

## # QUALITY OF WATER

- Quality of water can be found with the help of certain indicators or parameters termed as water quality parameters.
- These are further classified into:
  - (a) Physical WQP
  - (b) Chemical WQP
  - (c) Biological WQP

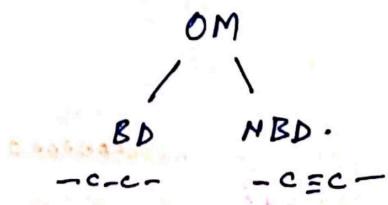
### (A) PHYSICAL WATER QUALITY PARAMETER:

- These parameters indicate physical quality of water and are those which can be sensed by eyes
- Ex (i) Suspended solids (ss)
  - ss in water may come from organic and inorganic matter

#### ORGANIC MATTER

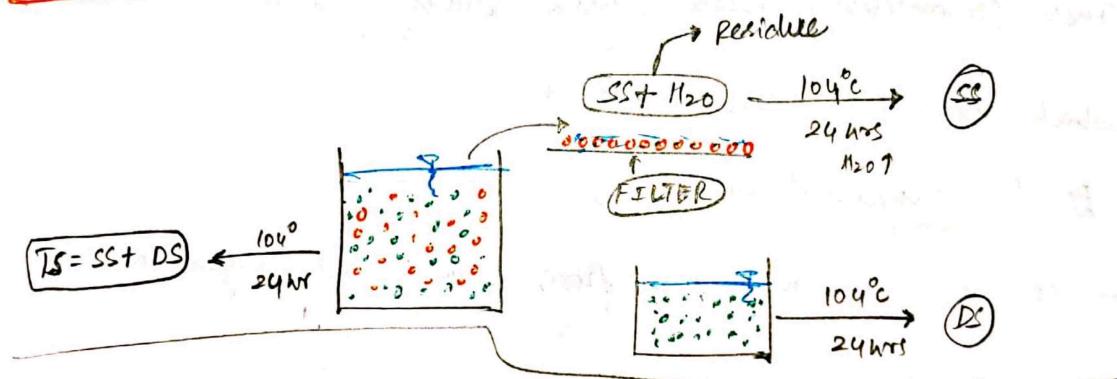
[ $\text{C}_6\text{H}_5\text{N}_2\text{P}_2\text{O}_7$ ].

Ex  $\text{C}_6\text{H}_{12}\text{O}_6$ ,  $\text{CH}_4$ ,  $\text{C}_6\text{H}_6$



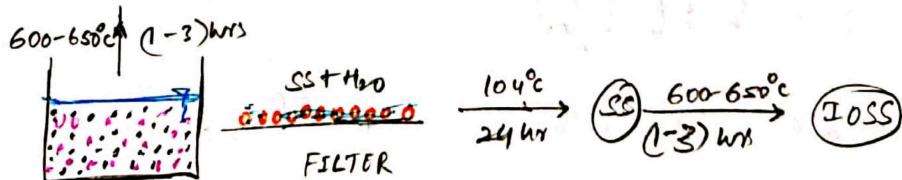
- SS if biological in nature can promote the growth of disease causing micro-organisms.
- They interfere with treatment of water their by increasing its cost (b) reducing its efficiency
- SS in water leads to formation in pipes, due to which their discharge carrying capacity decreases
- They make the water aesthetically displeasing
- Measurement of the solids is done by technique termed as

### "GRAVIMETRIC"



$TDS/NVS/FS$ ,  
in MUFFLE FURNACE

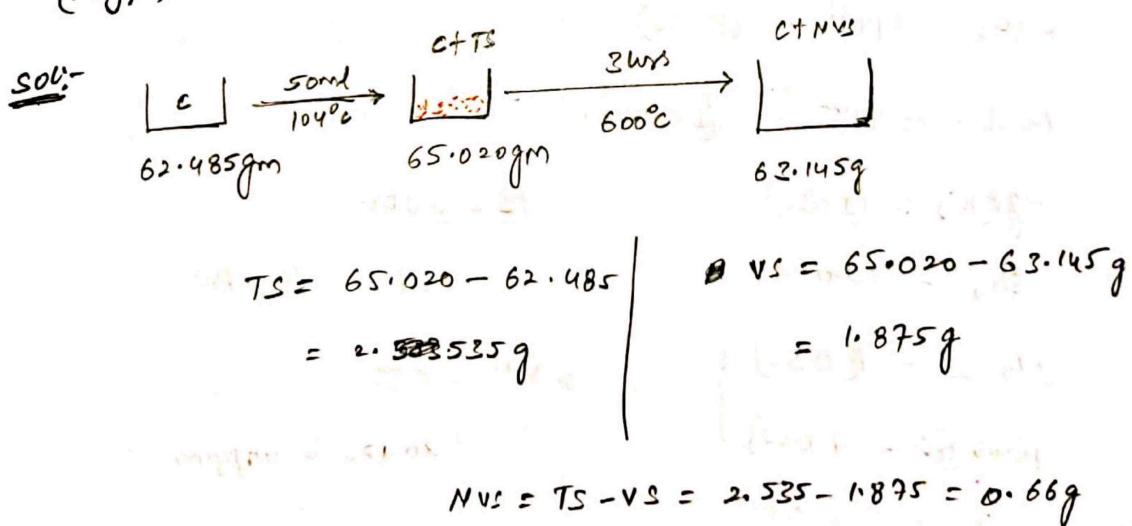
$$ODS = TS - TSS$$



$$\begin{aligned} OSS &= SS - SDS \\ ODS &= OS - OSS \\ SDS &= DS - ODS \end{aligned}$$

Following observations were being made on the analysis of  
some raw water sample

- ① A crucible was dried to a constant mass of  $62.485\text{g}$
  - ② Raw water sample was then placed in crucible
  - ③ The crucible with the sample was dried to a constant mass  $65.020\text{gm}$  in the drying oven @  $104^\circ\text{C}$ .
  - ④ The crucible with the dried sample was then placed in muffle furnace at  $600^\circ\text{C}$  for 3 hrs. and after cooling the mass of crucible with residue was  $63.145\text{g}$
- Compute the concentration of FS & VS in the sample in  $(\text{mg/l})$ ?



$$[\text{FS}] = 0.66\text{g} = \frac{0.66 \times 10^3}{50 \times 10^{-3}} = 1200\text{mg/l}$$

$$[VS] = \frac{1.875 \times 10^3}{50 \times 10^{-3}} = 37500 \text{ mg/l}$$

Q2 Analysis of raw water sample received following quality

$$\text{MgSO}_4 = 20 \text{ ppm}$$

$$\text{C}_6\text{H}_5\text{O} = 5 \text{ ppm}$$

$$\text{CaCO}_3 = 30 \text{ ppm}$$

$$\text{plankton} = 20 \text{ ppm}$$

$$\text{NaCl} = 25 \text{ ppm}$$

$$\text{kaolinite} = 10 \text{ ppm}$$

$$\text{Mg(OH)}_2 = 10 \text{ ppm}$$

$$\text{SO}_2 = 10 \text{ ppm}$$

$$\text{Algae} = 20 \text{ ppm}$$

Find the concentration of FS and volatile suspended solids?

(VSS)

Sol.

$$\text{MgSO}_4 = 20 \text{ ppm } (\text{DS}) (\text{IOS}) - (\text{IOS DS}) \checkmark$$

$$\text{CaCO}_3 = 30 \text{ ppm} - (\text{IOSS})$$

$$\text{NaCl} = 25 \text{ ppm.} - [\text{IOS DS}] \checkmark$$

$$\text{Mg(OH)}_2 = (\text{IOSS})$$

$$\text{FS} = \text{IOSS.}$$

$$\text{SO}_2 = (\text{IOSS})$$

$$= 20 + 25 = 45 \text{ ppm.}$$

$$\text{Algae} = [\text{OSS}] \rightarrow \text{VSS} = \text{OSS}$$

$$\text{Plankton} = [\text{OSS}]$$

$$= 20 + 20 = 40 \text{ ppm}$$

$$\text{Phenol} - \text{C}_6\text{H}_5\text{O} = [\text{ODS}]$$

$$\text{Kaolinite} = [\text{IOSS}]$$

[IEC - 14]

Acceptable / required  
limit

Permissible limit in  
absence of alternate  
source / ~~cause~~ cause for  
segregation limit.

TDS -

500 mg/l

2000 mg/l

NOTE: All the limits discussed would be as per IS 10500 - 2012  
and are valid for only drinking water.

### (ii) TURBIDITY:

- It is extent to which light is either scattered or absorbed by the presence of suspended solids in water
- There is no quantitative relationship between turbidity and suspended solids in water and they are only linked qualitatively

I	II
0	0
0	0
0	0
0	0

100 mg/l

<

II
0
0
0
0

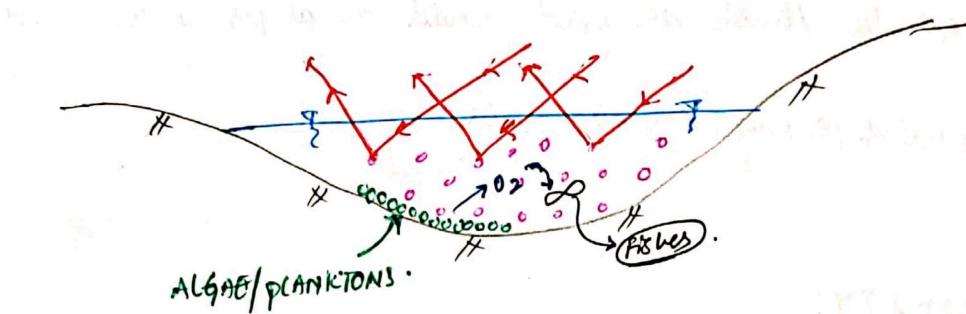
100 mg/l

III < I

III
0
0

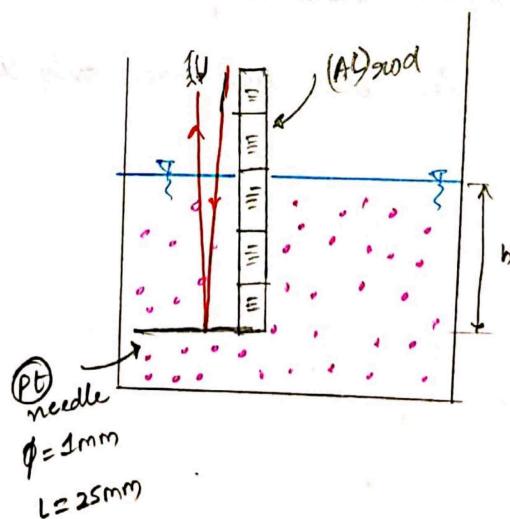
50 mg/l

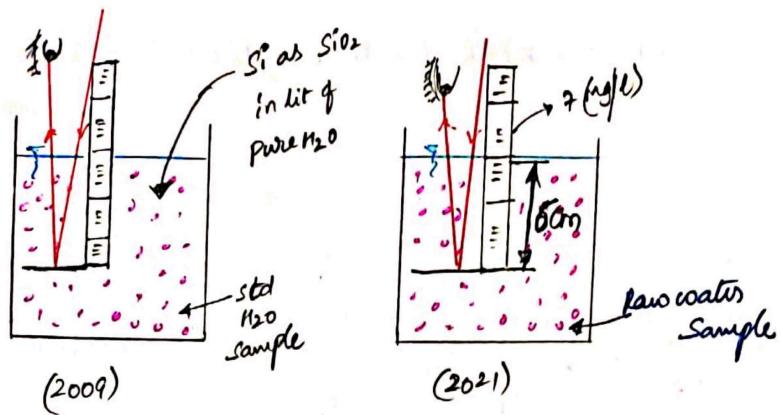
- Turbidity in water is induced either due to organic or inorganic solids.
- Impacts of turbidity <sup>are</sup> same as that of solids.
- Turbidity in natural water bodies interfere with penetration of sunlight, thereby effects the survival of aquatic plants.



- Turbidity of the water can be measured by any of the following

**A) Turbidity rod method: [Field method.]**

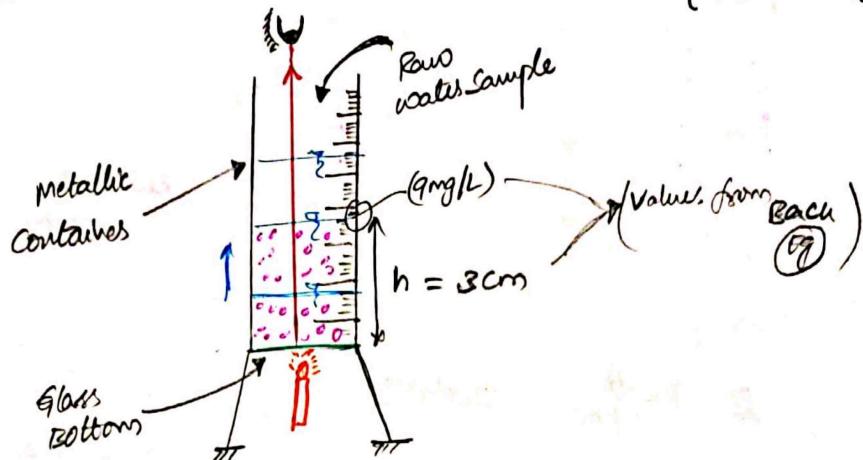




<u>Ex</u>	<u>Depth (cm)</u>	<u>Turbidity (mg/l), (PPM), (STU)</u>	<u>↳ (Silica Turbidity unit)</u>
	10	5	
	6	7	
	3	9	
	:	:	

- This test consists of graduated (Al rod) aluminium rod having platinum needle at its tip.
- To perform this test, rod is inserted in the water sample to be tested and its height/depth is noted where the platinum needle is not visible from ~~the~~ known standard height.
- This depth of the rod is further calibrated with the turbidity of standard water sample and is reported in terms of mg/l, ppm (B) STU.

(B) JACKSON TURBED METER METHOD / FLAME TURBIDMETER:  
 [lab method].

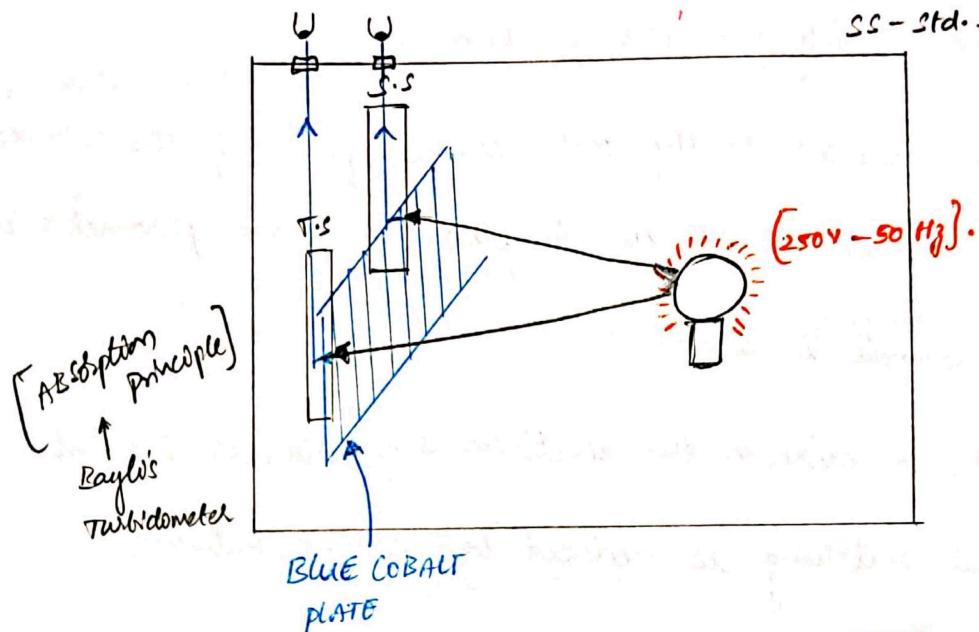


- It is a laboratory method which gives the turbidity of the water having value more than 25 units. Hence it is not suitable to find turbidity of water supplies. and is used for natural water body
- It consists of <sup>graduated</sup> metallic container placed over ignited flame
- water to be tested is filled in the container & its level is noted at which flame is not visible from a known fixed height
- this level of water is further calibrated with turbidity of standard water sample and is reported in terms of (mg/L), Ppm, STU, "JTU" [Jackson turbidity unit].

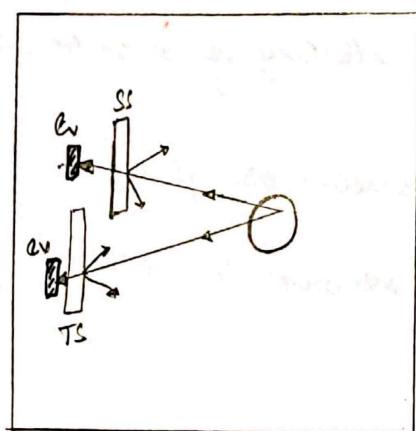
### (C) BAYLIS TURBIDMETER & NEPHLOMETER!

- Both these methods are based upon color matching technique, which can be ↑ for turbidity of even less than 1 unit, hence is suitable for testing of water supplies.

TS - Test Sample  
SS - Std. Sample

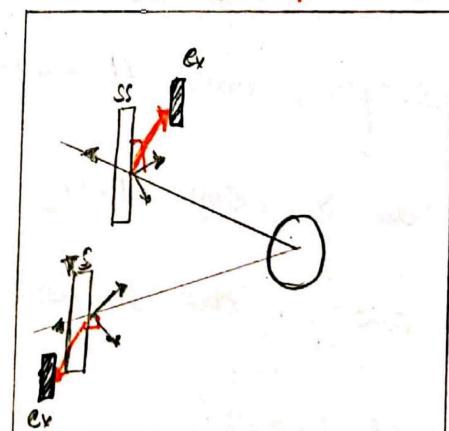


SS → Formazine in 1 lit. of pure water in nephrometer



BAYLIS'S TURBIDMETER

(modified)



NEPHLOMETER

[SCATTERING PRINCIPLE]

- colour matching technique consist of a test sample and a standard sample
- Test sample is that in which required quality parameter is to be noted and standard sample is that in which required quality parameter is known
- colour is induced to the both the sample & if the intensity of color matches in both the samples required parameter in both the sample is same
- In order to increase the effectiveness of this test intensity of colour matching is replaced by current matching.
- As in "Baylor's Turbid meter" the photometers are placed behind the samples, hence it measures the intensity of absorbed light
- whereas in "NEPHLOMETER" the photometers are placed at right angles to the samples hence it measures the intensity of SCATTERED LIGHT.

- An nephelometer standard sample is prepared by addition of FORMAZINE in 1 lit of pure water and turbidity is reported in terms of mg/l, ppm, NTU [Nephrometer, Turbidity unit], FTU [Formazin turbidity unit] as it gives the turbidity in more readable form.

**NOTE:** To measure the turbidity "Ratio TURBID METER" can also be used.

- which can measure the ratio of  $90^\circ$  scattered light to the transmitted light.

Turbidity	Acceptable limit	Permissible limit
	1 NTU	5 NTU

LFC-15

LFC-15

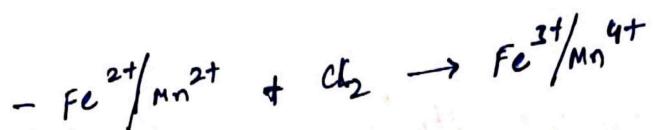
(iii) COLOUR:

Apparent colour  
TS  
(SS+DS)

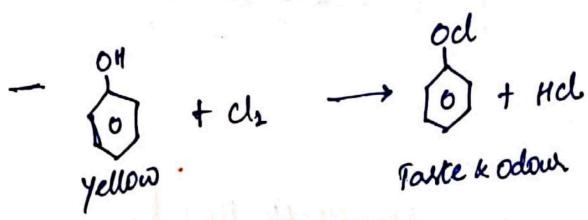
True color  
DS

- colour in water may be induced due to organic  
and inorganic solids

- coloured water cannot be used for washing of clothes



colour causing compound increases the demand of chlorine in  
water



(phenol)

Taste & odour

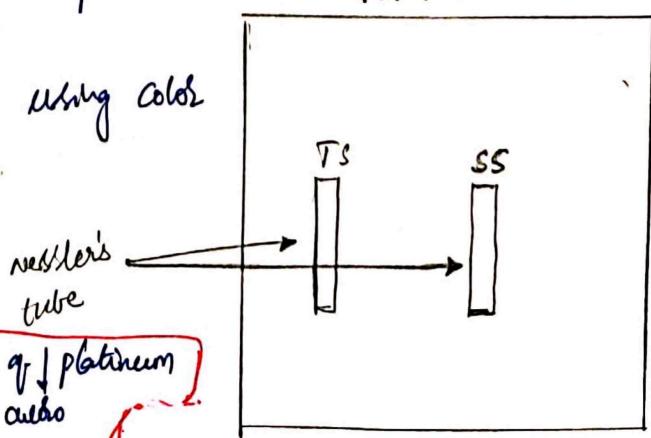
colour causing compound reacts with chlorine to impart taste and  
odour in water

- colour causing compound also reacts with chlorine to form Greenogenes [Cancer causing compounds].

- colour is also measured using color  
matching technique

\* \* \* - platinum cobalt in form of platinum  
ion in 1 lit of pure  $\text{H}_2\text{O}$

TINTOMETER.



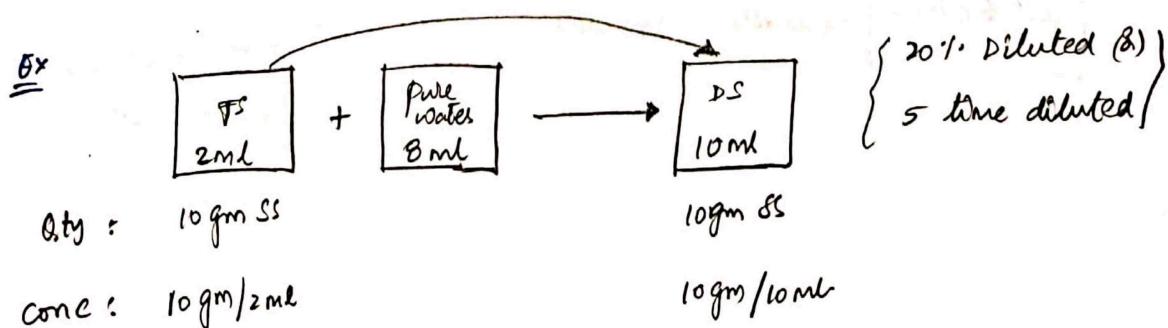
- The intensity of colour is reported in terms of unit TCU [True color unit] (B) HAZEN UNIT
- Measurement of colour other than yellow can be done using SPECTROPHOTOMETER.
- Colour - 

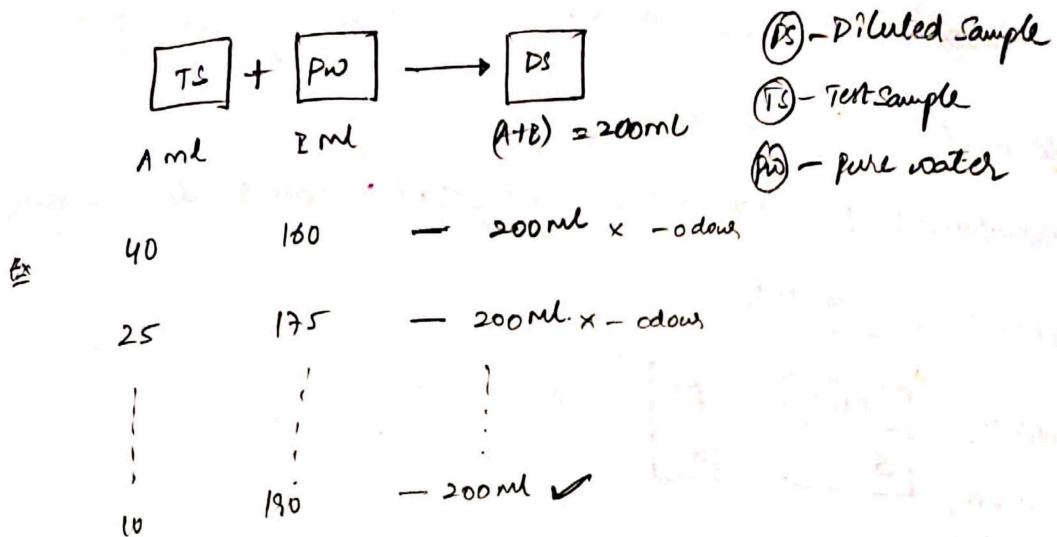
AL	PL
5	15

  
 (TCU/Mayer unit)

#### (iv) TASTE & ODOUR:

- Taste & odour is imparted by inorganic, organic solids (B) dissolved gases in water
- Ex NaCl, MgCl<sub>2</sub>, C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, H<sub>2</sub>S, CO<sub>2</sub> etc  
 (in) gases.
- It imparts physiological effect
- Taste & odour in water form. Carcinogens.
- Taste & odour in water is measured by dilution of sample upto an extent taste and odour becomes hardly perceptible.  
 In diluted sample of 200ml





### OSMOSCOPE.

- Intensity of taste & odour is reported in terms of TON [Threshold odour number]. which signifies the dilution ratio at which taste and odour is hardly perceptible.

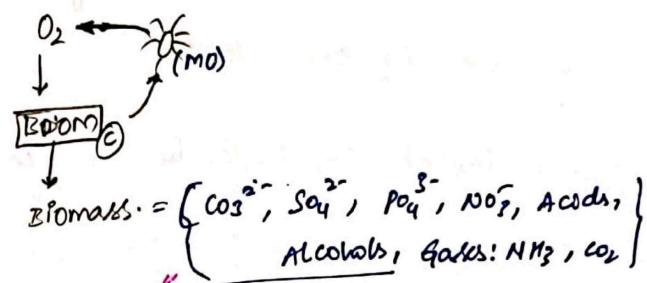
$$\text{TON} = \text{DILUTION RATIO} = \frac{\text{Final vol. of DS free from taste & odour}}{\text{Initial vol. of test sample}}$$

$$\boxed{\text{TON} = \frac{A+B}{A} = \frac{200}{10A}}$$

Taste & odour	AC	PL
Agreeable	Agreeable	

## ① Temperature:

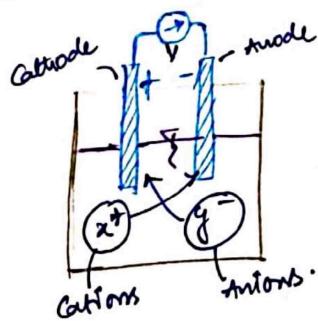
- Temperature effects the rate of both chemical and biological reaction.
- For water supplies temperature must be in the range of  $[10 - 25^{\circ}\text{C}]$



## ② CHEMICAL WATER QUALITY PARAMETER:

### ① DISSOLVED SOLIDS:

- Dissolved solids can also be determined approximately by measuring the electrical conductivity of water



$$\text{Electrical conductivity / Specific conductance} \times (0.65)$$

In  $\mu\text{mho/cm}$  @  $25^{\circ}\text{C}$ .

$$= \text{TDS (mg/l)}$$

$$\begin{cases} \text{Electrical conductivity} \\ \text{specific conductance} \end{cases} \times 0.65 = \text{TDS (mg/l)}.$$

@  $25^{\circ}\text{C}$

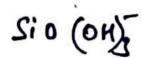
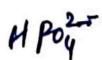
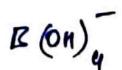
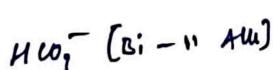
$$\left( \frac{\mu\text{mho}}{\text{cm}} \right)$$

- It is an option method as it gives concentration of only ions in water and there are certain dissolved solids, which are not in ion form.
- Hence electrical conductivity is related to dissolved solids on one to one basis.
- Electrical Conductivity is found with the help of "DI-IONIC-TESTER."

### (ii) ALKALINITY:

- Ability of water to neutralize acid (B)  $H^+$  ion
- It may also be defined as sum of all the ions in water which are capable of neutralizing the  $H^+$  ions
- 

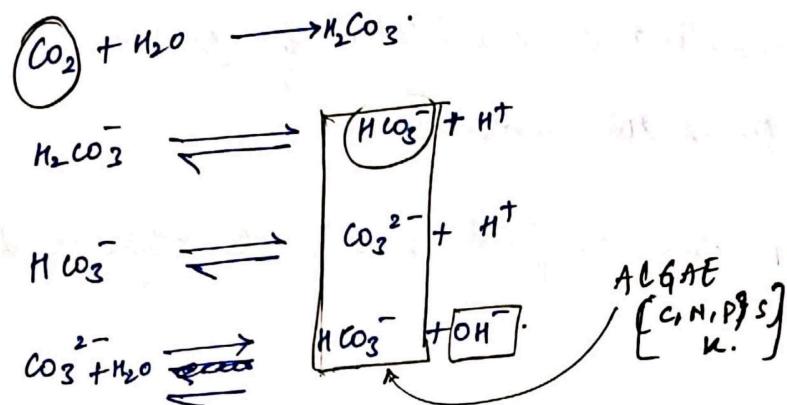
#### MAJOR IONS                          MINOR IONS.



NOTE: For calculation point of view.  $H^+$  is considered to impart

negative alkalinity ( $\text{eq}$ )

- alkalinity in water may be induced due to organic (R) inorganic solids (S) dissolved gases.



NOTE:  $aA + bB \rightleftharpoons cC + dD$

$k_f$  - rate concn forward

$k_b$  - " " in backward

$$k_f = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

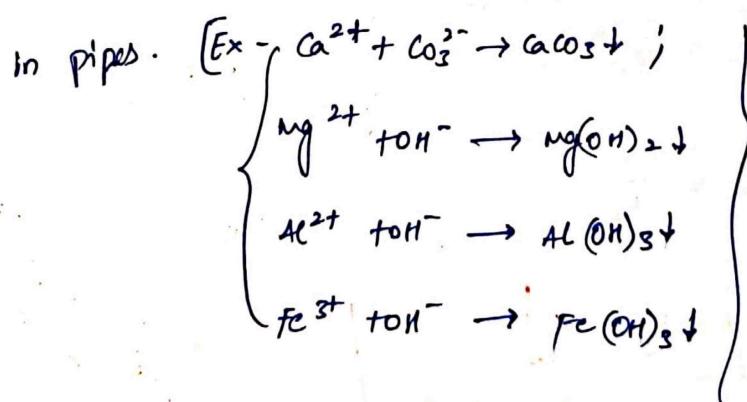
$$k_b \approx \frac{1}{k_f}$$

$$k_b \cdot k_f = 1$$

### NOTES

The last reaction is very weak reaction but if algae is found in water, it consumes  $\text{HCO}_3^-$  ion, due to the presence of carbon in it which acts as nutrient for algae

- This drives the reaction in forward direction at a very fast rate resulting in accumulation of  $(\text{OH}^-)$  ion in water which turns the water basic
- Hence if algae is found in water its pH is found in range of (8-10).
- Alkalinity in water in excess, imparts bitter taste
- Prime affection of alkalinity is that it leads to Incrustation in pipes.



- Measurement of alkalinity is done by Technique termed as "TITRATION".

LEC-16

**NOTE:** (i) molecular wt = wt. of 1 mole =  $\sum$  atomic wt.

$$\text{wt of 1 mole of } \text{CaCO}_3 = 40 + 12 + 16 \times 3 = 100 \text{ gm.}$$

$$\text{wt of 1 mole of } \text{Hg(OH)}_2 = 24 + (16+1)_2 = 58 \text{ gm.}$$

$$\text{wt of 1 mole of } \text{H}_2\text{SO}_4 = 1 \times 2 + 32 + 16 \times 4 = 98 \text{ gm.}$$

$$\text{wt of 1 mole of } \text{SO}_4^{2-} = 32 + 16 \times 4 = 96 \text{ gm.}$$

$$\text{wt of 1 mole of } \text{HCO}_3^- = 1 + 12 + 16 \times 3 = 61 \text{ gm.}$$

$$\text{wt of 1 mole of } \text{CO}_3^{2-} = 12 + 16 \times 3 = 60 \text{ gm.}$$

$$\rightarrow \text{No. of moles} = \frac{\text{Given wt}}{\text{molecular wt}}$$

$$\text{Ex. No. of moles in 200 gm of } \text{CaCO}_3 = \frac{200 \times 10^3}{100} = 2 \times 10^3 \text{ moles.}$$

(ii) Equivalent wt = wt. of 1 gm-eq = wt. of compound that reacts with 1 mole of electron.

$$\text{Eq. wt} = \frac{\text{molecular wt}}{\text{Valency}}$$

$$\text{wt. of } 1\text{ gm eq. of } \text{CaCO}_3 = \frac{100}{2} = 50 \text{ gm.}$$

$$\text{wt. of } 1\text{ gm eq. of } \text{Mg(OH)}_2 = \frac{58}{2} = 29 \text{ gm.}$$

$$\text{wt. of } 1\text{ gm eq. of } \text{SO}_4^{2-} = \frac{96}{2} = 48 \text{ gm.}$$

$$\text{wt. of } 1\text{ gm eq. of } \text{H}_2\text{SO}_4 = \frac{98}{2} = 49 \text{ gm.}$$

$$\text{wt. of } 1\text{ gm eq. of } \text{HCO}_3^- = \frac{61}{2} = 30.5 \text{ gm.}$$

$$\text{wt. of } 1\text{ gm eq. of } \text{CO}_3^{2-} = \frac{60}{2} = 30 \text{ gm.}$$

$$\text{No. of gm-eq} = \frac{\text{Given wt}}{\text{Eq. wt.}}$$

$$\text{No. of gm-eq in } 200 \text{ mg of } \text{CaCO}_3 = \frac{200 \times 10^{-3}}{50} = 4 \times 10^{-3}$$

(vii) MOLARITY = no. of moles / lit.

(viii) NORMALITY = no. of gm-eq / lit.

Example: 10 lit of sample of water has 500 gm of  $\text{CaCO}_3$

Express its conc in different ways?

Solt-

$\text{CaCO}_3$

$$\frac{500}{10} = 50 \text{ gm/l.}$$

$$\frac{500/100}{10} = 0.5 \text{ mole/l}$$

$$\frac{500/50}{10} = 1 \text{ gm-eq/lit.}$$

0.5 molar

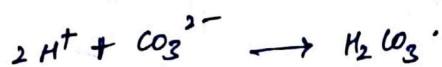
1 Normal

NOTE: V. imp points

i) 1 gm-eq of anything = 1 gm-eq of any other thing

$$\therefore N_1 V_1 = N_2 V_2$$

ii) 1 gm-eq of anything reacts with 1 gm eq of any other thing & leads to the formation of 1 gm-eq of the p<sub>h</sub> product.



moles	2	1	1.
wt g/mole (gm)	2	60	62
gm-eq	2	2	2

- Alkalinity of water is reported in terms of gm-eq of CaCO<sub>3</sub>.

