out-let. Time of concentration can be estimated as—

$$t_c = \frac{FL}{A^{0.1} S^{0.2}}$$

where,
$t_c$ = time of concentration in minutes
$F$ = factor of proportionality
= 58.5 when A in $km^2$

Md. Miraz Gazi
B.Sc. in CE, KUET

L : Mainstream length. km
A = Catchment Area
S : Mainstream slope (m/km)

# Run-off Estimation:

$$Q = FCIA$$

where, Q = peak discharge in $m^3$/sec
F = a factor of proportionality
= 0.278 when A in $km^2$ and I in mm/hr
= 0.00278 when A in hectares and I in mm/hr
= 1 when A in $m^2$ and I in m/sec
C = Co-efficient of Run-off.
I = Rainfall intensity.
A = Area of catchment.

# Design Flow:

$$Q = \frac{f q P_f}{1 - 0.01W}$$

where, Q = peak design flow per day
$P_f$ = Design population.
f = peak factor.
q = average water consumption per capita per day
W = loss and wastage in percent (%)

$$Q = \frac{f q P_p (1+r)^n}{1 - 0.01W}$$

where, $P_p$ = present population
n = Design period (yrs)
r = rate of population growth per year.

* Design a Strainer for a 38 mm diameter tube well to be operated by a No-6 handpump at the rate of 40 lpm. Slot No 10 strainer having 40% open area is to be used. The entrance velocity should be around 0.01 m/sec.

Soln:

We know,

$$Q = \pi D L (0.01P) v_0$$

$$\Rightarrow L = \frac{Q}{\pi D (0.01P) v_0}$$

$$= \frac{0.67 \times 10^{-3}}{\pi \times .038 (0.01 \times 40) \times .01}$$

$$= 1.4 \text{ m}$$

Ans

$D = 38 \text{ mm} = 0.038 \text{ m}$

$P = 40\%$

$v_0 = 0.01 \text{ m/sec}$

$Q = 40 \text{ lpm}$

$= \frac{4}{1000 \times 60}$

$= 0.67 \times 10^{-3} \text{ m}^3/\text{s}$

* A fully penetrating tube-well in a confined aquifer has a maximum discharge capacity of 3000 lpm. The thickness of the aquifer is 22 m. Design the length of the well screen, assuming the effective open area of the Strainer to be 15% and the dia of the tubewell Screen is 20 cm.

Soln:

$$L = \frac{Q}{\pi D (0.01P) v_0}$$

$$= \frac{0.05}{\pi \times .2 \times (.01 \times 15) \times .03}$$

$$= 17.69 \text{ m}$$

$$\simeq 18 \text{ m}$$

Ans

$Q = 3000 \text{ lpm}$

$= \frac{3000}{1000 \times 60}$

$= 0.05 \text{ m}^3/\text{s}$

$v_0 = 0.03 \text{ m/s}$ [let]

$D = 0.2 \text{ m}$

$P = 15\%$

* Calculate the rainwater available for a family having a roof area of $20 m^2$ in the central region of Bangladesh, where rainfall intensity is 2.0 m per year. Assume a runoff co-efficient of 0.75.

Soln: $Q = CIA = 0.75 * 2 * 20 = 30 m^3/yr$ Ans

* The average rainfall intensity in Bangladesh is 2.4 m/yr and the runoff co-efficient is 0.70. Calculate the minm catchment area required for a family of 7 persons to be supplied with 15 lpcd of water.

Soln:

$$A = \frac{0.365 qN}{CI}$$

$$= \frac{0.365 * 15 * 7}{0.70 * 2.4}$$

$$= 22.8 m^2$$ Ans

$q = 15$ lpcd
$N = 7$
$C = 0.70$
$I = 2.4 m/yr$

BPDB-16

* Calculate the minimum capacity of the storage tank for a family of 8 persons to be supplied with 10 lpcd of rainwater. The yearly rainfall intensity is 2.5m and the rainfall distribution is such that at least 35% of the rainwater must be stored for uninterrupted water supply throughout the year. Also calculate the minimum catchment area required when the co-efficient of runoff is 0.7.

Soln:

$V = 0.365 f qN = 0.365 * 0.4 * 10 * 8 = 11.68 m^3$ Ans
↳ Take

$$A = \frac{0.365 qN}{CI} = \frac{0.365 * 10 * 8}{0.70 * 2.5} = 16.69 m^2$$ Ans

* Calculate the per capita water available and the capacity of the storage tank required for a family of 6 persons having a roof area of 20m² with a runoff co-efficient of 0.8. The family lives in a part of Bangladesh having a yearly rainfall of 2.5m. The distribution demands 40% storage requirement for full utilization of rainwater.

Soln:

Available Rainwater, $Q = CIA$

$$\Rightarrow Q = 0.8 * 2.5 * 20$$
$$= 40 m^3/yr$$

∴ Available Rainwater per capita per day

$$= \frac{40*1000}{6*365} = 18.26 \text{ lpcd}$$

Ans

Capacity of storage tank $= 40 * \frac{40}{100}$

$$= 16 m^3$$

Ans

* Determine the peak discharge for use in the design of a highway crossing a canal. The catchment has the following characteristics -

Main stream length, $L = 3.0 km$

Catchment Area, $A = 7.5 km^2$

Main stream slope, $S = 5.0 m/km$

Catchment type: Medium soil ($c = 0.48$)

A recurrence interval of 5 years is assumed to be suitable for the crossing.

Soln:

$$t_c = \frac{FL}{A^{0.1} S^{0.2}} \qquad \Big| \; F = 58.5$$

$$= \frac{58.5*3}{(7.5)^{0.1} * (5)^{0.2}} = 104 \text{ mins}$$

From intensity - duration - frequency curve

$I = 70$ mm/hr

peak discharge $Q = \frac{1}{f}CIA$

$= 0.278 \times 0.98 \times 70 \times 1.5$

$= 70$ $m^3$/sec

Ans

* Determine the diameter of the storm sewer crossing the highway, for the peak discharge 70 $m^3$/sec and laid at a slope of 0.001. The velocity at full flow should be less than 3 m/s

Sol$^n$:

$Q = aV$

$\Rightarrow 70 = \frac{\pi D^2}{4} \times 3$

$\Rightarrow D = \sqrt{\frac{70 \times 4}{3\pi}} = 5.45$ m

Ans

* Calculate the peak water demand of a rural community having a present population of 500 for a design period of 5 years. The average per capita water consumption is 50 L/capita/day with a peak factor of 3.0. The population growth rate is 2% and the loss & wastage is 20%.

Sol$^n$:

$$Q = \frac{f q P_P (1+r)^n}{1 - 0.01W} = \frac{3 \times 50 \times 500 \left(1 + \frac{2}{100}\right)^5}{1 - 0.01 \times 20}$$

$= 103,508$ lit/day

Ans

* Determine the discharge in lit/sec when velocity is 2.5 m/sec and dia of pipe 15 mm.

Sol$^n$:

$Q = AV$

$= \frac{\pi}{4} (.015)^2 \times 2.5$

$= 4.417 \times 10^{-4}$ $m^3/s$

$= 0.4417$ lit/sec

Ans

# Irrigation structures :

## # Head work:

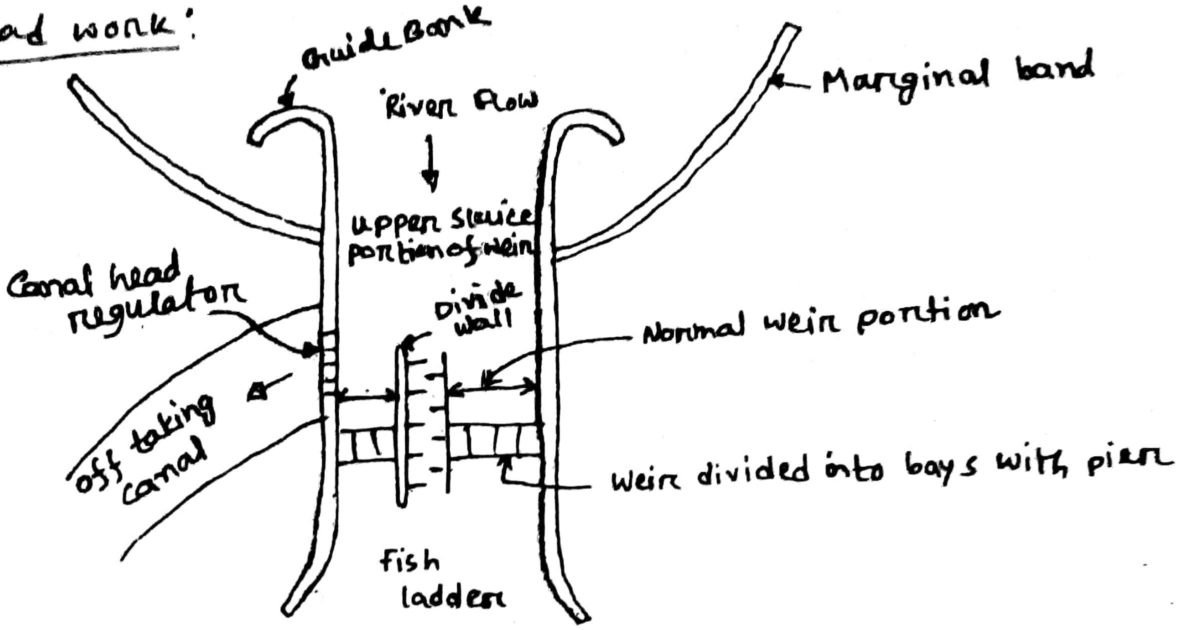
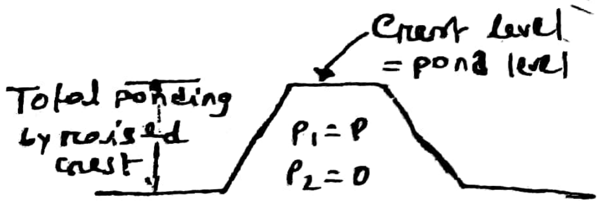
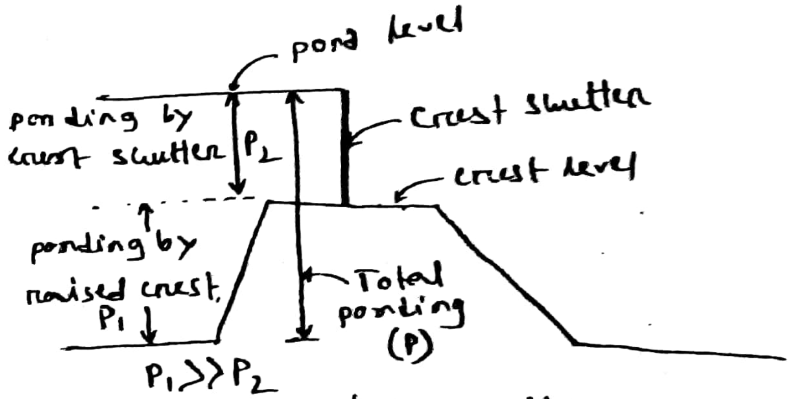



Fig: Typical layout of Diversion Head-works.

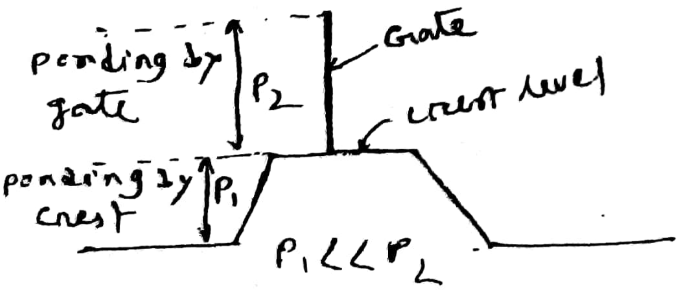
## # Weir and Barrage:



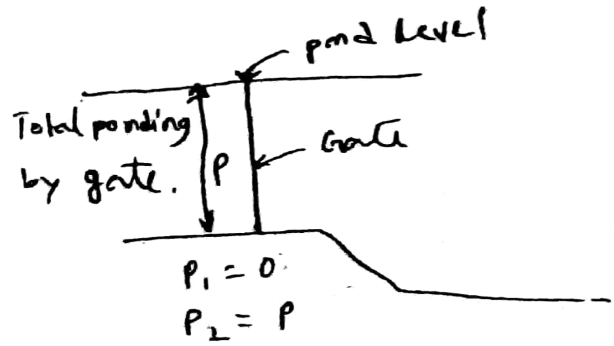

(a) weir without shutter




(b) weir with shutter




a) Barrage with raised crest




b) Barrage without raised crest.

**Weir:** If the major part or the entire ponding of w[illegible] is achieved by a raised crest and a smaller or nil part of it is achieved by shutters, then the barrie[r] is called weir (Fig before).

**Barrage:** If most of the ponding is done by gates [and] smaller or nil part of it is done by the raised c[rest] then the barrier is known as barrage or a rive[r] regulator.

# **Afflux:** The rise in the Highest Flood level (HFL) upstream of the weir due to construction of the w[eir] across the river is called afflux.

# Difference between weir & Barrage:

| Weir | Barrage |
|---|---|
| 1) High set crest. | 1) Low set crest. |
| 2) ponding is mostly done by raised crest and partly or nil by shutters. | 2) ponding is mostly done by [gates] and partly or nil by raised cr[est] |
| 3) shutters are of smaller height. | 3) Gates are of greater heigh[t] |
| 4) cheaper structure. | 4) costly structure. |
| 5) Longer construction period. | 5) Shorter construction perio[d] |

# Objective of diversion head work:

1) To rise water level at the head of the canal.
2) To control the entry of silt into the canal.
3) To control deposition of silt at the head of the ca[nal]
4). To Control the fluctuation of water level.

# Exit Gradient:

Exit Gradient, $G_E = \frac{H}{d} \frac{1}{\pi\sqrt{\lambda}}$

$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2}$

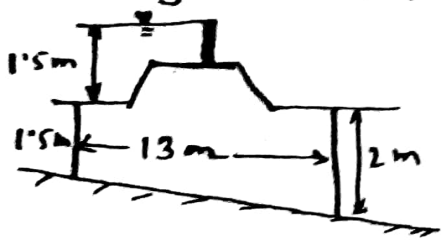
$\alpha = \frac{b}{d}$

b = Total floor length

d = Depth of d/s cut-off

H = Depth of water

* Calculate the exit gradient for the following figure.