Q A 200 ml sample of water has 240 gm of CO<sub>3</sub><sup>2-</sup>, 244 gm of HCO<sub>3</sub><sup>-</sup>

and pH of 8, Report the Alkalinity of this water sample

as CaCO<sub>3</sub>? in (mg/l)

Sol- gm-eq of CO<sub>3</sub><sup>2-</sup> =  $\frac{240}{80} = 3$  = gm-eq of CaCO<sub>3</sub>.

gm-eq of HCO<sub>3</sub><sup>-</sup> =  $\frac{244}{61} = 4$  = gm-eq of CaCO<sub>3</sub>.

pH = 8  $\Rightarrow -\log_{10}(H^+) = 8 \Rightarrow (H^+) = 10^{-8}$  moles/l

$$[H^+] = 10^{-8} \times 1 \text{ gm/l.} = 10^{-8} \times \frac{1}{17} \text{ gm-equiv/lit.} = (CaCO_3)$$

$$pH \rightarrow pH = 14 - 8 = 6. \quad [pH + pOH = 14].$$

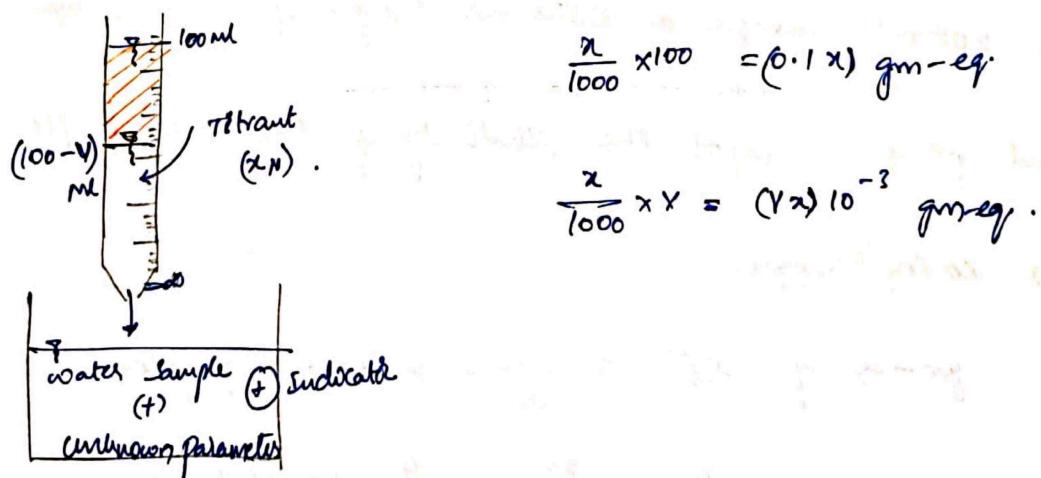
$$-\log_{10} (OH^-) = 6 \Rightarrow [OH^-] = 10^{-6} \text{ mole/lit.}$$

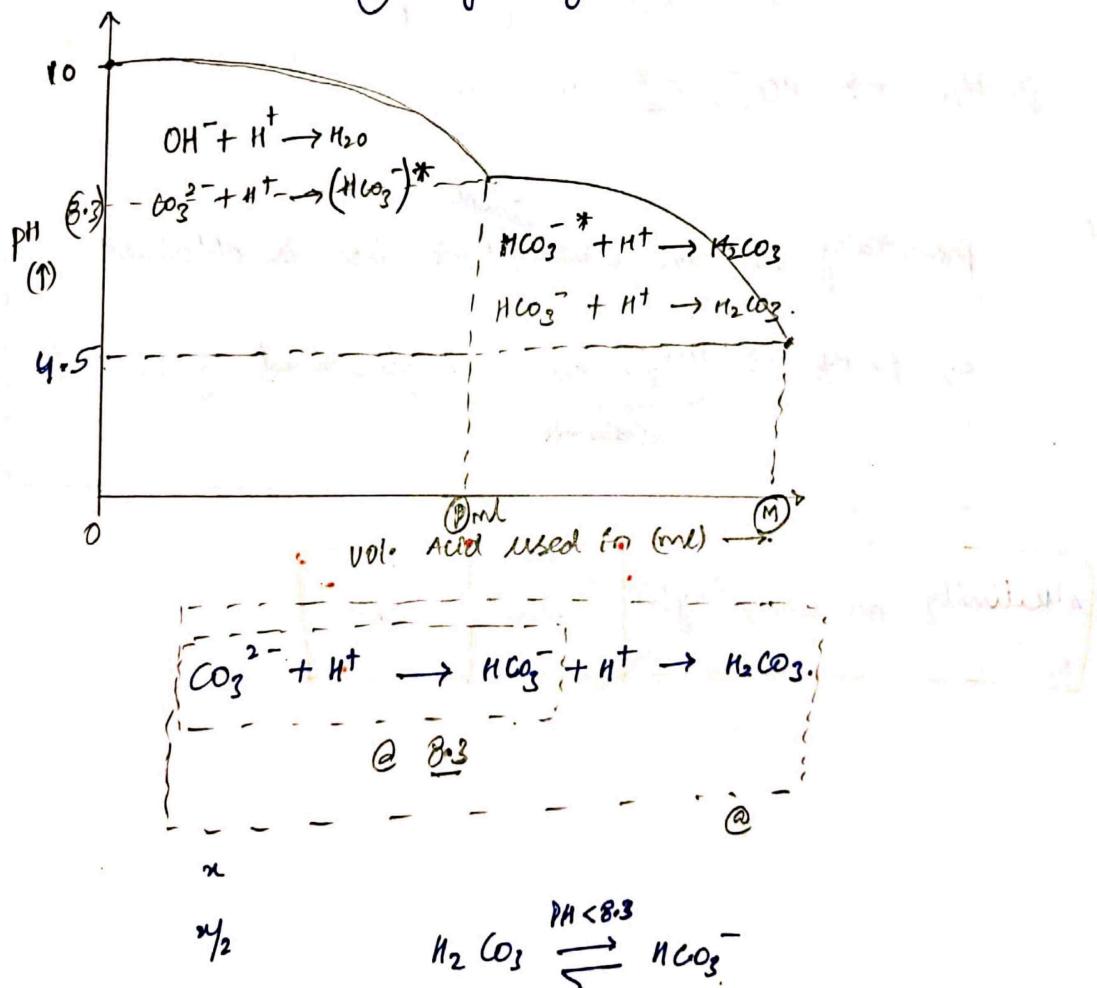
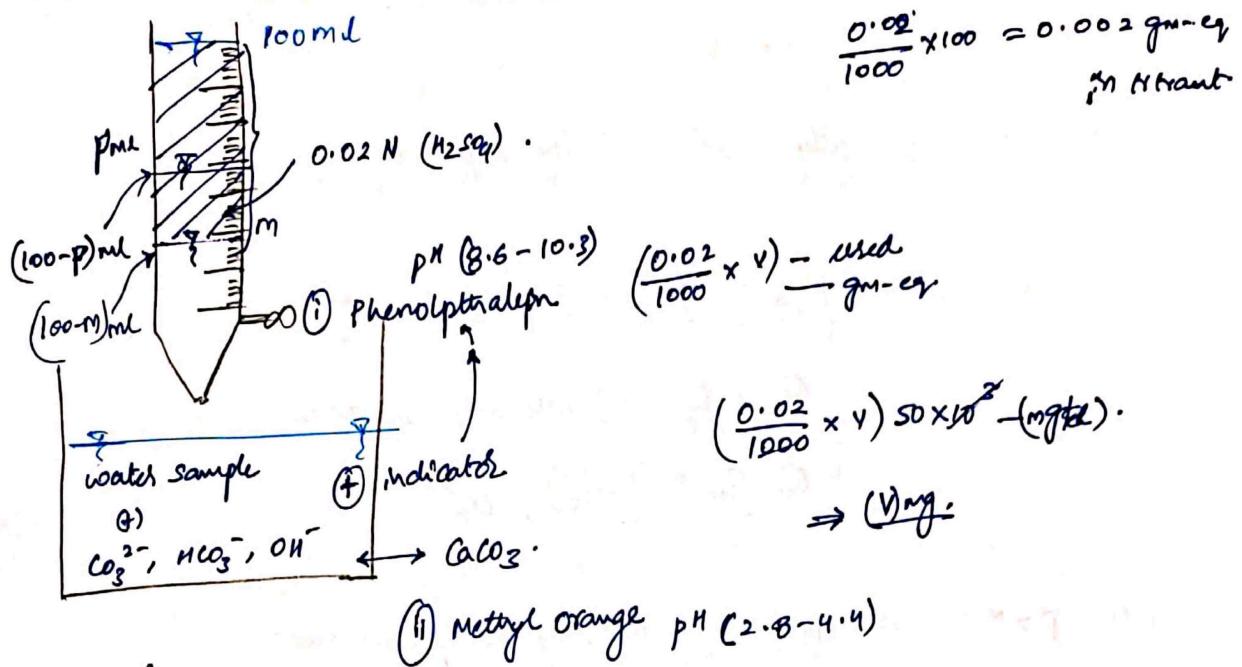
$$[OH^-] = 10^{-6} \times 17 \text{ gm/l.} = 10^{-6} \times \frac{17}{17} \text{ gm-equiv/lit} = CaCO_3.$$

$$\text{Alkalinity of } CaCO_3 = \frac{(8+4)}{200} \times 1000 \approx \frac{12}{200} \times 1000 = 60$$

$$= \left[ \frac{(8+4)}{200} \times 1000 + 10^{-6} - 10^{-8} \right] \times 50 \times \frac{10^3}{1000}$$

$$= 3.0495 \times 10^6 \text{ mg/l}$$





- If,  $P=0, M \neq 0 \rightarrow$  only bi-carbonate alkalinity is present.

④  $P=M \rightarrow$  only  $(OH^-)$  alkalinity is present

⑤  $P=M/2 \rightarrow \begin{cases} \textcircled{a} [OH^-] = [HCO_3^-], CO_3^{2-} \text{ is absent} \\ \textcircled{b} \text{ only } CO_3^{2-} \text{ alkalinity is present} \\ \textcircled{c} [OH^-] = [HCO_3^-], CO_3^{2-} \end{cases}$

⑥  $P > M/2 \rightarrow OH^-, CO_3^{2-}$  alkalinity are predominant.

⑦  $P < M/2 \rightarrow HCO_3^-, CO_3^{2-} \text{ " " "$

NOTE! practically in raw water <sup>sample</sup> first case is obtained

i.e.,  $P < M/2 \rightarrow \underbrace{HCO_3^-, CO_3^{2-}}_{\text{alkalinity}}$  are predominant of 97-98 %

Al	pL
200	600

LEC - 17

Q A 800 ml sample of water has initial pH of 10, 120 ml of 0.02 N Sulphuric acid is used to bring the pH of this water up to 4.5 and 44 ml sol of 0.02 NH<sub>2</sub>SO<sub>4</sub> is used to bring the pH up to 8.3

Compute:

- ① Total Alkalinity as CaCO<sub>3</sub> (mg/l).
- ② conc of all the alkalinity as CaCO<sub>3</sub> (mg/l).
- ③ methylorange and phenolphthalein alkalinity?

Sol:- ① Total Alkalinity =

$$\text{pH} = 10 \rightarrow [\text{H}^+] = 10^{-10} \text{ moles/lit.} = 10^{-10} \text{ gm eq/lit.}$$
$$= 40 \times 10^{-10} \text{ gm eq/lit}$$

$$[\text{H}^+] = 10^{-10} \text{ gm eq/lit} = \text{CaCO}_3.$$

$$\text{POH} = 14 - 10 = 10^4 \rightarrow [\text{OH}^-]^P = 10^{-4} = 10^{-4} \times 17 \text{ gm eq/lit}$$

$$= 10^{-4} \times \frac{17}{17} \text{ gm. eq/lit} = \text{CaCO}_3$$

Total Alkalinity  $(\text{OH}^- + \text{CO}_3^{2-} + \text{HCO}_3^-)$  as  $\text{CaCO}_3$ .

$\text{M}_2\text{SO}_4$

$$= \left[ \frac{0.02}{1000} \times \frac{120 \times 50 \times 10^3 \times 10^3}{800} \right]$$

$$= \cancel{\frac{120 \times 50 \times 10^3}{800}}^{30} = 150 \text{ mg/l}$$

alkalinity @ 8.3.  $[(\text{OH}^-) + \frac{1}{2} \text{HCO}_3^{2-}]$  as  $\text{CaCO}_3$

$$= \left[ \frac{0.02}{1000} \times \frac{44 \times 50 \times 10^3 \times 10^3}{800} \right]$$

$$= 55 \text{ mg/l}$$

i) Total Alkalinity as  $\text{CaCO}_3$

$$= 150 - 10^{-10} \times 50 \times 10^3 = 149.9995 \text{ mg/l}$$

ii)  $[\text{H}^+]_{\text{alk}} = 10^{-10} \times 50 \times 10^3 = 5 \times 10^{-6} \text{ mg/l as CaCO}_3$ .

$$[\text{OH}^-]_{\text{alk}} = 10^{-4} \times 50 \times 10^3 = 50 \text{ mg/l as CaCO}_3$$

$$[\text{CO}_3^{2-}]_{\text{alk}} = (55 - 5) 2 = 100 \text{ mg/l as CaCO}_3$$

$$[\text{HCO}_3^-]_{\text{alk}} = 150 - 5 - 100 = 45 \text{ mg/l as CaCO}_3$$

(iii) Phenolphthalein alkalinity  $\{OH^- + \frac{1}{2} CO_3^{2-}\}_{alk} = 55 \text{ mg/l as } CaCO_3$ .

Methyl orange alkalinity  $\left\{ \left( \frac{1}{2} CO_3^{2-} + HCO_3^- \right)_{alk} \right\} = 95 \text{ mg/l } CaCO_3$ .

---

(iv) pH:

- It is a scale in range of (0-14), which is used to indicate acidity or basicity of water sample.

- $pH = -\log_{10} [H^+]$ ;  $pOH = -\log_{10} [OH^-]$ .

$$[H^+] / [OH^-] \text{ in (moles/l)}$$

$$[H^+] [OH^-] = 10^{-14} \rightarrow \text{(i)}$$

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

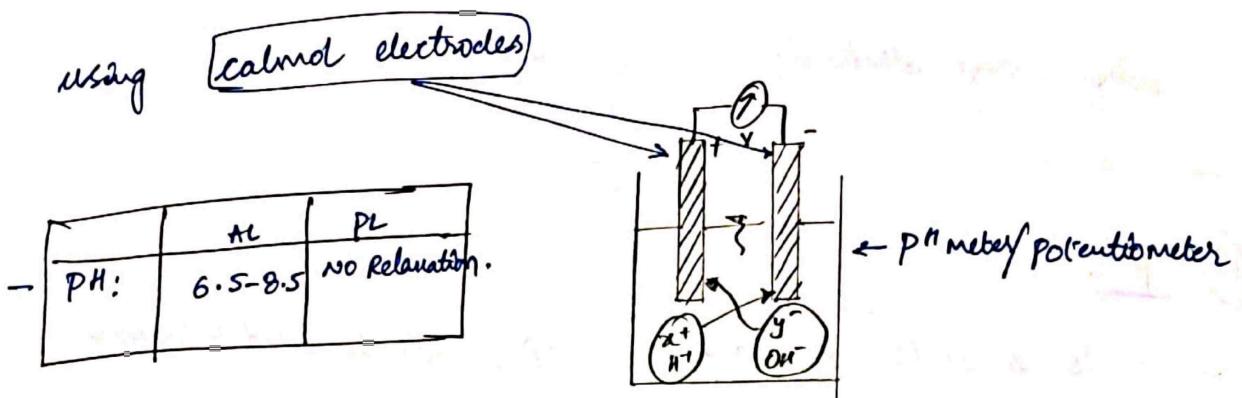
$$\log_{10} [H^+] + \log_{10} [OH^-] = -14$$

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

$$pH + pOH = 14 \rightarrow \text{(ii)}$$

- It can be measured by colour indicators. like methyl orange, phenolphthalein, bromothymol blue  
 $(pH = 6.7 \pm 6)$

- It can also be measured by potentiometer (or) pH meter



Q pH of a waste water from industry A = 4.5, if the conc of  $\text{OH}^-$  in waste water from industry B is 3 times the  $\text{OH}^-$  in waste of industry A. compute pH of waste from industry B?

Sol:-

$$A = 4.5 ; \quad B = ?$$

$$(A) \rightarrow \text{pH} = 14 - (\text{H}^+) + (\text{OH})^{-} = 14 - 4.5 = 9.5$$

$$(\text{OH})^{-} = 9.5 \cdot$$

$$\text{pH}_A = 4.5 , \quad \text{pH}_B = ?$$

$$[\text{OH}]_B = 3 [\text{OH}]_A$$

$$(\text{OH})_A = 14 - 4.5 = 9.5$$

$$[\text{OH}]_A = 10^{-9.5} \text{ mole/lit}$$

$$[\text{OH}_B]_0 = 3 \times 10^{-9.5} \text{ moles/lit}$$

$$\text{pH}_B = -\log_{10} 3 \times 10^{-9.5} = 9.02.$$

$$\text{pH}_B = 14 - 9.02 = 4.98 \text{ moles/lit}$$

Q2 At the start of the plant the pH of water coming into it is ⑥  
after a day it increases to ⑦ due to influent coming into the  
plant from some other source

Compute the time mean pH value over the period of 24 hrs.

(a) Assume  $[\text{H}^+]$  conc varies parabolically

(b) "  $[\text{H}^+]$  conc varies linearly

(c) Assume  $(\text{pH})$  varies linearly.

Soln  $\text{pH}_0 = 6 \rightarrow [\text{H}^+]_0 = 10^{-6} \text{ moles/lit}$

$$\text{pH}_f = 9 \rightarrow [\text{H}^+]_f = 10^{-9} \text{ moles/lit.}$$

(a)  $[\text{H}^+]_{\text{avg}} = [\text{H}^+]_0 - \frac{1}{2} \{ [\text{H}^+]_0 - [\text{H}^+]_f \}$ .

$$= 10^{-6} - \frac{1}{2} \left[ 10^{-6} - 10^{-9} \right].$$

$$= 3.34 \times 10^{-7}$$

$$\text{pH}_{\text{avg}} = -\log_{10} [\text{H}^+]_{\text{avg}} = -\log_{10} (3.34 \times 10^{-7}) = 6.97 \text{ mole/lit}$$

$$\textcircled{b} \quad [\text{H}^+]_{\text{avg}} = \frac{[\text{H}^+]_0 + [\text{H}^+]_f}{2} = \frac{10^{-6} + 10^{-9}}{2} = 5.005 \times 10^{-7}$$

$$p\text{H}_{\text{avg}} = -\log_{10} [\text{H}^+]_{\text{avg}} = 6.3$$

$$\textcircled{c} \quad p\text{H}_{\text{avg}} = \frac{6+9}{2} = 7.5$$

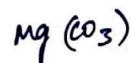
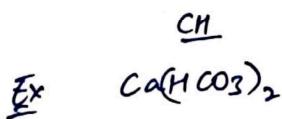
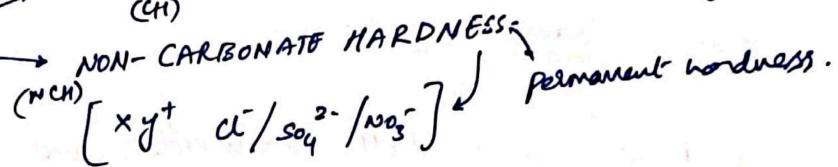
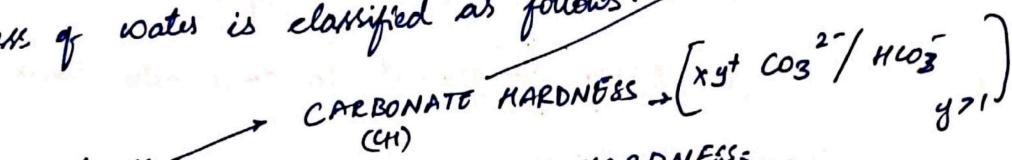
\textcircled{iv) HARDNESS:}

- It is ability of the water to destroy the surfactant property of soap.
- surfactant property of soap is that by virtue of which it form foam/leathes with water.
- It may also be defined as conc. of all the multivalent cations present in water.

Major constituents	minor constituents
$\text{Ca}^{2+}$	$\text{Al}_3^+$
$\text{Mg}^{2+}$	$\text{Fe}^{2+/3+}$
	$\text{Mn}^{2+}$
	$\text{Sn}^{2+}$
	$\text{Pb}^{2+}$
	↓

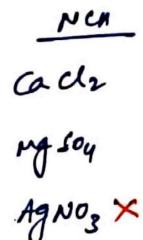
NOTE: UNIVALENT cations are said to impart pseudo hardness  
 in water (B) hypothetical hardness.

- Hardness of water is classified as follows: (a) temporary hardness

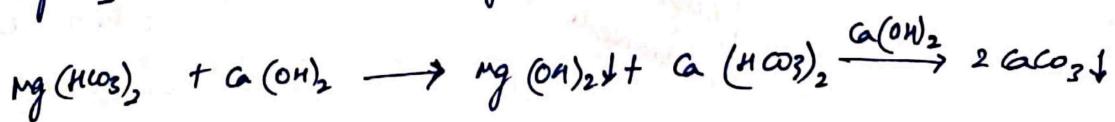
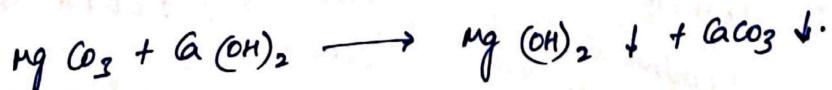
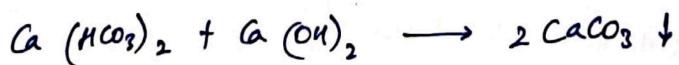


$\text{Na}_2(\text{CO}_3) \times$  — no hardness na it is univalent

$\text{Ca CO}_3 \times$  — precipitate



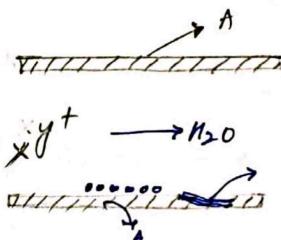
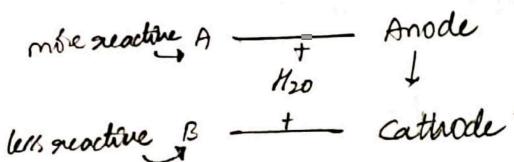
- Carbonate hardness is also termed as temporary hardness as it can be easily remove either by boiling (B) by addition of lime



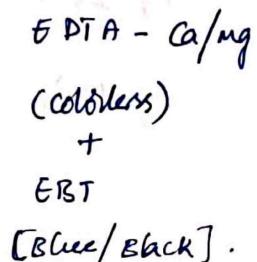
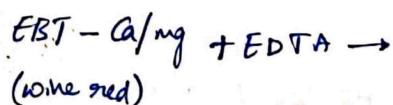
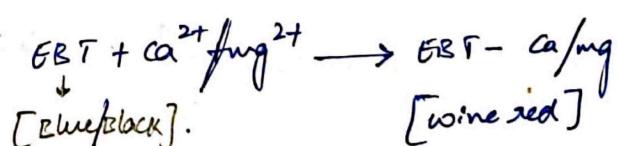
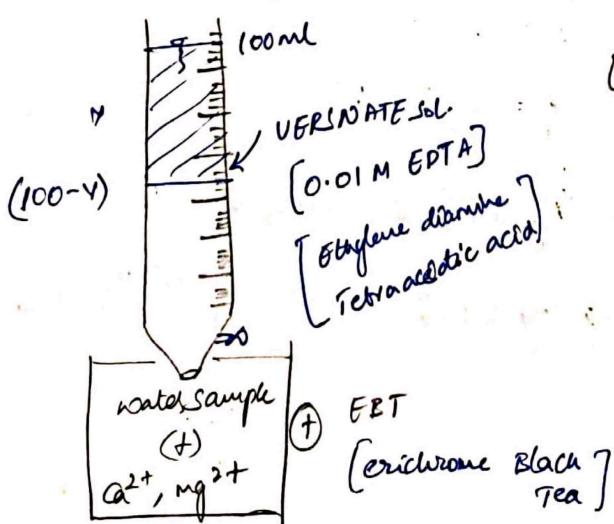
- Hardness in water may be induced due to organic & inorganic solids
- Hardness imparts bad taste in water
- Hardness increases the consumption of soaps.
- Hardness due to MgSO<sub>4</sub> if present in conc more than 50 ppm causes lather effect.
- Hardness causes both incrustation and corrosion in pipes

NOTE!

corrosion



- Hardness of water is measured by titrating it with std. VERSANATE solution using EBT as an indicator.



- Hardness of the water is also reported as equivalents of  $\text{CaCO}_3$ .

Hardness as $\text{CaCO}_3$ (mg/l)	AL	PL
	200	600

NOTE:

① For domestic water supplies water must be in range of 75-115 mg/l

② Degree of Hardness can also be related with the hardness of the water as follows.

Hardness as $\text{CaCO}_3$ (mg/l)	Degree of hardness
0 - 55	soft
56 - 100	slightly hard
101 - 200	moderately hard
201 - 500	very hard

③ Hardness can also be expressed in terms of different units as follows.

ⓐ 1 CLARK DEGREE [ ${}^{\circ}\text{CLARK}$ ] (or) ENGLISH HARDNESS.

$$= 14.254 \text{ mg/l of hardness as } \text{CaCO}_3.$$

ⓑ 1 FRENCH DEGREE ( ${}^{\circ}\text{F}$ ) = 10 mg/l of hardness as  $\text{CaCO}_3$ .

LEC-18

## # HARDNESS & Alkalinity.

$\text{Ca}^{2+}, \text{Mg}^{2+}$	$\text{Na}^+, \text{CO}_3^{2-}, \text{HCO}_3^-$
$\text{CO}_3^{2-}, \text{HCO}_3^-$	

Alkalinity:

① If  $\text{Na}_{\text{alk}}$  {  $\text{Na}_2\text{CO}_3, \text{NaHCO}_3$  } is absent

}

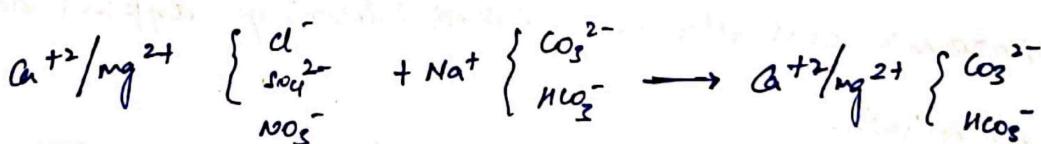
$$\boxed{\text{ALK} = \text{CH}}$$

$$\text{TH} = \text{CH} + \text{NCH}$$

$$\text{TH} = \text{ALK} + \text{NCH}$$

$$\boxed{\text{TH} > \text{ALK.}}$$

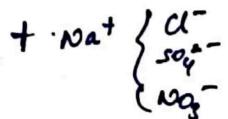
-  $\text{Na}_{\text{alk}}$  is absent from water only if NCH is present.



NCH

Na<sub>alk</sub>

$$\text{Ca/Mg alk} = \text{CH}$$



Na salt.

(ii) If  $\text{Na}_{\text{ALK}}$  { $\text{Na}_2\text{CO}_3$ ,  $\text{NaHCO}_3$ } is present

$$\rightarrow \text{NCH} = \text{O}$$

$$\text{TH} = \text{CH} + \text{NCH}^{\bullet}$$

$$\boxed{\text{TH} = \text{CH} \cdot}$$

$$\boxed{\text{ALK} > \text{CH} \cdot} ; \quad \boxed{\text{ALK} > \text{TH} \cdot}$$

From (i) & (ii)

$$\boxed{(\text{TH}, \text{ALK})_{\min} = \text{CH} \cdot}$$

Q A 200 ml water sample contains following constituents.

Report the hardness of the water as  $\text{CaCO}_3$  (mg/l).

$\text{Ca}^{2+}$	—	120
$\text{Mg}^{2+}$	—	96
$\text{Al}^{3+}$	—	27

Sol: — TH as  $\text{CaCO}_3 = \left[ \frac{120}{20} + \frac{96}{12} + \frac{27}{9} \right] \times 50 \times 10^3 \times \frac{1000}{200}$ .

$$= 4.25 \times 10^6 \text{ (mg/l)}.$$

Q<sub>2</sub> Find the carbonate hardness, NCH and Alkalinity of given

water sample  
(mg/l)

- Ca<sup>2+</sup> 40

- Mg<sup>2+</sup> 48

- Na<sup>+</sup> 46

- Al<sup>3+</sup> 18

HCO<sub>3</sub><sup>-</sup> 244

SO<sub>4</sub><sup>2-</sup> 96

NO<sub>3</sub><sup>-</sup> 103

pH = 7

Sol:- TH =  $\left[ \frac{40}{20} + \frac{48}{12} + \frac{18}{9} \right] \times 50 = 400 \text{ mg/l as CaCO}_3$

~~Ans~~

$$\text{pH} = 7 \Rightarrow [\text{H}^+]_{\text{alk}} = 10^{-7} \text{ moles/lit.}$$

$$= 10^{-7} \text{ gm/lit.}$$

$$[\text{H}^+] = 10^{-7} \text{ gm-equiv/lit}$$

$$\text{pOH}_{27} \Rightarrow [\text{OH}^-] = 10^{-7} \text{ moles/lit} = 10^{-7} \times 17 \text{ gm/l}$$

$$[\text{OH}^-] = 10^{-7} \text{ gm-equiv/lit}$$

$$ALK = \left[ \frac{244}{61} + 10^{-7} \times 10^3 - 10^{-7} \times 10^3 \right] \times 50$$

$$ALK = 200 \text{ mg/l as } \text{CaCO}_3$$

$$(TH, ALK)_{\min} = CH = 200 \text{ mg/l as } \text{CaCO}_3$$

$$NCH = TH - CH = 400 - 200 = 200 \text{ mg/l as } \text{CaCO}_3$$

Q.3 Find the NCH for given sample of the water.

meq/l	0	2	4.5	5	7	10
meq/l	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	Al <sup>3+</sup>	K <sup>+</sup>	
meq/l	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Cl <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	CO <sub>3</sub> <sup>2-</sup>	
0	1.5	4.8	4.9	7.5	10	

Sol:-  $TH = 2 + 2.5 + 2 = 6.5 \text{ meq/l}$

$$ALK = 1.5 + 2.5 = 4 \text{ meq/l}$$

$$(TH, ALK)_{\min} = CH = 4.$$

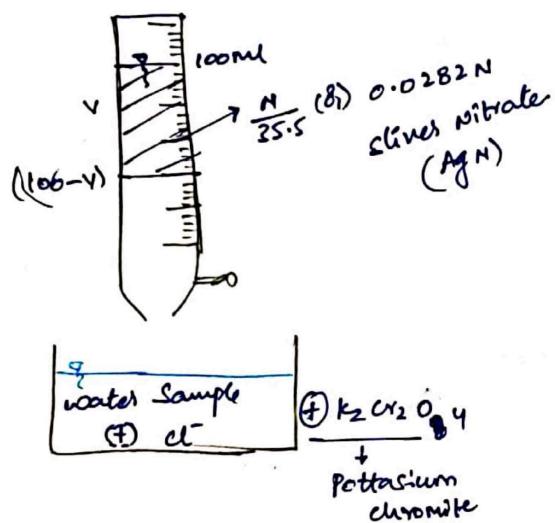
$$NCH = TH - CH = 6.5 - 4 = 2.5 \text{ meq/l}$$

$$= 2.5 \times 50$$

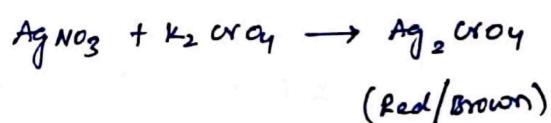
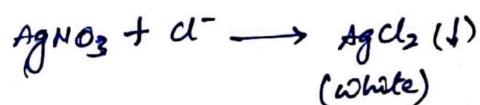
$$= 125 \text{ mg/l as } \text{CaCO}_3$$

## (IV) CHLORIDE CONTENT:

- Presence of chloride in excess in water indicates its pollution due to sewage and industrial waste
- Excess of chloride in water causes hypertension
- It impacts HEART & KIDNEY in excess
- It is measured by titration [MORRIS METHOD].



	AL	PL
Chloride (mg/l)	250	1000



## (V) FLUORIDE CONTENT:

- Fluoride upto 1 mg/l is required to be present in water as it helps in growth of permanent teeth by combining with tooth enamel and making it strong and hard
- This fluoride also helps in to prevent dental cavities

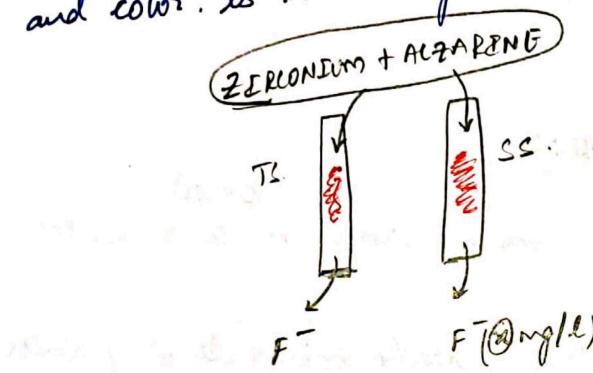
- fluoride beyond 1.5 mg/l causes decolorisation of teeth and mottling of.

and results in disease termed as "FLUOROSIS".

- fluoride beyond single causes chemical deformation of bones and leads to "bone fluorosis".

	AC	PL
Fluoride (mg/l)	1	1.5

- fluoride is measured in water using color matching technique and color is induced by the addition of ZIRCONIUM (f) ALAZARINE.

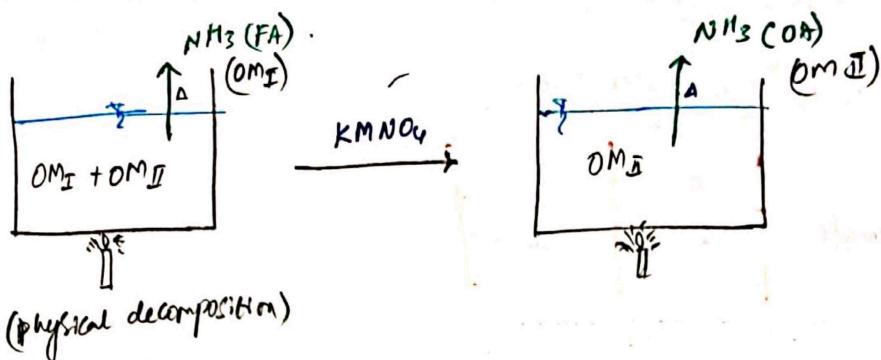


### (vii) NITROGEN CONTENT:

- presence of nitrogen in water in excess indicates its pollution due to organic matter.
- Nitrogen is found in water in different forms
  - ① FREE Ammonia
- presence of free ammonia indicates its recent pollution

due to organic matter. ( $OM_2$ )

- It is determined by simply boiling the water and noting the amount of ammonia gas liberated



	AL	PL
Free Ammonia (mg/l)	0.15	no separation

### (b) ORGANIC AMMONIA / ALBUMINODOL:

- It signifies the presence of complex organic matters in water
- It is determined by boiling the already boiled sample of water with the addition of potassium permanganate ( $KMNO_4$ ) and noting the amount of ammonia gas liberated

**NOTE:** Free ammonia & organic ammonia taken together is termed as "KJELDHAL'S AMMONIA"

- |                           |     |               |
|---------------------------|-----|---------------|
| organic Ammonia<br>(mg/l) | AL  | PL            |
|                           | 0.3 | NO Relaxation |

② NITRITE ( $\text{NO}_2^-$ ):

- Presence of  $\text{NO}_2^-$  in water is highly dangerous. as it indicates the partial decomposition of organic matter, hence indicates the presence of micro-organisms in water.