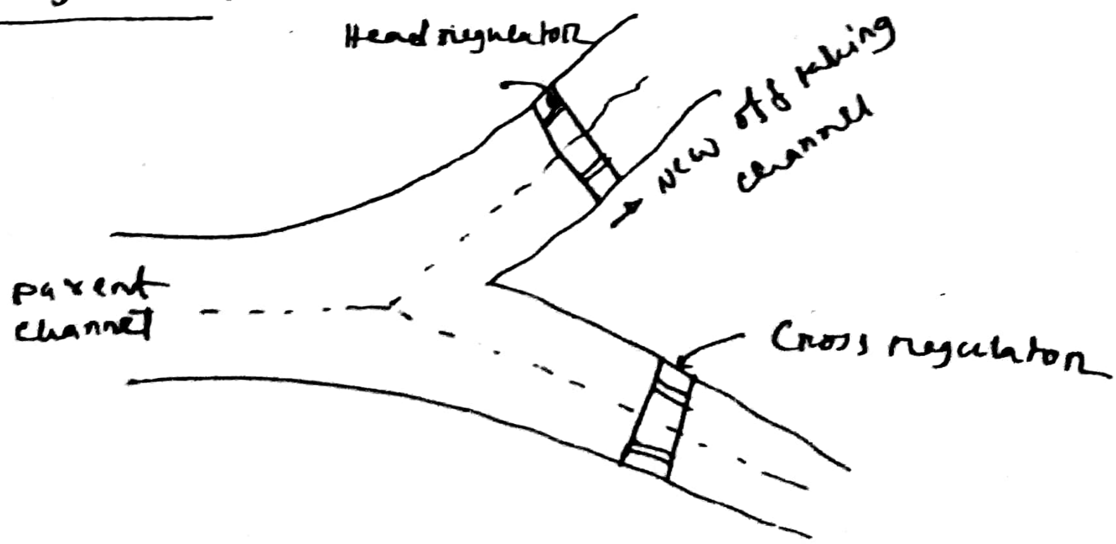

Soln:

$H = 1.5m$, $d = 2m$, $b = 13m$.

$\alpha = \frac{13}{2} = 6.5$, $\lambda = \frac{1+\sqrt{1+6.5^2}}{2} = 3.79$

$G_E = \frac{1.5}{2} \frac{1}{\pi\sqrt{3.79}} = 0.123$ Ans.

# Canal regulator:



# Horsepower Required:

1) Water horse power (WHP) $= \dfrac{QH}{76}$ ; $Q \rightarrow$ lit/s, $H \rightarrow$ m

$= \dfrac{QH}{273}$ ; $Q \rightarrow m^3/s$, $H \rightarrow$ m

$= \dfrac{QH}{3960}$ ; $Q \rightarrow$ gpm, $H \rightarrow$ ft

2) Shaft/Brake horse power (BHP) $= \dfrac{WHP}{E}$

where,

Q = Discharge

H = total lift/head of the pump

E = Efficiency of the pump

* Design a suitable set of pumping unit to deliver 450000 gph from a intake well of a river bank to the treatment plant. Total length of rising main from the intake well to the treatment plant is 800 ft and the static head is 60 ft. Design also the cast iron main. Given – efficiency = 70%, velocity of water = 12 fps, friction factor = 0.0075

Soln.: $Q = \dfrac{450000}{60} = 7500$ gpm

| |
|---|
| $1 ft^3 = 7.48$ gallon (US) |
| $1 ft^3 = 6.24$ gallon (UK) |

Again, $Q = \dfrac{450000}{60 \times 60 \times 7.48} = 16.71\ ft^3/s$

$\therefore A = \dfrac{Q}{v} = \dfrac{16.71}{12} = 1.39\ ft^2$

$\Rightarrow \dfrac{\pi}{4} d^2 = 1.39 \quad \Rightarrow d = 1.33$ ft $= 16$ inch

Head loss due to friction, $h_f = \dfrac{4flv^2}{2gd} = \dfrac{4 \times 0.0075 \times 800 \times 12^2}{2 \times 32.2 \times 1.33}$

$= 40$ ft

velocity head, $h_v = \dfrac{v^2}{2g} = \dfrac{12^2}{2 \times 32.2} = 2.24$ ft

55 $\therefore$ Total head $= h_s + h_f + h_v = 60 + 40 + 2.24 = 102.24$ ft.

$$WHP = \frac{QH}{3910} = \frac{7550 \times 102.24}{3960} = 194$$

$$BHP = \frac{WHP}{E} = \frac{194}{0.70} = 277$$

Ans.

* Water is supplied from an impounding reservoir 30 miles to a service reservoir near the town. A cast iron main is be designed to supply 425 mgd. Loss of head due to friction the pipe is estimated to be 300 ft. All other head looses are neglected. What size cast iron pipe would you use? f = 0

Soln:

$$h_f = \frac{4flv^2}{2gd} \Rightarrow \frac{v^2}{d} = \frac{2gh_f}{4fl} = \frac{2 \times 32.2 \times 300}{4 \times .0075 \times (5280 \times 3}$$

$$\Rightarrow \frac{v^2}{d} = 4.06 \quad [1 \text{ mile} = 5280 \text{ ft}]$$

Again,

$$A = \frac{Q}{V} \Rightarrow V = \frac{Q}{\frac{\pi}{4}d^2} \Rightarrow V^2 = \frac{16Q^2}{\pi^2 d^4}$$

∴ we get,

$$\frac{16Q^2}{\pi^2 d^5} = 4.06$$

$$\Rightarrow d^5 = \frac{16 \times (657.6)^2}{\pi^2 \times 4.06}$$

$$\Rightarrow d = 11.15 \text{ ft}$$

$$\simeq 12 \text{ ft} \quad \text{Ans.}$$

$$Q = 425 \text{ mgd} = \frac{425 \times 10^6}{24 \times (3600) \times 7.4} = 657.6 \text{ ft}^3/s$$

Scanned by CamScanner

Design a pumping unit capable of lifting 5 mgd of water from an intake well to the treatment plant against a static head of 60 ft. Length of suction main is 120 ft and that of rising main is 400 ft. The pump will work in <u>two</u> shifts of <u>eight</u> hours each. velocity of flow = 6 fps, f = 0.01, efficiency = 75%.

<u>Soln:</u> Here, Total length, $l = 400 + 120 = 520$ ft.

$$Q = 5\,mgd = \frac{5\times10^6}{7.48} = 6.68\times10^5\ ft^3/day$$

Total pumping time $= 8\times2 = 16$ hrs/day.

$$\therefore \text{pumping capacity} = \frac{6.68\times10^5}{16} = 41778\ ft^3/hr$$

$$= 11.61\ ft^3/s.$$

$$\therefore A = \frac{Q}{v} = \frac{11.61}{6} = 1.934$$

$$\Rightarrow \frac{\pi}{4}d^2 = 1.934 \Rightarrow d = \sqrt{\frac{1.934\times4}{\pi}} = 1.57\ ft$$

$$= 19\ inch.$$

$$h_f = \frac{4flv^2}{2gd} = \frac{4\times.01\times520\times6^2}{2\times32.2\times1.57} = 7.4\ ft.$$

$$h_v = \frac{v^2}{2g} = 0.56\ ft.$$

$$\text{Total head} = h_s + h_f + h_v = 60 + 7.4 + .56$$

$$= 67.96\ ft.$$

$$\therefore Q = \frac{5\times10^6}{16\times60} = 5208\ gpm$$

$$WHP = \frac{QH}{3960} = \frac{5208\times67.96}{3960} = 89.4$$

$$BHP = \frac{WHP}{E} = \frac{89.4}{.75} = 119.2$$

<u>Ans.</u>

* Design the transmission main and the pumping unit from the following data -
water supply rate = 40 gpcd, population = 85,000, Groun[d] at the pump house = 102.50 ft, Treatment plant RL = [193] velocity through pipes = 8 fps, pumping time = 10 hrs/day Total length of pipe = 3500 ft, friction factor = 0.01, Efficiency = 65%.

Soln: Total water required = (40 × 85000)

$= 3400000$ gpd

$= \frac{3400000}{7.48} = 4.55 \times 10^5$

∴ pumping time = 10 hrs/day

pumping rate $= \frac{4.55 \times 10^5}{10} = 4.55 \times 10^4\ ft^3/hr$

$= 12.63\ ft^3/s$

We know,

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

$\Rightarrow \frac{\pi}{4} d^2 = \frac{12.63}{8} \Rightarrow d = 1.42\ ft = 17$ inch

Static head $= 193 - 102.50 = 90.50$ ft.

$h_f = \frac{4 f l v^2}{2 g d} = \frac{4 \times .01 \times 3500 \times 8^2}{2 \times 32.2 \times 1.42} = 98$ ft.

$h_v = \frac{v^2}{2g} = \frac{8^2}{2 \times 32.2} = 0.9938$ ft.

Total head, $H = h_s + h_f + h_v = 90.50 + 98 + .9938$

$\simeq 189$ ft.

$Q = \frac{3400000}{10 \times 60} = 5667$ gpm

$WHP = \frac{QH}{3960} = \frac{5667 \times 189}{3960} = 270.5$

$BHP = \frac{WHP}{E} = \frac{270.5}{.65} = 416.11$

Ans.

* A pump lift 95000 litres of water per hour against total head of 23m. If the pump has an efficiency of 75%, Compute the horse power & shaft horse power.

**soln:**

$$WHP = \frac{QH}{76}$$

$$= \frac{26.39 \times 23}{76}$$

$$= 7.98$$

$$SHP = \frac{WHP}{E}$$

$$= 10.64 \text{ Ans.}$$

$Q = 95000$ lit/hr
$= 26.39$ lit/s
$H = 23$m
$E = 75\%$
$= .75$

Md. Mirraz Quazi
B.Sc. in EE, KUET

# Waste water

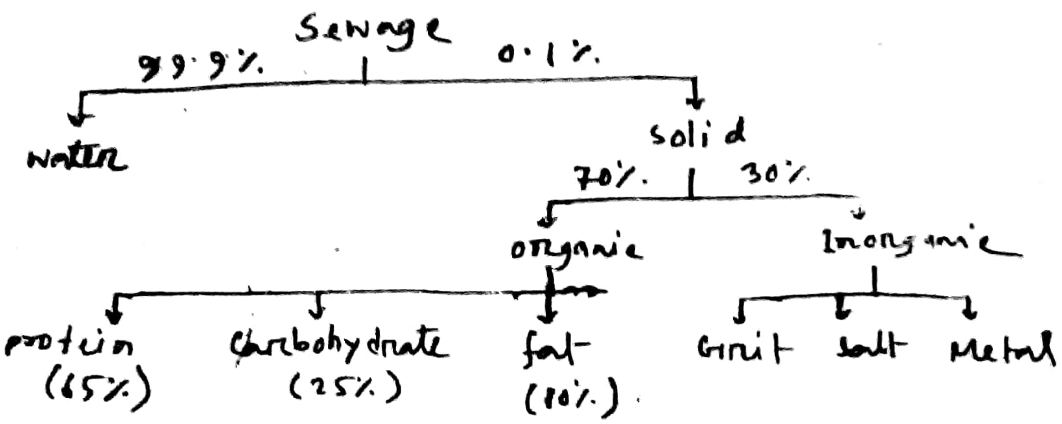
\# **Wastewater/sewage**: It is the liquid waste conveyed by a sewer and may include domestic, industrial and storm water.

\# **Sewer**: It is the pipe or conduit generally closed but normally not following full which carries sewage.

ADD-16!

\# **Sewerage**: It refers to the entire system of collection, treatment and disposal of sewage.

\# **Sullage**: It is the liquid discharge from kitchens, wash basins, etc and excludes discharge from water closet and urinals.




\# **Classification of sewer system/collection system:**

① **separate sewerage system:**

| Advantage | Disadvantage |
| --- | --- |
| i) Sewers are of smaller size. | i) two sets of sewers may prove costly. |
| ii) only Sanitary sewage is treated | ii) Smaller sewers may be difficult to clean. |

② **partially combined or partially separate system**

| Advantage | Disadvantage |
| --- | --- |
| i) Sewer size is not very large | i) velocity is low at dry period |
| ii) Min$^{m}$ solid deposition problem | ii) increased loads on pump. |

③ Combined sewerage system:

| Advantage: | Disadvantage |
| --- | --- |
| 1) one set of sewers may prove economical. | 1) Increased load on treat plant. |
| 2) larger sewer is easy to clean. | 2) storm water is pollute unnecessarily. |

# Factors affecting the pattern of sewage collecting synt

- Type of system
- Street lines & right of way.
- topography, hydrology & the geology of the area
- Nature of treatment & disposal work.

# Why circular sewer section is preferable?

Ans: Because of -

① Cross sectional ~~is~~ area is greater.

② fabrication is convenient.

③ Stable in shape.

④ Good hydraulic quality.

# potable water: The water which is safe to drink (free from pathogenic organisms), plesent to taste & suitable for domestic use is called potable water.

# palatable water: The water which is physically acceptable but chemically or bacteriologically not acceptable is called ~~acceptable~~. palatable water

# Factors affecting generation of waste:

① Geographic location

② Season of the year

③ Collection frequency.

④ Characteristics of population

# Basic requirements of drinking water:

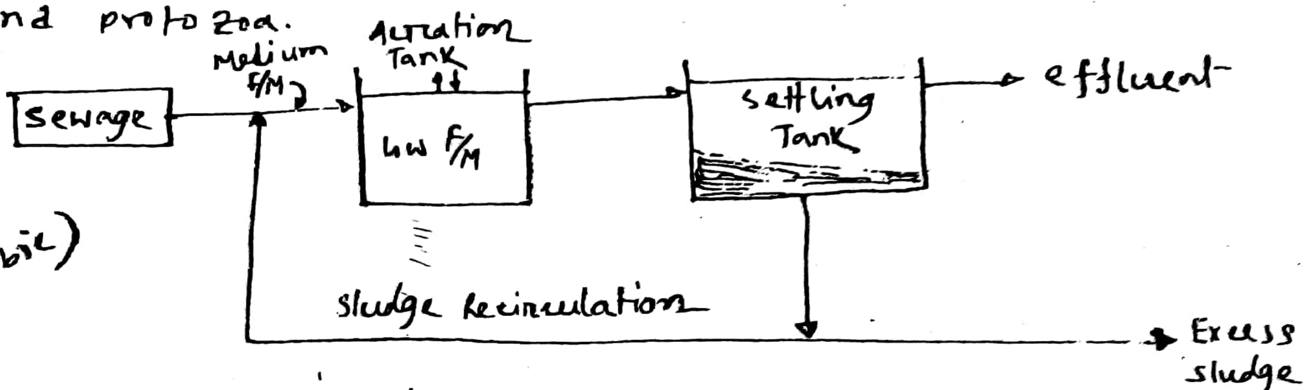
① Quantity & Quality
② location
③ cost & Sustainability
④ protect source of water
⑤ Appropriate treatment of raw water.
⑥ Safe distribution.

# Night soil: Night soil is a euphemism for human faces collected at night from cesspools, privies, etc and sometimes used as a fertilizer.

# Activated sludge process: The activated sludge process is a secondary process treating sewage and industrial waste water using air and biological flocs composed of bacteria and protozoa.

ACC-17
D-China-16

(Aerobic)



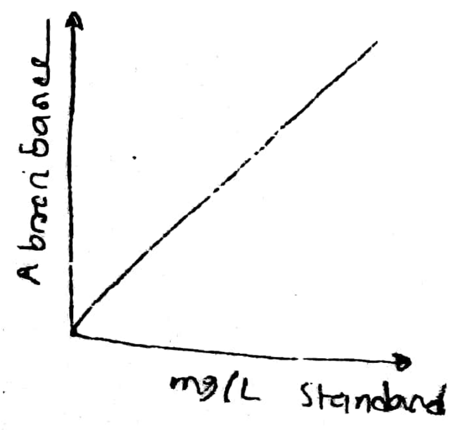

In activated sludge process, some sludge from settling tank is returned to aeration tank for better treatment, this is called activated sludge which contain micro-organisms.

Advantage:- Remove 97% suspended solid approximately
- Cost effective

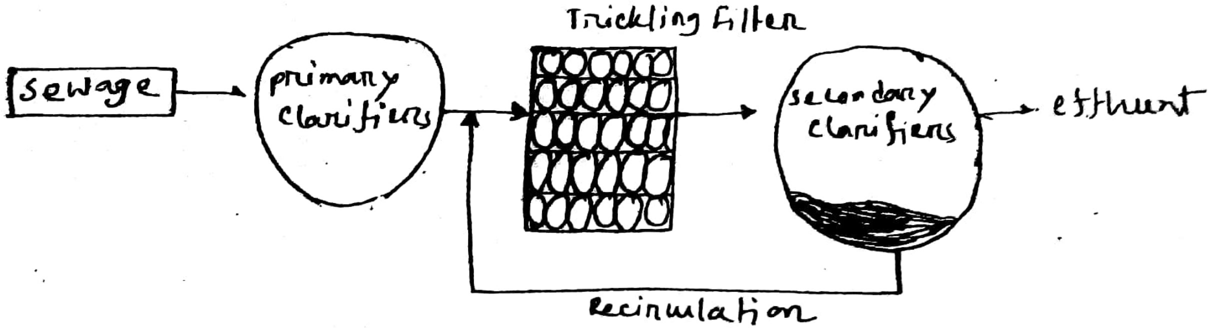
Disadvantage: Most plant needs 3 tanks.

# Draw the standard curve for iron determination:

Ans:



# Flow Diagram of trickling filter process: (Anaerobic)




# Draw the mutualism diagram of algal - bacteria in waste stabilization pond / Symbiosis between algae & bacteria.

Soln:

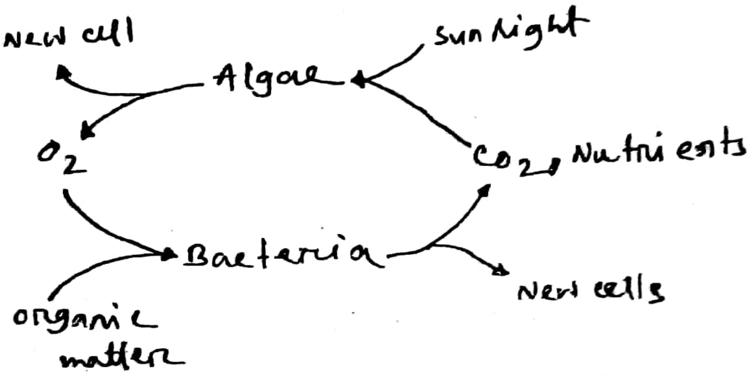



Fig: Symbiosis between algae & bacteria.

# Describe 4 phase of bacterial growth.

Ans:

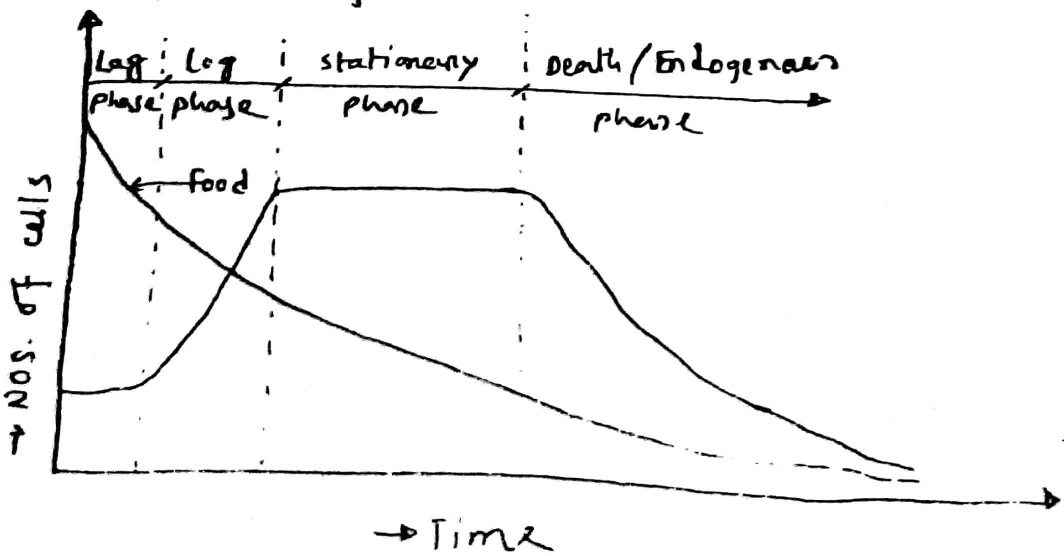



Fig: phase diagram for bacterial growth.

Lag phase: The time required for bacteria to acclimate to their new environment.

Leg phase: - Max$^m$ growth is occured.
- Rate of reproduction is exponential.

Stationary phase: - The reproduction of new cellular materials is roughly offset by death and endogenous respiration.

Death phase: The production of new cells and biomass decreases exponentially and approaching zero asymptotically after a very long time.

# Coliform Bacteria: These bacteria are always present in very large number in faces. The average excreta produce about $2\times10^9$ coliform each day. Two group -
① Faecal coliform Bacteria
② Non-faecal coliform bacteria.

# Leaching: It is the process of dissolving the soluble salts and removing them from the layers by downward movement of water.

# Formula for disinfection timing:

$$t = \frac{2}{K} \log \frac{N_0}{N_t}$$

where,
$t$ = Disinfection period in killing micro-organism (sec)
$N_0$ = Initial Nos. of organisms
$N_t$ = Nos. of organisms at time $t$
$K$ = $1.6\times10^{-2}$/sec → for free residuals
= $1.5\times10^{-5}$/sec → for combined residuals

* Compare the contract period necessary to kill E-coli of 99.99 NoS in water with a) free chlorine residuals of 0.2 mg/L b) Combined chlorine residuals of 1 mg/L. K values are $10^{-2}$/sec & $10^{-5}$/sec respectively

**Sol$^n$:**

$N_0 = 100$

$N_t = 100 - 99.99$

$= 0.01$ NoS.

$K_f = 10^{-2}$/sec

$K_c = 10^{-5}$/sec

a) $t = \frac{2}{K_f} \log \frac{N_0}{N_t}$

$\Rightarrow t = \frac{2}{10^{-2}} \log \frac{100}{.01}$

$\Rightarrow t = 28.28$ sec

b) $t = \frac{2}{K_c} \log \frac{N_0}{N_t}$

$\Rightarrow t = \frac{2}{10^{-5}} \log \frac{100}{0.01}$

$\Rightarrow t = 894$ sec

Ans.

# Waste stabilization ponds: Waste stabilization ponds are large shallow basins enclosed by earthen embankment in which raw sewage is treated by entirely natural process involving both algae and bacteria. Three Types –

① Anaerobic ponds ② Facultative ponds ③ Maturation (aerobic) ponds.

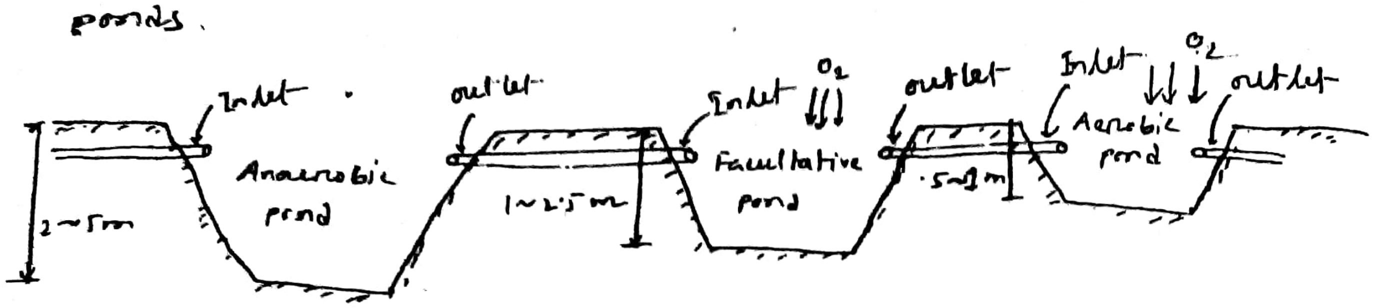



Fig: Typical scheme of waste stabilization pond.

Anaerobic pond: Requires no dissolve oxygen, since anaerobic bacteria breakdown the complex organic matters.

Facultative pond: Upper aerobic zone (maintained by algae) and a lower anaerobic zone. Aerobic, anaerobic and facultative organisms are found here.

Maturation pond: Aerobic bacteria breakdown the waste and algae, through photosynthesis, provide sufficient oxygen to maintain aerobic environment.

Advantage:

① Cheapest and simplest of all treatment technology

② No mechanical or external energy is required.

Disadvantage:

① Large land area is required

② Localized odour problem may occur.

* Design a oxidation pond for treating sewage from a hot- climate residential colony having a population about 5000. The contribution of sewage is at a rate of 120 lpcd and 5 day BOD is 300 mg/L."

**Soln:** Quantity of sewage treated = $5000 \times 120 = 6 \times 10^5$ L/day.

$\therefore$ BOD content = $300$ mg/L $\times 6 \times 10^5$ L/day

$= 300 \times 10^{-6}$ kg/L $\times 6 \times 10^5$ L/day

$= 180$ kg/day

Assume, organic loading = 300 kg/hectare/day.

$\therefore$ surface area $= \frac{180}{300} = 0.6$ ha $= 6000\ m^2$.

$\Rightarrow L \times B = 6000$   $[L = 2B]$

$\Rightarrow 2B \times B = 6000$

$\therefore B = 55$ m, $L = 110$ m

Assume depth = 1.2 m.

$\therefore$ Capacity of pond $= 110 \times 55 \times 1.2 = 7260\ m^3$ **Ans.**

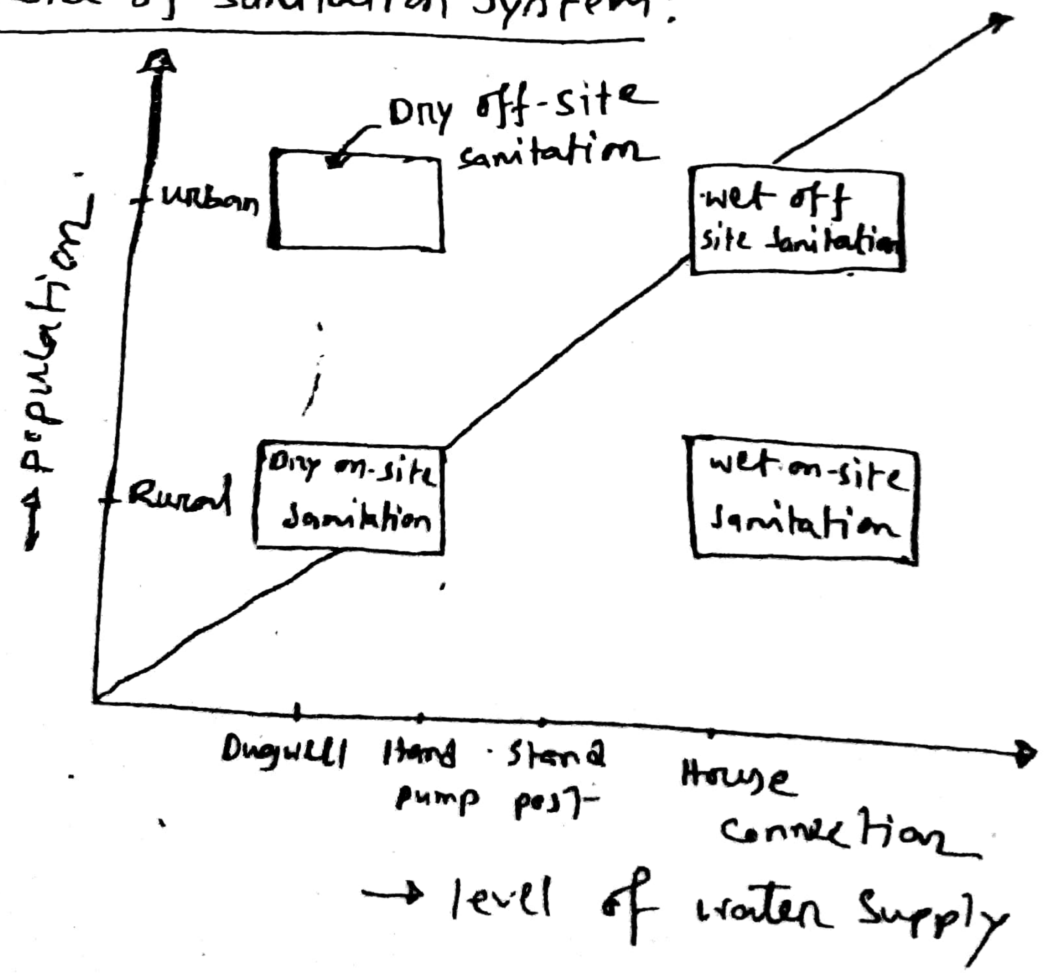
# Sanitation System

## # Types of sanitation system:

① **on-site sanitation system:** when the wastes are collected, treated and disposed of at the point of generation, then it is called on-site system. Ex- pit latrine, septic tank system.

② **off-site sanitation system:** when the wastes are collected and transported to somewhere else for treatment and disposal, then the system is called off-site sanitation system. Ex- Bucket latrine system, conventional sewerage system.

## # Choice of sanitation system:



## # Design of pit latrine:

Effective pit volume, $V = CPN = 1.33\, CPN$ (to ensure clean space)

where,

$C$ = solid accumulation rate.

$= 0.04\ m^3/person/yr$ for wet pits.

$= 0.06\ m^3/person/yr$ for dry pits.