- |                           |    |    |
|---------------------------|----|----|
| $\text{NO}_2^-$<br>(mg/l) | AL | PL |
|                           | 0  | 0  |

- It is determined by color matching technique and color is induced by addition of SULPHONIC ACID and NAPHTHAMINE

③ NITRATE ( $\text{NO}_3^-$ ):

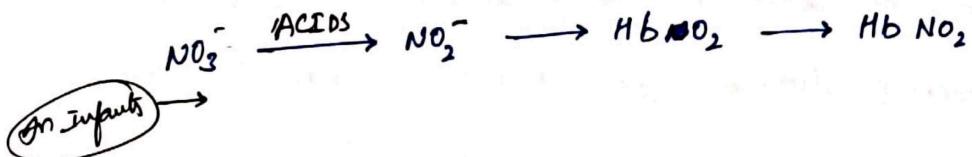
- presence of nitrate is not harmful, as it signifies complete decomposition of OM. which intern represents the removal of micro-organisms by the process termed as

"ENDOGENOUS RESPIRATION"

- |                         |    |    |
|-------------------------|----|----|
| $\text{NO}_3^-$<br>mg/l | AL | PL |
| 45                      |    | -  |

- if it is found in conc more than 45 mg/l, it effects INFANTS & results in disease termed as

**"MATHEMOGLOBINEMIA / BLUE BABY DISEASE."**



- It is determined by color matching technique and color is induced by "PHENOL-DI-SULPHONIC ACID (+) KOH".

LFC-19

[atm -  $\text{N}_2 = 78$ ;  $\text{O}_2 = 21$ ; others  $< 1\%$ ]

### Viii) Gases:

$\text{CO}_2$ : It adds taste & odour <sup>to</sup> makes water corrosive

$\text{H}_2\text{S}$ : It gives rotten egg/pungent smell in water

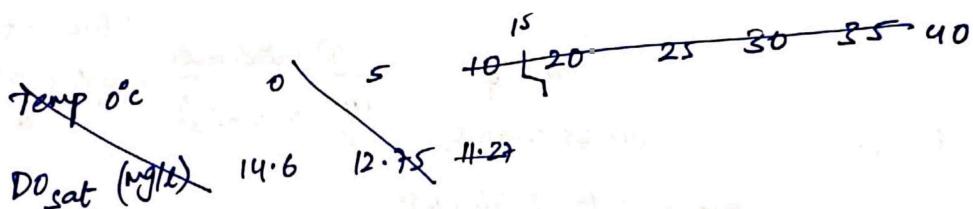
$\text{NH}_3$ : It gives info about organic matter

$\text{O}_2$ :

$\text{CH}_4$ : It is an explosive gas.

- All these gases indicates the presence of OM in water
- $\text{CO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{CH}_4$ ,  $\text{NH}_3$  is formed during decomposition of OM; whereas  $\text{O}_2$  is consumed during decomposition of OM

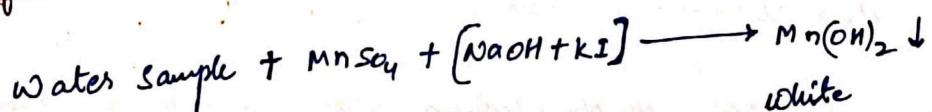
- Deficiency of  $O_2$  in water w.r.t saturated dissolved  $O_2$  (DO) indicates the presence of OM in water.
- max  $O_2$  which may be dissolved in water at any given temp is termed as saturated dissolved  $O_2$ .
- NOTE: solubility of  $O_2$  in water is inversely dependent upon temperature as per HENRY'S LAW.



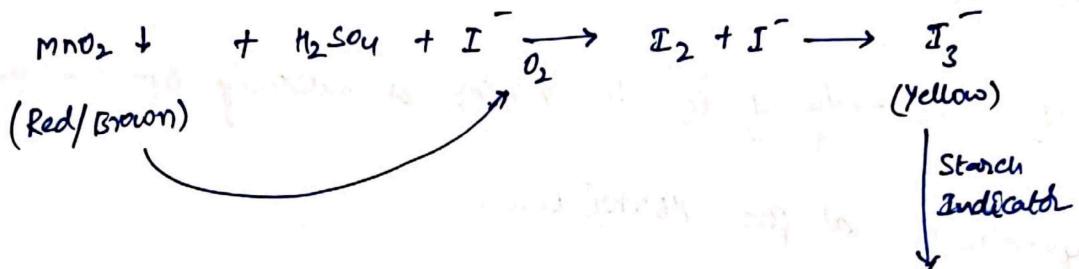
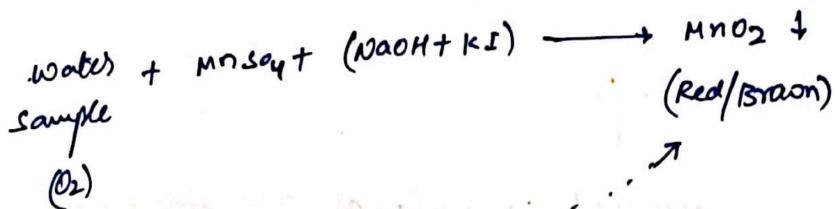
Temp $^{\circ}\text{C}$	0	5	10	15	20	25	30	35	40
$\text{DO}_{\text{sat}} \text{ (mg/l)}$	14.6	12.75	11.27	10.07	9.07	8.24	7.54	6.93	6.41

- minimum  $O_2$  required for survival of fish is 4 ppm.
- DO in water is determined by performing WINKLER'S TEST as follows.

② if DO is absent:



(b) If DO is present



Blue coloured  
couple solution

$V(mL)$  of  
 $0.025\text{ N } Na_2S_2O_3$       Titrated with  
 $(\frac{N}{40} Na_2S_2O_3)$

required to decolorise  
the sample

$$DO(\text{mg}) = \frac{V \times 0.025}{1000} \times 8 \times 10^3 \text{ mg} = 0.2 V$$

mono oxygen.

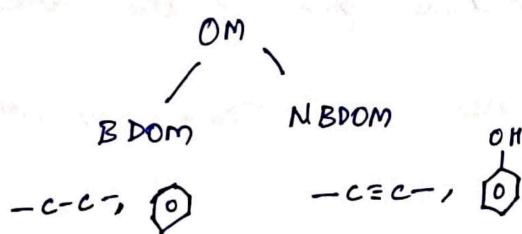
NOTE:

- If water sample consists of other oxidising agent like ( $NO_3^-$ ), they also oxidise  $I^- \rightarrow I_2$  resulting in reporting of more DO than actual.
- In such case  $Na_2S_2O_3$  (sodium thiosulfate) which is strong

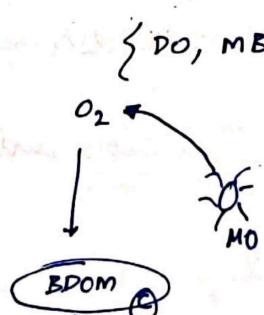
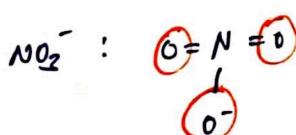
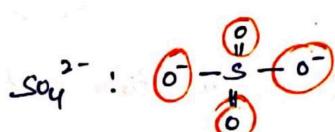
reducing reagent is also added along with ( $\text{NaOH} + \text{KI}$ ) to reduce the effect of other oxidising reagent & the test is termed as 'modified WINKLER'S TEST'.

### (III) BIOLOGICAL WATER QUALITY PARAMETERS!

- micro organisms are present in water due to the presence of OM in it
- these organic are further classified into
  - Bio-Degradable organic matter (BDOM)
  - Non Bio-degradable OM. (NBDOM)



MBO { molecular bonded oxygen }

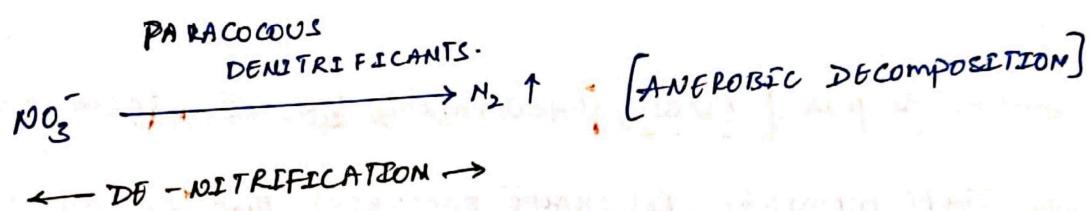
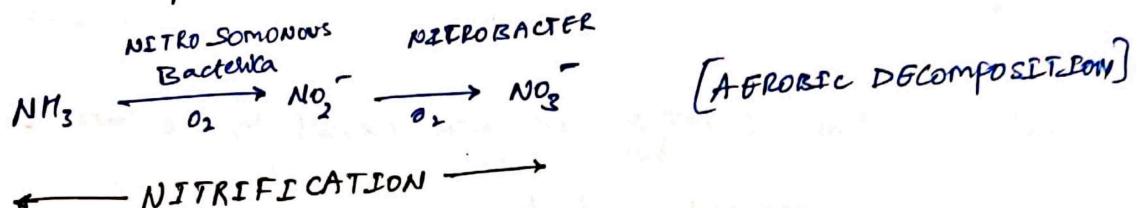


$$\text{BIOMASS.} = \left\{ \begin{array}{l} \text{CO}_2^-, \text{NO}_3^-, \text{SO}_4^{2-} (\text{DO}) \\ + \\ \text{Acids, ALCOHOLS, GASES (MBO)} \end{array} \right.$$

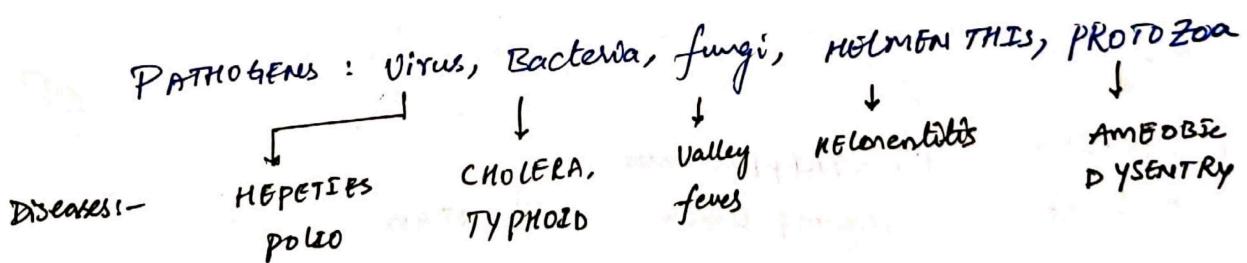
- BDOM is that which can be decomposed by the action of MD & NBDOM is that which cannot be decomposed (B)  
require more time for its decomposition by MD
- If this decomposition takes place in the presence of  $O_2$ , it is termed as AEROBIC Decomposition and is being carried out by the action of AEROBIC MD.
- End product of AEROBIC Decomposition is comparatively stable and includes  $CO_3^{2-}$ ,  $NO_3^-$ ,  $SO_4^{2-}$ ,  $PO_4^{3-}$
- If same decomposition takes place in the absence of  $O_2$  (B) or in the presence of MBO, it is termed as ANEROBIC DECOMPOSITION.
- End product of anaerobic decomposition is unstable and it includes acids, alcohols and gases ( $CO_2$ ,  $CH_4$ ,  $H_2S$ ,  $NH_3$ )
- Anaerobic MD utilizes MBO which requires both time and energy, hence its rate is ③ times less than rate of aerobic decomposition

- There are certain types of MO which connect both in presence and absence of  $O_2$  and are termed as FACULTATIVE MO

- For Example:



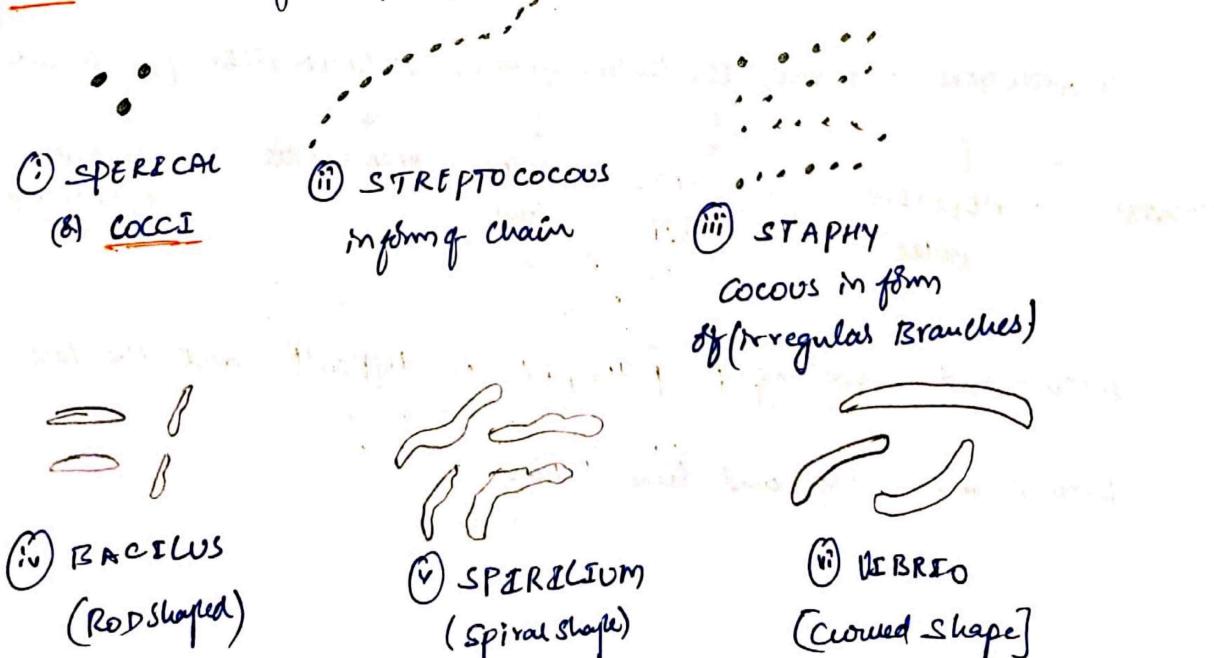
- The most important type of MO in water are those which are capable of carrying out diseases to us and are termed as pathogens.



- Testing and counting of pathogens is difficult and the test involved are costly and time taking

- Hence instead of testing pathogens, coliforms are being tested which themselves are harmless micro-organisms but their presence & absence, indicate the presence & absence of pathogens in water.
- coliforms like E-coli & B-coli are present in the intestines of all warm blooded animals.
- Coliform group is **AEROBIC**, **FACULTATIVE**, **ANEROBIC**, **GRAM-NEGATIVE**, **NON SPORE FORMING**, **ROD SHAPED BACTERIA** that **FERMENT LACTOSE** with gas formation within 48 hrs at 35°C and they are **non ACID FAST** organisms.

**NOTE:** Following shapes of M.O. are observed



NOTE!

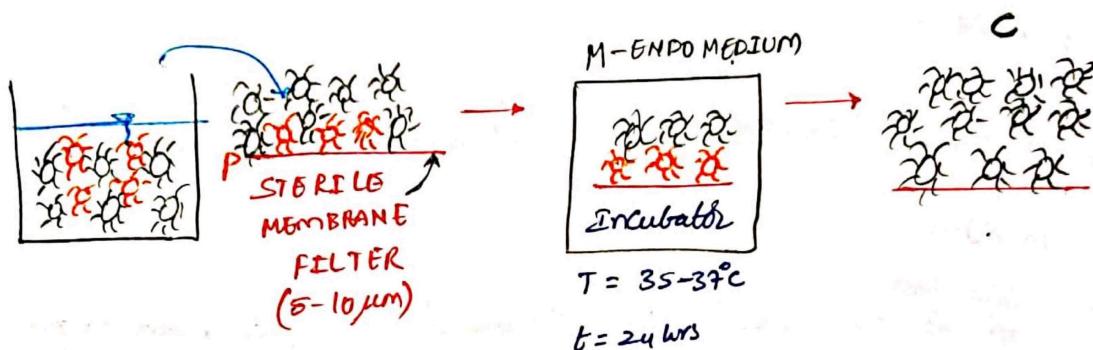
- ① If in staining technique bacteria gives red strain it is termed as Gram negative & if it gives blue strain it is termed as Gram positive.
- ② A spore is a non-vegetative state resistant to temp, water & acid.
- ③ Ferment lactose species will grow pink colonies in acidic medium.
- ④ ~~It is~~ ACID FAST is also one of the staining technique. An organism is termed as ACID FAST if it resists de-staining with alcho & acid.

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## # TESTING OF COLIFORMS:

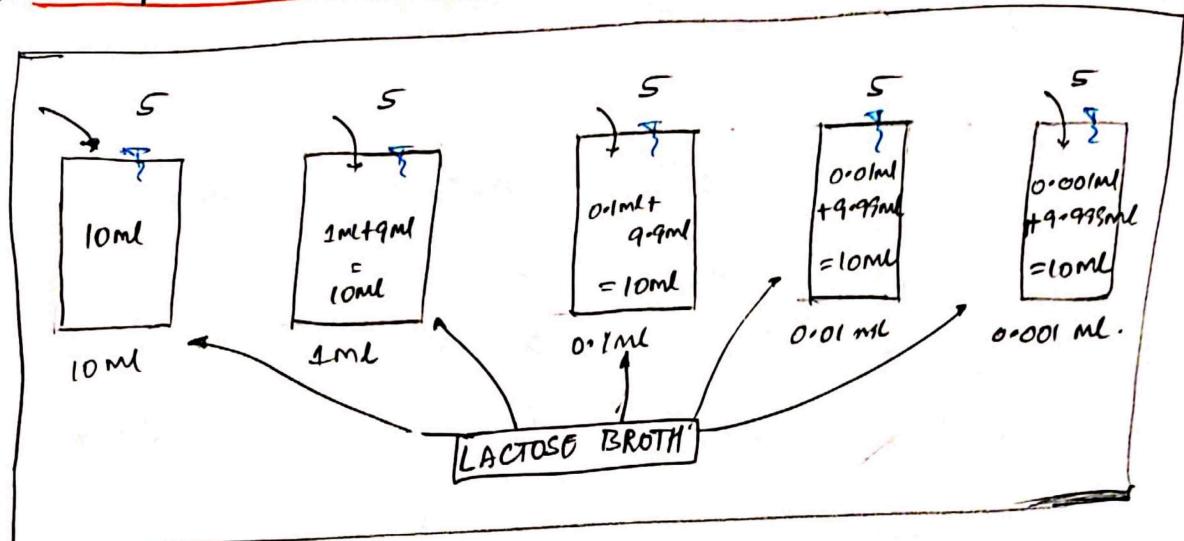
- Testing of coliforms can be done by any of the following methods.

### (i) MEMBRANE FILTER TECHNIQUE:



- In this process water sample to be tested is passed through the sterile membrane filter size of voids in which (5-10 $\mu$ m) which retains the MO over it
- These MO are then placed in incubator at standard conditions and the presence of the coliforms after incubation is noted and is further linked with that of pathogens originally present in the water.

## (i) MOST PROBABLE NUMBER (MPN) TEST

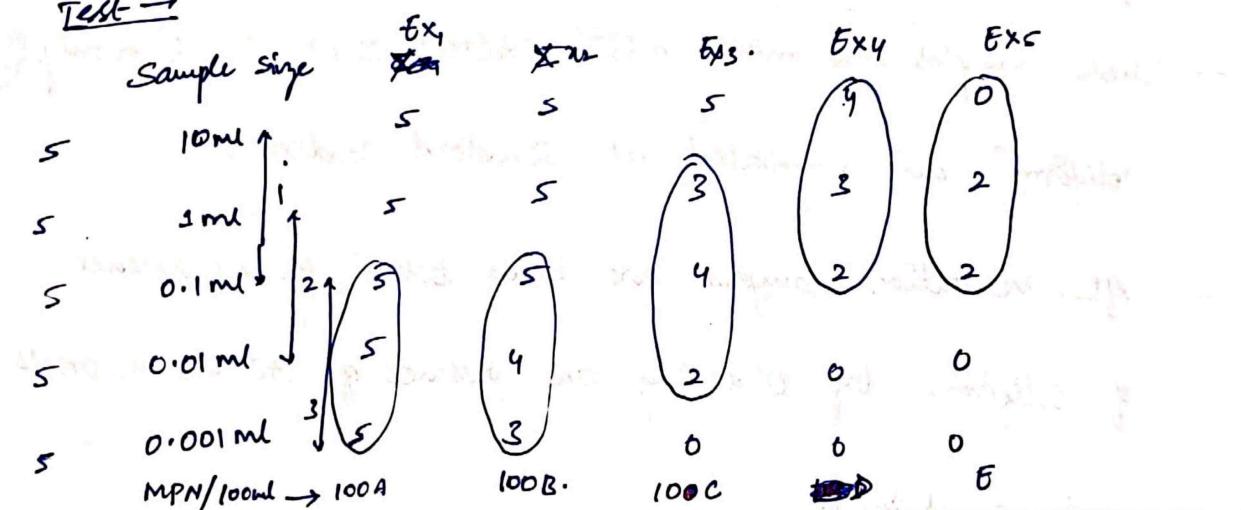


INCUBATOR

$$T = 35-37^\circ\text{C}$$

$$t = 48 \text{ hrs.}$$

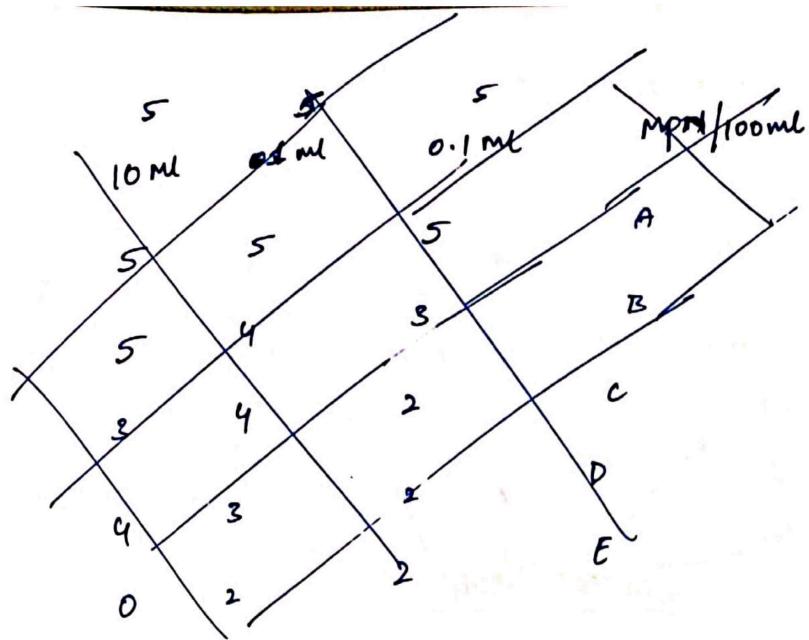
Test →



Calibration → microbial density.

10 mL      1 mL      0.1 mL      MPN / 100 mL

	A	B	C	D	E
5	5	3	2	0	2
5	4	2	1	2	2
3	4	2	1	1	1
4	3	2	1	1	1
0	0	0	0	0	0



- It is multiple tube fermentation test, having water samples of different dilution ratios.
- These samples are mixed with LACTOSE BROTH [food for only coliform] and incubated at standard condition
- After incubation samples are being tested for the presence of coliforms by observing the presence of ACIDS, ALCOHOLS and gases in it
- The result of coliform obtained is then further calibrated with those of pathogens in water and is reported in terms of mpn/100ml which represents the microbial density.

that is most likely to be present in water.

### NOTE:

MPN value can also be computed empirically by

### THOMAS EQUATION.

$$\text{MPN}/100\text{ml} = \frac{\text{no. of positive tubes} \times 100}{\sqrt{\text{ml. of sample in negative tube}}}$$

(x) ml. of sample in all tubes.

Q Sample size (ml)      No. of positive tubes      No. of negative tubes.

10	(1)	4
1	(2)	2
0.1		1
0.01		0

MPN table is as follows:

Combination of (ml)s.			MPN/100 ml
10 ml	1 ml	0.1 ml	
5	4	3	280
4	3	1	23
4	2	1	26
2	1	0	7

Soln find MPN/100ml?

solt (i)  $\text{MPN}/100\text{ml} = 26$  from MPN table

(ii) 
$$\text{MPN}/100\text{ml} = \frac{7 \times 100}{\sqrt{(10 \times 1 + 3 \times 1 + 4 \times 0.1 + 5 \times 0.01) \times [5(10 + 1 + 0.1 + 0.01)]}}$$
  
 $= \frac{700}{\underline{800}} = 25.62 \approx 26.$

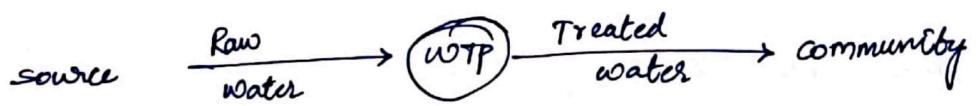
### (iii) COLIFORM INDEX TEST (CI)

- In general terms it is not the method of testing of coliform, it is simply a method to report the presence of coliforms in water in terms of the parameter coliform index that signifies ~~the presence of~~ the reciprocal of smallest quantity of sample in which coliform is present.

V (ml)	CI	Pathogens
10	0.1	A
0.01	100	B
1	1	C
0.1	10	D

~~Note~~  
NOTE: Both MPN Test and Coliform Test are obsolete

## Ch. IV TREATMENT OF WATER.



- Treatment of water depends upon quality of raw water and desired quality of treated water. [which in turn depends upon use of water]

- Treatment of the water can be done by any of following methods.

- |                   |                   |                      |
|-------------------|-------------------|----------------------|
| (a) screening     | (f) Filtration    | (k) De-fluoridation  |
| (b) Aeration      | (g) Disinfection  | (l) De- fluorination |
| (c) Coagulation   | (h) softening     |                      |
| (d) flocculation  | (i) de-salination |                      |
| (e) Sedimentation | (j) Fluoridation  |                      |

### (A) SCREENING:

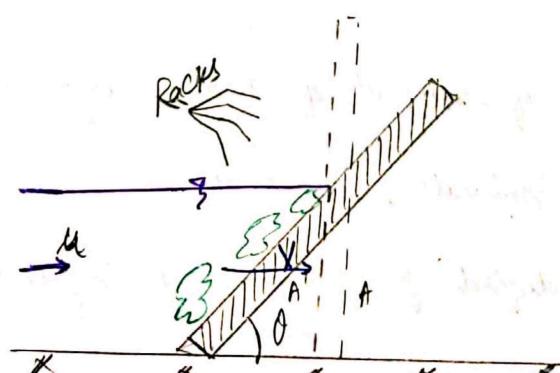
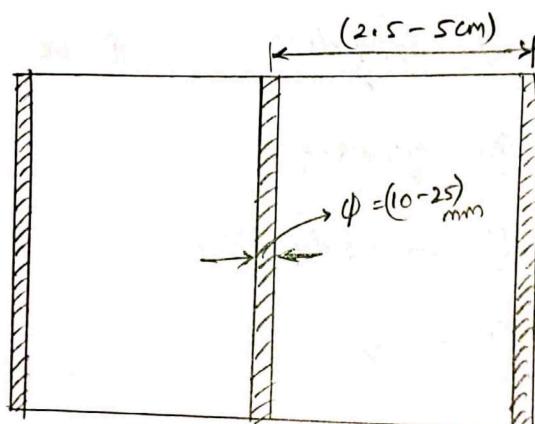
- It is the process of removal of heavy solids from the water like plants, trees, animals, stones etc
- It is generally adopted for treatment of surface water as ground water is free from heavy solids.

- ~~This~~ This treatment is generally carried out in intake structures
- It is done with the help of units termed as screens, which are broadly classified as follows:

① Coarse screen      ② Fine screen

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### ① COARSE SCREEN / BAR SCREEN / TRASH RACK:



$$A' = \frac{A}{\sin \theta}$$

$$\sin \theta < 1$$

$$A' > A$$

- These screens are in the form of bars of dia (10-25mm) and having the spacing of (2.5-5cm) between them [can extend upto to 10cm].
- These screens are always placed at an inclination of ( $45^{\circ}$ - $60^{\circ}$ ) as it helps in effective cleaning of the screens by Packing mechanism.

(b) Increase in efficiency of screening process by increasing the area through which water flows. [ $A' > A$ ].

- when water passes through the screen loss in its head takes place, which is given by

$$h_L = \frac{K}{2g} (v^2 - u^2)$$

v - velocity through screen

$$\frac{K}{2g} = 0.0729$$

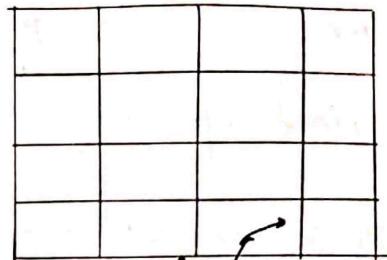
u - velocity of approach

$$h_L = 0.0729 (v^2 - u^2)$$

- while designing the screens, clear opening should ~~not~~ have sufficient total area, such that velocity through the screen is not more than (0.8-1m/sec)

### ii) FINE SCREEN!

- These screens are in the form of wire mesh of size approx 6mm [Can go upto 10 mm].
- Under normal treatment condition fine screens are avoided and fine suspended particles are removed in following sedimentation and filtration processes, as these screens get frequently choked requiring frequent cleaning, which increases their operational cost.



Q A trash screen is provided for treatment of  $50000 \text{ m}^3/\text{day}$  of raw water. velocity through the screen is maintained at  $3 \text{ m/sec}$ . Size of the bar is  $20\text{mm}$  and clear spacing is  $50\text{mm}$ .

Compute (i) Head loss through the screen

(ii) net and gross area of the screen

(iii) If half of screen is clogged due to leaves & debries then compute the head loss through the screen

any  
Assume ↑ data not given?

Soln

$$Q_0 = 50000 \text{ m}^3/\text{sec}$$

$$V = 4 \text{ m/sec}$$

$A_n$  - net area.

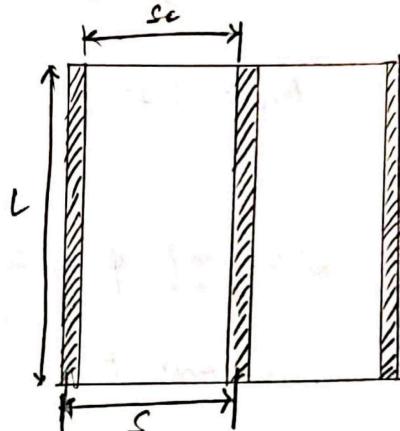
$A_T$  - ~~gross~~ area  $\frac{\text{TOT}}{\text{TOT}}$

$$A_n = \frac{Q_0}{V} = \frac{50,000}{1 \times 86400} = 0.578 \text{ m}^2$$

$$A_n = s_c \cdot L \cdot n = 0.578$$

$$A_T = s \cdot L \cdot n = \frac{s}{s_c} \cdot (0.578)$$

$$A_T = \frac{(s_0 + \frac{20}{2} \times 2) \times 0.578}{s_0}$$



$$A_T = 0.809 \text{ m}^2$$

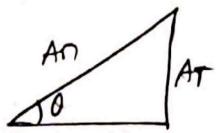
$$h_L = V^2 - u^2 (0.0729).$$

$$Q = A_T u = A_n \cdot V$$

$$u = \frac{A_n V}{A_T} = \frac{0.578 (1)}{0.809} = 0.714 \text{ m/sec.}$$

$$h_L = 0.0729 (1^2 - 0.714^2) = 0.035 \text{ m.}$$

(ii)  $AH = 0.578 \text{ m}^2$



Assume,  $\theta = 45^\circ$

$$AG = \frac{AT}{\sin 45^\circ}$$

$$= \frac{0.809}{\sin 45^\circ}$$

$$AG = 1.24 \text{ m}^2$$

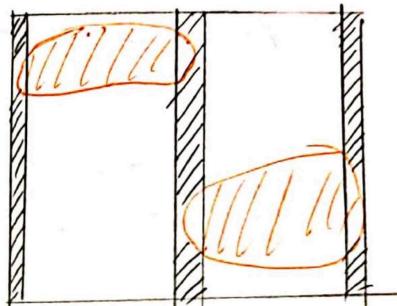
(iii) When half of screen is clogged

$$AT = \text{constant}$$

$$V = \text{constant} = 0.714 \text{ m/sec}$$

$$\text{but } AH = \frac{A_1}{2} \Rightarrow V' = 2V = 2(1) = 2 \text{ m/sec.}$$

$$h_L' = 0.0729 (2^2 - 0.714^2) = 0.254 \text{ m.}$$



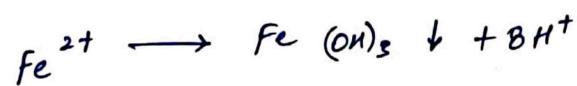
### (B) AERATION:

- It is the process in which water is brought in contact with air, so as to allow the absorption of oxygen ( $O_2$ ) through it, so as to carry out the removal of following dissolved solids from the water

(a) It removes dissolved gases from the water like



(b) It removes dissolved minerals from water e.g. Fe, Mn.



(c) It removes volatile liquid like phenol and humic acid from water

- Aeration is done for the water which is devoided of oxygen

Ex waters at bottoms of lakes and ground waters.

NOTE: It is taken proper care that over aeration of the water does not takes place, as it would ~~lead to make~~ ~~corrode~~ the water corrosive

- In such case De-Aeration is to be carried out

- Aerated

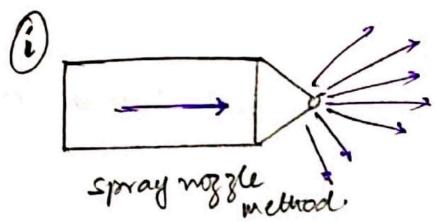
- Aeration can be done by any of following methods -

(i) spray nozzle method

(ii) Cascade aerator

(iii) Tray tower

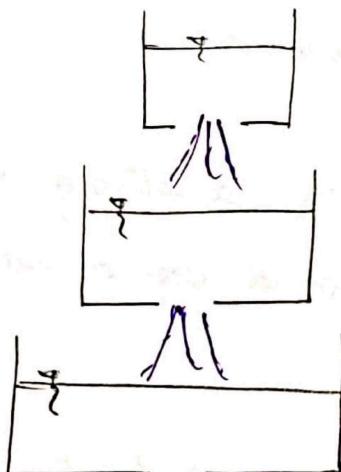
(iv) Diffused air method.



$$(\eta_{CO_2} = 90\%) \quad (h = 10-14M)$$

spray nozzle method.

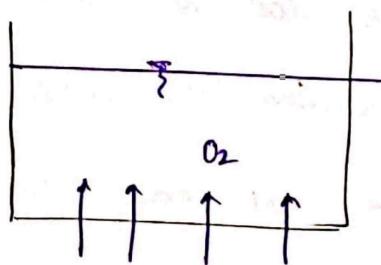
(ii)



$$[\eta_{O_2} \uparrow, \eta_{CO_2} = 60-70\%]$$

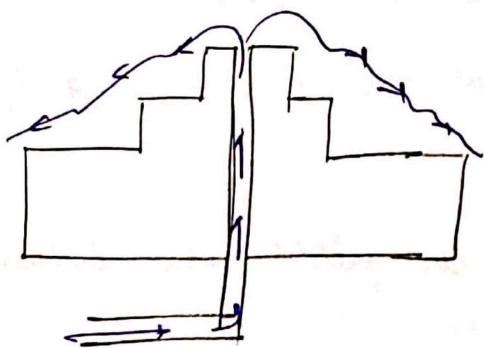
Tray tower

(iii)



Diffused air method

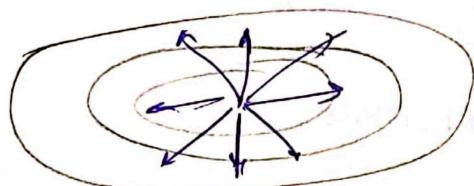
(ii)



Gas bubble aeration

$$\eta_{O_2} \uparrow$$

$$\eta_{CO_2} \approx (60-70\%)$$



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(iii) SEDIMENTATION:

- It is the process of removal of suspended particles from the water.
- The entire theory of sedimentation is based upon a single parameter termed as sp. gravity.

$$g = \frac{\text{wt. g solid of given volume}}{\text{wt. g std. fluid of same volume}} = \frac{\omega_s}{\omega_w} = \frac{\omega_s}{V_s} \frac{V_s}{\omega_w}$$

$\downarrow$   
water

$$(V_s = V_w)$$

$$G = \frac{\omega_s}{V_s} \frac{V_w}{\omega_w} = \frac{\rho_s}{\rho_w} = \frac{\rho_s}{\rho_w}$$

$$G = \frac{\rho_s}{\rho_w} = \frac{\rho_s}{\rho_w}$$

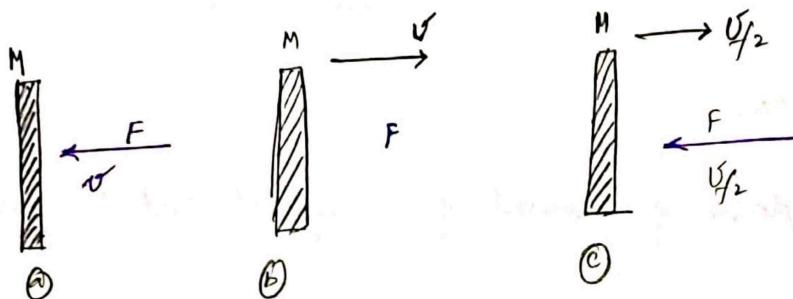
$$G > 1 \quad \left\{ \begin{array}{l} \text{for organic solids } g = e(-2) [1.2] \\ \text{for inorganic solids } g = e^{-2.6-2.9} [2.65]. \end{array} \right.$$

$f_s > f_w$

- During sedimentation all the factors which opposes the tendency of settlement are taken proper care of.

### i) VELOCITY OF WATER/TURBULANCE ( $v_f$ ): (↓)

ii)



M - medium

F - fluid

v - velocity

Viscosity ( $\mu$ ) ↓

### iii) Size of the particle (d)

$$F_B = f(d)$$

$$F_D = f(d)$$

$$= \frac{1}{2} c_D \rho_w V_r^2$$

$$w = f(d)$$

$$V_r = V_p - V_w$$

$d_1 > d_2$

$V_{S1}$

$V_{S2}$

$w - \text{self wt}$

$F_B = \text{Buoyant force}$

$F_D = \text{Drag force}$

## # STOKE'S LAW :

Assumptions:

- Particle undergoing settlement is spherical.
- medium in which settlement takes place is infinite
- During sedimentation discrete settling takes place

$$\text{for } v_p = v_s \Rightarrow a_p = 0$$

$v_p$  - vel of particle

$v_s$  - settling vel.

$$\sum F_y = 0$$

$a_p$  - acc of particle

$$\omega = F_B - F_D = 0$$

$$\omega = F_B = F_D$$

$\beta_w$  = buoyant wt

$$\therefore \beta_w = F_D$$

$$\omega = v_s \beta_s$$

$$v_s \beta_s - v_w \beta_w = F_D$$

$$[v_w = v_s]$$

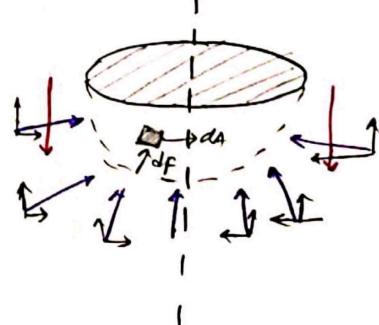
$\frac{\text{vol.}}{\text{vol. of solid}} \beta_s$

$$v_s \beta_s - v_w \beta_w = \frac{1}{2} C_D \cdot \rho_w \cdot A \cdot (v_s)^2$$

$$v_s \beta_w \left[ \frac{\rho_s}{\rho_w} - 1 \right] = \frac{1}{2} C_D \cdot \rho_w \cdot A (v_s)^2$$

$$\frac{\pi d^2}{6} \beta_w [g - 1] = \frac{1}{2} C_D \cdot \rho_w \cdot \left( \frac{\pi d^2}{4} \right) \cdot (v_s)^2$$

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



(i) For LAMINAR FLOW CONDITION:

$$\left[ \frac{(d < 0.1 \text{ mm}) / Re < 1 \text{ (or) } 0.5}{(or)} \right]$$

$$C_D = \frac{24}{Re}, \quad Re = \frac{\rho \cdot v_s \cdot d}{\mu}$$

$$(8) \quad v_s = \frac{(g-1) \cdot g \cdot d^2}{18 \mu}$$

$$v_s = 418 (g-1) d^2 \left[ \frac{3T + 70}{100} \right] \quad \begin{array}{l} \text{mm} \\ \text{mm/sec} \end{array} \quad \begin{array}{l} {}^{\circ}\text{C} \end{array}$$

(ii) For TRANSITION FLOW CONDITION:

$$\left[ 0.1 \text{ mm} < d < 1 \text{ mm} / 1 < Re < 10^4 \text{ or } 10^3 \right].$$

$$C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34, \quad Re = \frac{\rho \cdot v_s \cdot d}{\mu}$$

$$(8) \quad v_s = 418 (g-1) d \left( \frac{3T + 70}{100} \right) \quad \begin{array}{l} \text{mm} \\ \text{mm/sec} \end{array} \quad \begin{array}{l} {}^{\circ}\text{C} \end{array}$$

(iii) For TURBULENT FLOW CONDITION:

$$\left[ d > 1 \text{ mm} / Re > 10^4 / 10^3 \right].$$

$$C_D = 0.4$$

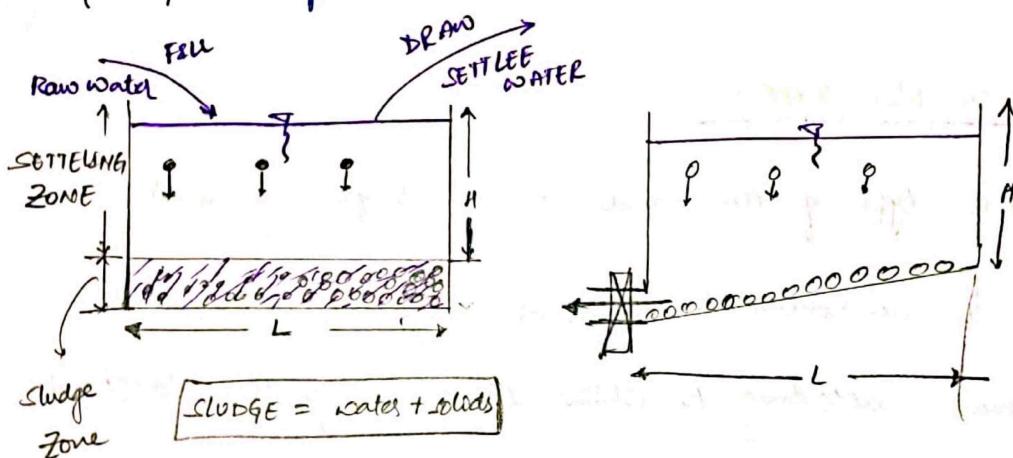
$$v_s = 1.8 \sqrt{(g-1) g d} \rightarrow [\text{As per Newton's law}]$$

NOTE: Stoke's law is not applicable for Turbulent flow

# Sedimentation is carried out in units termed as sedimentation tank which are broadly classified into two.

(A) QUIESCENT / FIXED / FILL & DRAW TYPE TANK:

(static/stationary)



- In these tanks raw water is filled and is allowed to undergo settlement for 24 hrs during which suspended particles are collected at the bottom of the tank leading to the formation of sludge and settled water is drawn out for the next treatment
- Detention time of the tank  $D_t = 24 \text{ hrs.}$

$$D_f = 24 \text{ hrs.}$$

- cleaning period 6-12 hrs.
- minimum of 2-tanks are required for operation.
- minimum of 3 tanks are provided total
  - (1) Standby can also be provided

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### (i) CONTINUOUS FLOW TYPE :

- It is one type of the tank in which flow of water is maintained to be continuous either in horizontal plane (B) or vertical plane according to which these are further classified as

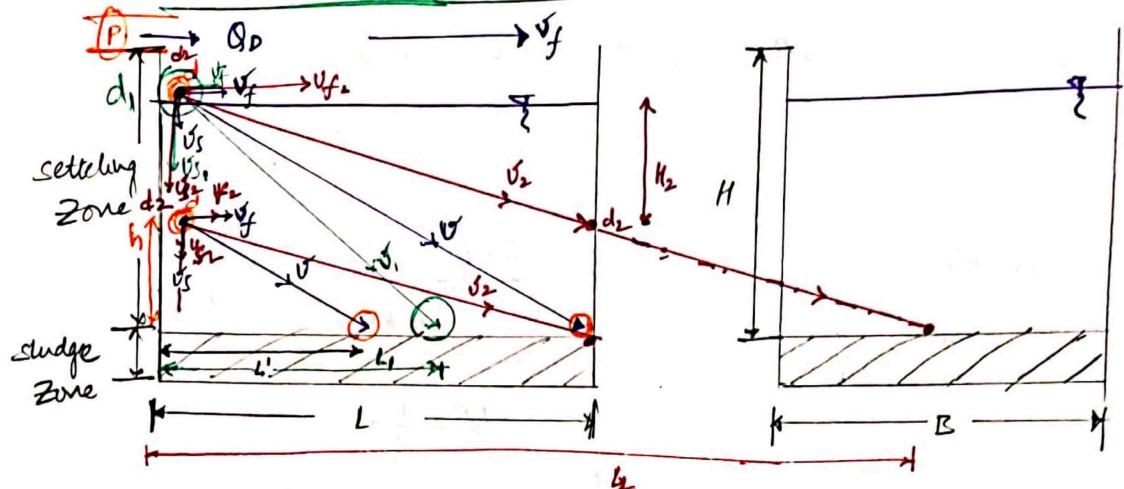
(a) Horizontal flow type      (b) Vertical flow type.

### (a) HORIZONTAL Flow TYPE:

- In these tanks the flow of wastes is ensured in horizontal plane to carryout the sedimentation

- These are further classified as follows

## ① RECTANGULAR TANK WITH LONGITUDINAL FLOW



$$Q = AV \quad * * * * *$$

Area  $\perp$  to  $V$  always

$d_1$  - Biggest than considered size

$d$  - concerned size

$d_2$  - Smaller than concerned size

Ex	Size (mm)	conc (mg/l)
	10	150
	9	250
	8	100
	7	300
	6	$\frac{200}{1000} = 0.2$

Let acceptable limit for  $SS = 500 \text{ mg/l}$

### — Assumptions:

- ① conc. of particles of all the sizes are same @ all the points of the vertical section at the inlet end.



(ii) A particle is said to be removed in the tank if it reaches the bottom of the settling zone

case(i)  $d \leq h$

$$t_d = \frac{H}{V_f} = \frac{L}{V_f}$$

(Retention time)

$$V_f \cdot x\text{-area} = Q_D$$

$$\frac{x\text{-area}}{(BH)} = \frac{Q_D}{V_f}$$

$$\boxed{\text{Plan area} = \frac{Q_D}{V_f}}$$

$$V_f = \frac{H V_f}{L} = \frac{H Q_D}{x\text{-area} L}$$

$$V_f = \frac{H Q_D}{(BH) L}$$

$$V_f = \frac{Q_D}{L B}$$

Conc.

100% removal of concerned size

$$\text{Plan area} = \frac{Q_D}{V_f}$$

f particle takes place in the tank

$Q_D$  - design discharge  
[i.e. man daily demand]

Case(ii)

$d > h$

$$t_d' = \frac{h}{V_f}$$

$$t_d > t_d'$$

$$L' = V_f t_d'$$

$$L = V_f t_d$$

$$(L' < L)$$

(iii)  $d_1 (H)$ ,  $d_1 > d$ ,  $v_{s_1} > v_s$ . |  $d$ - considered size.

$$t_{d_1} = \frac{H}{v_{s_1}}, \quad t_d = \frac{H}{v_s}$$

$$t_{d_1} < t_d.$$

$$L' = v_f \cdot t_{d_1}, \quad \text{so, } L_1 < L$$

$$L = v_f \cdot t_d.$$

Cone- 100% removal of bigger size particle also takes place in the tank

(iv)  $d_2 (h)$ ,  $d_2 < d$ ,  $v_{s_2} < v_s$ . | (v)  $d_2 (h)$ ,  $d_2 < d$ ,  $v_{s_2} < v_s$ .

( $h < H$ ).

$$t_{d_2} = \frac{H}{v_{s_2}}, \quad t_d = \frac{H}{v_s}$$

$$t_{d_2}' = \frac{h}{v_{s_2}}, \quad t_d = \frac{H}{v_s}$$

$$t_{d_2} > t_d$$

| for some  $h & v_{s_2}$

(vi)  $H_2 = v_{s_2} t_d$

$$\textcircled{a} \quad t_{d_2}' = t_d$$

$$H = v_{s_2} t_{d_2}.$$

$$\left| \left( \frac{h}{v_{s_2}} = \frac{H}{v_{s_2}} \right) \quad (h) \right.$$

$$H_2 < H.$$

$$\textcircled{b} \quad t_{d_2}' < t_d \quad (0 \text{ to } h).$$

(vii)  $L = v_f t_d$

$$\textcircled{c} \quad t_{d_2}' > t_d \quad [h \text{ to } H].$$

$$L_2 > L$$

Conc -

Smaller sized particles are partially removed in sedimentation tanks.

$$\therefore \text{Removal of smaller sized particles} = \frac{\left(\frac{W}{H}\right) H}{W} \times 100$$

$$\begin{aligned} W &= \text{Tot wt. of smaller size particles} \\ \left(\frac{W}{H}\right) &= \text{conc. of particle in uniform wt.} \\ \text{From } td_s^1 &= td_h \\ \left(\frac{h}{V_s}\right) &= \left(\frac{H}{V_s}\right) \Rightarrow \frac{h}{H} = \frac{V_{S2}}{V_S} \end{aligned}$$
$$\begin{aligned} &= \frac{h}{H} \times 100 \\ &= \frac{V_{S2}}{V_S} \times 100 \\ &= \frac{(g-1) \gamma_w d_2^2}{18 \mu} \times 100 \\ &= \frac{(g-1) \gamma_w d_2^2}{18 \mu} \\ &= \frac{d_2^2}{d^2} \times 100 \end{aligned}$$

$$\therefore \boxed{\therefore \text{Removal of smaller sized particles} = \left(\frac{d_2}{d}\right)^2 \times 100.}$$

LEc-24

LEC-24

Size (mm)	conc (mg/l)	% Removal
0.10	150	100%
0.08	150	100%
d <u>0.07</u>	200	100%
0.05	320	$51.02\% \approx 51\% \left[ \frac{0.05}{0.07} \right]^2 \times 100$
0.04	<u><math>\frac{180}{1000}</math></u>	$\left( \frac{0.04}{0.05} \right)^2 \times 100 = 82\%$

$$\eta = \left\{ \frac{\left[ 150 + 150 + 200 \right] \frac{100}{100} + 320 \times \frac{51}{100} + \frac{180}{1000} \times \frac{82}{100}}{1000} \right\} \times 100 = 72.08\%$$

$$\eta = 72\%$$

$$\eta(\%) = \sum \% \cdot c \times \% R$$

NOTE: settling velocity of concerned size of particle is also termed as "surface overflow rate (SOR)" and it governs the efficiency of sedimentation tank

$$(U_s)_{SOR} \propto \frac{1}{\eta \cdot r}$$

Q A tank having overflow rate of  $2 \text{ m/hr}^{-1}$  is designed for treatment of following water sample

Type of particle	Settling velocity (m/hr)	Conc (mg/l)
A	3	500
B	2	300
C	1	100

compute the conc of the particle in settled water?

Sol:

Particles	$v_s$ (m/hr)	Conc (mg/l)	$+ R$
A	3	500	100
B	2	300	100
C	1	100	$\left(\frac{1}{2}\right) \times 100 \approx 50 +$ $\left(\frac{v_{s2}}{v_s}\right)$

$$\text{Conc. of particle in settled water} = 900 - 850 = 50 \text{ mg/l}$$

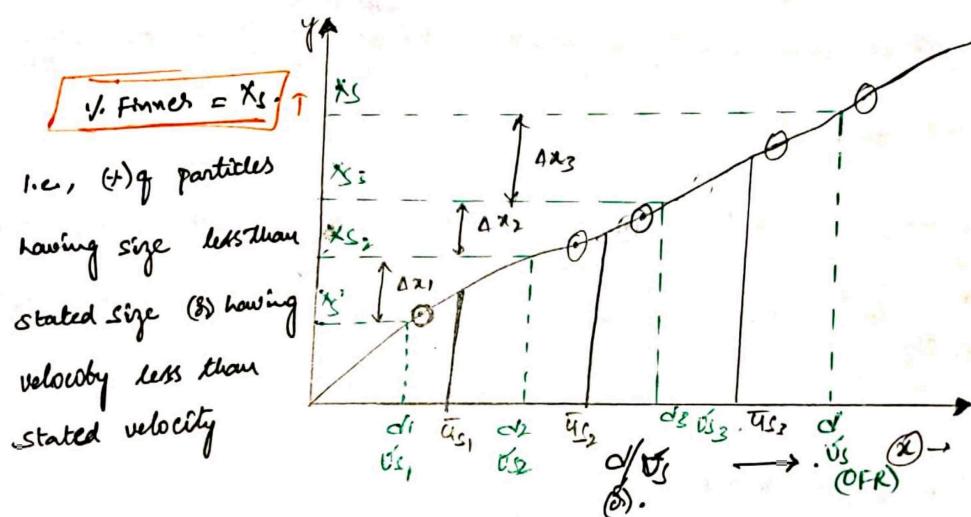
# of all sizes of particles are present in water.

$$\eta_f = \sum f_c \times f_R$$

(mg/l)    (mg/l)

200 —————— 000000000      16

100	000000000	9
200	000000000	8
400	000000000	7



$$\left. \begin{aligned} \Delta x_1 &= x_{s2} - x_{s1} \\ \bar{u}_{s1} &= \frac{u_{s1} + u_{s2}}{2} \end{aligned} \right| \quad \left. \begin{aligned} \Delta x_2 &= x_{s3} - x_{s2} \\ \bar{u}_{s2} &= \frac{u_{s2} + u_{s3}}{2} \end{aligned} \right| \quad \left. \begin{aligned} \Delta x_3 &= x_s - x_{s3} \\ \bar{u}_{s3} &= \frac{u_{s3} + u_s}{2} \end{aligned} \right.$$

$$\eta_f = \sum f_c \times f_R$$

$$= \frac{100}{100} [100 - x_s] + \frac{\bar{u}_{s1}}{u_s} \Delta x_1 + \frac{\bar{u}_{s2}}{u_s} \Delta x_2 + \frac{\bar{u}_{s3}}{u_s} \Delta x_3 + \frac{\bar{u}_{s_n}}{u_s} \Delta x_n$$

$$\eta(\theta) = (100 - x_s) + \sum_{i=1}^n \left( \frac{u_{si}}{v_c} \right) \Delta x_i$$

$$\bar{u}_{si} = \frac{u_{si} + u_{si+1}}{2}$$

Q A settling basin is designed to have a surface overflow rate

of 32.6 m/d. Determine the overall removal obtained for

a suspension with size distribution as follows.

$\eta = 1.2$ ; water temp =  $20^\circ\text{C}$  at which ~~dynamic viscosity~~  $(\eta) = 1.027 \text{ centi poise}$

$$\rho_w = 0.997 \text{ gm/cm}^3$$

Particle size (mm)	0.1	0.08	0.07	0.06	0.04	0.02	0.01
wt. fraction greater in size ( $f_i$ )	10	15	40	70	93	99	100

SOL:-  $\eta(\theta) = \sum f_i c \times f_i R$

size (mm)	wt. fraction ( $f_i$ ) greater in size	wt. fraction smaller in size ( $x_s$ )	Settling velocity (mm/sec)
0.1	10	90	$u_{s1} = 1.058$
0.08	15	85	$0.6757$
0.07	40	60	$0.5173$
0.06	70	$x_{s3} \quad 30$ } $\Delta x_3$	$0.380$ } $u_{s3}$
0.04	93	$x_{s2} \quad 7$ } $\Delta x_2$	$0.168$ } $\bar{u}_{s2}$
0.02	99	$x_{s1} \quad 1$ } $\Delta x_1$	$0.0422$ } $\bar{u}_{s1}$
0.01	100	$x_s \quad 0$	$0.010$

$$\begin{aligned}
 U_s &= \frac{(g-1) g \omega d^2}{18 \mu} = \frac{(1.2-1)(0.997 \times 9.81)}{18} \\
 &= \frac{(1.2-1)(0.997 \times 10^{-3} \times 10^6 \times 9.81) \times (d^2 \times 10^{-6})}{18[(1.027) \times 10^{-2} \times 10^{-1}]} \times 10^3. \\
 &\quad \text{Centipoise} \\
 &\quad \left( \frac{\text{N-sec}}{\text{m}^2} \right). \\
 U_s &= 10588 d^2 \text{ (mm/sec)}
 \end{aligned}$$

$$OFR = 32.6 \text{ } \eta/d = \frac{32.6 \times 10^3}{86400} = \frac{326}{864} = 0.38 \text{ mm/sec}$$

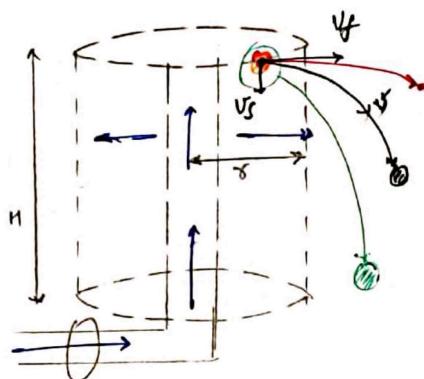
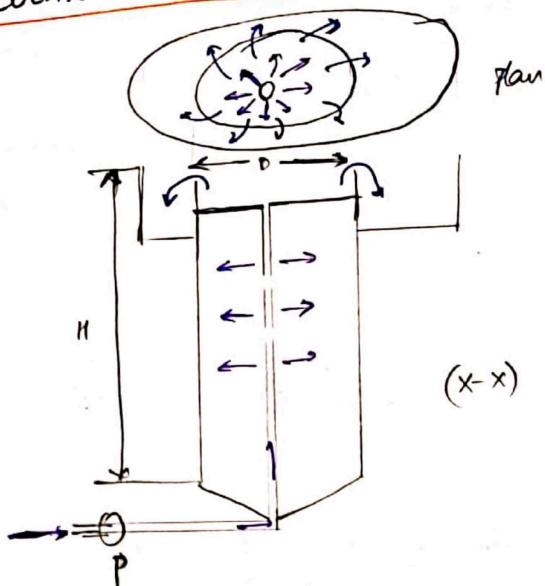
$$\begin{aligned}
 \eta(t) &= \sum t_i C_i \times t_i R_i = (100 - x_1) + \sum_{i=1}^n \frac{\bar{U}_{S_i}}{U_s} \Delta x_i \\
 \Delta x_1 &= 100 - 10 = 90 ; \quad \bar{U}_{S_1} = \frac{U_{S_1} + U_{S_2}}{2} = \frac{0.010 + 0.0422}{2} = 0.026 \text{ (mm/sec)} \\
 \Delta x_2 &= 71 = 6 + ; \quad \bar{U}_{S_2} = \frac{U_{S_2} + U_{S_3}}{2} = \frac{0.0422 + 0.168}{2} = 0.105 \text{ (mm/sec)}. \\
 \Delta x_3 &= 30 = 23 + ; \quad \bar{U}_{S_3} = \frac{U_{S_3} + U_{S_4}}{2} = \frac{0.168 + 0.380}{2} = 0.274 \text{ (mm/sec)}
 \end{aligned}$$

$$\eta(t) = (100 - 30) + \left( \frac{0.026}{0.38} \right)(1) + \left( \frac{0.105}{0.38} \right)(6) + \left( \frac{0.274}{0.38} \right)(23)$$

$$\eta(t) = 88.28 \text{ mm/sec}$$

continuous flow type — horizontal — circular tank

## ② CIRCULAR TANK WITH RADIAL FLOW!



- In this type of tank when the water flows in radial horizontal direction, its area of flow increases that results in decrease in velocity of flow
- As resultant velocity of flow is not constant in this case particle follows parabolic path during settlement instead of

- st-line path as in longitudinal flow type tank
- As in this case, smaller size particles are not removed partially, its efficiency is observed to be comparatively less than longitudinal flow type tank.

**LEC-25**

## # DESIGN DATA FOR HORIZONTAL FLOW TYPE SEDIMENTATION TANKS

$$\text{i) OVER FLOW RATE (OFR)} = 12000 - 18000 \text{ l/m}^2/\text{d} - [\text{plain sedimentation}]$$

$$24000 - 30,000 \text{ l/m}^2/\text{d.} [\text{coagulation, flocculation and sedimentation}]$$

$$\text{Plan Area (LB)} = \frac{Q_D}{OFR} \quad [\text{Rectangular}] ; \quad \text{Plan area} \left( \frac{\pi D^2}{4} \right) = \frac{Q_D}{OFR} \quad [\text{for circular tank}]$$

**NOTE:** Efficiency of sedimentation tank depends upon OVER FLOW RATE, which gives the area of tank, hence efficiency depends upon L, B of the tank and is independent of DEPTH of the tank

$$\text{ii) DETENTION TIME: } (t_d) \quad 4-8 \text{ hrs} - (\text{PST})$$

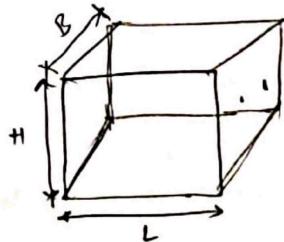
$$2-4 \text{ hrs} - [\text{C+F+T}] - \text{coagulation aided sedimentation}$$

$$V = Q_D \cdot t_d$$

$$V = Q_D t_d$$

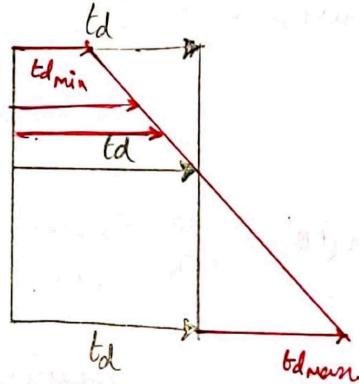
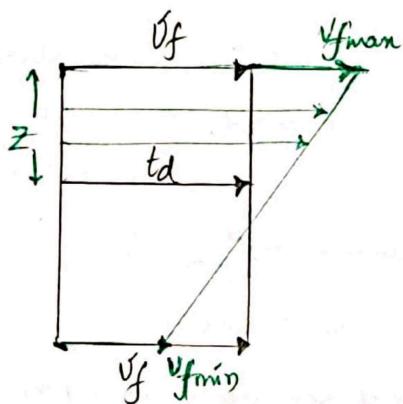
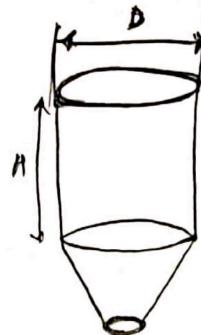
(LBH)

[For rectangular flow  
type tank]



$$(8) \quad V \left\{ D^2 (0.04D + 0.785H) \right\} = Q_D t_d.$$

[FB circular type].



- Detention time ( $t_d$ ) Considered above is on the basis of the fact that velocity of flow is assumed to be constant throughout the height of the tank
- But in actual velocity of flow in upper layers of tank is comparatively more, hence particles in this layer ~~not~~ gets comparatively lesser time to get settled

in the tank

**NOTE:** actual time for which particles remains in tank is termed as "flow through period"  
(FTP)

- hence these particles are not able to settle in the tank and this process is termed as "SHORT CIRCUITING", that results in reduced efficiency of the tank
- the extent of short circuiting is reported in terms of the parameter "DISPLACEMENT EFFICIENCY ( $\eta_d$ )"

$$\eta_d = \frac{\text{Avg (FTP) flow through period } (t_{fang})}{\text{Theoretical detention time } (t_d)} \times 100 \quad \rightarrow \frac{(t_{fmax} + t_{fmin})}{2}$$

$\eta_d (\uparrow) \rightarrow t_{fang} \uparrow \rightarrow t_{fmax} (\uparrow) / t_{fmin} (\uparrow) \rightarrow$  short circuiting sc ( $\downarrow$ )

iii) horizontal velocity of flow ( $v_f$ ) =  $0.15 - 9$  (m/min).  
 $\{0.3 \text{ m/min}\}$

**L =  $v_f t_d$ .** — [For only rectangular tank].

$$B = \frac{P_A}{L} ; H = \frac{V}{P_A} . \quad (P_A - \text{plan area})$$

(iv)  $\frac{L}{B} = 4$

(v)  $Q_D = Q_{MD}$

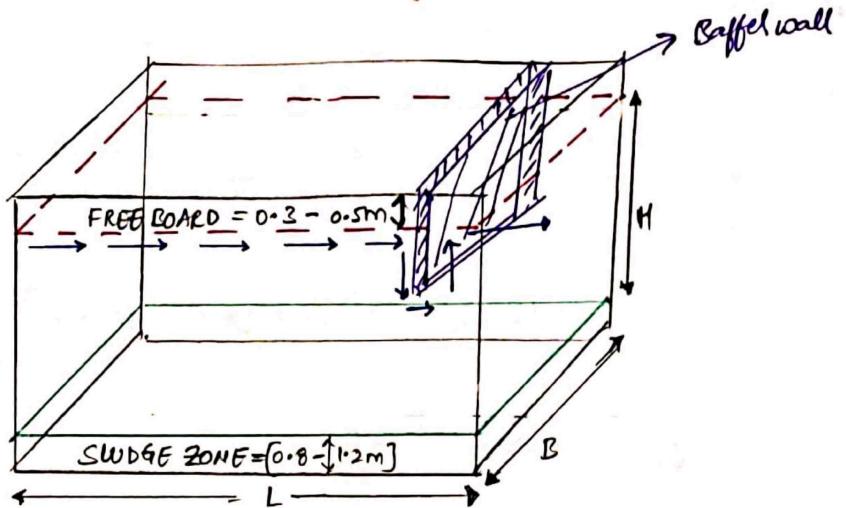
+  
design Q = max daily Q.

(vi) In order to prevent overflow of the tank additional volume is provided @ the top of the tank termed as "free board"

depth of which is kept in range of (0.3 - 0.5m)

(vii) If cleaning of the tank is done manually, additional volume is provided @ the bottom of the tank for accumulation of sludge depth of which is kept in the range of (0.8 - 1.2m)

(viii) To avoid "short circuiting", Baffle walls are provided  
@ the top, @ the outlet of the tank



Q A rectangular sedimentation tank is to handle 10MLD of raw water, ~~a~~ detention width to length ratio is 1:3 is proposed to trap all particles larger than 0.04 mm in size assuming a relative density of 2.65 for the particles and 20°C as avg temp. Compute the Basin size, if the depth (H) of the tank is (2.5m). Calculate detention time ( $t_d$ ) also?

Solt  $\frac{L}{B} = \frac{3}{1} ; H = 2.5m ; d = 0.04 \text{ mm} = 0.04 \times 10^{-3} \text{ (M)}$

$$T = 20^\circ\text{C}, \beta_w = 2.65 \quad t_d = \frac{H}{V_s}$$

$$V_s = \frac{(G-1)\beta_w \cdot d^2}{18 \mu}$$

$$\frac{B}{L} = \frac{1}{3} \Rightarrow L = 3B.$$

$$OFR (\sqrt{c}) = 418 (G-1) d^2 \left( \frac{3T+70}{100} \right).$$

$$= 418 (2.65-1) (0.04 \times 10^{-3})^2 (0.04)^2 \left[ \frac{3(20)+70}{100} \right] \times 10^{-3}$$

$$v_s = 1.434 \times 10^{-3} \text{ m/sec}$$

$$PA = \frac{Q_D}{v_s} = \frac{10 \times 10^6 \times 10^{-3}}{1.434 \times 10^{-3} \times 86400} = 80.43 \text{ m}^2$$

$$UB = 80.43$$

$$(B) B = 80.43 \Rightarrow B^2 = \frac{80.43}{3} \Rightarrow B = 5.18 \text{ m}$$

$$L = 3B = 3(5.18)$$

$$L = 15.56 \text{ m}$$

$$\text{so, } L = 15.56 \text{ m}; B = 5.18 \text{ m}; H = 3.5 \text{ m}$$

$$\textcircled{ii} \quad \underline{\underline{t_d = ?}}$$

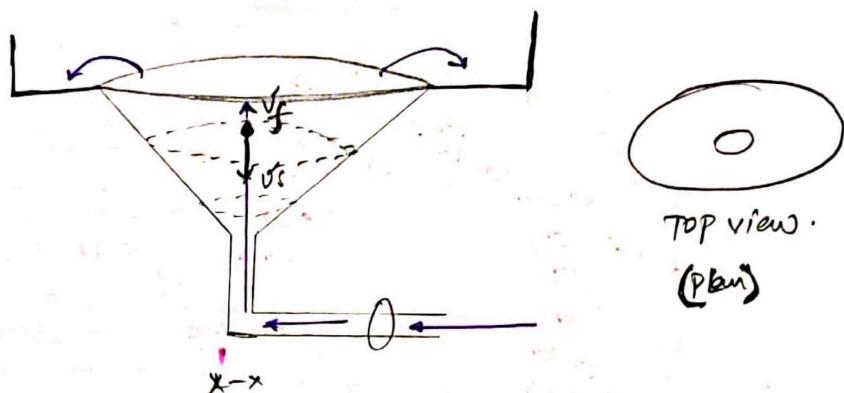
$$t_d = \frac{V}{Q_D} \quad (8) \quad t_d = \frac{H}{v_s} \cdot \frac{2.5}{80.434} \times 10^{-3}$$

$$Q_D = Q_{MD}$$

$$= \frac{\frac{UBH}{10 \times 10^6 \times 10^{-3}}}{\frac{12 \times 60}{60}} \quad \left| \quad = \frac{3.5}{1.434 \times 10^{-3}} \times \frac{1}{60} = 40.65 \text{ mins} \right.$$

## (II) VERTICAL FLOW TYPE TANK:

- These are the tank in which ~~flow~~ flow of the water is ensured to be continuous in vertical plane in order to carry out sedimentation.