$P$ = Nos. of person using the latrine

$N$ = Design life in years.

$$\text{Effective depth} = \frac{V_{eff}}{A} \quad [A = \text{X-sectional Area}]$$

Total depth of pit = Effective depth + 0.5

## # Design of pour flush leach pit latrine:

The sidewall area required for infiltration,

$$A_i = \frac{Q}{I}$$


$A_i = \pi D h$

$\Rightarrow h = \frac{A_i}{\pi D}$

For a circular pit of dia $D$,

$$V_i = \frac{\pi}{4} D^2 h$$

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

$$= \frac{A_i D}{4} = \frac{QD}{4I}$$

volume w.r.t to storage and digestion

$$V_s = CPN$$

Effective pit volume –

① single pit pour flush latrine

$$V = V_s + V_i$$

② Alternating twin off set- pit pour flush latrine

$V$ = Greater of $V_i$ or $V_s$

* Design a low cost simple pit latrine for a family of 6 persons. The ground water table is 5m below ground level. Determine the size of the pit required for a period of 5 years. The family uses water for anal cleansing.

**Sol$^n$:** For anal cleansing $C = 0.06\ m^3/person/yr$.

$V = 1.33\,CPN$

$= 1.33 \times 0.06 \times 6 \times 5 = 2.4\ m^3$

**For circular section:**

Assume, dia $= 1.25\ m$

Depth of pit $h = \frac{V}{A} = \frac{2.4}{\frac{\pi}{4} \times (1.25)^2} \approx 2.4\ m$.

pit size = Dia $1.25\ m$ × Depth $2.4\ m$.

**For rectangular section:**

Assume, size $L \times B = 1.25\ m \times 1.25\ m$.

$\therefore$ Depth of pit, $h = \frac{V}{A} = \frac{2.4}{1.25 \times 1.25}$

$= 2.57\ m$

Ans:

* Design a VIP latrine for a family of 8 members. The family uses water for anal cleansing. The GWT is only 2m below the ground surface. Design life 3 yrs.

**Sol$^n$:** $V = CPN$

$= 0.05 \times 8 \times 3 = 1.2\ m^3$

Let, pit size $= 1\ m \times 1.2\ m$

$\therefore$ Depth of pit $= \frac{1.2}{1 \times 1.2} = 1\ m$

Let a free space of $0.5\ m$.

Total depth $= 1 + 0.5 = 1.5\ m$

Ans.

* Design a leach pit for both single and alternating twin off-set pit pour-flush latrines serving a family of eight members living in a peri-urban area. Wastewater flow is 12 lpcd and the soil is a porous silty loam with long term infiltration rate of 20 l/m² day. Design period 2 years.

Soln:

$V_s = CPN$

$= 0.04 \times 8 \times 2 = 0.64\ m^3$

$V_i = \frac{QD}{4I} = \frac{12 \times 8 \times 1.2}{4 \times 20}$ | Let, $D = 1.2\ m$

$= 1.44\ m^3$

For single pit:

$V = V_i + V_s = 2.08\ m^3$

$\therefore$ Effective depth, $h = \frac{V}{A} = \frac{2.08}{\frac{\pi}{4} \times 1.2^2} = 1.9\ m$

Add a clear space of 0.5 m

$\therefore$ Total depth = 2.4 m

Ans.

Alternating twin-pit pour-flush latrine:

$V = V_i = 1.44\ m^3$

$\therefore$ effective depth, $h = \frac{1.44}{\frac{\pi}{4} \times 1.2^2} = 1.3\ m$

Add a clear space of 0.5 m

Total depth = 1.8 m

pit size = 1.2 m dia × 1.8 m deep

Ans

# septic tank:

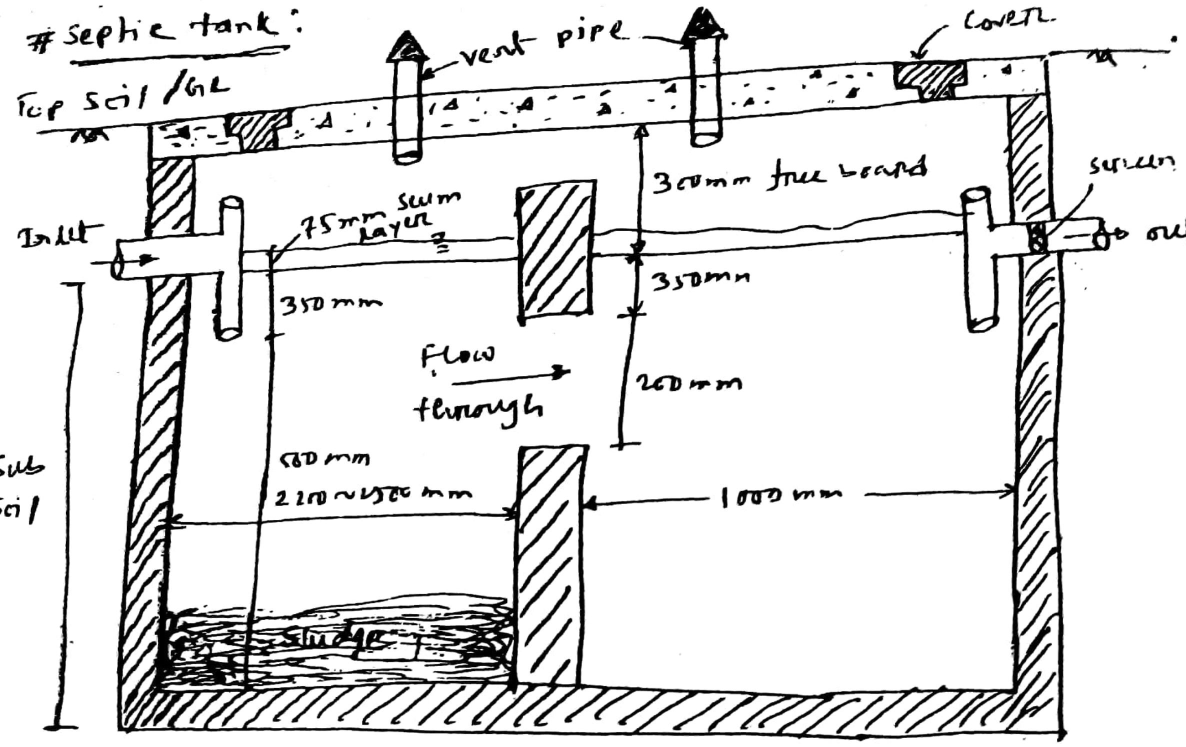



Fig: Septic tank.

# Design of septic tank:

① Scum storage zone:

$$V_{sc} = 0.4 V_{st}$$

② Sedimentation:

Time required for sedimentation,

$$t_h = 1.5 - 0.3 \log(Pq)$$

Tank vol^m for sedimentation,

$$V_h = 10^{-3} pq t_h \text{ in } m^3$$

$t_h$ = min^m retention time for sedimentation in days.

P = No. of population

q = wastewater flow per person, l/day.

③ Digestion:

Time for digestion, $t_d = 30(1.035)^{35-T}$

vol^m of sludge digestion zone,

$$V_d = 0.5 \times 10^{-3} P t_d$$

T = Ambient Temp. = 20°c ~ 30°c

Md. Miraz Gazi
B Sc. in CE, KUET

④ Sludge storage zone:

$V_{SL} = CPN$

| $c = 0.06\ m^3/person/yr$ for $N < 5$ years
$= 0.04\ m^3/person/yr$ for $N > 5$ years.
$N$ = Design period.

Overall Design Capacity:

Total tank volume, $V = V_{sc} + V_h + V_d + V_{SL}$
$= 0.4 V_{SL} + V_h + V_d + V_{SL}$
$= 1.4 V_{SL} + V_h + V_d$

Clear space depth:

Scum clear depth $= 75$ mm (min^m)
Sludge clear depth $= 0.82 - 0.26A \geq 0.3$ m

* Design a septic tank to serve a household of ten persons who produce 90 lpcd of wastewater. The tank is to be desluged every three years.

Sol^n: ① Sedimentation: $P = 10$, $q = 90$ lpcd

$t_h = 1.5 - 0.3\log(Pq) = 1.5 - 0.3\log(10 \times 90) = 0.61$ days.

$V_h = 10^{-3} P q t_h = 10^{-3} \times 10 \times 90 \times 0.61 = 0.55\ m^3$

② Digestion:

$t_d = 30(1.035)^{35-T}$ | $T = 25°C$ (let)
$= 42.3$ days.

$V_d = 0.5 \times 10^{-3} P t_d = 0.5 \times 10^{-3} \times 10 \times 42.3 = 0.21\ m^3$

③ Sludge Storage:

$V_{SL} = CPN$
$= 0.06 \times 10 \times 3 = 1.8\ m^3$

Total tank vol^m $= 1.4 V_{SL} + V_h + V_d = 3.28\ m^3$

Clear space: Let, Surface Area $= 3\ m^2$ | Length $= 3$ m
width $= 1$ m

Scum clear depth = 75 mm (min^m)

Sludge " " = $0.82 - 0.26A$

$= 0.82 - 0.26 \times 3$

$= 0.04\,m < 0.3\,m$.

∴ sludge clear depth = ·3 m = 300 mm.

∴ Total clear space depth = 75 + 300

= 375 mm Ans.

# Environmental Impact Assessment (EIA): EIA is a systematic process to predict and evaluate the environmental effects of propose action in order to aid decision making regarding the significant environmental consequences of projects development and programs.

# purposes of EIA:

- To inform and facilitate the environmental effects.
- To ensure important ecological function and commonly values are more consistent with sustainable development principles.
- To promote the optional adjustment.

# Fire hydrant: A fire hydrant is an outlet provided in water pipe for tapping water mainly in case of fire. It is used for fire fighting purposes.

Fire demand:

① National Board of fire, $Q = 1020(\sqrt{P} - 0.01P)$

② Kuichling, $Q = 7000\sqrt{P}$

where, $Q$ = fire demand in gpm
$P$ = population in thousand

Fire stream:

No. of fire stream, $F = 2.8\sqrt{P}$ ; P → population.

Distance between two fire hydrant is 200 ~ 300 ft

Scanned by CamScanner

* Calculate the total stream flow in gpm for a town having a population of 10,000. Assume that, each stream will spray 250 gpm on the fire simultaneously.

Soln:

Nos. of fire stream $= 2.8\sqrt{P}$

$= 2.8\sqrt{10}$

$= 9$

$\therefore$ Total stream flow $= 9 \times 250$

$= 2250$ gpm Ans.

Scanned by CamScanner

# Irrigation & Flood Control

*** Irrigation:** It may be defined as the science of artificial application of water to the land, in accordance with the 'crop requirements' through the 'crop period' for full nourishment of the crops.

*** Types of irrigation:**

- Irrigation
  - Surface irrigation
    - Flow Irrigation
      - perennial Irrigation
      - Flood irrigation
    - Lift irrigation
  - Sub-surface irrigation
    - Natural Irrigation
    - Artificial Irrigation

*** perennial Irrigation:** In this system of irrigation, constant and continuous water supply is assured to the crops in accordance with the requirements of the crop throughout the crop period.

*** write down the methods of irrigation:**

1. Free flooding
2. Border flooding
3. Check flooding
4. Basin flooding
5. Furrow irrigation
6. sprinkler irrigation
7. Drip irrigation.

*** Impurities of irrigated water:**

- sediment concentration in water
- Total concentration of soluble salt in water
- proportion of sodium ions to the other cations

# Identify types of irrigated water:

1) Sodium Absorption Ratio (SAR):

i) SAR → 0 to 10 → Low sodium water → $S_1$
ii) SAR → 10 to 18 → Medium " " → $S_2$
iii) SAR → 18 to 26 → High " " → $S_3$
iv) SAR → > 26 → very high " " → $S_4$

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

The proportion of sodium ions present in the soils is generally measured by a factor called Sodium Absorption Ratio (SAR).

2) Electrical conductivity (EC):

i) EC → 100 ~ 250 micro mhos/cm → Low salinity water → $C_1$
ii) EC → 250 ~ 750 " → medium " " → $C_2$
iii) EC → 750 ~ 2250 " → High " " → $C_3$
iv) EC → > 2250 " → very high " " → $C_4$

* a) What is the classification of irrigation water having the following characteristics: concentration of Na, Ca and Mg are 22, 3 and 1.5 milli-equivalents/litre respectively and the electrical conductivity is 200 micro mhos/cm at 25°C. (b) What problems arise in using this water on fine ~~texen~~ textured soil? (c) What remedies do you suggest to over come this trouble?

Soln: a) EC = 200 micro mhos/cm → low salinity water, $C_1$

$$SAR = \frac{22}{\sqrt{\frac{3+1.5}{2}}} = 14.67$$ → Medium sodium water, $S_2$

$C_1S_2$ water

b) problems:

- soil become less permeable
- It starts, crusting when dry
- It becomes plastic & sticky when wet.

c) Remedy: Add gypsum ($CaSO_4 . 2H_2O$) to the soil or water

# A relationship between Q, Y, f & A to calculate the time required to cover the given area, A:

$$t = 2.3 \frac{Y}{f} \log\left(\frac{Q}{Q - fA}\right)$$

where, t = Time required to cover the given area A
Q = Discharge through supply ditch.
Y = Depth of water flowing over the border strip.
f = Rate of infiltration of soil

The maximum area that can be irrigated –

$$A_{max} = \frac{Q}{f}$$

* Determine the time required to irrigate a strip of land of 0.04 hectares in area from a tube-well with a discharge of 0.02 cumec. The infiltration capacity of the soil may be taken as 5 cm/hr and the average depth of flow on the field as 10 cm. Also determine the maximum area that can be irrigated from this tube well.

Soln: $Q = 0.02 m^3/s = 0.02 \times 60 \times 60 = 72 m^3/hr$, $Y = 10 cm = 0.01 m$
$f = 5 cm/hr = 0.05 m/hr$, $A = 0.04 \times 10^4 = 400 m^2$

$$\therefore t = 2.3 \frac{.01}{.05} \log\left(\frac{72}{72 - .05 \times 400}\right) = 0.65 hr$$

$$A_{max} = \frac{Q}{f} = \frac{72}{.05} = 1440 m^2$$

Ans.

## Water requirements of crops

* **Crop period:** The time period that elapses from the instant of its sowing to the instant of its harvesting.

* **Base period:** The time between the first watering of a crop at the time of its sowing to its last watering before harvesting.

Crop period > Base period.

* **Delta:** The total depth of water required by a crop to come to maturity is called it's delta (Δ).

* **Duty:** The number of hectors of land irrigated for full growth of a given crop by supply of 1 cumec of water continuously during the entire base period of that crop.

* **Kor watering:** The first watering which is given to a crop when the crop is few cm high, is called kor watering. Kor watering for rice, wheat & sugar cane are 19 cm, 13.5 cm & 16.5 cm.

* **Kharif-Rabi ratio/ crop ratio:** The ratio of areas to be irrigated in kharif season to that in rabi season is called crop ratio. This ratio is 1:2 generally.

* **paleo:** The first watering before sowing the crop is called paleo.

* **Cash crops:** A cash crop may be defined as a crop which has to be encashed (বিক্র) in the market for processing or it cannot be consumed directly by the cultivators.

* Relation between Duty (D) & Delta (Δ):

Let, there be a crop of base period = B days.

1 $m^3/s$ of water be applied to this crop on the field for B days.

∴ volume of water applied during B days

$= 1 \times (B \times 24 \times 60 \times 60)$

$= 86400 B \ m^3$

By definition of duty, 1 $m^3$ supplied for B days matures D hectares of land.

∴ The volume of water matures D hectares or $D \times 10^4 m^2$ of area.

∴ Total depth of water applied on this land –

$$\Delta = \frac{\text{Volume}}{\text{Area}} = \frac{86400B}{10^4 D} = \frac{8.64B}{D} \ m$$

$$= \frac{864B}{D} \ cm$$

* If rice requires about 10 cm depth of water at an average interval of about 10 days and the crop period for rice is 120 days. Find out the delta for rice?

Soln: $\Delta = \frac{120}{10} \times 10 = 120 \ cm$ Ans.

* If wheat requires about 7.5 cm of water after every 28 days, and the base period for wheat is 140 days. Find out the value of delta for wheat.

Soln: $\Delta = \frac{140}{28} \times 7.5$

$= 37.5 \ cm$

Ans.

* Find the delta for a crop when its duty is 864 hec/cumec on the field, the base period of this crop is 120 days.

Soln: $\Delta = \frac{864B}{D} = \frac{864 \times 120}{864} = 120$ cm

* The kor depth for rice 19 cm and kor period is 14 days. The outlet factor for the crop in hectares/cumec will be? (↳ Duty)

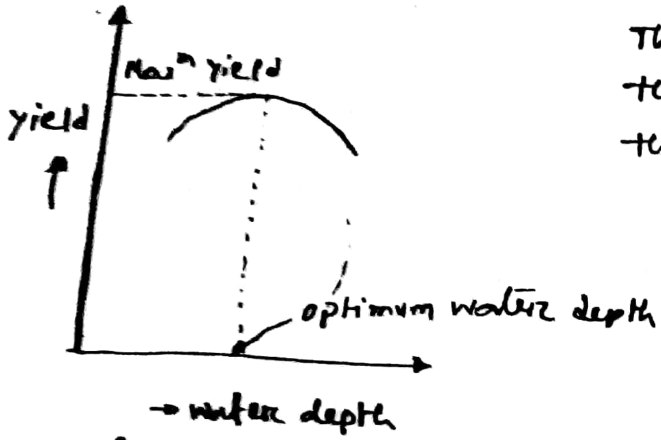
Ans: $\Delta = \frac{864B}{D} \Rightarrow D = \frac{864 \times 14}{19} = 637$ hectors/cumec

Ans.

* Rabi season → 1st Oct to 31th March

Kharif season → 1st April to 30th September.

* optimum irrigation water depth:




The quantity of water at which the yield is maximum is called the optimum irrigation water depth.

* A canal commands an irrigation area of 400 ha. The duty of water on the field during the peak period is 220 ha/cumec. Determine the design discharge of the canal at the off take if the water loss in canal is 30%?

Soln: Discharge $= \frac{\text{Area}}{\text{Duty}} = \frac{400}{220} = 1.82\ m^3/s$.

∴ Design discharge $= \frac{1.82}{0.7}$ ← (100 - 30 = 70%)

$= 2.60\ m^3/s$

Ans.

# Irrigation Efficiencies:

a) water conveyance efficiency, $\eta_c$

$$\eta_c = \frac{\text{Water delivered into fields from outlet of channel}}{\text{Water entering into channel at its starting point}} \times 100$$

b) Water application efficiency, $\eta_a$

$$\eta_a = \frac{\text{Water stored in the root zone of the crop}}{\text{water delivered into the field.}} \times 100$$

c) water storage efficiency, $\eta_s$

$$\eta_s = \frac{\text{water stored in the root zone of the crop during irrg}^n}{\text{water needed in the root zone prior to irrgation}} \times 100$$

d) Water distribution efficiency, $\eta_d$

$$\eta_d = \left(1 - \frac{d}{D}\right) * 100$$

D = Mean depth of water stored during irrigation

d = Average of the absolute values of deviations from the mean.

* 1 cumec of water is pumped into a farm distribution system. 0.8 cumec is delivered to a turn-out, 09 km from the well. Compute the conveyance efficiency/on farm efficiency.

Soln:

$$\eta_c = \frac{0.8}{1} \times 100 = 80\%.$$

* 10 cumec of water is delivered to a 32 hectare field for 4 hours. soil probing after the irrigation indicates that 0.3 metre of water has been stored in the root zone. compute the water application efficiency

Soln: $V = 10 \times (4 \times 60 \times 60) = 144000\ m^3 = 14.4 \times 10^4\ m^3$

$= \frac{144000}{10^4} = 14.4$ ha. m

output = 32 × 0.3 = 9.6 ha.m = $9.6 \times 10^4\ m^3$

$\therefore \eta_a = \frac{9.6 \times 10^4}{14.4 \times 10^4} \times 100 = 66.67\%$
Ans.

* The depths of penetrations along the length of a boarder strip at points 30 m apart were probed. Their observed values are 2, 1.9, 1.8, 1.6 and 1.5 m. compute the water distribution efficiency.

soln:

Mean depth, $D = \frac{2 + 1.9 + 1.8 + 1.6 + 1.5}{5} = 1.76\ m$

values of deviation from mean are (2−1.76), (1.9−1.76), (1.8−1.76), (1.6−1.76), (1.5−1.76)

i.e. 0.24, 0.14, 0.04, −0.16 and −0.26

$\therefore d = \frac{0.24 + 0.14 + 0.04 + |-0.16| + |-0.26|}{5}$ ← (absolute value use করো।)

$= \frac{0.84}{5} = 0.168\ m$

$\eta_d = \left(1 - \frac{.168}{1.76}\right) \times 100 = 90.5\%$
Ans.

* A Stream of 130 L/sec was diverted from a canal and 100 lit/sec were diverted to the field. An area of 1.6 ha was irrigated in 8 hours. The effective depth of root zone was 1.7 m. The runoff loss in the field was 420 $m^3$. The depth of water penetration varied linearly from 1.7 m at the head end of the field to 1.1 m at the tail end. Available moisture holding capacity of the soil is 20 cm per metre depth of soil. It is required to determin $\eta_c$, $\eta_a$, $\eta_s$ and $\eta_d$. Irrigation was started at a moisture extraction level of 50% of the available moisture.

Scanned by CamScanner

$\underline{Sol^n}$: (i) $\eta_c = \frac{100}{130} \times 100 = 77\%$

(ii) water supplied $= 100 \times (8 \times 60 \times 60)$

$= 2880000$ lit $= 2880\ m^3$

run of loss $= 420\ m^3$

water stored in the root zone $= 2880 - 420$

$= 2460\ m^3$.

$\eta_a = \frac{2460}{2880} \times 100 = 85.4\%$.

(iii) Moisture holding capacity of soil (WHC) $= 20\ cm/m \times 1.7\ m$

$= 34\ cm$

Available moisture $= \frac{50}{100} \times 34 = 17\ cm$

Additional water required in root zone $= 34 - 17$

$= 17\ cm$.

volume $= \frac{17}{100} \times 1.6 \times 10^4 = 2720\ m^3$

$\eta_s = \frac{2460}{2720} \times 100 = 90\%$.

(iv) $D = \frac{1.7 + 1.1}{2} = 1.4\ m$

deviation head $= |1.7 - 1.4| = 0.3$

" tail $= |1.1 - 1.4| = 0.3$

$\therefore d = \frac{0.3 + 0.3}{2} = 0.3$

$\therefore \eta_d = \left(1 - \frac{0.3}{1.4}\right) \times 100 = 78\%$.

Ans.

* A canal commands an irrigation area of 350 ha, the peak field irrigation requirement is 9 mm/day. Determine the design discharge of canal at the outlet, water loss 25%.

$\underline{Sol^n}$:

Total water requirement $= \frac{9}{1000} \cdot \frac{350 \times 10000}{24 \times 3600} = 0.364\ m^3/s$

$\therefore$ Design discharge $= \frac{0.364}{(100-25)\%} = \frac{.364}{.75} = .485\ m^3/s$

Ans

# Consumptive use (Cu) or Evapotranspiration: The total amount of water used by plant in transpiration and evaporation from adjacent soil or from plant leaves in any specified time.

# Effective Rainfall (Re): precipitation falling during the growing period of a crop that is available to meet the evapo-transpiration needs of the crop is called effective rainfall.

*
$$R_e = R - R_f - D_f$$

where, $R$ = precipitation
$R_f$ = surface run off.
$D_f$ = Deep percolation

* Consumptive Irrigation requirement, $CIR = Cu - Re$

* Net Irrigation requirement, $NIR = Cu - Re + \text{water loss}$

$= CIR + \text{water loss}$

* Field Irrigation requirement, $FIR = NIR + \text{water application losses}$

$$= \frac{NIR}{\eta_a}$$

* Gross Irrigation requirement, $GIR = NIR + \text{conveyance loss}$

$$= \frac{NIR}{\eta_c}$$

* Determine the net irrigation requirement of Jowar crop, assuming that water is not required for any other purpose except that of fulfilling the evapotranspiration needs of the crop. Note: water loss or wasted CIR = NIR

Soln:

| Dates | Cu (mm) | Re (mm) | NIR = Cu - Re (mm) |
|---|---|---|---|
| Oct 16-31 | 37.0 | 30.8 | 6.2 |
| Nov 1-30 | 84.2 | 20.4 | 63.8 |
| Dec 1-31 | 154.9 | 6.7 | 148.2 |
| Jan 1-31 | 188.1 | 2.4 | 185.7 |
| Feb 1-2 | 13.3 | 1.0 | 12.3 |

NIR = 416.2 mm Ans.

# Estimation of of consumptive use:

i) Blaney-Criddle Equation:

$$C_u = \frac{KP}{40}\left[1.8t + 32\right]$$

($t$ → °C)

ii) Class A pan evaporation method:

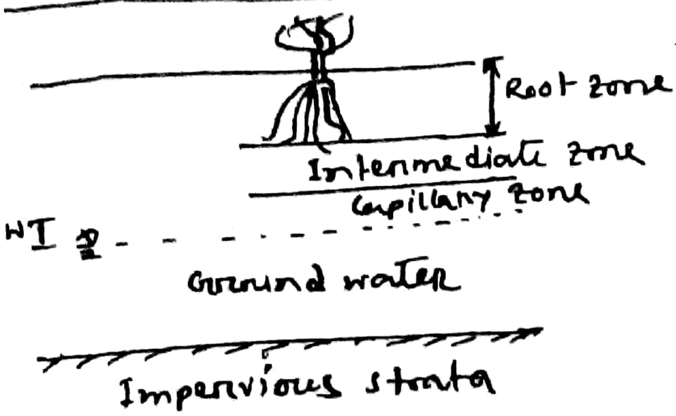
$$C_u = K E_P$$

$$E_p = 0.459 R C_t C_w C_h C_s C_e$$

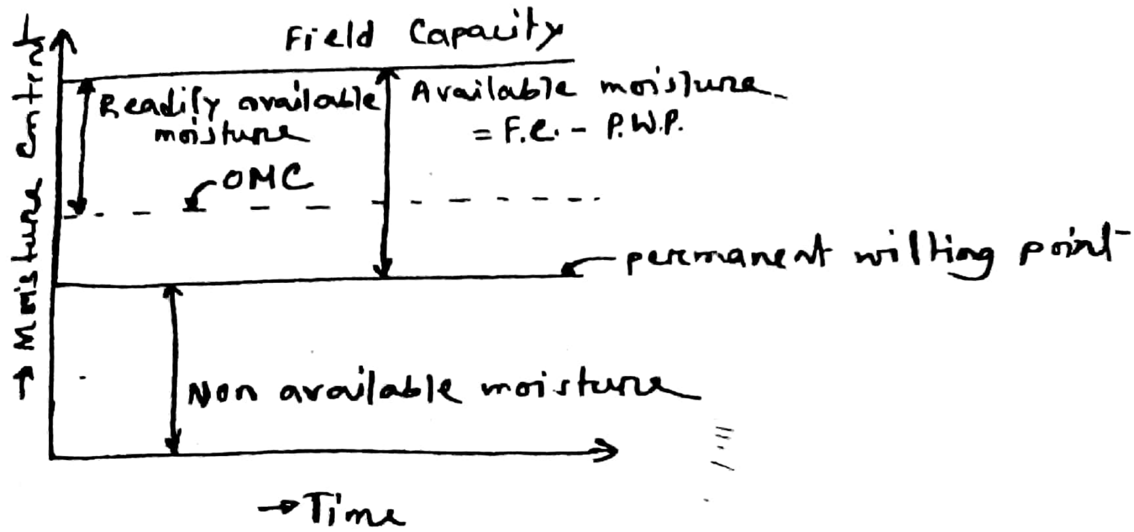
iii) Penman's equation:

$$E_t = \frac{A \cdot H_n + E_a \gamma}{A + \gamma}$$

# Soil moisture - Irrigation relationship :




The water above the WT is known as soil-moisture.




# Field Capacity: The field capacity is the amount of water content of a soil after free drainage has taken place for a sufficient period.

$$\text{Field Capacity} = \frac{\text{Wt. of water retained in a certain vol}^{m}\text{ of soil}}{\text{Wt. of same volume of dry Soil}} \times 10$$

# permanent wilting point: The permanent wilting point is that water content at which plant can no longer extract sufficien water for its growth.

* Available moisture = F.C. - P.W.P
* readily available moisture = 80% of available moisture
* optimum moisture content, OMC = F.C - R.A.M

Scanned by CamScanner

# Find the expression to calculate the depth of water stored in the root zone in filling the soil upto field capacity.

**Ans:** Let, soil area = $1 m^2$, Depth of root zone = d m

dry unit wt. of soil = $\gamma_d$ kg/$m^3$.

vol$^m$ of soil = 1 x d = d $m^3$

wt of that soil = d x $\gamma_d$ = $\gamma_d d$ kg

If F is the field capacity,

$$F = F_c$$

$$F = \frac{\text{wt. of water retained in unit area of soil}}{\gamma_d . d}$$

=> wt. of water retained in unit area of soil = $\gamma_d . d . F$ kg/$m^2$

Total storage capacity of soil in (in depth of water)

$$= \frac{\gamma_d . d . F}{\gamma_w}$$

Hence, the depth of water stored in the root zone in filling the soil upto field capacity

$$= \frac{\gamma_d . d . f}{\gamma_w}$$

* After how many days (Irrigation frequency) will you supply water to soil in order to ensure sufficient irrigation of the given crop, if i) Field Capacity of the soil = 28%, (ii) P.W.P. = 13%, (iii) Dry density of soil = 1·3 gm/cc (iv) Effective depth of root zone = 70 cm (v) Daily consumptive use = 12 mm. Assume any other data.