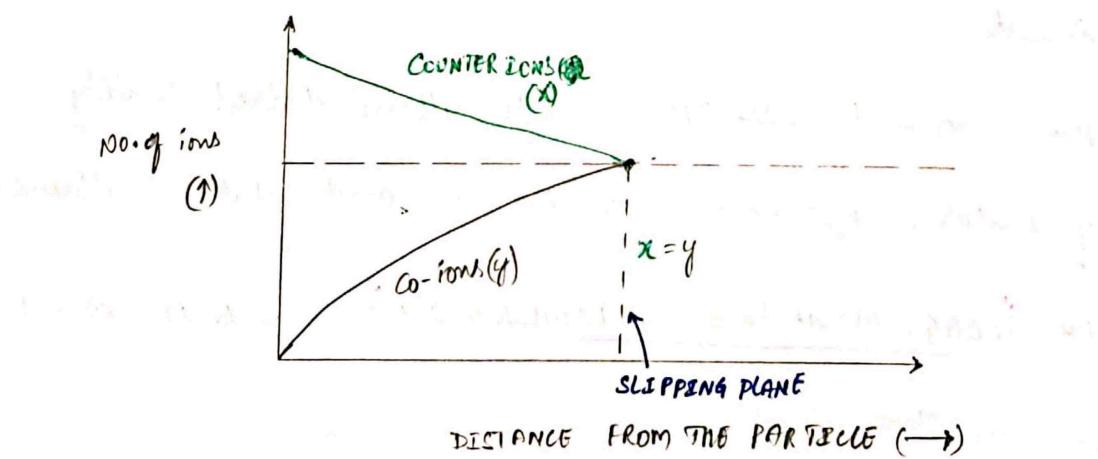
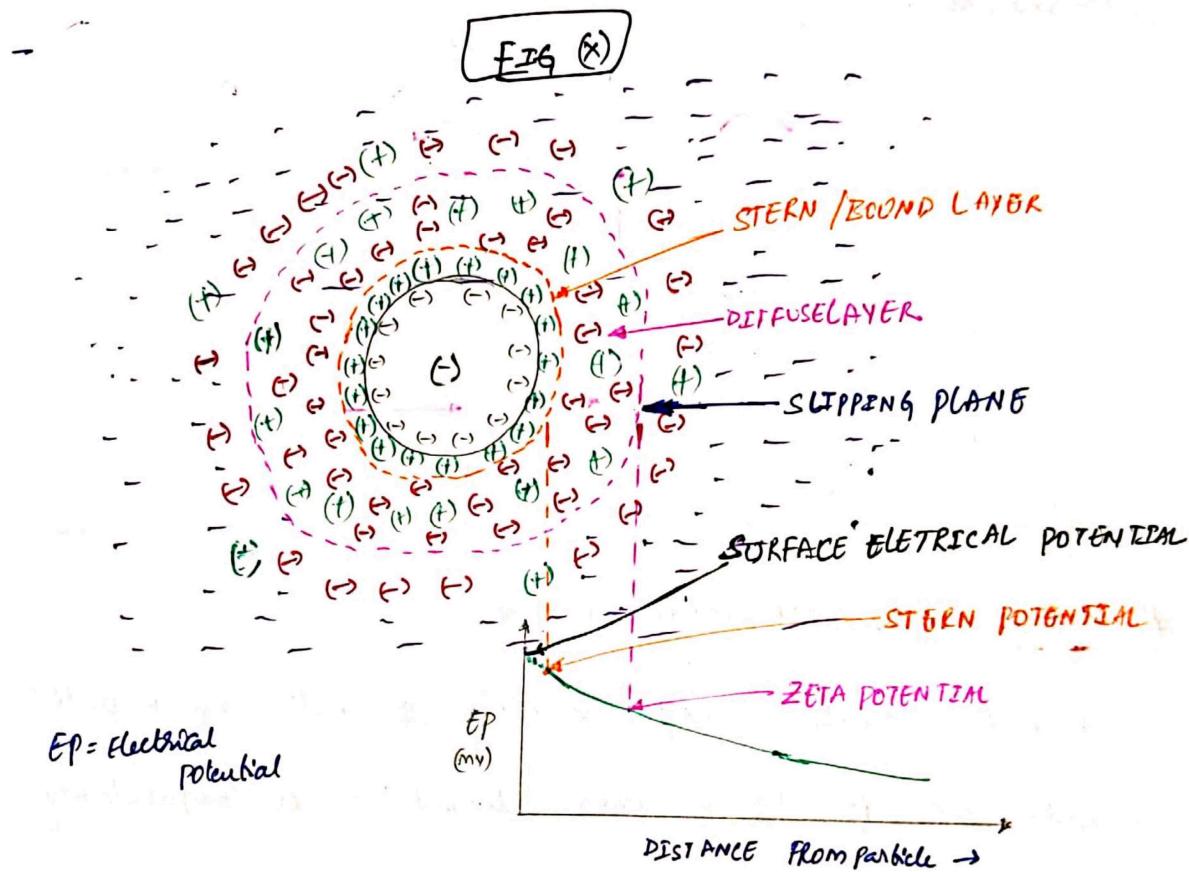


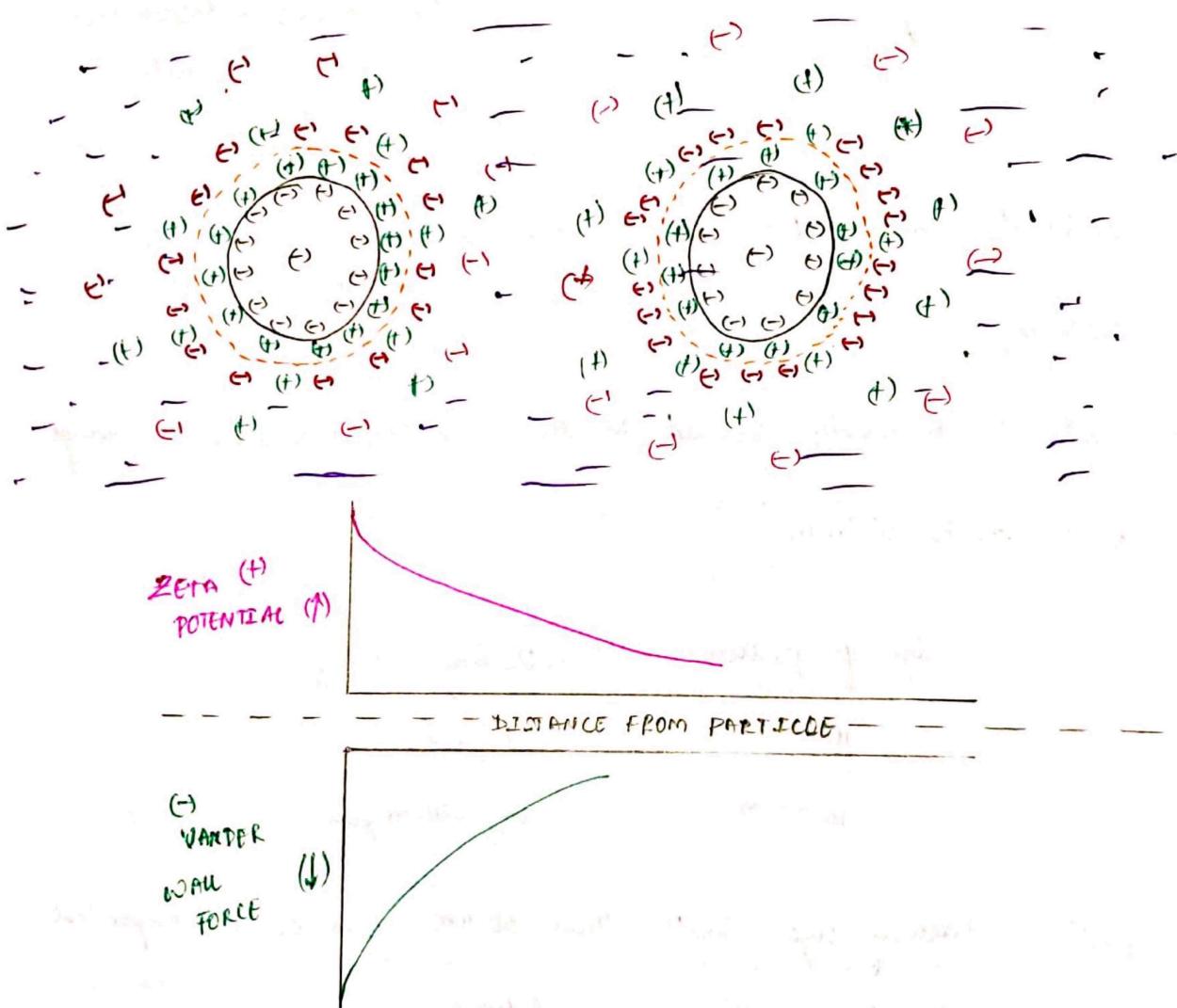
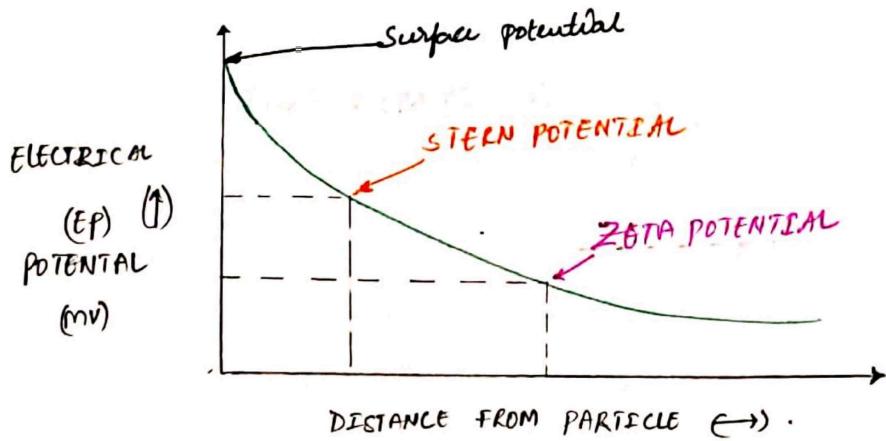
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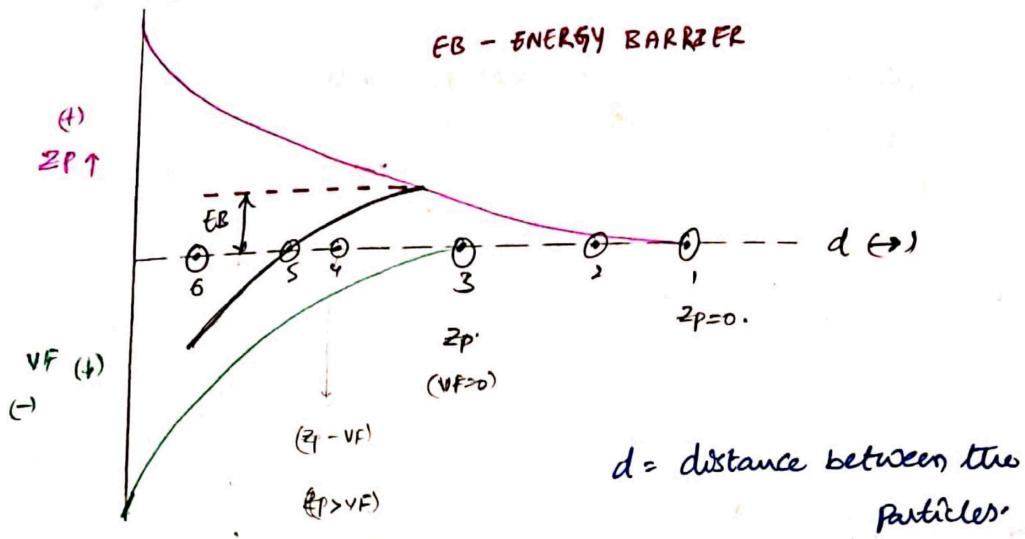
## # COAGULATION ASSISTED SEDIMENTATION:

- If water consists of high turbidity & smaller size of particles in such case efficiency of plain sedimentation is comparatively reduced
- Hence in such case in order to attain desired quality of water, efficiency is to be increased that is attained by "COAGULATION ASSISTED SEDIMENTATION", which is carried out in three stages

- ① coagulation [fast mixing]
- ② flocculation [slow mixing]
- ③ sedimentation







$d$  = distance between the particles.

- virtually all surface water sources consist of Perceptible turbidity.
- Particles commonly found in these sources varies in the range

of 10mm to  $10^{-6}$  mm

size of particle	settling velocity
10 mm	8m/4sec
$10^{-6}$ mm	3m/ million year

- Particles having size smaller than  $50\mu\text{m}$  cannot be expected to get settled in plain sedimentation

- Hence agglomeration of these particles must be carried out in order to carryout their sedimentation.

- There are certain properties of colloids [ $1 - 1000 \text{ nm}$ ], which prevents their agglomeration

nm = nanometer  
 $\text{nano} = 10^{-9}$

#### # COLLOIDAL STABILITY:

- colloidal suspension, which do not agglomerate naturally are termed as "STABLE SUSPENSION".
- This stability is due to their small size.
- Due to their small size, they possess very large specific surface area, thereby has large accumulation of surface charge over them.
- This charge over the particles is due to molecular arrangement of the particles and loss of atoms due to abrasion.
- mostly these particles are observed to posses (+ve) charge.

- A (-ve) charged particle with arrangement of ions around it in water is as follows. In FIG (X)
- positive counterions first attach themselves around the particles forming a rigid layer, termed as "STERN/BOUND LAYER"
- The particle continues to attract more counter ions, but now they face repulsion from the counter ions in Stern layer and other counter ions present in the vicinity, forming a second layer termed as. "DIFFUSE LAYER".
- Both the layers taken together are termed as double layers "DOUBLE LAYER".
- ELECTRICAL POTENTIAL decreased with increase in distance from particle.
- Electrical potential @ the surface of particle is termed as "SURFACE ~~POTENTIAL~~ ELECTRICAL POTENTIAL".

- Electrical potential @ Stern layer is termed as "STERN POTENTIAL"
- $\zeta$ P @ slipping plane is termed as "ZETA POTENTIAL"
- higher the value of zeta potential, more stable is the suspension
- when two colloids comes in close proximity with each other they are being subjected to two different forces.

(a) Electrostatic / ZETA POTENTIAL — which causes repulsion b/w the particles.

(b) VANDERWALL FORCES — which causes the attraction b/w the particles.

- both zeta potential and vanderwall force reduces with increase in distance between the particles.
- But the decay/decrease of vanderwall force is more rapid than zeta potential.

**NOTE!** These vanderwall forces are inversely proportional to 6<sup>th</sup> power of the size of the particle

- Hence vanderwall force is "strong" at "close distance" in relation to zeta potential.

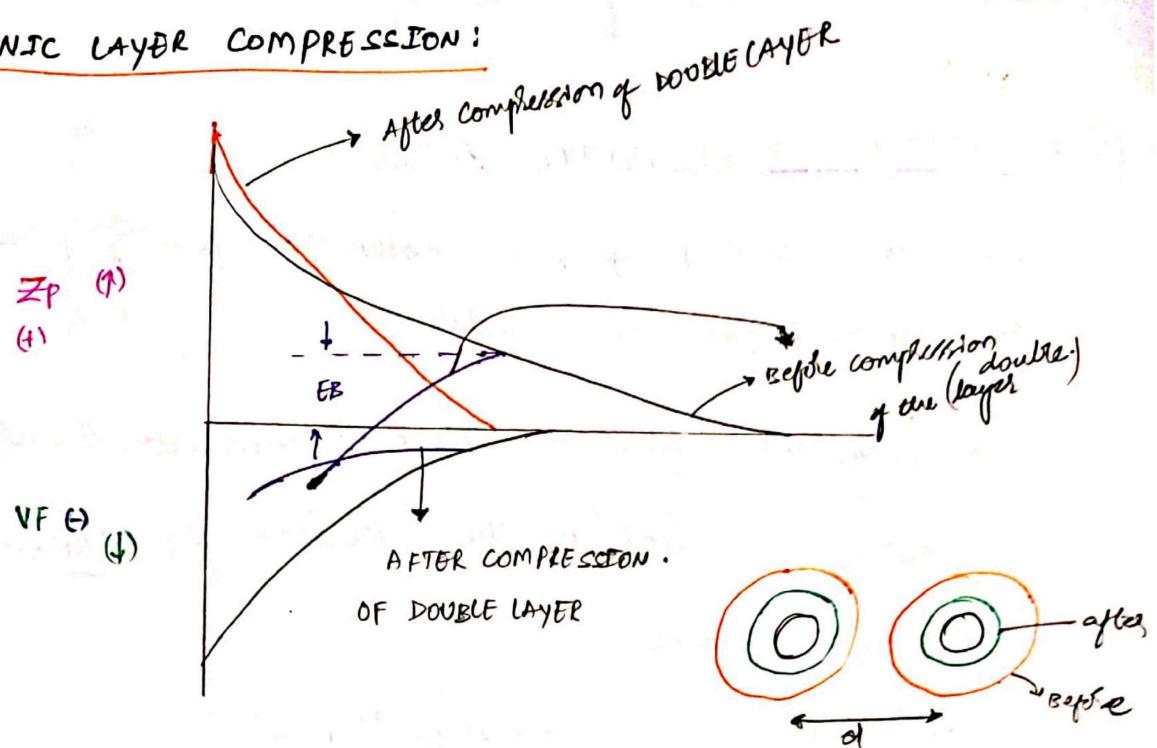
- Thereby if distance between the particles is reduced upto such an extent van der waal forces dominates over zeta potential, the particles would combine and results in higher efficiency of sedimentation
- But to achieve this "ENERGY BARRIER" is to be overcome
- This energy barrier can be overcome either by "BROWNIAN MOTION" between the particles (8) by inducing "MECHANICAL AGITATION".

## # COAGULATION THEORY!

- The exact mechanism of coagulation is still unknown, but however following theories are proposed

- (i) IONIC LAYER COMPRESSION
- (ii) ABSORPTION & CHARGE NEUTRALISATION
- (iii) SWEEP COAGULATION
- (iv) INTER PARTICLE BRIDGING

### i) IONIC LAYER COMPRESSION:



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- The quantity of ions in water suspension has significant effect on the decay of electrostatic potential
- A high ionic concentration completes the double layer around the particles
- If this layer is sufficiently compressed Van der waal forces becomes predominant force across the entire area of influence in such case no. energy barrier is required to be overcome, as particle would combine on their own

leading to the formation of bigger size particles-

### (ii) ADSORPTION & CHARGE NEUTRALIZATION!

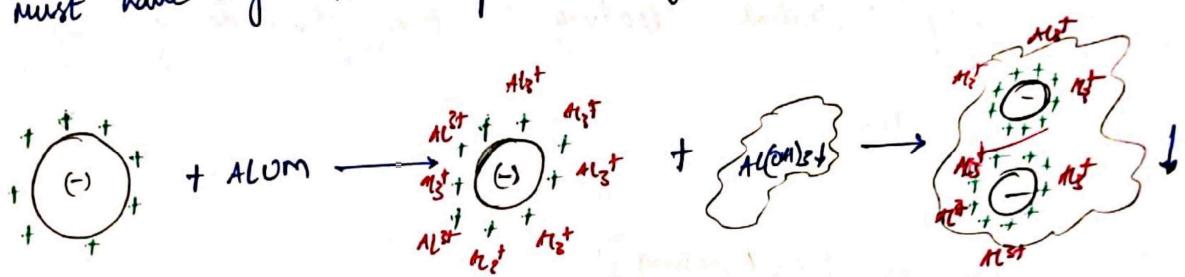
- Here the Quality of ions rather than quantity of ions play the important role in coagulation
- If coagulants, such as alum, copperas etc. is added in water, they lead to the formation of "AQUAMETALIC IONS" and "HYDROGEN IONS"



- These aquametallic ion formed, gets adsorbed over the colloidal particles and becomes the part of ions in Stern layer, thereby neutralizes the charge over the colloids
- These neutralized particles then combine with each other leading to the formation of bigger sized particle

- If excess of Aqueous ions are formed and absorbed, the charges on the particle becomes reversed and ionic cloud returns, which again causes repulsion between the particles

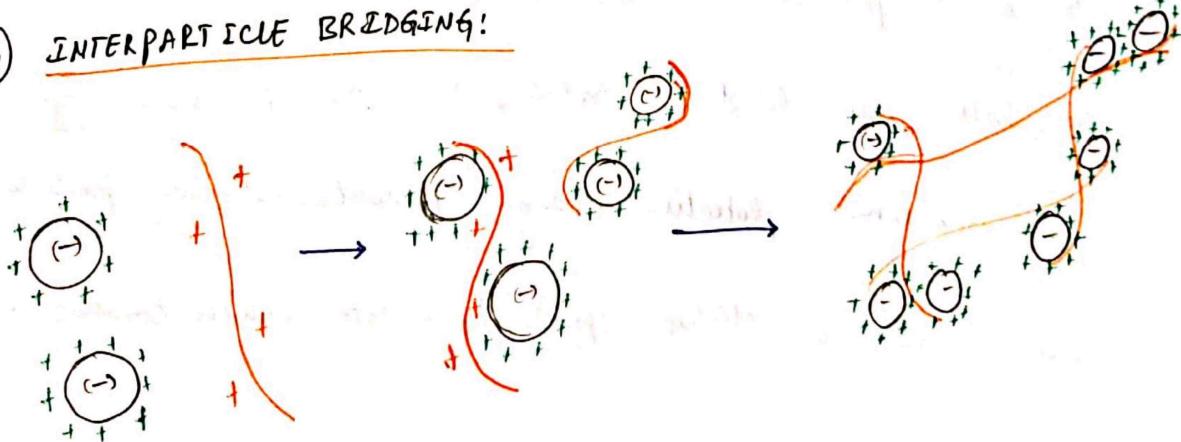
(iii) **SWEET COAGULATION:** - For sweet coagulation to occur  $H_2O$  must have high turbidity and high alkalinity



- The last product formed in hydrolysis of alum is  $Al(OH)_3$

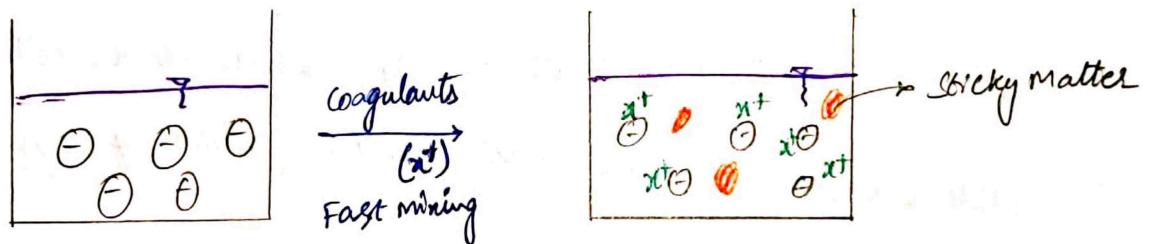
which is amorphous, GELATINOUS ppt, which attach, colloidal particles over its surface leading to the formation of bigger sized particle.

(iv) **INTERPARTICLE BRIDGING:**



- large molecules may be formed when them & other coagulants are added in water Ex:  $\text{Al}_7(\text{OH})_{17}^{4+}$
- synthetic polymer may also be used in this case which may be linear & branched and are highly surface reactive
- several colloids may be attached to one (S) many of the polymer chains leading to the formation of bigger sized particle

### i) COAGULATION [Fast mixing]:



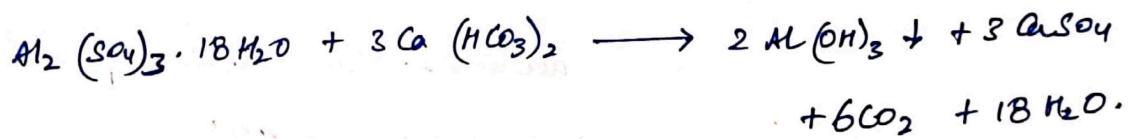
- It is a process in which certain chemicals termed as, coagulants are added in water, so, as to neutralize the negative protective charge present over the particles and to form a sticky (ppt) precipitate which combines.

these smaller particles over its surface, leading to the formation of bigger sized particles, which can get easily settled in sedimentation tank.

- In order to neutralize the charge, certain minimum energy, termed as THRESHOLD ENERGY is required which is induced by fast mixing

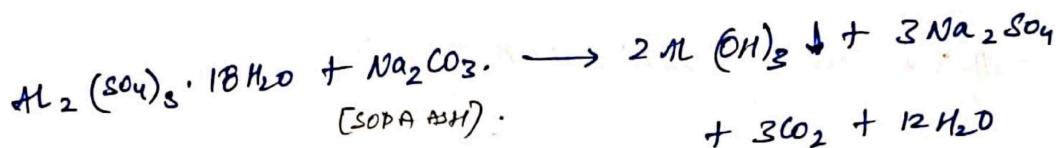
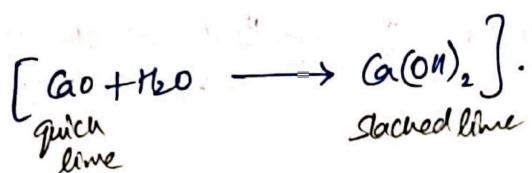
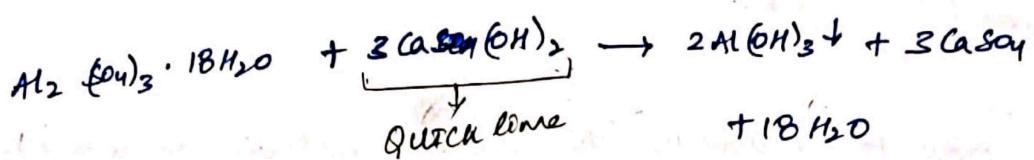
① Different chemicals used as Coagulants:

② ALUM:  $[Al_2(SO_4)_3 \cdot 18H_2O]$  [Hydrated aluminium Sulphate].



- Alum when added in water reacts with the alkalinity in it and leads to the formation of sticky precipitate of  $Al(OH)_3$  which attracts fine particles over its surface leading to the formation of bigger particle

- If alkalinity is not present in water naturally it is induced artificially by addition LIME (B) SODA ASH.

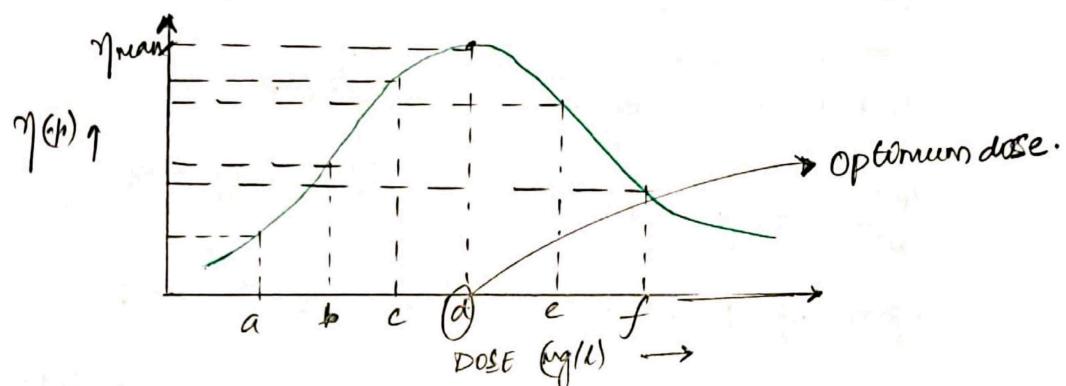
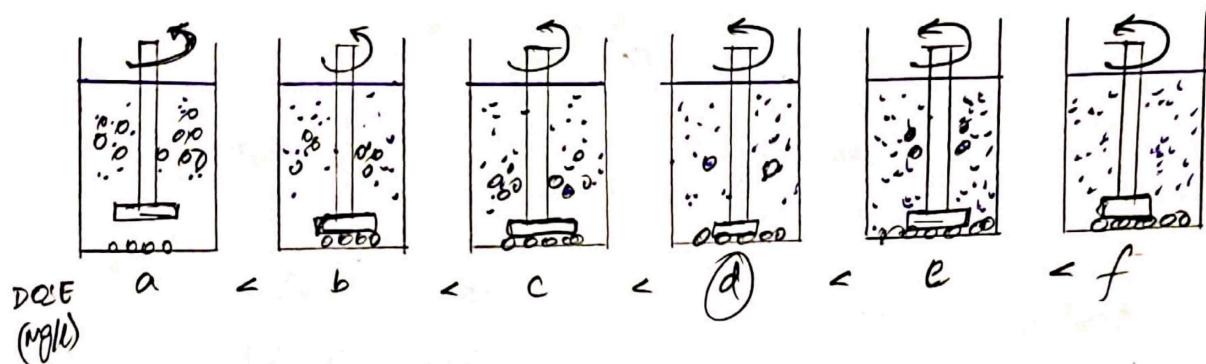


- By addition of Alum: alkalinity & pH of the water decreases. But turbidity and permanent hardness increases

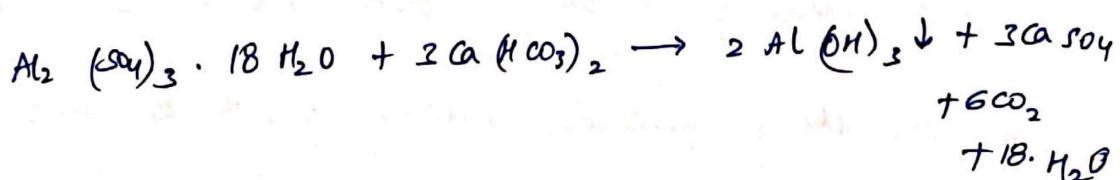
Alum works in pH range of (6.5 - 8.5)

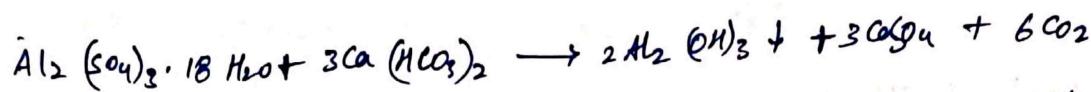
- Alum removes taste, colour, odour and micro organisms from the water
- Dose of Alum

→ Dose of alum depends upon turbidity of water and is determined using "JAR TEST"



- optimum dose of alum is range of (10-80 mg/l).
- large quantity of sludge is formed when alum is used as coagulant; which is difficult to dewater and
- dry wt of which can be computed as follow.





1 mole	3 mole	2 mole	3 mole	6 mole
666 gm	486 gm.	136 gm	408 gm	264 gm.
$\Rightarrow 1 \text{ gm}$	0.73 gm	0.234 gm	0.61 gm	0.40 gm.
(b)	$[0.45 \text{ gm of } \text{CaCO}_3 \text{ eq}]$		(b) $[0.45 \text{ gm of hardness}]$ as $\text{CaCO}_3$	

NOTE!

2 mole  $\text{Ca}(\text{HCO}_3)_2$   
(Calcium bicarbonate)

162 gm. ~~—~~

$$\frac{162}{81} = 2 \text{ gm eq.}$$

2 gm - eq of  $\text{CaCO}_3$ .

$$2 \times 50 = 100 \text{ gm of } \text{CaCO}_3.$$

$$\frac{100}{100} = 1 \text{ mole of } \text{CaCO}_3.$$

i.e., 2 mole  $\text{Ca}(\text{HCO}_3)_2 = 1 \text{ mole of } \text{CaCO}_3.$

2 mole of  $\text{CaSO}_4$ .  
(Calcium sulphate).

136 gm

$$\frac{136}{136/2} = 2 \text{ gm eq}$$

2 gm - eq of  $\text{CaCO}_3$

$$2 \times 50 = 100 \text{ gm of } \text{CaCO}_3$$

$$\frac{100}{100} = 1 \text{ mole of } \text{CaCO}_3$$

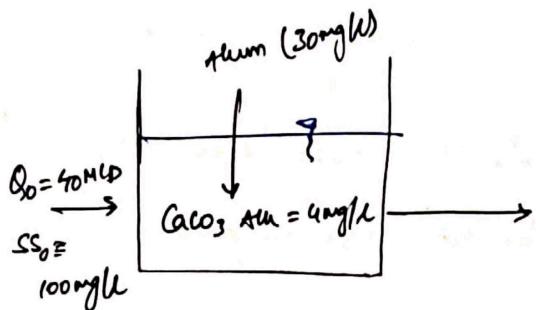
$$\begin{aligned} 1 \text{ mole of } \text{CaSO}_4 \\ = 1 \text{ mole of } \text{CaCO}_3 \end{aligned}$$

— that 1 mole of anything is also equal to 1 mole of  
any other thing provided, valency of both is same.

- Q A coagulation sedimentation plant is treating 40MCD of raw water, having 100mg of S.S in it. If ~~20mg/l~~ 20mg/l of alum is added to carryout coagulation then compute
- (i) Annual Quantity of alum & 85% pure Ca needed for the treatment of water.
  - (ii) Volume of sludge produced at the bottom of sedimentation tank in a day provided after coagulation unit assume efficiency of tank to be 75%,  $\text{t}_{\text{sludge}} = 1.8$ .  
Solid content of sludge = 2%
  - (iii) change in ionic character of water in a day  
Assuming raw water has natural alkalinity as  $\text{CaCO}_3$  of 4mg/l

SOL:

Sol:-



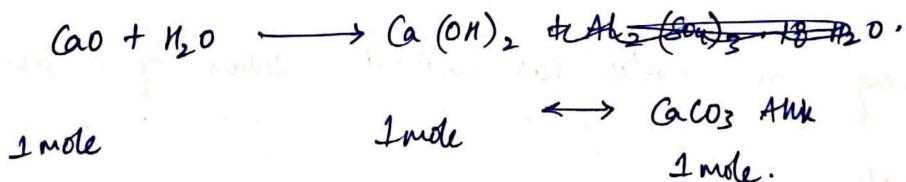
i) Qty of alum required =  $80 \times 40 \times 10^6 \times 365 \times \frac{10^{-6} \times 10^{-3}}{700}$   
= 43.8 tonnes/yr.

ii) 1gm of alum reacts with = 0.45 gm of CaCO<sub>3</sub> ATM

$$30 \text{ mg/l} \quad " \quad " \quad " = 80 \times 0.45 = 13.5 \text{ mg/l}$$

of CaCO<sub>3</sub> ATM

$$\text{Additional ATM required} = (13.5 - 4) = 9.5 \text{ mg/l as CaCO}_3$$



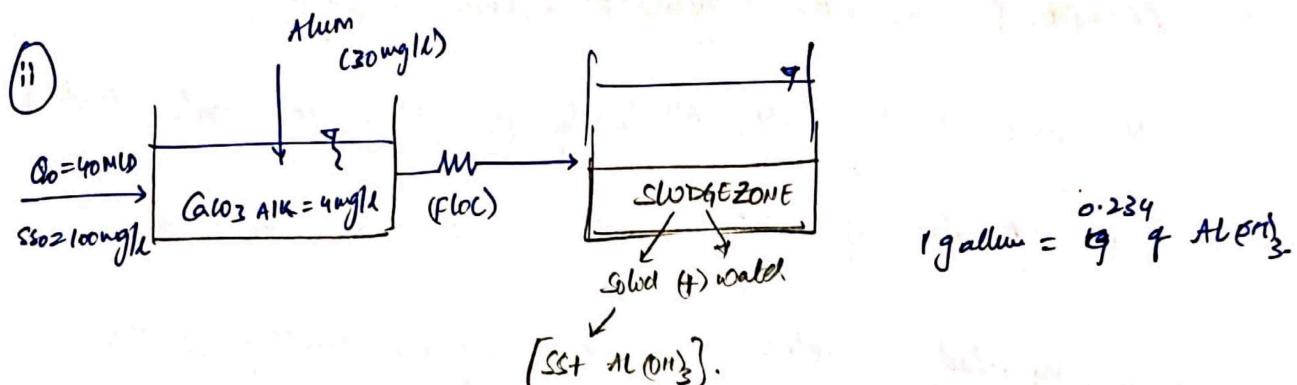
1 mole of CaCO<sub>3</sub> ATM is induced by = 1 mole of 100% pure CaO

$$100 \text{ gm } " \quad " \quad " \quad " = 50 \text{ gm of 100% pure CaO.}$$

95 mg/l of CaCO<sub>3</sub> ATM is induced by =  $\frac{50}{100} \times 9.5 = 5.32 \text{ mg/l of}$   
100% pure CaO

$$9.5 \text{ mg/l} \text{ of } \text{CaCO}_3 \text{ Alk is induced by } = \frac{5.32}{0.85} = 6.25 \text{ mg/l of } \\ 85\% \text{ pure } \text{CaO}.$$

$$\text{Alk of } 85\% \text{ pure lime required} = 6.25 \times 40 \times 10^6 \times 365 \times 10^{-9} \\ (\text{CaO}) \\ = 91.25 \text{ Tonnes/yr.}$$



$$\text{wt. of solids in sludge} = [100 + 30 \times 0.234] \times 40 \times 10^6 \times 10^{-6} \times 0.234 \text{ kg/d} \\ = 3210.6 \text{ kg/d}$$

$$\text{solid content} = 2+ \rightarrow 2 \text{ kg solids} + 98 \text{ kg H}_2\text{O} = 100 \text{ kg sludge}$$

$$\text{wt. of sludge formed} = \frac{100}{2} \times 3210.6 = 160530 \text{ kg/d}$$

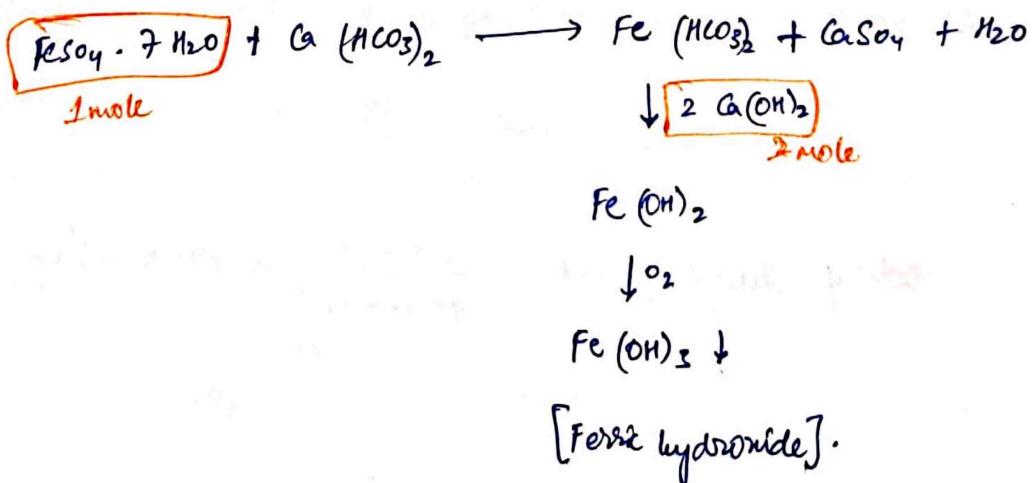
$$\text{Vol. of sludge formed} = \frac{160530}{G = 1.8 \times 10^3 \text{ cu}} = 89.18 \text{ m}^3/\text{day}$$

(iii) Am of water would be reduced  
 $= 30 \times 0.45 \times 40 \times 10^6 \times 10^{-6}$   
 by an amount of  
 and permanent hardness of the  
 water would be increased by  
 $= 540 \text{ mg/l}$

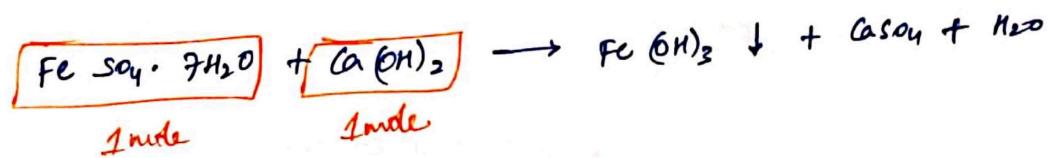
(ii) COPPER AS  $[\text{FeSO}_4 \cdot 7\text{H}_2\text{O}]$  (HYDRATED FERROUS SULPHATE).