**Sol$^n$:** Available Moisture (A.M.) = F.C. − P.W.P

= (28 − 13)% = 15%

Readily available moisture, R.A.M. = 80% of A.M.

= 0.8 x 15 = 12%.

$OMC = F.C - R.A.M$

$= 28 - 12 = 16\%$

Irrigation required = 16% ~ 28%.

$\text{Depth of water} = \frac{\gamma_d \cdot d}{\gamma_w} \times (F.C - OMC)$ | $d = 0.7m$

$= \frac{1.3 \times .70}{1} \times (.28 - .16)$

$= 0.1092 \text{ m}$

$\text{Nos. of days} = \frac{0.1092 \times 1000}{Cu} = \frac{0.1092 \times 1000}{12} \simeq 9 \text{ days}$ Ans.

* What is to be grown in a field having a field capacity equal to 27% and P.W.P is 13%, Find the storage capacity in 80cm depth of the soil, if the dry unit weight of the soil is 14.72 KN/m³. If irrigation water is to be supplied when the average soil moisture falls to 18%, find the water depth required to be supplied to the field if the field application efficiency is 80%. What is the amount of water needed at the channel outlet if the water lost in the water courses and the field channels is 15% of outlet discharge?

Solⁿ: Maximum storage capacity or Available moisture

$= \frac{\gamma_d \cdot d}{\gamma_w} (F.C. - P.W.P)$ | $d = 80cm = 0.8m$, $\gamma_w = 9.81 \text{ KN/m}^3$

$= \frac{14.72 \times 0.8}{9.81} (.27 - .13)$

$= 0.168 \text{ m} = 16.8 \text{ cm}$ Ans.

Since moisture is allowed to vary between 27% and 18%, the deficiency created in this fall -

$= \frac{\gamma_d \cdot d}{\gamma_w} (.27 - .18)$

$= \frac{14.72}{9.81} \times .8 \times (.27 - .18)$

$= 10.8 \text{ cm}$

$\therefore$ NIR = 10.8 cm.

$$FIR = \frac{NIR}{\eta_a} = \frac{10.8}{0.80} = 13.5 \text{ cm}$$ Ans

Quantity of water needed at canal outlet.

$$= \frac{FIR}{\eta_c} \qquad | \eta_c = 100 - 15 = 85\%$$

$$= \frac{13.5}{.85} = 15.88 \text{ cm}$$ Ans.

* 800 $m^3$ of water is applied to a farmer's rice field of 0.6 ha. When the moisture content in the soil falls to 40% of the available water between the field capacity 36% of soil and P.W.P. 15% of the soil crop combination, determine the field application efficiency. The root zone depth of rice is 60 cm. Assume porosity = 0.4.

Soln:

$$F = \frac{\text{wt. of water contained in a certain vol}^m\text{ of soil}}{\text{wt. of the same vol}^m\text{ of dry soil}}$$

$$= \frac{\gamma_w . V_v}{\gamma_d . V} \rightarrow (\text{vol}^m \text{ of void} \times \text{unit wt of water})$$

$$\Rightarrow F = \frac{\gamma_w}{\gamma_d} . n \quad \left[ \frac{V_v}{V} = n \right]$$

$$\Rightarrow \frac{\gamma_d}{\gamma_w} = \frac{n}{F} = \frac{0.4}{.36} = 1.11$$

$\therefore$ Water stored betn F.C & P.W.P

$$= \frac{\gamma_d d}{\gamma_w} (FC - P.W.P)$$

$$= 1.11 \times 0.6 \times (.36 - .15)$$

$$= 0.14 \text{ m}$$

Deficiency of water created when irrigation is done -

$$= 60\% \times 0.14 \quad [\because \text{m.c. falls to } 40\%]$$

$$= 0.084 \text{ m}$$

Hence, irrigation water is supplied to fill up 0.084 m depth of water.

vol$^m$ of irrigation water = $0.084 \times (0.6 \times 10^4)$
= 504 $m^3$

Actual irrigation water supplied = 800 $m^3$.

$\therefore \eta_a = \frac{504}{800} \times 100 = 63\%$

Ans.

* Determine the field capacity of a soil for the following data —
i) Depth of root zone = 1.8 m ii) Existing moisture = 8%
iii) Dry density of soil = 1450 kg/$m^3$ iv) Quantity of water applied to soil = 650 $m^3$ v) Water lost due to deep percolation and evaporation = 10% vi) Area to be irrigated = 1000 $m^2$.

Soln: Water wasted = 10% of 650 $m^3$ = 65 $m^3$

Water used to rise m.c. to F.C. = 650 − 65 = 585 $m^3$

Depth of water in rising m.c. to F.C. = $\frac{585}{1000}$ = 0.585 m

We get,
$$0.585 = \frac{\gamma_d \cdot d}{\gamma_w}(F.C. - M.C.)$$

$$\Rightarrow 0.585 = \frac{1450}{1000} \times 1.8 \times (F.C - 0.08)$$

$$\Rightarrow F.C = 0.144 = 14.4\%$$

Ans

* The field capacity & moisture content at the time of irrigation are 27% and 19%. The apparent specific gravity is 1.3 and the root zone depth is 100 cm. Determine the time required to irrigate 2 ha with a flow of 60 l/s if the water application losses are taken to be 20%.)

**Soln:** Readily available moisture = 80% of A.M.

$= 0.80 \times 19$

$= 15.2\%$

$OMC = FC - R.A.M = 27 - 15.2$

$= 11.8\%$

BWDB-16

Depth of water stored in the root zone,

$$y = \frac{\gamma_d d}{\gamma_w}(FC - OMC)$$

$$= \frac{1.3}{1} * 1m\,(.27 - .118)$$

$$= 0.1976\,m$$

Flow, $Q = 60$ lit/s $= 0.06\,m^3/s$

Application losses = 20%.

$$Q_d = 0.06 - (0.06 \times .2) = 0.048\,m^3/s.$$

$$\therefore f = \frac{Q_d}{A} = \frac{.048}{2 \times 10^4} = 2.4 \times 10^{-6}\,m/s$$

$$t = 2.3\frac{y}{f}\log\frac{Q}{Q - fA}$$

$$= 2.3\,\frac{.1976}{2.4 \times 10^{-6}}\log\frac{.06}{0.06 - 2.4 \times 10^{-6} \times 2 \times 10^4}$$

$= 132362\,s = 36.77$ hrs **Ans.**

# Gross Command Area (G.C.A): It is the total area, bounded within the irrigation boundary of a project. It includes the culturable as well as unculturable area.

# Culturable/cultivable Command Area (C.C.A): It includes all land of G.C.A. on which cultivation is possible.

C.C.A. = 80% of G.C.A.

# Intensity of irrigation: The percentage of C.C.A. proposed to be irrigate in a given season.

* The GCA for a distributary is 6000 ha, 80% of which is culturable. The intensity of irrigation for Rabi season is 50% and Kharif season is 25%. If the average duty at the head of the distributory is 2000 ha/cumec for Rabi season and 900 ha/cumec for Kharif season. Find out the discharge required at the head of the distributary from average demand considerations.

Sol$^n$: GCA = 6000 ha, CCA = 80% GCA = 4800 ha.

Area to be irrigated in Rabi season $= 4800 \times \frac{50}{100} = 2400$ ha.

" " " " " Kharif " $= 4800 \times \frac{25}{100} = 1200$ ha.

water reqd at head of distributory in Rabi season

$$= \frac{\text{Irr}^n \text{ area}}{\text{Duty}} = \frac{2400}{2000} = 1.2 \text{ cumec}$$

water reqd at head of distributory in kharif season.

$$= \frac{1200}{900} = 1.33 \text{ cumec}$$

∴ The required discharge is max$^m$ of the two. i.e. 1.33 cumec

↳ max$^m$ का design करना होता Ans.

* Determine the discharge required at the head of the distributory when area to be irrigated in Rabi and Kharif season are 2400 ha & 1200 ha, for fulfilling maximum crop requirement. Assume suitable values of kor depth and kor period.

Soln: Assume,

Kor depth & kor period for Rabi = 13.5 cm, 4 weeks

" " " " Kharif = 19 cm, 2.5 weeks

$\therefore$ Duty for rabi $= \frac{864B}{\Delta} = \frac{864 \times (4 \times 7)}{13.5} = 1792$ ha/cumec

Duty for kharif $= \frac{864 \times (2.5 \times 7)}{19} = 796$ ha/cumec.

Water reqd in head of distributory in rabi season

$= \frac{2400}{1792} = 1.34$ cumec

Water reqd at head of distributory in kharif season

$= \frac{1200}{796} = 1.51$ cumec

Ans (maxm GT)

* The CCA of a water course is 1200 ha. Intensities of sugarcane and wheat crops are 20% and 40% respectively. The duties for the crops at the head of the water course are 730 ha/cumec and 1800 ha/cumec. Find (a) the discharge required at the head of the water course (b) determine the design discharge at the outlet, assuming a time factor equal to 0.8.

Soln: Area to be irrigated under sugarcane

$= \frac{20}{100} \times 1200 = 240$ ha.

Area to be irrigated under wheat

$= \frac{40}{100} \times 1200 = 480$ ha.

Discharge for sugarcane = $\frac{240}{730}$ = 0.329 cumec

" " wheat = $\frac{480}{1810}$ = 0.271 cumec.

যেহেতু sugarcane 12 মাস পানি লাগবে, wheat 6 মাস পানি লাগবে, তাই যেকোন সময়ে সর্বোচ্চ (.329+.271) পরিমাণ পানি লাগবে।

∴ Discharge reqd at head of water course = (.329 + .271)
= 0.6 cumec

b) Design discharge = $\frac{0.6}{0.8}$ = 0.75 cumec

Ans.

* At a place, the transplantation of rice takes 16 days, and total depth of water required by the crop is 60 cm on the field. During the transplantation period of 16 days, rain starts falling and about 10 cm of rain is being utilised to fulfil the rice demand. Find the duty of the irrigation water required for rice during transplantation period.

a) Assuming 25% losses of water in water courses, find the duty of water at the head of the water course.

b) Also find duty for 15% losses at the head of the water course.

Soln: Depth of water required for transplation of rice = (60−10) = 50 cm.

∴ Duty = $\frac{864B}{\Delta}$ = $\frac{864 \times 16}{50}$ = 276.5 ha/cumec.

a) For 25% losses,

Duty = 0.75 × 276.5 = 207.4 ha/cumec.

b) For 15% losses

Duty = 0.85 × 207.4

= 176.3 ha/cumec

Ans

* A pump is installed on a well to lift water and to irrigate rice crop, sown over 3 hectares of land. If duty for rice is 864 ha/cumec on the field and pump efficiency is 48%, determine the minimum reqd input (H.P) of the pump, if the lowest well water level is 8 metres below the highest portion of the field. Assume negligible field channel losses.

**Soln:** Discharge reqd for rice for fulfilling duty demand

$$= \frac{3}{864} = \frac{1}{288} \text{ cumec}$$

∴ volume of water lifted per second $= \frac{1}{288} m^3$

weight of water lifted per second $= \frac{1}{288} \times 9.81$

$= 0.0341 \text{ KN/sec}$.

Min^m static lift of pump $= 8m$.

work done $= 0.0341 \times 8$

$= 0.273$ KN.m/sec

$= 0.273$ Kwatt

∴ output of pump $= \frac{0.273 \times 10^3}{746} = .37$ H.P.

∴ Input of pump $= \frac{0.37}{\eta} = \frac{0.37}{.48} = 0.77$ H.P

Ans.

# Sediment Transport & Design of Irrigation channels

## # Mechanics of sediment transport:

① Average unit Tractive force (shear stress)

$$\tau_o = \gamma_w R S$$

S → channel bed slope
R → Hydraulic mean depth, A/P (for wide channel R = y)

② The critical tractive force (stress)

$$\tau_c = 0.155 + \frac{0.409\, d_{mm}^2}{\sqrt{1+0.177\, d_{mm}^2}}$$

$\tau_c$ → N/m² ; → applicable for all values of d.

if $\tau_o > \tau_c$ → Scouring & sediment transport will occur.

## # Strickler's formula to find n:

$$n = \frac{1}{24} d^{1/6} \quad [d = \text{grain dia in m}]$$

* An irrigation channel is to be constructed in coarse alluvium gravel with D-75 size of 5cm. The channel has to carry 3 cumec of discharge and the longitudinal slop is 0.01. The banks of the channel will be protected by grass against scouring. Find the min^m width of the channel.

Sol^n:

$$n = \frac{1}{24} d^{1/6} \quad [d = 5cm = 0.05 m]$$

$$= \frac{1}{24} (0.05)^{1/6} = 0.025$$

$$R = \frac{d}{11S} = \frac{0.05}{11 \times 0.01} = 0.455 m$$

$$V = \frac{1}{n} R^{2/3} S^{1/2} = \frac{1}{.025} (.455)^{2/3} \times (0.01)^{1/2}$$

$$= 2.37 m/s$$

$$Q = AV$$

$$= by.V = bR.V$$

$$\Rightarrow 3 = b_{min} \times .455 \times 2.37$$

$$\Rightarrow b_{min} = 2.78 m$$

Ans.

# Waters flows at a depth of 0.6m in a wide stream having a bed slope of 1 in 2500. The median diameter of the sand bed is 1.0mm. Determine whether the soil grains are stationary or moving, and comment as to whether the stream bed is scouring or non-scouring.

Sol$^n$:

$$\tau_c = 0.155 + \frac{0.409\, d_{mm}^2}{\sqrt{1+.177 d_{mm}^2}}$$

$$= 0.155 + \frac{0.409 \times 1^2}{\sqrt{1+.177\times 1^2}} = 0.53 N/m^2$$

$\tau_0 = \gamma_w R S$ [R=y for wide channel]

$= 9.81 \times 0.6 \times \frac{1}{2500}$ kN/m$^2$

$= 2.35 \times 10^{-3}$ kN/m$^2$

$= 2.35$ N/m$^2$

$\because \tau_0 > \tau_c$, the soil grain will not be stationary and the scouring & sediment transport will occur.

# Regime channel: A channel is said to be in a state of regime if the flow is such that silting and scouring need no special attention.

# Design procedure for Lacey's regime channel: (alluvial channel)

① velocity, $v = \left(\frac{Qf^2}{140}\right)^{1/6}$ in m/sec

$f$ = silt factor $= 1.76\sqrt{d_{mm}}$

② Hydraulic mean depth, $R = \frac{5}{2}\left(\frac{v^2}{f}\right)$ in m

③ Area of channel section, $A = \frac{Q}{V}$

④ wetted perimeter, $P = 4.75\sqrt{Q}$ in m

⑤ Bed slope, $S = \frac{f^{5/3}}{3340\, Q^{1/6}}$

* Design a regime channel for a discharge of 50 cumec and silt factor 1.1, using Lacey's theory

Sol^n:

$$v = \left[\frac{Qf^2}{140}\right]^{1/6} = 0.87 \text{ m/s}$$

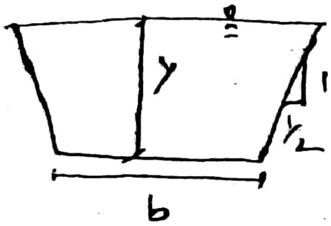
| $Q = 50 \text{ m}^3/\text{s}$
$f = 1.1$
$f = 1.76\sqrt{d_{mm}}$

$$R = \frac{5}{2}\frac{v^2}{f} = 1.72 \text{ m}$$

$$A = Q/v = 57.47 \text{ m}^2$$

$$P = 4.75\sqrt{Q} = 33.59 \text{ m}$$

$$S = \frac{f^{5/3}}{3340\, Q^{1/6}} = 0.000183 = 1:5465$$




Let side slope = $\frac{1}{2}(H) : 1(V)$

$$A = \left(b + \frac{y}{2}\right)y$$

$$P = b + \sqrt{5}\,y$$

$$\therefore by + \frac{y^2}{2} = 57.47$$

$$b + \sqrt{5}y = 33.59 \Rightarrow b = 33.59 - \sqrt{5}y$$

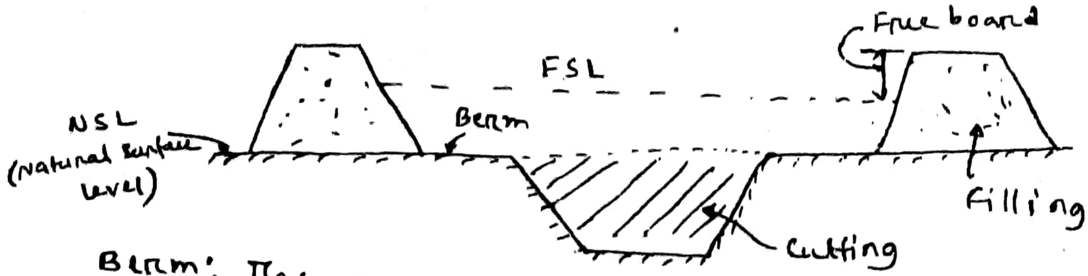
$$\therefore y = 1.9 \text{ m}, \quad b = 29.34 \text{ m}$$

Ans.

# Comparison between Kenedy's theory and Lacey's theory:

| Kenedy's Theory | Lacey's Theory |
|---|---|
| 1) Consider a trapezoidal section. | 1) consider a Shaped section. |
| 2) Channel to be in a state of true regime. | 2) channel is a combination of initial & final regime. |
| 3) has not given any importance on bed width & depth ratio. | 3) establish a relationship between bed and width. |

# Cross section of an irrigation channel:




**Berm:** The narrow strip of land at the ground level between the inner toe of the bank and the top edge of the cutting is known as berm.

**Purpose:**

- provide a bigger waterway.
- provide scope for future widening of canal.
- protect the bank from erosion.

**Free board:** The margin between full supply level (FSL) and bank top level is known as free board.

* The river Ganga flows bank full rate of 2500 $m^3/s$. Find
(i) Hydraulic geometry (ii) Scour depth. Bed material size is .15mm.

**Soln:** $f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{.15} = 0.68$

**(i)**

① velocity, $v = \left(\frac{Qf^2}{140}\right)^{1/6} = \left(\frac{2500 \times .68^2}{140}\right)^{1/6} = 1.42\ m/s$

② Hydraulic mean depth, $R = \frac{5}{2}\frac{v^2}{f} = 7.41m$

③ Area of channel section, $A = \frac{Q}{V} = 1760.56\ m^2$

④ Wetted perimeter, $P = 4.75\sqrt{Q} = 4.75\sqrt{2500} = 237.5m$

⑤ Slope, $S = \frac{f^{5/3}}{3340\ Q^{1/6}} = 4.27 \times 10^{-5}$

**(ii)**

Scour depth, $= 0.47\left(\frac{Q}{f}\right)^{1/3}$

$= 0.47 \times \left(\frac{2500}{.68}\right)^{1/3} = 7.25m$

Ans.

* What are the type of scour that can be near a bridge? Given discharge of a bridge is 5800 $m^3/s$. Hydraulic mean depth of the river is 58m & mean regime velocity is 10.5 m/s. calculate the scour depth using Lacey's silt factor.

Soln:

Type of scour:

(1) Degradation scour (2) Local scour

(3) Confluence scour (4) Constriction scour.

Now, $f = \frac{5}{2}\frac{v^2}{R} = \frac{5}{2} \times \frac{10.5^2}{58} = 4.75$

$\therefore$ scour depth $= 0.47\left(\frac{Q}{f}\right)^{1/3}$

$= 0.47\left(\frac{5800}{4.75}\right)^{1/3}$

$= 5.02$ m Ans.

* A reservoir with a storage capacity of 300 million cubic metre is able to irrigate 40,000 ha with 2 fillings each year. The crop season is 120 days. What is duty?

Soln: $V = 300 \times 10^6\ m^3$ for 1 filling, $A = 40000 \times 10^4\ m^2$

Height of water for 6 months $= \frac{V}{A}$

$= \frac{300 \times 10^6}{40000 \times 10^4} = 0.75$ m

$\Delta$ for 120 days $= \frac{0.75}{180} \times 120 = 0.50$ m

$\therefore$ Duty, $D = \frac{8.64B}{\Delta} = \frac{8.64 \times 120}{0.50}$

$= 2073.6$ ha/cumec

Ans

Scanned by CamScanner

# Water Logging: A land is said to be water logged when its productivity gets affected and when the root zone of the plants gets flooded with water by the high water table.

**Causes of water logging:**

1. Irregular or Flat Topography
2. Over & intensive irrigation
3. seepage of water
4. Inadequate natural drainage.
5. Excess Rainfall.

**Measures for controlling water logging:**

1. Lining of canal & water courses.
2. Reducing the intensity of irrigation
3. By introducing crop rotation
4. By optimum use of water.
5. By improving natural drainage.

# Leaching requirement:

$$LR = \frac{\text{Depth of water drained out per unit area}}{\text{Depth of irrigation water applied per unit area}}$$

$$\Rightarrow LR = \frac{D_d}{D_i} = \frac{D_i - C_u}{D_i} = \frac{C_i}{C_d} = \frac{EC_i}{EC_d} = \frac{EC_i}{2EC_e}$$

where,

$D_d$ = Depth of water drained out per unit area.

$D_i$ = Depth of irr$^n$ water applied per unit area.

$C_u$ = Consumptive use of water

$C_i$ = Salt content in irr$^n$ water

$C_d$ : salt content in drainage water.

$EC_i$ = Electrical conductivity in irrigation water.

$EC_d$ = Electrical conductivity in drainage water.

$EC_e$ = Electrical conductivity in saturated soil extract

* Estimate the leaching requirement when electrical con- -ductivity (EC) value of a saturated extract of soil is 10 micromhos/cm at 25% reduction in the yield of a crop. The EC of irrigation water is 1·2 m.mho/cm. What will be the required depth of water to be applied to the field if the consumptive use requirement of the crop is 80 mm?

Soln:
$$LR = \frac{EC_i}{2EC_e} \times 100 = \frac{1.2}{2 \times 10} \times 100 = 6\%$$

Again,
$$LR = \frac{D_i - C_u}{D_i} \times 100\%$$

$$\Rightarrow 0.06 = \frac{D_i - 80}{D_i} \times \frac{100}{100}$$

$$\Rightarrow D_i = 85.1 \text{ mm}$$ Ans.

* A tile drainage system draining 12 ha, flows at a design capacity for two days, following a storm. If the system is designed using a drainage co-efficient (D.C.) of 1·25 cm/day how many cubic metres of water will be removed during this period?

Soln: volm of water entering the drain/day

$$= \frac{1.25}{100} \times (12 \times 10^4) = 1500 \text{ m}^3/\text{day}$$

∴ volm of water removed during 2 days

$$= 2 \times 1500 = 3000 \text{ m}^3$$ Ans.

* Determine the size (dia) of a tile at the out let of a 6 ha drainage system, if the D.C. is 1 cm/day and the tile grade is 0·3%. Assume the rugosity co-efficient for the tile drain material as 0·011.

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

Run off per second

$$Q = \frac{1}{100} \times 6 \times 10^4$$
$$= 600 \text{ m}^3/\text{day}$$
$$= 600/(24 \times 60 \times 60)$$
$$= 0.00694 \text{ m}^3/\text{s}$$

$Q = AV$

$\Rightarrow 0.00694 = \frac{\pi}{4} D^2 \times \frac{1}{0.011} \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{.3}{100}\right)^{1/2}$

$\Rightarrow D^{8/3} = \frac{0.00694 \times 4 \times .011 \times 4^{2/3} \times 10}{\pi \times .3^{1/2}}$

$\Rightarrow D = 0.1315 \, m$

Ans.

$A = \frac{\pi}{4} D^2$

$P = \pi D$

$R = A/P = \frac{D}{4}$

$S = \frac{0.3}{100}$

# Cross drainage work: A cross drainage work is a structure which is constructed at the crossing of a canal and a natural drain to dispose of drainage water without interrupting the canal supplies.

* If the flow rate is 113 cusec and area is 5 ha. what is the time required for irrigation if dewatering in irrigated land 10.92 cm?

Soln: volume of irrigated water, $V = 5 \times 10^4 \times 0.1092$
$= 5460 \, m^3$

$Q = 113$ cu sec
$= 113$ lit/s $= .113 \, m^3/s$

$\therefore Q = \frac{V}{t} \Rightarrow t = \frac{V}{Q} = \frac{5460}{.113} = 48318.58$ sec

Ans.

# Terminology:

1) Water horse power (WHP) $= \frac{\text{Discharge (lit/s)} \times \text{total head (m)}}{76}$

$= \frac{\text{Discharge } (m^3/s) \times \text{total head (m)}}{273}$

2) Shaft horse power $= \frac{\text{water horse power}}{\text{pump efficiency}}$

3) pump efficiency $= \frac{WHP}{SHP}$

* A pump lifts 93600 litres of water per hour against a total head of 21m. Compute the WHP. If the pump has an efficiency of 72%, what size prime mover is required to operate the pump. If a direct drive electric motor, having an efficiency 80%, is used to operate the pump, compute the cost of electrical energy in a month of 30 days. The pump is operated for 12 hrs daily for 30 days. The cost of energy is 20 paise/day.

Soln: Discharge = 93600 lit/hr = 26 lit/sec

$\therefore$ WHP $= \frac{26 \times 21}{76} = 7.18$ Ans.

SHP $= \frac{7.18}{.72} = 9.98$ Ans.

Kilowatt input to motor $= \frac{\text{SHP} \times .746}{\text{Motor efficiency}}$

$= \frac{9.98 \times .746}{.80} = 9.31$ KW

Total energy/month $= 9.31 \times 12 \times 30 = 3351.6$ KWh

$\therefore$ Cost/month $= 3351.6 \times \frac{20}{100}$

$= 670.32$ TK Ans.

* Determine the spacing of the tile drain from the data - Annual rainfall = 100 cm, Drainage co-efficient = 1% to be drained in 24 hours. Depth of impervious layer from land surface = 10m, depth of drain below land surface = 2m. permeability of soil = $10^{-4}$ m/sec, Depth of WT below land = 1.5m

Soln: Let, Longitudinal length of drain = 1m

Runoff per second, $Q = \frac{\frac{100}{100} \times \frac{1}{100} \times S \times 1}{24 \times 60 \times 60} = \frac{S}{8.64 \times 10^6}$

We know,

$S = \frac{4K(b^2 - a^2)}{Q}$

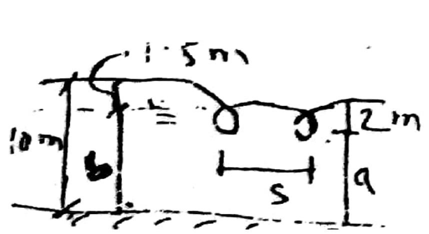
$= \frac{4 \times 10^{-4} \times (8.5^2 - 8^2)}{\frac{S}{8.64 \times 10^6}}$

$\Rightarrow S = 169$ m

Ans.

$b = 10 - 1.5 = 8.5$ m

$a = 10 - 2 = 8$ m



Md [illegible] Galib
B.Sc in CE, KUET

# Flood

**# Flood:** Flood is an unusual high stage of river at which the channel is filled up and above which it overflows the banks spreading the water over the land generally causing destruction of crops, properties and lives.

## # Causes of flood:

- Geographical location & climate pattern.
- Excessive rainfall.
- The influence of tides & cyclones.
- Melting of ice
- Reduction of river capacity.

## # Methods of estimating flood:

a) Rational method.

b) Empirical formulae

c) Unit Hydrograph method.

d) Flood frequency studies.

## # Rational method:

$$Q_p = CIA \quad \text{for } t > t_c$$

where,
$Q_p$ = peak discharge / Run off, $m^3/s$

$C$ = Co-efficient of run off.

$I$ = Intensity of rainfall.

$t_c$ = The time taken for a drop of water from the farthest part of the catchment to reach the outlet.

$A$ = Catchment Area, $Km^2$

**For field application:** $Q_p = \frac{1}{3.6} C \left(I_{t_c, P}\right) A$

where, $I_{t_c, P}$ = Average intensity, mm/h.

* Time of concentration:

By Kirpich Equation —

$$t_c = 0.01947\, L^{0.77}\, S^{-0.385}$$

Where,

$t_c$ = time of concentration (min)

$L$ = max^m^ length of travel of water, m

$S$ = slope of the catchment.

* An urban catchment has an area of 85 ha. The slope of the catchment is 0.006 and the maximum length of travel of water is 950 m. The maximum depth of rainfall with a 25-yr return period is as below —

| Duration (min) | 5 | 10 | 20 | 30 | 40 | 60 |
|---|---|---|---|---|---|---|
| Depth of rainfall (mm) | 17 | 26 | 40 | 50 | 57 | 62 |

If a culvert for drainage at the outlet of this area is to be designed for a return period of 25 years, estimate the required peak-flow rate, by assuming the runoff co-efficient as 0.3.

Sol^n^: Time of conc. $t_c = 0.01947 \times L^{0.77} \times S^{-0.385}$

$$= 0.01947 \times (950)^{0.77} \times (0.006)^{-0.385}$$

$$= 27.4 \text{ min}$$

By interpolating:

Max^m^ depth of rainfall $= 40 + \frac{50-40}{30-20} \times (27.4 - 20)$

$= 47.4$ mm

Average intensity, $I_{tc,p} = \frac{47.4}{27.4} \times 60 = 103.8$ mm/h

$\therefore Q_p = \frac{1}{3.6} C\, I_{tc,p}\, A$ | $A = 85$ ha $= 85 \times 10^4\ m^2$ $= 0.85\ km^2$

$= \frac{1}{3.6} \times 0.3 \times 103.8 \times 0.85 = 7.35\ m^3/s$

Ans.