- It also reacts with Alkalinity present in the water leading to the formation of sticky ppt of  $\text{Fe(OH)}_3 \downarrow$  which attracts fine suspended (particles) over its surface, leading to the formation of bigger sized particles.

② If copperas is added prior to addition of lime



(b) If lime is added prior to the addition of copperas.



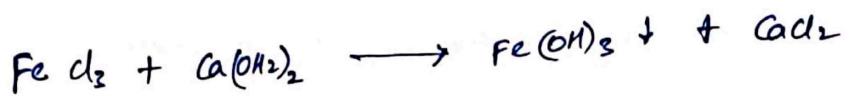
- Copperas is not used for treatment of coloured water.
- Its normal dose is also (10 - 30 mg/l) and is determined using JAR TEST, But it is comparatively cheaper than alum.

ALUM.

- Alum works in pH range of 8.5 and above, hence is always used in conjugation with lime.

(iii) CHLORINATED COPPERAS  $[\text{Fe}_2(\text{SO}_4)_3 + \text{FeCl}_3]$ .

- It is formed by addition of  $\text{Cl}_2$  in copperas
- $$\text{Fe SO}_4 \cdot 7\text{H}_2\text{O} + \text{Cl}_2 \longrightarrow \text{Fe}_2(\text{SO}_4)_3 + \text{FeCl}_3$$
- If Ferrichloride is used independently as a coagulant.  
it works in pH range of  $[3.5 - 6.5]$  & above 8.5
- If ferrous sulphate is used independently as a coagulant  
it works in pH of  $[4 - 7]$  & above 9.



$$\text{pH} = 3.5 - 6.5 \leftarrow \text{pH} > 8.5$$

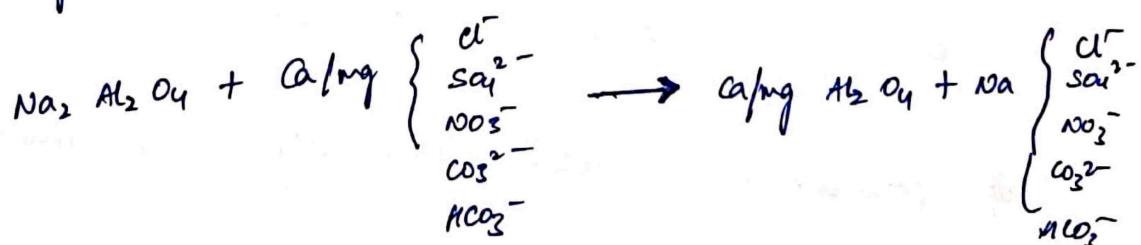


$$\text{pH} = \frac{8.5}{4} \leftarrow \text{pH} > 9$$

Hence chlorinated copperas works in wide pH range of (3.5-9)  
& greater than 8.5

### (d) SODIUM ALUMINATE $[\text{Na}_2\text{Al}_2\text{O}_4]$ :

- It reacts with the hardness present in the water leading to the formation of sticky precipitate of calcium ~~and~~ (B) magnesium aluminate which attracts fine particles over its surface leading to the formation of bigger sized particles.



- It does not requires alkalinity to be present in water, moreover also removes hardness from the water, unlike other coagulants which add the hardness.
- It normal dose dose in range of 10-20 mg/l, but it is costlier than the Alum.
- It is generally used for treatment of BOILER FEED water.
- It works in pH  $\in [6-8.5]$ .

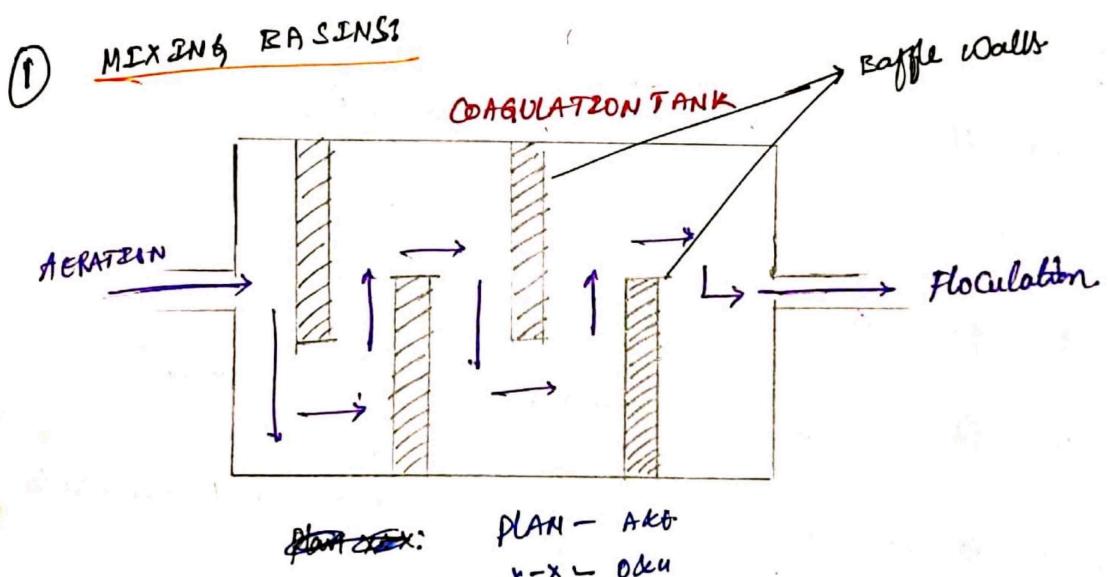
**NOTE!**

- Iron salts are cheaper than Aluminium salts.
- Iron salts are works in wide pH range.
- Iron flocs are heavier than aluminium flocs.
- Iron flocs are formed earlier than aluminium flocs.
- Alum is used for treatment of water supplies. and iron salts are used for treatment of sewage.
- use of the iron salts promotes the growth of IRON BACTERIA that causes pitting [localized corrosion] & TUBERCULATION.  $[Fe(OH)_3]$    
 [encrustation due to tubercles] in pipes

- Iron salts are deliquescent in nature, hence ~~heat~~ strict supervision is required for their handling

① coagulation → ② <sup>fast</sup> mixing

② To neutralize the charge of particles certain minimum energy termed as THRESHOLD ENERGY is required to be given, which is induced by fast mixing in this process as follows

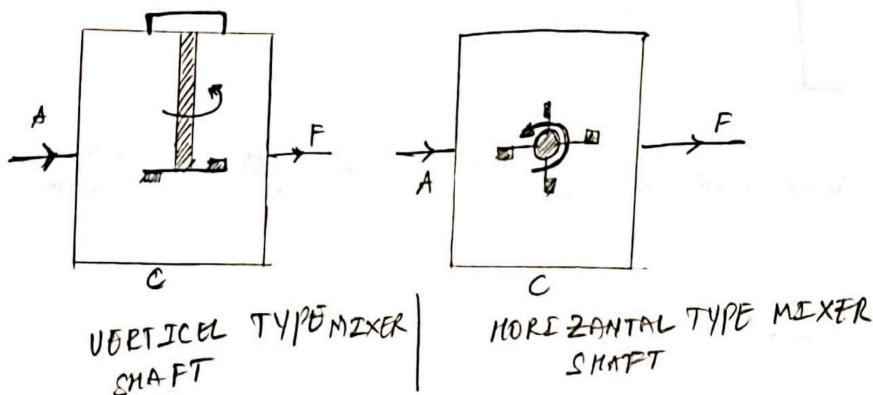


- In moving basin "mixing" is induced by generating the turbulence which is achieved by rapidly changing the direction of flow of water either in horizontal plane

(ii) in vertical plane according to which there are further classified as

- AROUND & END TYPE MIXING BASIN.
- OVER & UNDER TYPE MIXING BASIN. respectively

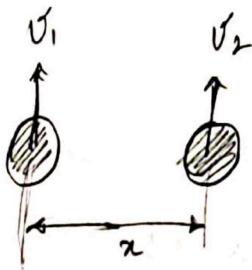
### (ii) Mechanical Mixer



- In mechanical mixers, mixing is induced mechanically, by vigorous agitation of coagulants into the wastes, intensity of which is represented in terms of parameter TEMPORAL MEAN VELOCITY GRADIENT "G"
- It is defined as relative velocity of particles w.r.t each other, located at a particular distance from each other.

$$g = \frac{V_1 - V_2}{n} \cdot (m/m/s)$$

(B)  $\text{sec}^{-1}$



$- g = f[p, \mu, V]$ .

$$g = P^a \mu^b V^c$$

$$g = \sqrt{\frac{P}{\mu V}}$$

$\rightarrow$  deep circular (B) square tank are provided having depth to width ratio

i.e.,  $\frac{\text{depth}}{\text{width}} = 1:1 - 3:1$

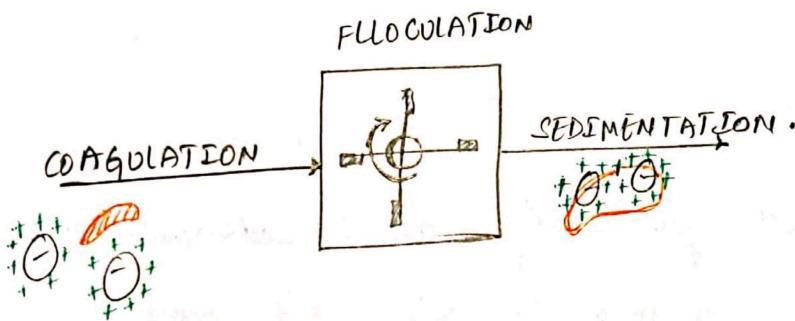
$\rightarrow t_d = (30-60 \text{ sec})$

$\rightarrow$  power supplied to shaft is 1-3 watts/unit discharge in ( $\text{m}^3/\text{hr}$ ).

$$g > 300 \text{ sec}^{-1}$$

(ii) FLOCCULATION (slow mixing):

- It is the process in which neutralized particles are brought in intimate contact with each other and sticky precipitates to form a bigger size particle [flocs] which can get easily settled in following sedimentation processes.
- To increase the opportunity of particles to agglomerate [to combine], slow mixing is also induced in this processes.

- Factors affecting rate of flocculation: (RoF)

	<u>RoF</u>	<u>RoF</u>
(i) Turbidity ( $\uparrow$ ) :	More	—
(ii) Intensity of mixing : optimum range	—	more
(iii) Type of coagulant : Iron salts	—	more
(iv) dose of coagulant : optimum dose	—	more

- In flocculation a parameter " $\eta t$ ", represents the coagulation opportunity, as it signifies the no. of collisions b/w the particles, thereby helps in identifying the types of flocs formed. as follows.

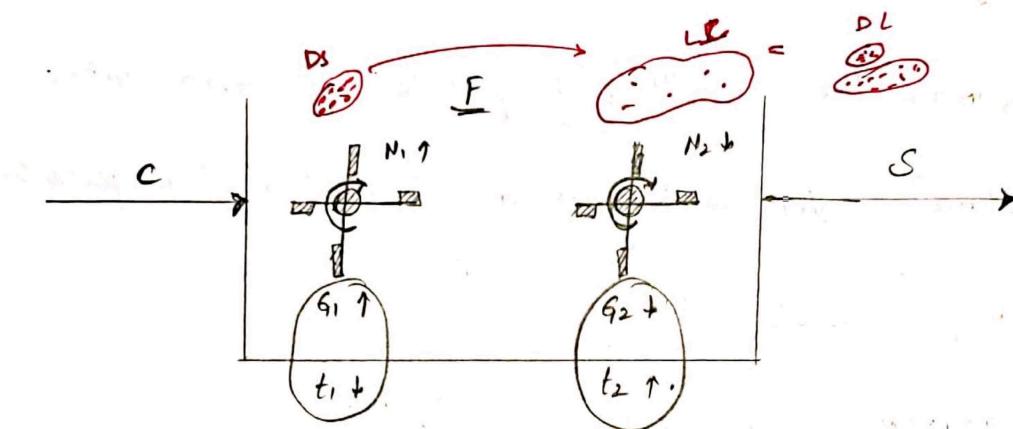
if  $G \uparrow, t \downarrow \Rightarrow$  Dense & small



if  $G \downarrow, t \uparrow \Rightarrow$  LIGHT & LARGE



$$\begin{aligned} \eta t &= \text{Constant,} \\ \eta &= \frac{v_1 v_2}{a}, \quad t = \text{time of contact}. \end{aligned}$$



- As large dense flocs gets easily settled in sedimentation tank, it is advantages to vary the value of ' $\eta$ ' along the length of flocculation tank
- small dense flocs formed in the initial sections of the tank ( $G \uparrow, t \downarrow$ ) combines with large light flocs formed in the subsequent section of the tank ( $G \downarrow, t \uparrow$ ). and lead to the formation of large dense flocs.

- Hence,  $G_I = 2 g_0$

[ $\frac{g_{\text{inlet}} - I}{g_{\text{outlet}} - O}$ ]

~~Principle~~

- As the power supply reduced along the length of this tank

to achieve the above condition, it is termed as "TAPERED FLOCCULATION"

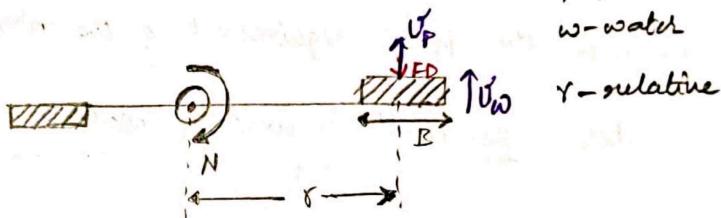
-  $H = 3 - 3.5 \text{ m.}$

-  $t_d = 10 - 20 \text{ min}$

-  $g = 10 - 75 \text{ sec}^{-1}$ ;  $g_t = \frac{20000 - 60,000}{(1 \times 10^5 - 1.5 \times 10^5)} - \text{for alum.}$

- Total area of paddles is  $(10-25t)$  of area of tank

-  $g = \sqrt{\frac{P}{\mu V}}$ ;  $V = Q_0 t_d$ .



$$P = F_D \cdot V_r.$$

$$V_r = V_p - V_w$$

$$V_p = \omega r$$

$$C_D \approx 1.8$$

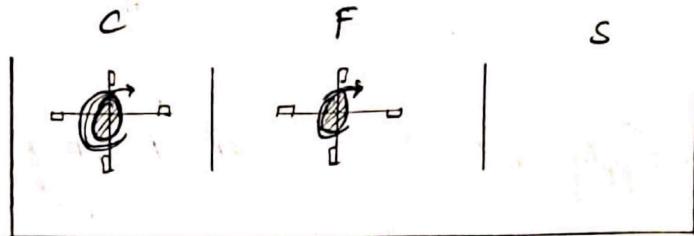
$$\omega = \frac{2\pi N}{60}$$

$$F_D = \frac{1}{2} C_D \cdot C_W \cdot A \cdot V_r^2$$

$$A = n(LB)$$

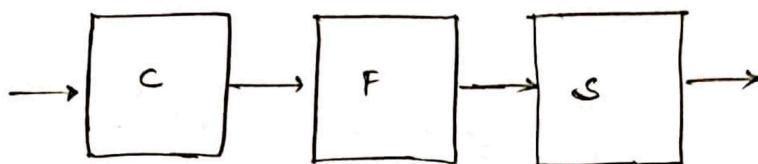
$$G = \sqrt{\frac{\frac{1}{2} C_D \cdot C_W \cdot n(LB) \cdot V_r^3}{\mu (Q_0 \cdot t_d)}}$$

### (iii) SEDIMENTATION!



CLARIFIER FLOCCULATOR.

(8).



Q A flash mixer is treating  $2\text{m}^3$  of water at mining rate of  $300 \text{ sec}^{-1}$ , @ the temp of  $20^\circ\text{C}$ , where viscosity of water =  $0.01 \text{ Poise}$ , compute the power requirement of the mixer for treating the water per unit volume of water

Soln-

$$Q = 2\text{m}^3 \quad T = 20^\circ\text{C}$$

$$G = 300 \text{ sec}^{-1} \quad \mu = 0.01 \text{ Poise}$$

$$V = Q_0 \cdot t_d$$

$$q = \sqrt{\frac{P}{\mu v}} \rightarrow \text{or } \cancel{q} = \sqrt{\frac{P}{\mu v}}$$

$$P = q^2 \mu v = (300)^2 \times 0.01 \times 0.1 \times 1$$

$$P = 90 \text{ Watts.}$$

Q A flocculation tank 30m long, 12m wide, 4m ~~width~~ depth is treating 10MLD of water. It is provided with ① shafts at mid-depth of the tank, supporting ② paddles each one opposite to each other. The center-line of the paddle is 1.8m from the center of the shaft. Size of paddle is 0.3m x 12m., velocity of water is  $\frac{1}{4}$  th the velocity of paddle. Assume N = 30

compute ① Detention time ② Power requirement of ~~shaft~~ tank

③ Intensity of mixing

$$\underline{\text{Soil}} \quad L = 30\text{m} \quad V = (L \cdot B)H \quad Q = 10 \text{ MLD} \\ B = 12\text{m} \\ H = 4\text{m}$$

$$① t_d = \frac{V}{Q} = \frac{L \cdot B \cdot H}{Q} = \frac{30 \times 12 \times 4 \times 24}{30 \times 10^6 \times \cancel{4} \times 10^{-3}} = 3.456 \text{ hr}$$

$$② P = F_D \cdot \bar{V}_r = \frac{1}{2} C_D \cdot \rho \omega \cdot A \cdot \bar{V}_r^3 \\ = \cancel{\frac{1}{2} (1.8) (1) \cancel{A}}$$

$$A = n (LR) = 8 [0.3 \times 12] = 28.8 \quad r = 1.8$$

$$\bar{V}_r = \bar{V}_p - \bar{V}\omega \\ = \bar{V}_p - \bar{V}_p/4 \\ = \cancel{3/4} \bar{V}_p$$

$$\bar{V}_p = \omega r \\ = \frac{2 \pi N r}{60} \rightarrow \frac{2 \times 3.14 \times 30 \times \cancel{1.8}}{60} = \cancel{5.654} \text{ m/sec}$$

$$\bar{V}_p = 5.654 \text{ m/sec}$$

$$\text{So, } P = \frac{1}{2} 1.8 \times 10^3 \times 28.8 \times \left(\frac{3}{4} \times 5.65\right)^3 \times 10^{-3} \text{ (kW)}$$

$$\cancel{P = 109.16 \text{ kW}}. \quad P = 1975.75 \text{ kW}$$

Assume  
 $\mu = 0.01 \text{ poise}$

$$\textcircled{c} \quad f = \sqrt{\frac{P}{\mu v}} = \sqrt{\frac{1975.75 \times 10^3}{0.01 \times 0.1 (20 \times 12 \times 4)}}$$

$$f = 37.04 \text{ sec}^{-1}$$

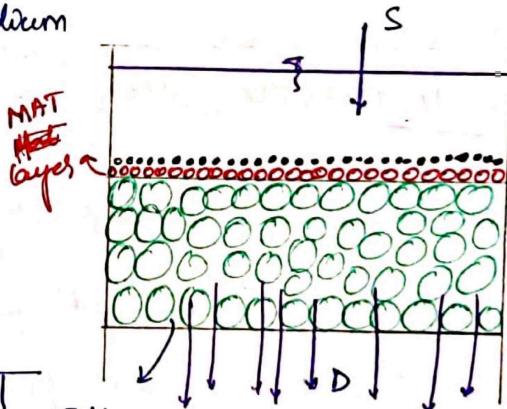
## FILTRATION

- It is the process of removal of fine suspended particles and flocs which could not be removed in sedimentation.
- Apart from removal of S.S., it also removes organic matter, micro-organisms and dissolved solids from the water.
- This wide range of impurities is removed from water, by following mechanisms taking place during filtration

### a) MECHANICAL STRAINING:

- When the water passes the filter medium suspended particles having size, greater than the size of voids of filter medium are not able to pass through it, hence are strained out from the water -

{ Sand, Anthracite, Activated carbon  
GARNET, FIBROTEXTILE }

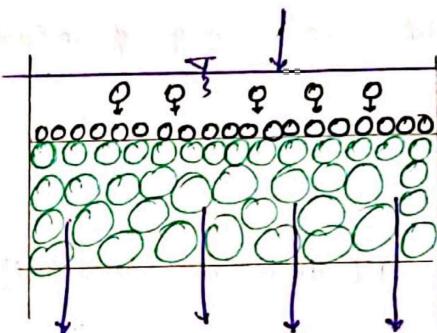


leading to the formation of layer of entrapped impurities over the surface termed as "MAT LAYER"

- suspended particles, having size smaller than the size of voids of filter medium are retained over the mat layer
- hence, both suspended particles having size smaller and greater than the size of <sup>voids of</sup> medium particles are removed by filtration

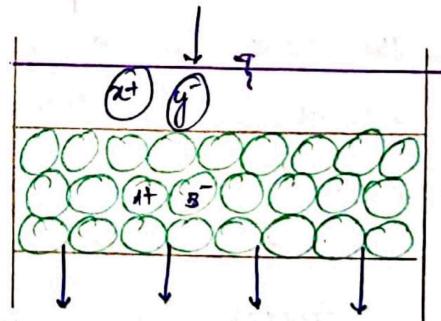
### B) SEDIMENTATION:

- Due to the removal of turbulence from the water above the filter medium, suspended particles get settled over the medium surface



### C) ELECTROLYTIC CHANGES:

- when water passes through the filter medium dissolved solids in it gets neutralized by the charge present over the medium particles.
- These neutralized particles are then further removed during cleaning process.



## LEC-30

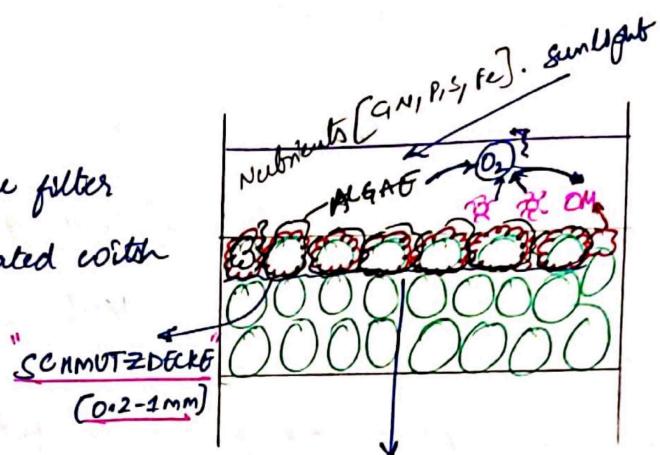
### IV) BIOLOGICAL CHANGES:

- when water flows through the filter medium, the upper layer gets coated with sticky deposits of partially decomposed organic matter, along with the nutrients of algae
- over the period of time due to the growth of algae presence of oxygen increases ~~which~~ [due to photosynthesis] which is utilized by micro organisms for decomposition of organic matter
- As the growth of micro organism takes place, food is not available for all the MO, which results in their depletion by the process termed as "ENDOGENOUS RESPIRATION"

### # TYPES OF FILTERS!

- filtration is carried out in the units termed as filters, which are broadly classified into two

(A) GRAVITY FILTERS    (B) pressure filters.

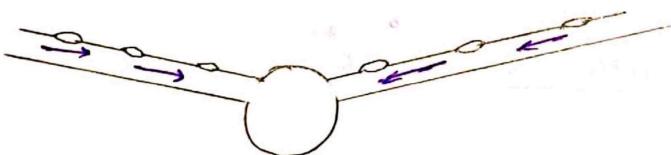


### A) GRAVITY FILTERS:

- These are type of filters in which energy required by the water to overcome the resistance of medium particles, is obtained by the weight of water itself
- Gravity filters are further classified as follows

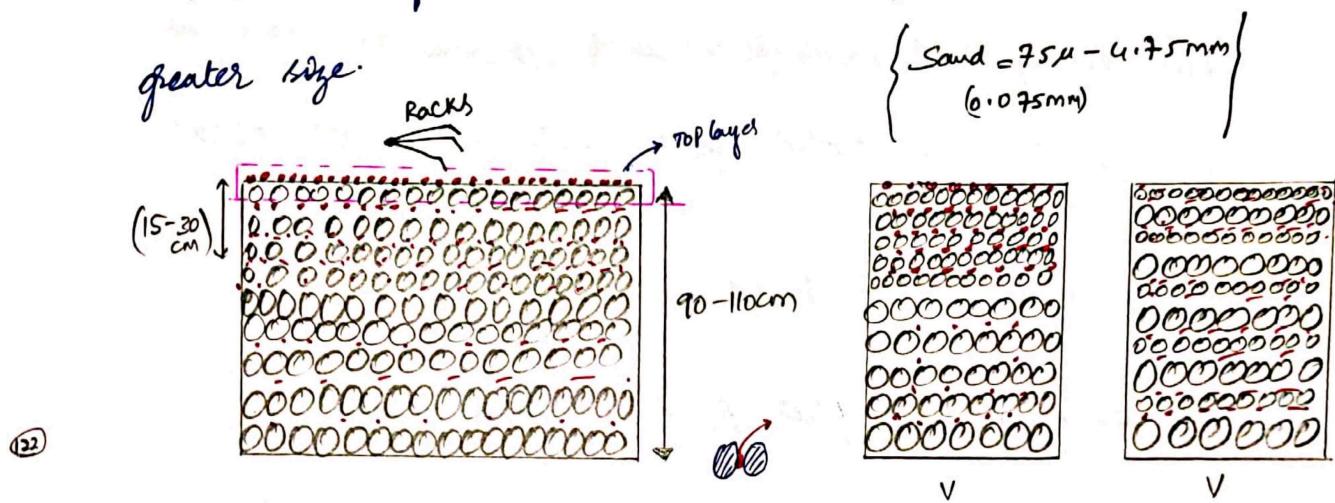
### B) SLOW SAND FILTER (SSF)

- SSF utilizes either raw water or settled water from plain sedimentation
- sand is used as filter medium
- Gravel is used to support the sand particles.



- Depth of the tank in the range of (2.5 - 3.5 m).
- Area of filter unit varies in range of  $100 - 2000 \text{ m}^2$
- Effective size of medium particles ( $D_{10}$ ) =  $0.2 - 0.3 \text{ mm}$ .

- Co-efficient of uniformity  $(Cu) = 3-5$
- Depth of sand medium is  $(90-110)$  cm
- Depth of the water above the sand medium is kept equal to depth of sand medium itself
- TOP  $(15-30)$  cm of the sand is fine variety and rest is of uniform greater size.



- Freshly cleaned filter has head loss of  $(10-15)$  cm, which goes on increasing with time, hence the ht. of the telescope tube is adjusted in accordance with head loss to maintain the constant discharge.
- When head loss becomes  $[0.7-0.8]$  cm, depth of filter medium, cleaning of filter should be done.

- For cleaning of filter, top (1.5-3cm) sand layer ~~is~~ removed and the remaining surface is scraped with the help of the rocks, which loosens up the impurities; and is further washed away with clarified water
- once cleaning is completed, filter is again loaded with settled water, but filtered water is not used for next 24-26 hrs, as sufficient time is provided for the growth of SCHMIDT-ZDECKE
- Frequency of cleaning is (1-3) months.
- Efficiency of this filter for removal of Mo: 98-99%
- Effluent of SSF is deficient in nutrients [ $N, P, S$ ], hence offers lesser opportunity for regrowth of organisms in distribution system
- This filter must be avoided for treatment of water having turbidity more than 50 units; as it would get frequently clogged, requiring frequent cleaning, which in turn increase its operational cost

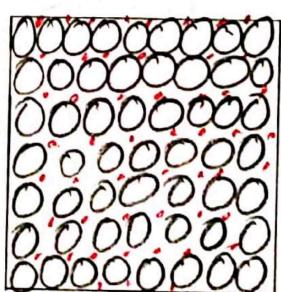
- Rate of filtration is in range of  $[2400 - 4800] \text{ l/m}^2/\text{day}$
- plan Area =  $\frac{Q_o}{R_o P}$ .
- It is suitable to be provided for small villages & communities having lower water demand.
- No. of filters required depending upon the area is as follows -

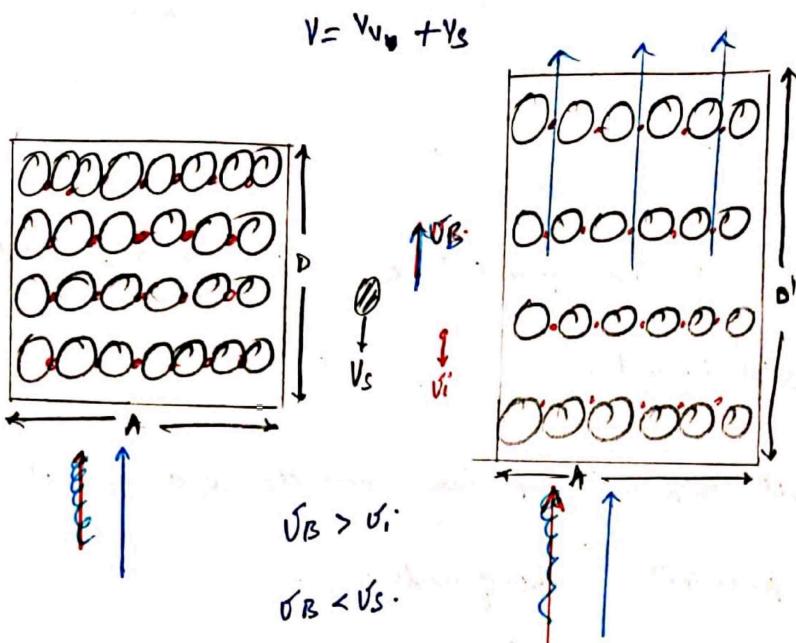
Area ( $\text{m}^2$ )	No. of units
<20	2
20-249	3
250-649	4
650-1200	5
>1200	6.

LEC-31

### (IV) RAPID SAND FILTER (RSF)

- operation of (RSF) is same as that of SSF
- During operation valve no (1&4) are opened and (2,3,5&6) are closed
- Settled water enters into the filter through valve no(1) & filtered water is collected @ valve no(4)





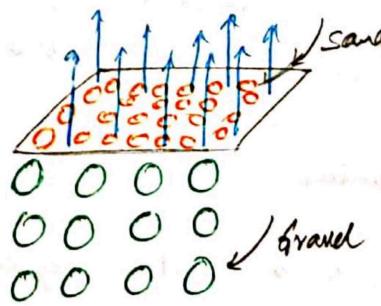
- As the size of medium particles is comparatively bigger and medium is comparatively poorly graded, impurities are able to penetrate upto the lower parts of the filter medium.
- Hence surface cleaning alone is not sufficient and is accompanied by back washing.
- During backwashing valves (1&4) are closed and (2,5,6) are opened.
- Compressed air and pressurized water then enter into the filter medium, causing it to expand, thereby increasing the opportunity of entrapped impurity to get carried away.

along with the backwash water into the wash water

### Trough

- From wash water Trough water enters into the Inlet chamber & finally into the wash water GUTTER through value <sup>no</sup>(2).
- Once backwashing is completed value no (2,5,6) are closed and filter is again loaded by settled water by opening value <sup>no</sup>(1) but filtered water is not used and is bypassed in wash water gutter through value <sup>no</sup>(3).
- This is done to permit the growth of SCHMIDT DECKE removed during cleaning process and for maturity of the filter.
- After sufficient time value no (3) is closed and value <sup>no</sup>(4) is opened
- The entire process of backwashing is completed within (15-30 min).
- Cleaning period is 24-48 hrs.
- Amount of water required for cleaning is only (2-5%) of the water to be filtered by the filter in a day

- The Rate of Backwashing is  $(15-90) \text{ cm/min} \approx (45 \text{ cm/min})$   
 [The above range is on the basis of the fact that backwash velocity must not be greater than settling velocity of smallest sand particle].
- Rate of filtration in this case is  $3000-6000 \text{ l/m}^2/\text{hr}$ .  
 [This value is atleast 30 times greater than that of ROF of SSF hence it requires 30 times less area for treatment of same quantity of water].
- Since ROF is less than Rate of Backwashing, flow during filtration is laminar and during backwashing is in TRANSITION.
- In RSF, distribution of backwash water is a critical function which takes place through gravel layer only, hence in this case gravel layer is properly graded to maintain the flow to be uniform during Backwashing

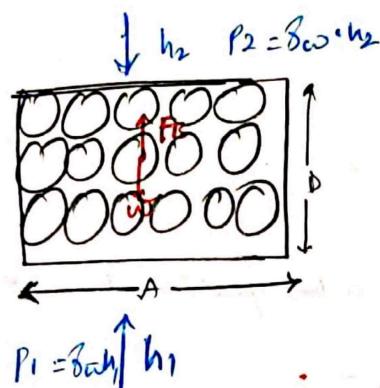


- Effective size of the medium particle ( $D_{10}$ ) = 0.35 - 0.55 mm.
- Co-efficient of uniformity ( $C_u$ ) = [1.2 - 1.6].
- Depth of the sand layer (60 - 90 cm).
- No. of operational filters to be provided here can be computed empirically as 
$$N = 1.22 \sqrt{Q_s}$$

$Q_s$  = design discharge [MLd].

- Bacteriological efficiency of this filter is 80-90%.
- If 'D' is the depth of sand medium, then top of the wash water trough, is kept atleast at a distance of "D/2" from the top surface of the filter medium as filter medium is not likely to expand by more than 50% during backwashing.
- To hydraulically expand the filter bed loss of head through it is equal to ~~less~~ buoyant wt. of the particles forming the filter medium.

- Thus head loss is given by  $h_L = D(1-\eta)(G-1)$



For equilibrium net forces  $\sum F_y = 0$

$$p_1 A + F_B - p_2 A - w = 0.$$

$$p_1 A - p_2 A = w - F_B.$$

loss of energy of water = buoyant wt of particles.

(in terms of force)

$$\rho_{\text{water}} h_1 A - \rho_{\text{water}} h_2 A = v_s \rho_s - v_s \rho_{\text{water}}. \quad [v_s = v_w].$$

$$\rho_{\text{water}} A (h_1 - h_2) = v_s \rho_{\text{water}} \left[ \frac{\rho_s}{\rho_{\text{water}}} - 1 \right]. \quad \left( v_s = \frac{v}{1+\epsilon} \right)$$

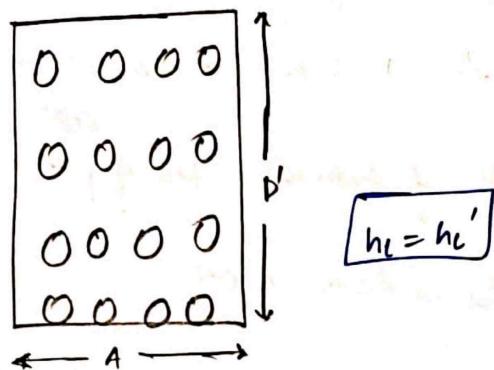
$$\rho_{\text{water}} A \cdot h_L = \frac{v}{1+\epsilon} \rho_{\text{water}} (G-1)$$

$$\rho_{\text{water}} \cdot A \cdot h_L = v (1-\eta) (G-1) \rho_{\text{water}} \quad \left( \frac{1}{1+\epsilon} = 1-\eta \right)$$

$$\rho_{\text{water}} \cdot A \cdot h_L = A D (1-\eta) (G-1) \rho_{\text{water}}. \quad (X = AD)$$

$$h_L = D (1-\eta) (G-1). \rightarrow \textcircled{i}$$

- loss of head through expanded bed is equal to loss of head through unexpanded bed. as there is no change in Bouyant wt. of particles.



$$h_L' = D'(1-\eta') (G-1) \quad \text{--- (ii)}$$

$$D(1-\eta)(G-1) = D'(1-\eta')(G-1).$$

$$D(1-\eta) = D'(1-\eta').$$

LEC-32

- on the basis of experiments/observations ( $\eta'$ ) can be computed empirically as follows  $\{\eta' = f(U_B, U_S)\}$ .

$$\eta' = \left(\frac{U_B}{U_S}\right)^{0.22}$$

$U_B$  = Back washing velocity

$U_S$  = Settling velocity of medium particles.

Q A RSF is to treat water for 2,75000 people with avg water demand of 200 l/c/d and ROF  $q = 20 \text{ m}^3/\text{m}^2\text{hr}$  determine the no. of filters required for treating this water if the available surface area of each unit is  $5 \times 2 \text{ m}^2$ . Also compute the upflow velocity and the head loss of expanded bed of  $0.66 \text{ m}$ , ~~water~~ of the original depth of the filter medium is  $0.6 \text{ m}$   
 - The porosity of the bed is  $0.5$ ,  $q = 2.5$ ,  $d = 0.55 \text{ m}$ ,  $C_D = 0.502$   
 flow is in transition during backwashing.

Soln

- Design discharge through filter  $Q_D = Q_{MD} = 1.8 \text{ l/sec}$

$$= 1.8 \times 200 \times 2.75 \times 10^5 \times 10^{-6}$$

$$= 99 \text{ MLD.}$$

Assuming 5% of water is required for backwashing for 30 mins

Net design discharge through filter  $Q_{ND} = 1.05 \times 99$

$$= 103.95 \text{ MLD}$$

Net effective design discharge through filter

$$Q_{DD} = 103.95 \text{ MLD} / 23.5 \text{ hr}$$

$$= \frac{103.95 \times 10^6 \times 10^{-3}}{23.5}$$

$$SA = \frac{Q_D}{ROP} \cdot \left( \frac{m^3/hr}{m^3/m^2/hr} \right) = m^2$$

$$Q_{ND} = 4423.04 \text{ m}^3/\text{hr}$$

$$SA = \frac{Q_{ND}}{ROP} = \frac{4423.04}{20} = 221.152$$

$$SA_{\text{filter}} = 5 \times 2 = 10 \text{ m}^2$$

$$\text{no. of filters reqd } N = \frac{SA}{SA_{\text{filter}}} = \frac{221.152}{10} = 22+1 \text{ std by}$$

$$= 23 (22+1) @ 5 \times 2 \text{ m}^2$$

$$(ii) \quad h_L' = h_L = D(1-\eta)(\cancel{g-1}) = 0.6(1-0.5)(2.5-1) = 0.45 \text{ m.}$$

$$(iii) \quad h_L' = h_L \Rightarrow b'(1-\eta')(\cancel{g-1}) = D(1-\eta)(\cancel{g-1}).$$

$$0.66(1-\eta') = 0.6(1-0.5)$$

$$\cancel{\eta'} \approx \eta' = 0.545$$

$$\eta' = \left( \frac{V_B}{V_S} \right)^{0.22}$$

$$V_B = \eta^{0.22} \cdot V_S$$

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

$$v_s = 0.046 \text{ m/s}$$

$$v_B = \gamma^{1/0.22} \cdot v_s = 0.545^{1/0.22} (0.046)$$

$$v_B = 0.00291 \text{ m/s}$$

NOTE: When water passes through the filter medium loss in head takes place to overcome the resistance offered by the medium particles.

- This initial head loss through the filter medium can be computed using "ROSE EQUATION."

$$h_L = \frac{1.067 \frac{v^2 \cdot D}{\phi \cdot g \cdot n}}{\left(\frac{C_D}{d}\right)}$$

$h_L$  = head loss through the filter medium (m)

$v$  = velocity of approach ( $\text{s}^{-1}$ ) filtration velocity ( $\text{m/s}$ )

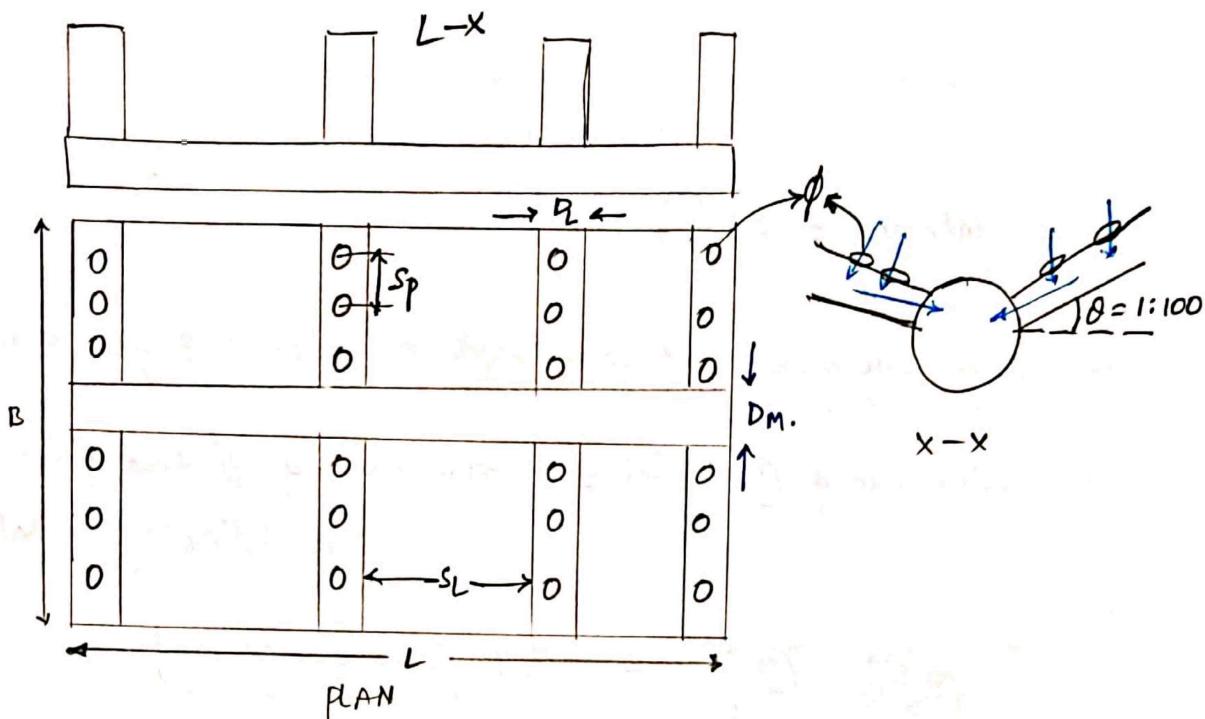
$d$  = dia of particle (sand) ( $\text{m}$ )

$D$  = depth of filter m ( $\text{m}$ )

$C_D$  = Newton's drag co-effecient

$\phi$ - shape factor $n$ - porosity $g$ - acc due to gravity
---

## # Designing of under drainage system:



— Lateral and manifold system of underdrains is being provided  
 (central)  
 In this case, which will be designed for backwash discharge.

as follows.

(i) Dia of perforations is  $(6-13)$  mm

(ii) spacing between the perforations  $(7.5-20)$  cm c/c  
 $(S_p)$ .

**NOTE:** lesser spacing is kept for smaller perforation and more spacing  
 for bigger perforation

(ii) spacing between the laterals is in the range of (15-30) cm  
 (Sl).

$$(iv) \frac{L}{B} = (1.5 - 2.5)$$

$$(v) \text{no. of laterals} = 2 \left( \frac{L}{S_L} \right).$$

(vi) Total cross-section area of ~~laterals~~ perforations = 0.2% of filter area

(vii) Cross-section area of ① lateral = 2 (8) 4 times of c/s Area of perforations in ① lateral

$$\left( \frac{\pi D_L^2}{4} \right) = 2 (8) 4 \frac{[0.2 + \text{filter area}]}{N}.$$

(N = no. of laterals);  $D_L$  = dia. of lateral;

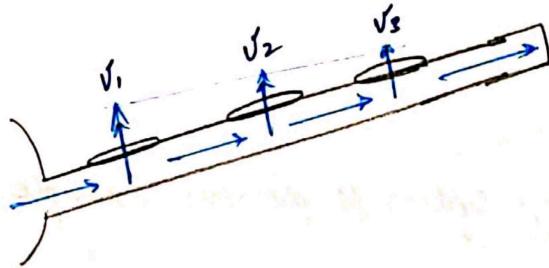
$\Rightarrow$

NOTE: Factor (2) is used when 13mm perforation is adopted  
 and factor (4) is used when 6mm perforation is adopted

(viii) Cross-section area of central (8) manifolds drain = 2 [c/s Area of all laterals]

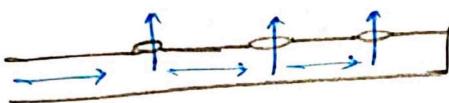
$$\left( \frac{\pi D_m^2}{4} \right) = 2 [ \text{c/s Area of one lateral} \times N ]$$

(ix)  $\frac{\text{Length of lateral}}{\text{dia of lateral}} \leq 60$ .

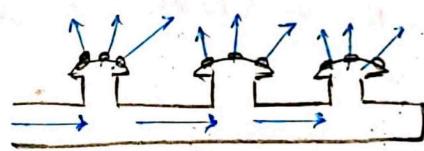


[NOTE!], laterals provided in under drainage systems are generally of two types.

### (a) PERFORATED PIPE TYPE



### (b) STRAINER TYPE.



- when perforated pipe type lateral is used, compressed air is not utilized for back washing & is termed as "high velocity wash" ~~what is it~~

- whereas if strainer type lateral is used, compressed air is also utilized for back washing and is termed as "slow velocity wash."

Q Design the under-drainage system for previous Example

Sol:- (i) Let area of perforation be 6 mm<sup>2</sup>

(ii) (sp). " " 7.5 cm/s  
Let

(iii) " spacing b/w the laterals be 20 cm.

$$\text{iv) no. of laterals} = 2 \left( \frac{L}{S_L} \right) = 2 \left( \frac{25}{20} \right) = 2.5 \quad \cancel{= 10}$$

$$= 2 \left( \frac{5 \times 10^2}{20} \right) = 50$$

v) sp area of all perforations = 0.2% of filter area

$$= \frac{0.2}{100} \times (5 \times 2) \times 10^4 = 200 \text{ cm}^2$$

vi) sp area of one lateral =  $4 \times \left( \frac{200}{50} \right) = 16 \text{ cm}^2$

$$\frac{\pi D_L^2}{4} = 16 \Rightarrow D_L = 4.574 \text{ cm}^2$$

(vii) ~~the~~ area of manifold =  $2$  (area of all lateral)  
 $= 2 [16 \times 50] = 32 \times 50 = 1600$

$$\frac{\pi D_m^2}{4} = 1600$$

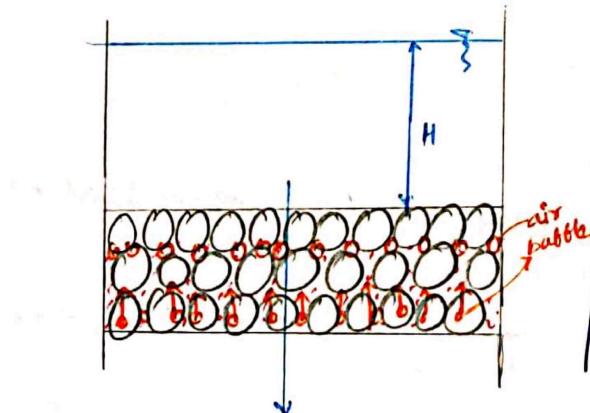
$$D_m = 45.14 \text{ cm}^2$$

(viii)  $\frac{\text{length of the lateral}}{\text{dia of lateral}} = \frac{B - \cancel{D_m}/2}{\cancel{D_m L}} = \frac{2 - 0.45/2}{0.851}$   
 ~~$= 1.71 < 60$~~   
 $= 17.1 < 60$

LEC-33

### # OPERATIONAL PROBLEMS OF RSF:

#### i) AIR BINDING:

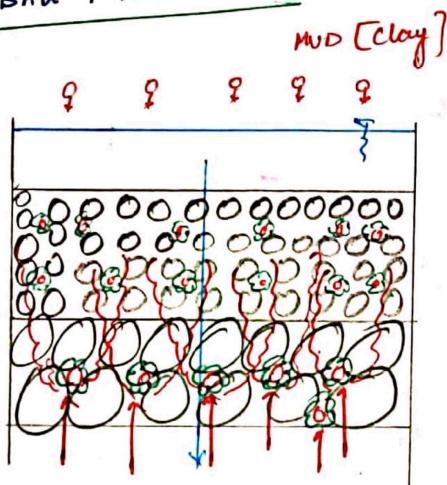


- initial head loss through the filter is (15-30cm), which goes on increasing during filtration as more and more impurities get entrapped in the voids of filter medium.

- A stage comes during operation when the friction resistance, offered by the medium particles becomes more than energy available with the water.
- At this stage the bottom of the medium acts like a vacuum, resulting in pulling (or) sucking of water into the filter medium without getting filtered
- It leads to development of negative head in the lower parts of the filter medium, which when becomes equal to vapour pressure, causes the air to get released from water.
- Bubbles of air comes to the surface and leads to the blocking of the voids of the filter medium
- To avoid air blocking
  - ② Proper cleaning of filter must be done when head loss becomes  $(2.5 \text{ to } 3.5) \text{ m}$  & negative head becomes  $(1.2 \text{ m})$ .

- ⑥ Increase in temperature during filtration must be avoided
- ⑦ Remove algae from the source, from where water is derived
- ⑧ Pumping in air

### 11) MUD - BALL FORMATION:

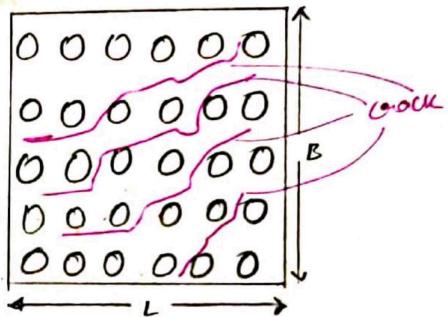


- mud from the atmosphere enters into the filter medium & combines with the impurities present in it leading to the formation of mud balls, size of which goes on increasing with time.
- Once these mud balls enter into the Gravel layer they generate the turbulence around them; leading to the removal of medium particles along with backwash water.

- There by reducing the efficiency of the filter
- To avoid mud ball formation, compressed air scouring for (3-5 min) must be done during backwashing along with surface racking

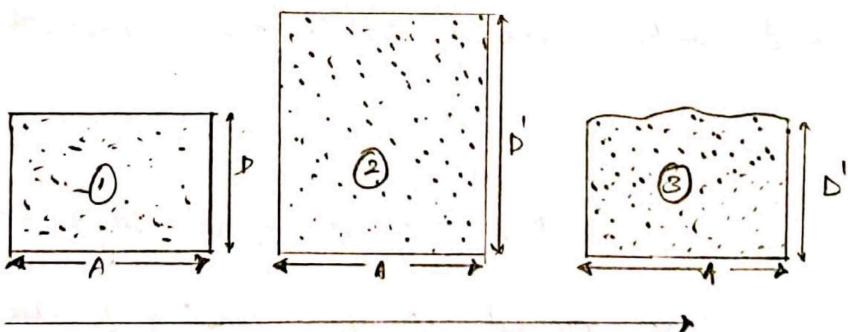
### (c) CRACKING OF FILTER:

- since the sand particles shrinks over the period of time, due to alternate wetting and drying process, cracks are developed over the medium surface reducing the efficiency of the filter medium.



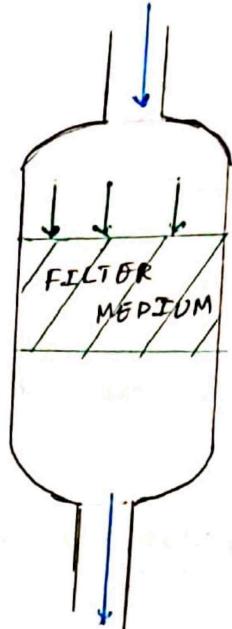
$$V = V_v + V_s$$

### (d) BUMPING OF BED:



## II PRESSURE FILTERS:

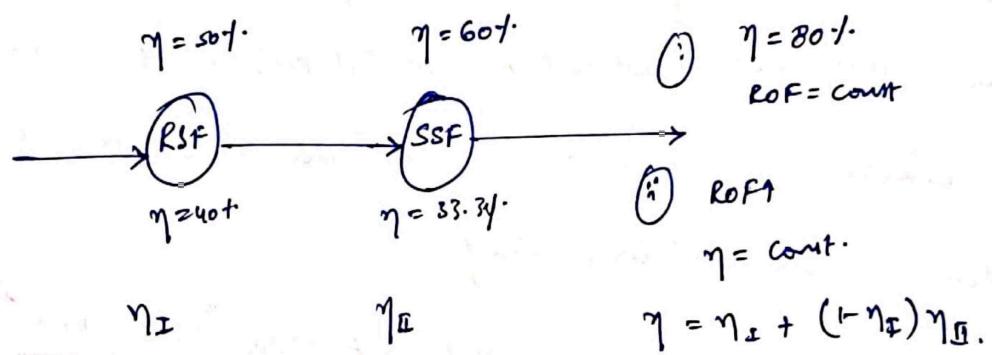
- There are the type of filters in which energy required by the water to overcome the resistance offered by the medium particles is obtained by the application of the pressure over the medium.
- It is same as that of RSF with the only difference, that here treatment is carried out in close container & it utilizes raw coagulated water and flocculation is carried out in the container itself.
- These are less efficient than RSF but offers higher ROF
- ROF is in range of  $6000 - 15000 \text{ l/m}^2/\text{hr}$ .
- Depth ( $H$ )  $\in (3.5 - 8) \text{ m}$ .
- Diameter ( $D$ )  $\in [1.5 - 3] \text{ m}$ .
- They are suitable to be used for treatment of water in swimming pools and industrial wastes.
- They are comparatively smaller than ~~RSF~~ GRAVITY FILTERS.
- Water cleaning is done by back washing.



- There are further of two types on the basis of direction of flow of water. (i) on basis of manner in which water enters the filter

(i) horizontal    (ii) vertical.

### # ROUGHNESS FILTERS & DOUBLE FILTRATION:



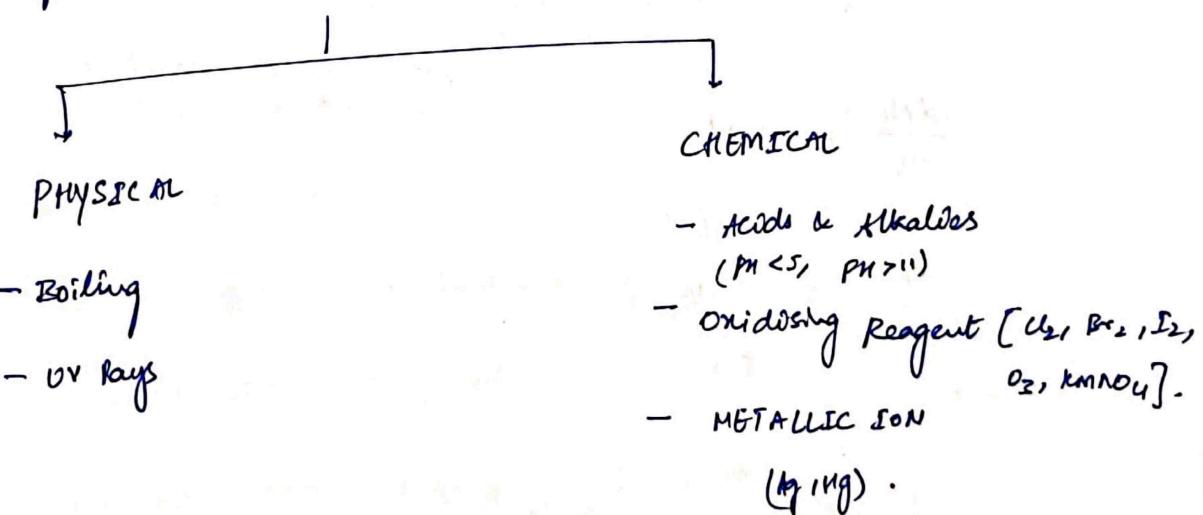
- In order to increase the ROF of SSF, without compromising with its efficiency, RRF is provided before SSF.
- This process is termed as DOUBLE FILTRATION / DUAL MEDIA FILTRATION / MIXED MEDIA FILTRATION and RRF is used is termed as "ROUGHNESS FILTER."

## # DIATOMIC FILTER / DIATOMIC EARTH FILTER!

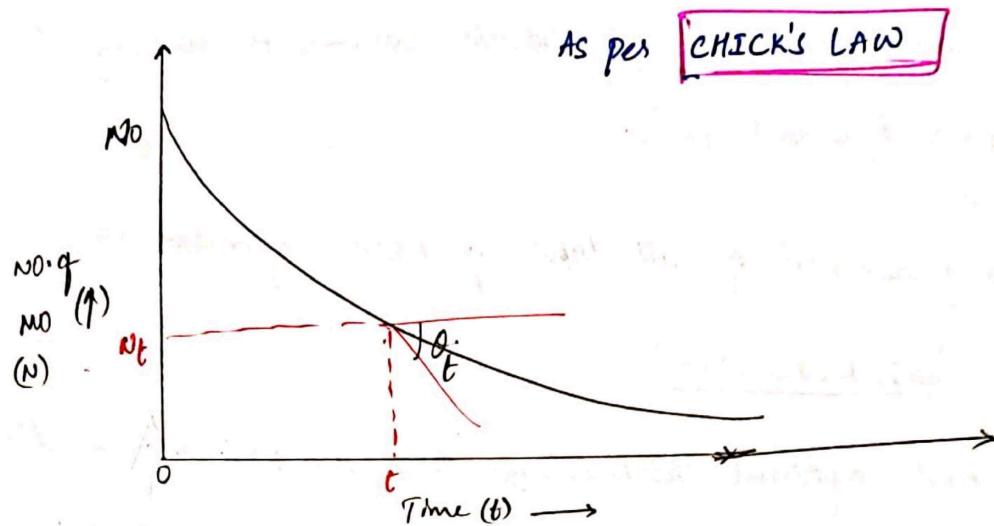
- These filters are used to remove chlorine resistant dysentery cysts, larvae [eggs of organism] of SCHISTOSOMASES.
- Diatomaceous earth (DE) Diatom is a natural occurring salt of siliceous sedimentary rock that is easily ground into a fine white (DE) off white ppt (DE) powder

## # VII DISINFECTION.

- It is the process of removal of disease causing micro-organisms from the water (i.e Pathogens).
- The process of removal of all types of micro-organisms is termed as STERILISATION.
- It is the most important treatment (b) It is the minimum essential treatment required to be given to water and is adopted at the final stage in the chain of water purification.
- Disinfection can be carried out by any of the following methods.



## # KINETICS OF DISINFECTION



$$\frac{dN_t}{dt} \propto -N_t$$

$$\text{at } t=0 \quad \left\{ \begin{array}{l} N_t = N_0 \\ \alpha = k \end{array} \right.$$

$k$  = disinfection constant.

$$\frac{dN_t}{dt} = -k N_t$$

$$N_t = N_0 e^{-kt}$$

$$\int \frac{dN_t}{N_t} = -k \int dt$$

$$N_t = N_0 e^{-kt}$$

$$\ln N_t / N_0 = -k t$$

$$\ln N_t - \ln N_0 = -k (t-0)$$

$$\ln \left( \frac{N_t}{N_0} \right) = -k t$$

$$N_t = N_0 e^{-kt}$$

NOTE Growth of micro-organisms also exponential and is given by

$$N_t = N_0 e^{kt}$$

$k$  = growth rate constant  
( $\text{time}^{-1}$ )

### LEC- 26

Q 20 MLD of water is disinfected by adding 20 mg/l of chlorine  
Find the removal of micro-organisms after 15 mins of addition of  
chlorine. (i) Also compute volume of tank required to achieve 99%  
efficiency of disinfection.

(ii) Find the efficiency of same tank if addition of chlorine is  
discontinued after  $\frac{1}{4}$  th operation

Assume disinfection and growth rate constant to be  $0.284 \text{ min}^{-1}$

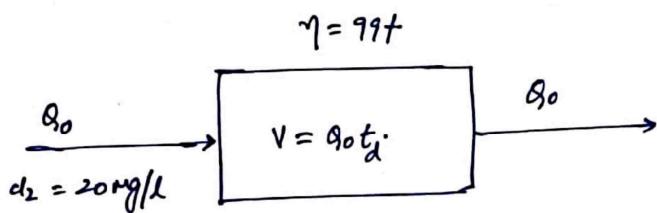
and  $0.45 \text{ min}^{-1}$ ?

Sol: ①  $\gamma R = \frac{N_0 - N_t}{N_0} \times 100 = \frac{N_0 - N_0 e^{-kt}}{N_0} \times 100$

$$= (1 - e^{-0.234 \times 15}) \times 100$$

$$\gamma R = 97\%$$

②



$$\gamma R = 99 = \frac{N_0 - N_t}{N_0} \times 100$$

$$99 = \frac{N_0 - N_0 e^{-kt}}{N_0} \times 100$$

$$t = 19.68 \text{ min}$$

$$V = Q_0 \cdot t_d = 20 \times 10^6 \times \cancel{\frac{19.68}{24 \times 60}} \cdot \frac{10^{-3}}{\text{(m}^3\text{)}} \text{ m}^3$$

$$V = 273.33 \text{ m}^3$$

(iii)

$$N_t = N_0 e^{-kt}$$

$$N_t = N_0 e^{-0.234 \left( \frac{19.68}{q} \right)}.$$

$$N_t = 0.316 N_0.$$

After one-fourth operation growth of NO takes place

$$N_t = N_0 e^{kt}$$

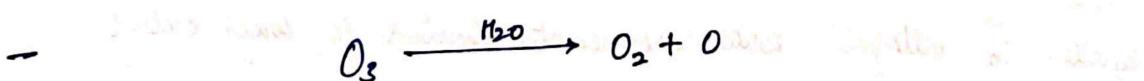
$$= 0.316 N_0 e^{0.45 \times 19.68 \times 0.75}.$$

$$N_t = 242.25 N_0.$$

$$\therefore R = \frac{N_0 - N_t}{N_0} \times 100 = \frac{N_0 - 242.25 N_0}{N_0} \times 100 \\ = -24150\%.$$

### # MINOR METHOD OF DISINFECTION!

#### (I) TREATMENT WITH OZONE ( $O_3$ )!



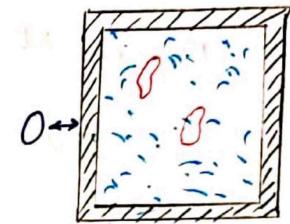
$O_2$  — molecular oxygen

$O$  — nascent oxygen

- $O_3$  when added in water, dissociates into molecular & Nascent oxygen which is a strong oxidising reagent, that carries out

oxidation of organic matter and removal of MO.

- since it is highly reactive, it is not capable of safeguarding the water against future recontamination
- It gives pleasant taste in the water, but is comparatively costlier than other disinfectants.
- Nascent oxygen destroys the cell wall of "MO" in order to carry out disinfection
- Its normal dose is in range of (2-3) mg/l
- It is less effective in killing bacteria and virus than chlorine(Cl<sub>2</sub>) but is more effective in killing protozoa.



## II TREATMENT WITH KMNO<sub>4</sub>:

- It is a popular disinfectant used for treatment of well water supplies in villages which are contaminated to lower extent
- KMNO<sub>4</sub> added in water imparts pink colour, which if disappears indicates the presence of MO and OM, hence more KMNO<sub>4</sub> is added upto an extent pink colour stands in water, which indicates

Removal of OM & MD.

- It increases the permeability of cell walls of MD to carryout disinfection
- It removes 98% of bacteria in general and 100% of cholera causing bacteria
- Normal dose varies in between (1-2 mg/l). @ the contact period of 4-6 hrs.

NOTE 1

$$\text{Solubility} = f [ \text{concentration, time of contact} ]$$

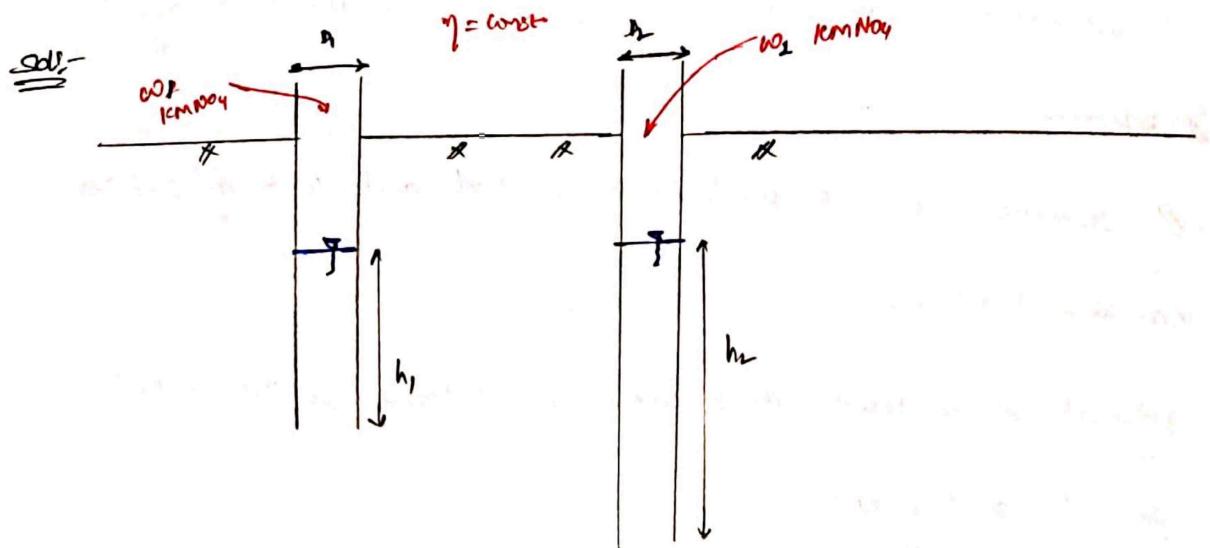
As per WATSON LAW

$$\text{for a given solubility } \Rightarrow t C^n = \text{constant}$$

$n$  = dilution co-efficient.