# Runoff co-efficient:

Equivalent runoff co-efficient, $C_e = \frac{\sum_1^N C_i A_i}{A}$

* If in a urban area, the landuse of the area and the corresponding runoff co-efficients are as given below, Calculate the equivalent runoff co-efficient.

| Landuse | Area (ha) | Runoff co-efficient |
|---|---|---|
| Roads | 8 | 0.70 |
| Lawn | 17 | 0.10 |
| Residential Area | 50 | 0.30 |
| Industrial Area | 10 | 0.80 |

Soln:

$$C_e = \frac{\sum_1^N C_i A_i}{A} = \frac{(8\times .7)+(.1\times 17)+(.3\times 50)+(.8\times 10)}{8+17+50+10}$$

$= 0.36$ Ans.

# Gumbel's Equation:

Magnitude of flood with return period T

$$x_T = \bar{x} + k\,\sigma_{n-1}$$

where, $\sigma_{n-1}$ = standard deviation of sample size, N

$$= \sqrt{\frac{\Sigma(x-\bar{x})^2}{N-1}}$$

K = frequency factor $= \dfrac{y_T - \bar{y}_n}{S_n}$

$y_T$ = reduced variate $= -\left[\ln . \ln \dfrac{T}{T-1}\right]$

$y_n$ = reduced mean, = 0·577 (when sample size large)

$S_n$ = reduced standard deviation = 1·2825

* An analysis of annual flood series of a stream indicated the mean value and standard deviation of the flood series as 940 $m^3/s$ and 203 $m^3/s$ respectively. What is the magnitude of a flood of return period of 500 years in this stream? Assume that the annual flood series follow Gumbel's distribution and the sample size is very large.

Sol$^n$: For return period, T = 500 years.

$$y_T = -\left[\ln . \ln \frac{T}{T-1}\right] = -\left[\ln . \ln \frac{500}{500-1}\right] = 6·2136$$

Frequency factor, $k_T = \dfrac{y_T - y_n}{S_n}$

$= \dfrac{6·2136 - ·577}{1·2825}$

$= 4·395$

| $y_n = 0·577$ |
| --- |
| $S_n = 1·2825$ |
| $\bar{x} = 940\ m^3/s$ |
| $\sigma_{n-1} = 203\ m^3/s$ |

$x_T = \bar{x} + k_T\,\sigma_{n-1} = 940 + 4·395 \times 203$

$= 1832\ m^3/s$

Ans.

Md Miraz Gazi
B. Sc. in CE, KUET

* The mean annual flood of a river is 600 $m^3/s$ and the standard deviation of the annual flood series is 150 $m^3/s$. What is the probability of a flood of magnitude 1000 $m^3/s$ occuring in the river within next 5 years? The sample size is assumed very large.

Soln:

$\bar{x} = 600\, m^3/s$, $\sigma_{n-1} = 150\, m^3/s$, $x_T = 1000\, m^3/s$

$x_T = \bar{x} + K_T \sigma_{n-1} \Rightarrow 1000 = 600 + K_T \times 150$

$\Rightarrow K_T = 2.6667$

Again, $K_T = \dfrac{Y_T - Y_n}{S_n}$

$\Rightarrow 2.667 = \dfrac{Y_T - 0.577}{1.2825} \Rightarrow Y_T = 3.997$

$\therefore Y_T = -\left[\ln . \ln \dfrac{T}{T-1}\right]$.

$\Rightarrow 3.997 = -\left[\ln . \ln \dfrac{T}{T-1}\right] \Rightarrow \dfrac{T}{T-1} = 1.0185$

$\therefore T \simeq 55$ years.

$\therefore$ probability of occurrence of a flood of magnitude 1000 $m^3/s$, $P = 1/55 = 0.0182$

The probability of a flood of magnitude 1000 $m^3/s$ at least ~~once~~ once in 5 years, $P_1 = 1 - (1-P)^n$

$= 1 - (1 - .0182)^5$

$= 0.0877$

$= 8.77\%$

Ans.

* Return period, T (Yr) — peak flood ($m^3/s$)

| Return period, T (Yr) | peak flood ($m^3/s$) |
|---|---|
| 50 | 40,809 |
| 100 | 46,300 |

Estimate the flood magnitude in the river with a return period of 500 years.

Soln: Here, $x_{100} = \bar{x} + k_{100}\sigma_{n-1}$ , $x_{50} = \bar{x} + k_{50}\sigma_{n-1}$

$$\therefore x_{100} - x_{50} = (k_{100} - k_{50})\sigma_{n-1}$$

$$\Rightarrow (k_{100} - k_{50})\sigma_{n-1} = 46300 - 40809 = 5491$$

$$\Rightarrow \left(\frac{Y_{100} - Y_n}{S_n} - \frac{Y_{50} - Y_n}{S_n}\right)\sigma_{n-1} = 5491$$

$$\Rightarrow \left(\frac{Y_{100}}{S_n} - \frac{Y_{50}}{S_n}\right)\sigma_{n-1} = 5491$$

$$\Rightarrow (Y_{100} - Y_{50})\frac{\sigma_{n-1}}{S_n} = 5491 \quad \text{--- (1)}$$

Again,

$$Y_{100} = -\left[\ln.\ln\frac{100}{100-1}\right] = 4.6$$

$$Y_{50} = -\left[\ln.\ln\frac{50}{50-1}\right] = 3.9$$

$$Y_{500} = -\left[\ln.\ln\frac{500}{500-1}\right] = 6.20$$

From (1) $\Rightarrow$

$$\frac{\sigma_{n-1}}{S_n} = 7864$$

Again,

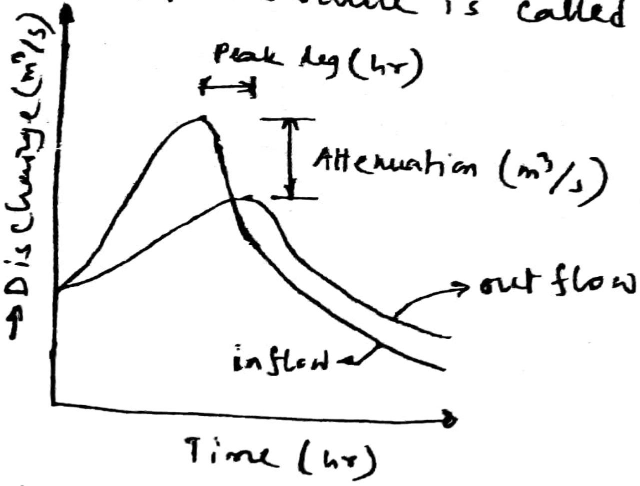
$$(Y_{500} - Y_{100})\frac{\sigma_{n-1}}{S_n} = x_{500} - x_{100}$$

$$\Rightarrow x_{500} = 46300 + (1.20 - 4.6) \times 7864$$

$$= 58883 \ m^3/s$$

Ans.

# Attenuation: The peak of the outflow hydrograph will be smaller than that of the inflow hydrograph. This reduction in the peak value is called attenuation.




# Chance Flood: If a flood of a given magnitude occurs with an average frequency of 100 years, then there exist $\frac{1}{100} \times 100\% = 1\%$ chance and is called 1% chance flood.

# Probability of occurrence or exceedance, P:

The probability of occurrance of a flood equal to or greater than 100 yrs.-

$$P = \frac{1}{100} = 0.01 \; ; \; F = 100$$

# Probability of non-occurance:

$$q = 1 - P = 1 - \frac{1}{F}$$

# 170 floods have occured in 120 years of record. It is desired to find out the chance of flood having a frequency of 1000 years?

Soln:

Flood in one year $= \frac{170}{120}$

Flood in 1000 year $= \frac{170}{120} \times 1000$

∴ chance for 1000 yrs frequency flood -

$$= \frac{1}{\frac{170}{120} \times 1000} \times 100\% = 0.07\%$$

Ans.

* **Design flood**: flood adopted for the design of a structure.

\# **structural measures for controlling flood**:

1. Storage & detention reservoir.
2. Leeves (Flood embankment).
3. Flood ways (new channel)
4. channel improvement.
5. watershed management.

* **Draw flood control operation of a reservoir**:

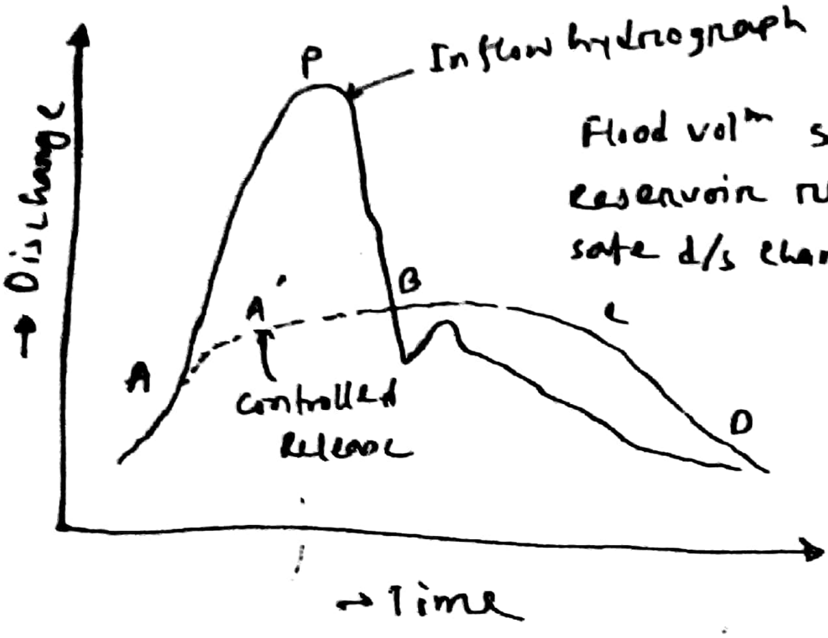



Fig: Flood control operation of a reservoir.

\# **Risk and Reliability**: The probability of occurrence of an event at least once over period of n successive year is called the risk, $\bar{R}$.

$$\bar{R} = 1-(1-P)^n$$
$$= 1-\left(1-\frac{1}{T}\right)^n$$

$P$ = probability $= \frac{1}{T}$
$T$ = return period.

Reliability,

$$R_e = 1-\bar{R}$$

* A bridge has an expected life of 25 years and is designed for a flood magnitude of return period 100 years. (a) What is the risk of this hydrologic design? b) If 10% risk is acceptable, what return period will have to be adopted?

Soln:

a) $\bar{R} = 1-\left(1-\frac{1}{T}\right)^n = 1-\left(1-\frac{1}{100}\right)^{25} = 0.222 = 22.2\%$ Ans.

(b) $\bar{R} = 10\% = 0.1$

$0.1 = 1-\left(1-\frac{1}{T}\right)^{25}$

$\Rightarrow T = 238$ years Ans.

* What return period a highway engineer must assume if he allows 10% risk that flooding may occur in the next 5 years?

Soln: $\bar{R} = 1-\left(1-\frac{1}{T}\right)^n$

$\Rightarrow 0.1 = 1-\left(1-\frac{1}{T}\right)^5 \Rightarrow T \simeq 48$ years Ans

# Levees/ Dikes/ Flood embankment: These are earthen banks constructed parallel to the course of the river to confine it to a fixed course and limited cross-sectional width.

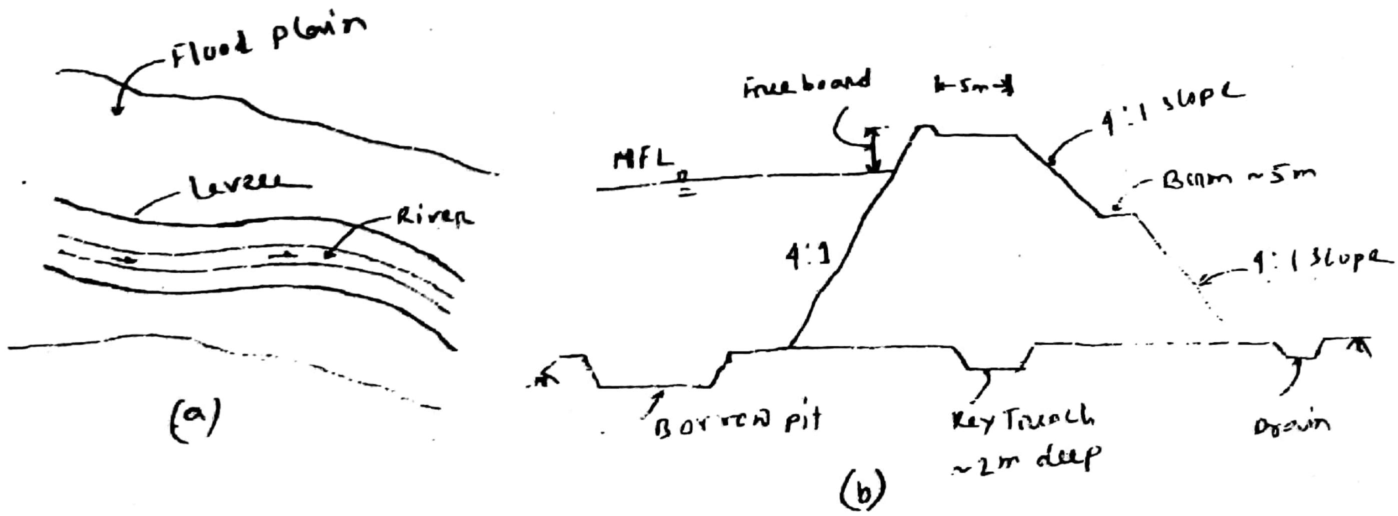



Fig: A typical levee (a) plan (b) cross section.

# Flood walls: Masonry structures used to confine the river in a manner similar to levee is known as flood walls.

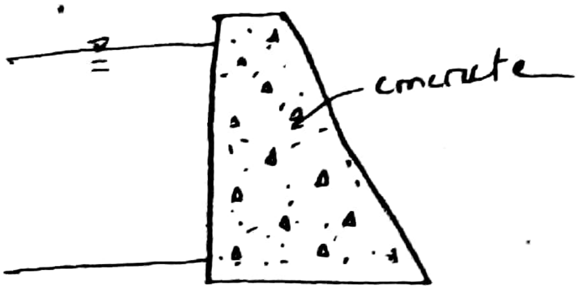



Fig: Typical flood wall

# Flood plain: The total area which is affected by a flood is called flood plain.

# Flood routing: Flood routing is the technique of determining the flood hydrograph at a section of a river by utilising the data of flood flow at one or more upstream sections.

- Reservoir Routing
- Channel Routing

# Floodways: are natural channels into which a part of the flood will be diverted during high stages of flood.

Scanned by CamScanner