- Q 45 kg of KMNO<sub>4</sub> is added in water & in well of dia 8.5m having standing water depth of 15m in it. Compute the ~~date~~ level of water in another well for same medium. To achieve same degree of disinfection by addition of 30 kg of KMNO<sub>4</sub> added with with size being 1m in half time

Assume  $n = 0.95$



For same degree of disintegration in both well

→ solubility of KMNO4 in both wells must be same

$$t_1 C_1^n = t_2 C_2^n$$

$$t_1 \left(\frac{w_1}{V_1}\right)^n = t_2 \left(\frac{w_2}{V_2}\right)^n$$

$$t_1 \left(\frac{45}{\left(\frac{\pi D^2}{4} h_1\right)}\right)^{0.95} = \frac{t_2}{2} \left(\frac{80}{\left(\frac{\pi D^2}{4} h_2\right)}\right)^{0.95}$$

$$t_1 \left[\frac{45}{\frac{\pi}{4}(2.5)^2 \cdot 15}\right]^{0.95} = \frac{t_2}{2} \left[\frac{80}{\frac{\pi}{4}(1)^2 \cdot h_2}\right]^{0.95}$$

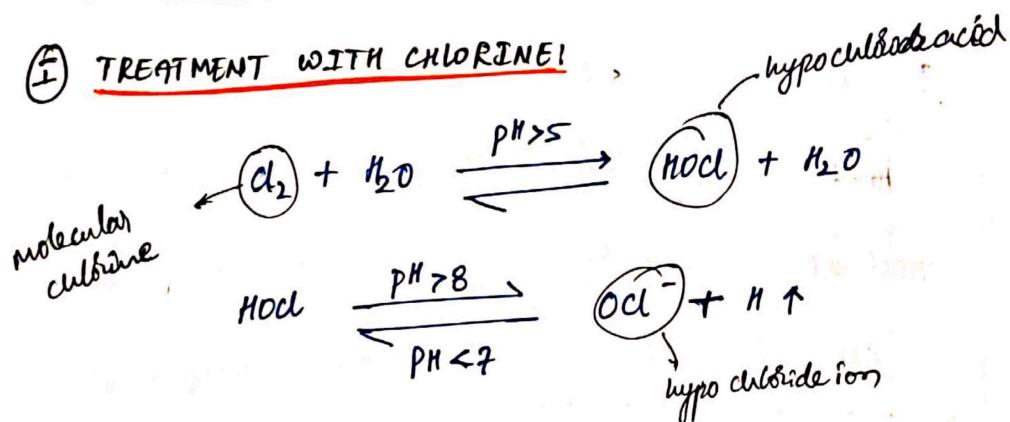
$H_2 F$

$$t_1 (0.230) = \frac{t_2}{2} \left[\frac{80}{0.785(1)^2 \cdot h_2}\right]^{0.95}$$

$$\Rightarrow H_2 = 59.05 M$$

## # MAJOR METHOD OF DISINFECTION:

### (1) TREATMENT WITH CHLORINE!



- chlorine when added in water reacts with it at  $\text{pH} > 5$  and leads to the formation of highly unstable hypochlorous acid ( $\text{HOCl}$ ), which further dissociates into hypochloride ion ( $\text{OCl}^-$ ).
- Here all above three forms of chlorine ( $\text{Cl}_2, \text{HOCl}, \text{OCl}^-$ ) are termed as "freely available chlorine" and are capable of carrying out disinfection.
- out of all the above three forms of chlorine, "HOCl" is most destructive disinfectant [80 times more effective than  $\text{OCl}^-$ ], hence  $\text{pH}$  during disinfection is maintained to be slightly less than (7)

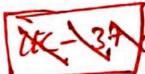
Forms of chlorine

Forms of $\text{Cl}_2$	pH
$\text{Cl}_2$	< 5
$\text{HOCl}$	5-7
$\text{HOCl}, \text{OCl}^-$	7-8
$\text{OCl}^-$	> 8

- chlorine enters into the cell wall of the micro-organisms and destroy the enzymes which are responsible for metabolism to kill them to carryout disinfection

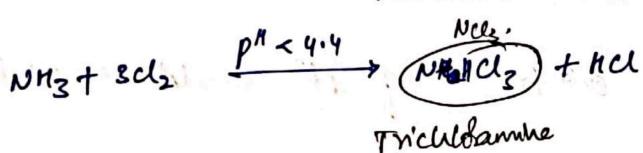
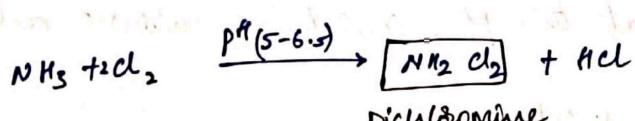
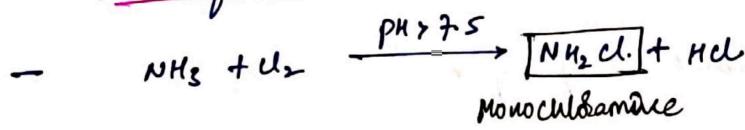
[NOTE! metabolism is a process in which bigger nutrients are broken into the smaller one, releasing the energy [Catabolism], which is used by the body to grow new cells [Anabolism]]

CATABOLISM = CATABOLISM + ANABOLISM



LFC-37

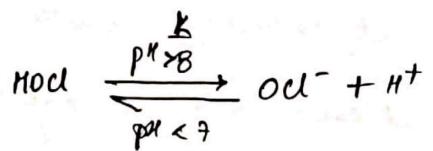
- chlorine when added in water, immediately reacts with ammonia and leads to the formation of "CHLORAMINES" which are also termed as combined form of chlorine and are capable of carrying out disinfection, but are 25 times less effective than free chlorine.



**NOTE!** order of effectiveness of chloramines as disinfectant  
 $\text{NHCl}_2 > \text{NH}_2\text{Cl} > \text{NH}_2\text{Cl}_2$ .

- Dose of chlorine is such that, residual after 10 mins of contact period is 0.2 mg/l, to safe guard water against future recontamination.

Q 15 mg/L of chlorine is added to water to carryout disinfection. Equilibrium of which is governed by following reaction



$$K = 2.5 \times 10^{-7} \text{ mol/lit}$$

(i) Compute

- i) fraction of HOCl in water at pH of 7
- ii) concentration of  $OCl^-$  at this pH, considering chlorine added dissociates into HOCl &  $OCl^-$
- iii) at what pH of water 0.7 fraction of  $OCl^-$  would be available in this water

SOLN  $pH = 7 \Rightarrow [H^+] = 10^{-7} \text{ mol/lit}$

$$K = \frac{[OCl^-][H^+]}{[HOCl]}$$

$$2.5 \times 10^{-7} = \frac{(OCl^-) 10^{-7}}{[HOCl]}$$

$$[HOCl] = 0.4 [OCl^-]$$

$$f[HOCl] = \frac{[HOCl]}{[HOCl] + [OCl^-]} = \frac{0.4 [OCl^-]}{0.4 [OCl^-] + [OCl^-]} = \frac{0.4}{1.4}$$

$$f[\text{HOC}] = 0.285$$

ii)  $[\text{Cl}_2] = [\text{HOC}] + [\text{OCl}^-]$

$$\left(\frac{15}{71}\right)^{\text{wt}} = 0.4 [\text{OCl}^-] + [\text{OCl}^-]$$

$$\left(\frac{\text{wt}}{\text{Mol. wt}}\right) [\text{OCl}^-] = \frac{15}{71 \times 1.4} = 0.15 \text{ milli-moles/lit}$$

iii)  $f[\text{OCl}^-] = 0.7$

$$\frac{[\text{OCl}^-]}{[\text{HOC}] + [\text{OCl}^-]} = 0.7$$

$$\frac{[\text{HOC}]}{[\text{HOC}]} \frac{[\text{OCl}^-]}{[\text{HOC}]} = 2.33$$

$K = 2.33$

$$K = \frac{[\text{OCl}^-][\text{H}^+]'}{[\text{HOC}]}$$

$$2.5 \times 10^{-7} = 2.33 [\text{H}^+]'$$

$$[\text{H}^+]' = 1.07 \times 10^{-7}$$

$$pH = -\log [\text{H}^+] = -\log_{10} [1.07 \times 10^{-7}]$$

$$pH = 6.97$$

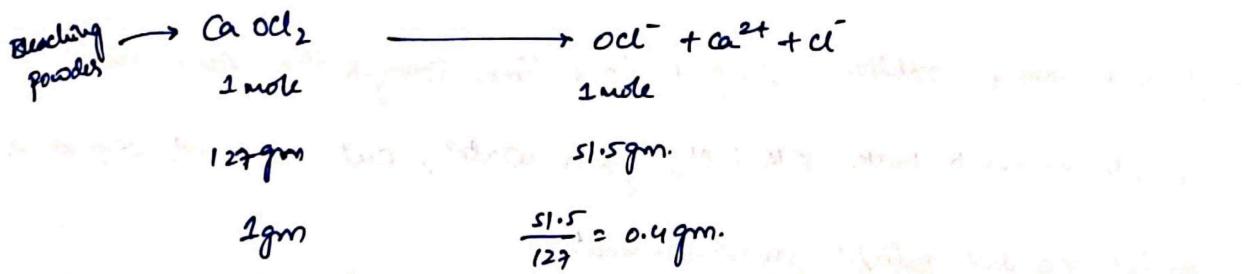
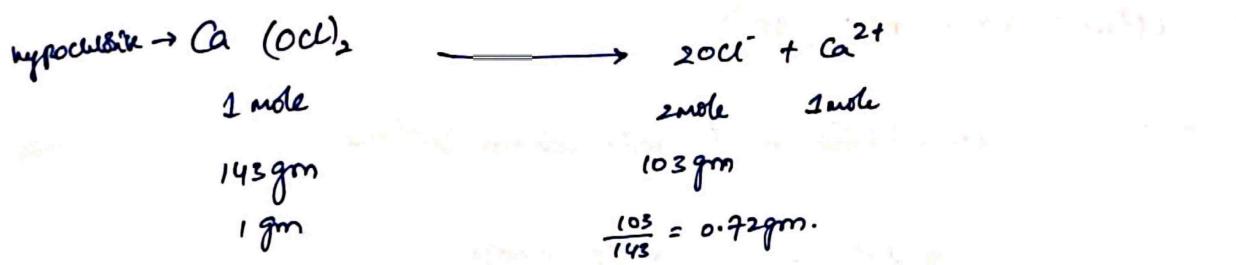
## # DIFFERENT FORMS OF ADDITION OF CHLORINE IN WATER!

### (i) FREE CHLORINE [liquid, gas, solid].

- Free chlorine in liquid phase is added in treatment plant to carry out disinfection [as its handling is easier]
- It is sensitive to temperature, as it freezes below  $10^{\circ}\text{C}$  and burns the container above  $92^{\circ}\text{C}$  in which it is kept for storage
- optimum temperature for chlorination ( $32-48^{\circ}\text{C}$ )
- It does not lead to the formation of sludge while carrying out disinfection and its quality is not reduced with time

### (ii) HYPCHLORITES (B) BLEACHING POWDER

- In this case disinfection is being carried out by  $\text{OCl}^-$  &  $\text{HOCl}$ , depending upon pH of water
- For 100% pure calcium hypochlorite, freely available chlorination ability is approx 72+, which also goes on reducing with time



- for 100% pure bleaching powder, freely available chlorination ability is approximately 40%, which also goes on reducing with time.
- use of these compounds, also leads to the formation of sludge
- they are not suitable to be used in treatment plant for disinfection and are used for treatment of water in swimming pools & well water supplies.

### (iii) CHLORAMINES

- it is used for disinfection of water in treatment plant when phenol is present in it, as it gives taste and odour in presence of chlorine

#### ④ Chlorine Dioxide: ( $\text{ClO}_2$ )

- It is formed by addition of  $\text{Cl}_2$  with sodium chloride



- It is a strong oxidizing reagent [2.5 times stronger than free chlorine]. which removes both OM & Mo from water, but does not safeguard against future recontamination
- It can also be used when phenol is present water

Q) If the oxidizing power of free chlorine is 35.5 and that of dichloramine is 21.48, find the percentage of free chlorine in dichloramine?

$$\underline{\text{Soln}} \quad \text{Cl}_2 - 35.5 \quad x [35.5] = 21.48.$$

$$\text{NHCl}_2 - 21.48 \quad x = \frac{21.48}{35.5} = 0.605$$

$$x \cdot 100 = 60.5\%$$

Q) A city with population of 2L has per capita demand of 200 lpcd. It is to be provided with disinfectant water. Compute the amount of 30% pure bleaching powder to be added per day at dose of

tonnes for treatment of 1000 m³ water?

$$\text{Sol} \quad \text{Q by g bleaching powder req} = \frac{10^5 \times 200 \times 50 \times 10^{-9}}{0.3} \text{ tonnes}$$
$$= 3.33 \text{ tonnes/d}$$

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### # FACTORS AFFECTING EFFICIENCY OF CHLORINATION:

- |   |         |
|---|---------|
|   | ↑ (↑)   |
| ① Turbidity (↑)   | (↓)     |
| ② PRESENCE OF ( $\text{Fe}^{2+}/\text{Mn}^{2+}$ )<br>METALLIC ION | (↑) (↓) |
| ③ PRESENCE OF AMMONIA (↑)   | (↓)     |
| ④ pH (↑)  | (↓)     |
| ⑤ TEMPERATURE (↑)   | (↑)     |
| ⑥ TIME OF CONTACT (↑)   | (↑)     |

## # TYPES OF CHLORINATION!

### (i) PLAIN CHLORINATION:

- If chlorination is the only treatment given to the water it is termed as plain chlorination.
- It removes taste, color, odour and NO ~~water~~ from the water.
- It is adopted <sup>when</sup> if the turbidity is in permissible range.
- Normal dose of chlorine is approx (0.5 mg/l).

### (ii) PRE-CHLORINATION:

- If chlorination is done either during coagulation & filtration it is termed as PRE-CHLORINATION
- It is done when quality of water is poor w.r.t OM & Mo.
- Pre-chlorination is always succeeded by post-chlorination  
but visa-versa is not
- Dose of chlorine required depends upon, point of addition of chlorine, if added during coagulation it is [5-10 mg/l] and added during Filtration it is [0.1 - 0.5 mg/l]

### (iii) POST-CHLORINATION:

- If chlorination is the last treatment given to the water it is termed as post chlorination.
- Dose of chlorine should be such that a residual of ( $0.2 \text{ mg/l}$ ) is ensured at contact period (~~2-4 hr~~) of (10 min).

### (iv) DOUBLE CHLORINATION:

- If both pre & post chlorination is done simultaneously is termed as DOUBLE CHLORINATION.
- It is adopted to attain higher efficiency.

### (v) SUPER CHLORINATION:

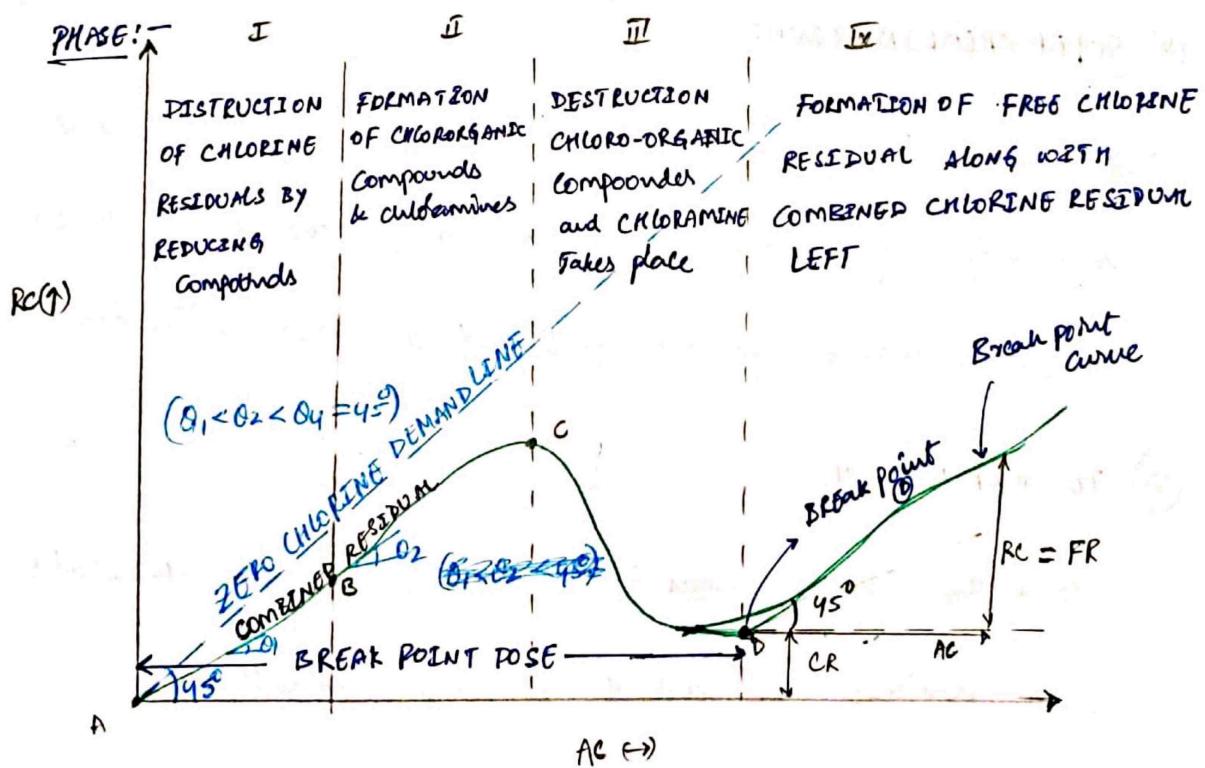
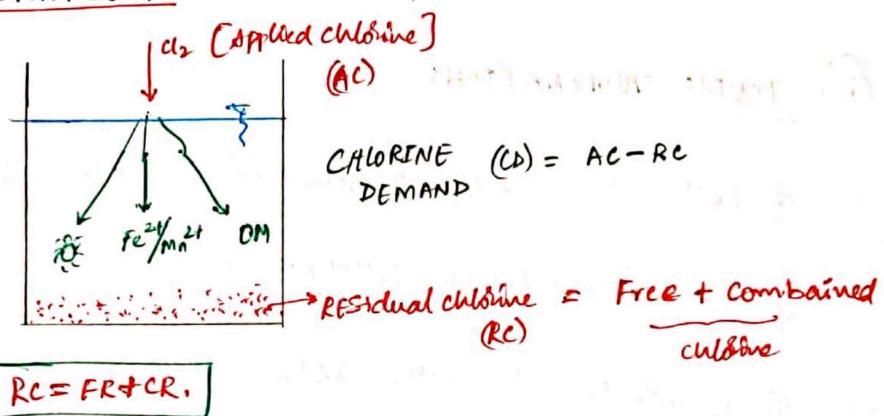
- If excess chlorine is added in range of 5-15 mg/l such that a residual of ( $1-2 \text{ mg/l}$ ) is ensured at the contact period of (10 min) during epidemic is termed as Super chlorination.

### (vi) DE CHLORINATION:

- It is the process of removal of excess chlorine from the water.
- It is achieved by use of following chemicals are

- (a)  $\text{Na As}$  [Sodium arsenite]  
 (b)  $\text{Na}_2\text{SO}_3$   
 (c) Activated Carbon
- (d)  $\text{OH}_4\text{OH}$   
 (e)  $\text{SO}_2$
- most Economical
- most effective

### (vii) BREAK POINT CHLORINATION!



LFC-39

Q For the given data compute

- chlorine demand
- break point dose
- chlorine demand @ dose of 3mg/l.
- dose of chlorine <sup>g/l</sup> to be added to achieve free chlorine residual of 0.7 mg/l

AC (mg/l)	RC (mg/l)
0.5	0.4
1.0	0.83
1.5	1.25
2.0	1.15
2.5	0.95
3.0	1.45
3.5	1.95

$$CD = AC - RC$$

solv	AC (mg/l)	RC (mg/l)	CD	
			CD	CD
	0.5	0.4	0.1	0.1
+ 0.5	1.0	0.83	0.17	0.17
+ 0.5	1.5	1.25	0.08	0.25
+ 0.5	2.0	1.15	0.6	0.85
+ 0.5	2.5	0.95	0.7	1.95
+ 0.5	3.0	1.45	0.50	1.55
+ 0.5	3.5	1.95	0.40	1.55

(b) Breakpoint dose  $AC = RC$

i.e. 2.5 mg/l

(c) Chlorine demand = 1.55 mg/l

(d) CD @ 3mg/l = 1.55 mg/l

(e) Dose corresponding to free residual of 0.7 mg/l

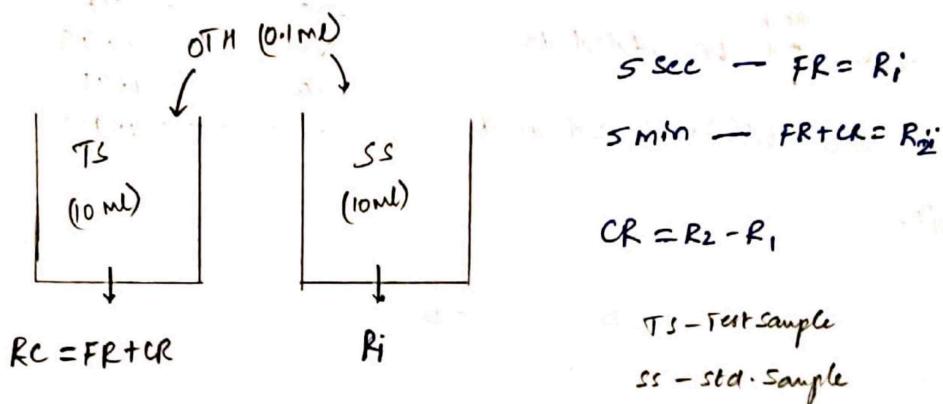
$$= 2.5 + 0.7 = 3.2 \text{ mg/l}$$

## # TESTING OF CHLORINE RESIDUES

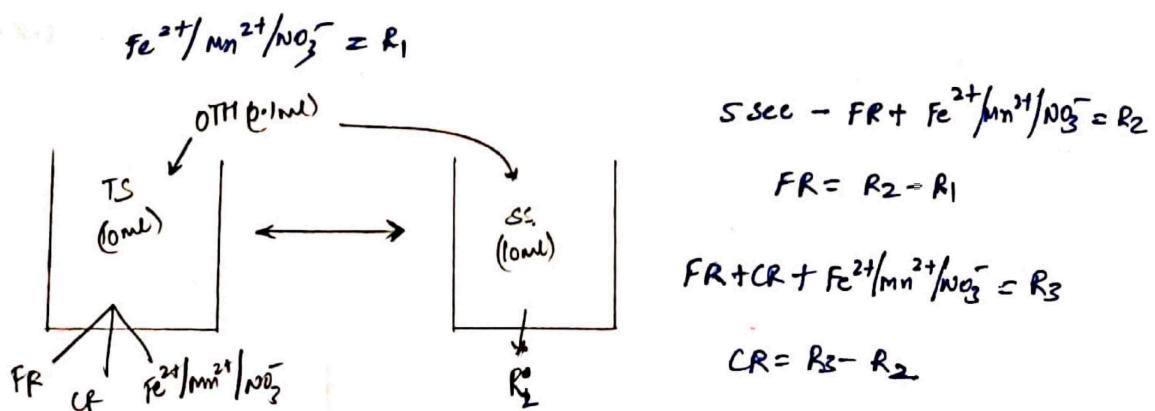
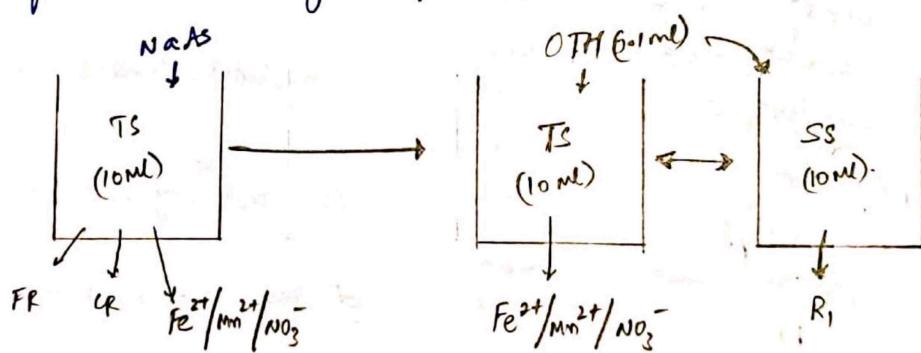
- Testing of chlorine residues can be done by any of following

### ① ORTHO TOLIDINE TEST / SNORT [Stabilised neutral ORTHOTOLIDINE TEST]

a) If ~~water~~ colour causing compounds are not present in water



b) If colour ~~causing~~ are present in water



- This test is based upon colour matching technique, which is imparted by the reaction of chlorine with ORTHOTOLIDINE (8)  
2-TOLIDINE
- Orthotolidine when added in water reacts with chlorine to give yellow intensity of which is matched with that of present in std. sample
- If color causing compounds are also present in water, they also gives false yellow color, with Orthotolidine, hence in this case
- ARSENITE ORTHOTOLIDINE TEST is used.

**NOTE:** In order to attain higher effectiveness during the test Orthotolidine is being replaced by CHLOROTEX & DPD [Di-ethyl phenylene diamine]

- Both these reagents are patented reagents and are termed as BDM [British Drug House] reagent

### (ii) STARCH IODIDE TEST / IODIMETRIC TEST!

- This test is used when colouring causing Compounds are present in water

→ Next Page

(1 lit) (10 ml) (5 ml)  
Water Sample + KI + starch → Blue coloured complex solution

( $\text{Cl}_2$ )

titrated with

$\text{Na}_2\text{S}_2\text{O}_3$

[ $\frac{0.12}{40} \text{ g} / 0.025 \text{ N}$ ]

vol. of  $\text{Na}_2\text{S}_2\text{O}_3$  req. to decolorize

the sample

### # MINOR METHODS OF TREATMENT:

#### ① TREATMENT WITH ACTIVATED CARBON:

- Activated Carbon in powdered form can be added in water to remove:  
taste, colour, odour, Mo, chloride, fluoride,  $\text{CO}_2$ ,  $\text{H}_2\text{S}$ , Fe, Mn, phenol etc
- It is added during Coagulation & FILTRATION
- Its normal dose is (5-20 mg/l)

#### ② TREATMENT WITH $\text{CuSO}_4$ :

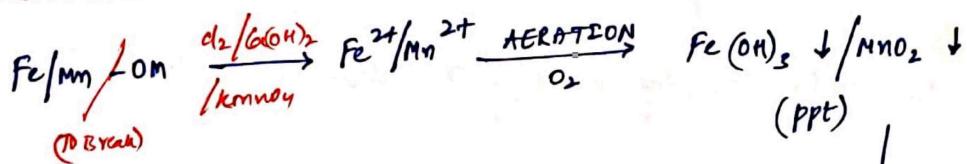
- Due to its strong ALGACIDIC property it is used to remove algae from the water

- It is added just before water is fed into the distribution system.
- Its dose varies between (0.5-0.6 mg/l).

**NOTE:** Algae can also be removed from water by addition of lime &  $\text{Cl}_2$ .

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### (iii) REMOVAL OF Fe/Mn!



Sedimentation



FILTRATION

- $\text{Fe/Mn}$  are generally present in conjugation with OM, hence in order to remove  $\text{Fe/Mn}$  by aeration, bond b/w  $\text{Fe/Mn}$  and OM is first broken, by addition of chlorine & lime &  $\text{KMNO}_4$

→ This process is termed as De-Ferrisation

**NOTE!**  $\text{Fe/Mn}$  can also be removed from the water using

"magnese zeolite" [It is a green sand Coated with magnese ~~zeolite~~ oxide].

#### iv) FLOURIDATION:

- It is the process of addition of fluoride in water
- It is achieved by use of any of these chemicals  
are  $\text{NaF}$ ,  $\text{Na}_2\text{SiF}_6$ ,  $\text{H}_2\text{SiF}_6$ , etc

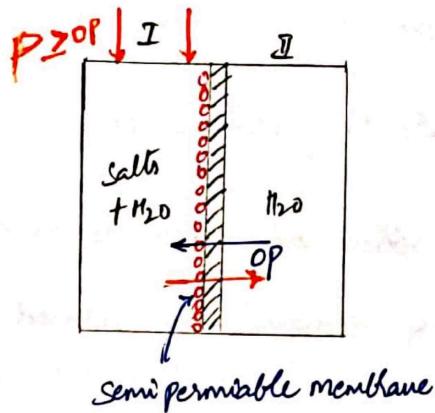
#### v) DE-FLOURIDATION:

- It is the process of removal of fluoride from the water
- It can be achieved by any of the following chemicals.
  - $\text{Ca}_3(\text{PO}_4)_2$ ,
  - Bone charcoal
  - Activated Carbon
  - Alum +  $\text{Ca}(\text{OH})_2 \rightarrow$  "NALAGONDA TECHNIC"
  - Activated Alumina  $\rightarrow$  "PRASHANTHE METHOD".

#### vi) DE-SALINATION:

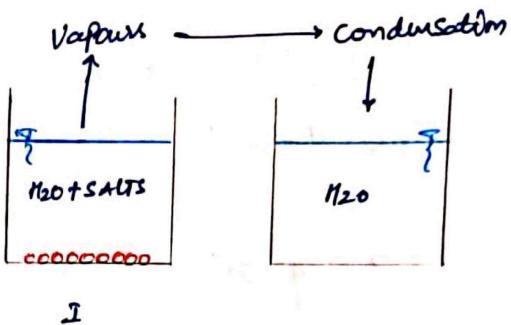
- process of removal of salts from the water
- It can be achieved by any of the following methods.

(a) REVERSE OSMOSIS:

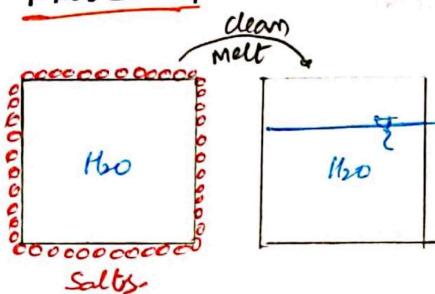


OP - osmotic pressure

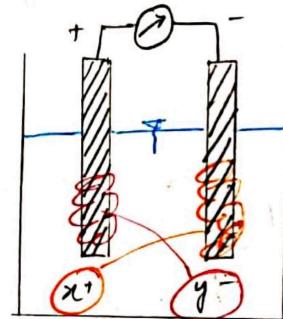
(b) EVAPORATION & FREEZING.  
DISTILLATION.



(c) FREEZING.

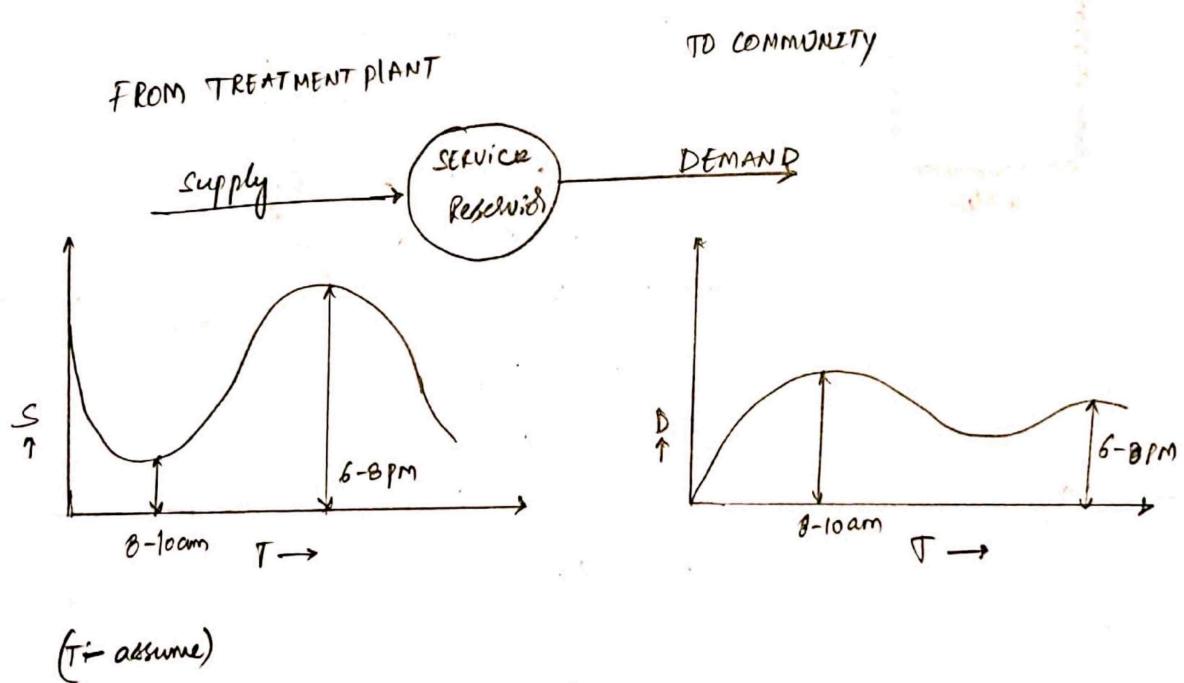


(d) ELECTROLYSIS



## **SERVICE RESERVOIR**

- The primary function of service reservoirs is to balance the fluctuating demand with constant (or) fluctuating supply.
- The quantity of water required to be stored in these reservoirs to balance (or) to meet this fluctuating demand is termed as "balancing storage".
- Apart from balancing storage, reservoirs are also designed to store water for meeting FIRE DEMAND & EMERGENCY STORAGE.



- The balancing storage can be computed by any of the following methods.

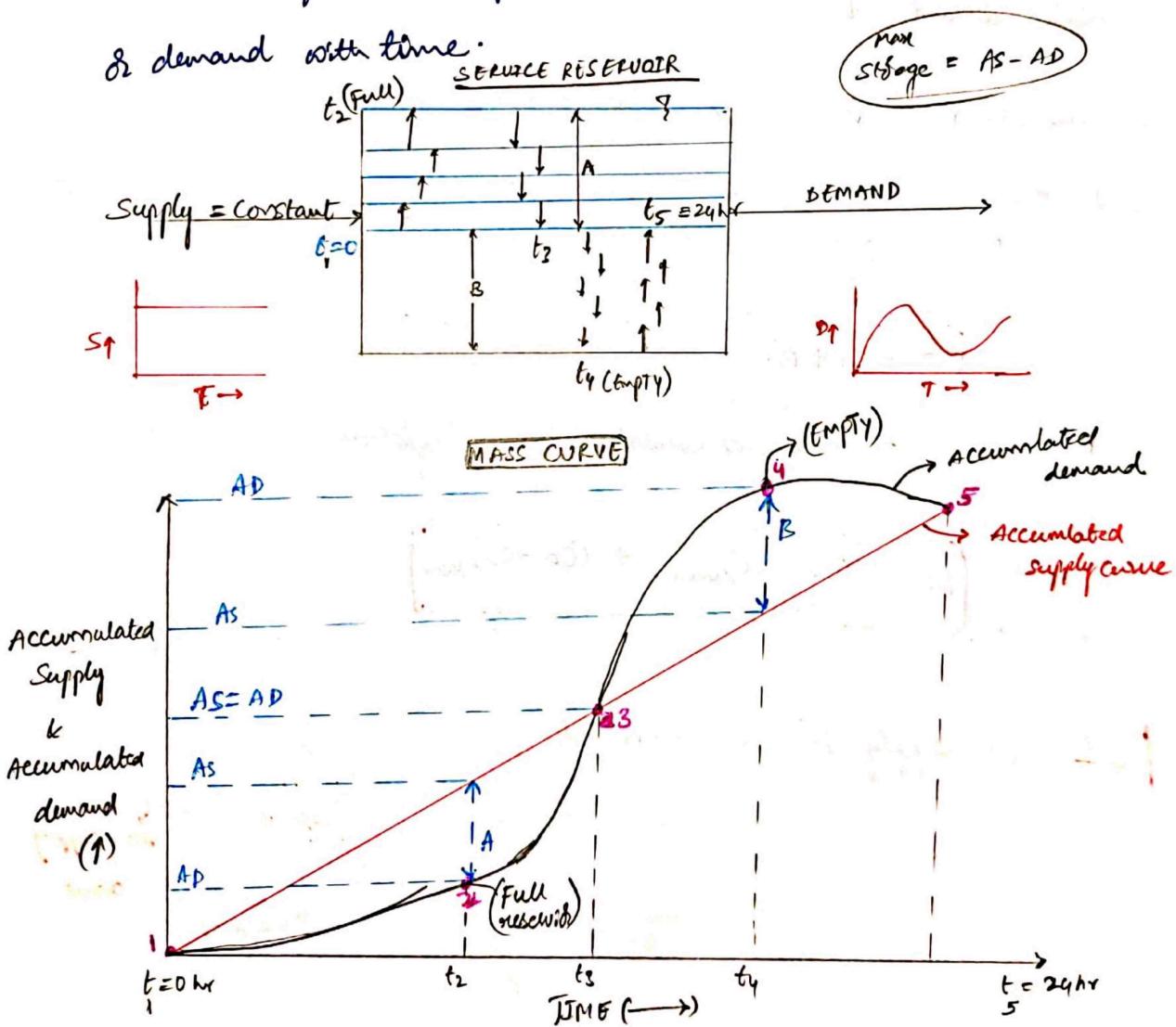
(A) utilizing the hydrographs of inflow and outflow.

(B) mass curve method

(C) analytical method

#### (B) MASS CURVE METHOD:

- It is the plot showing the variation of accumulated supply & demand with time.



Lec-4)

Phase	I	II	III	IV.	
Rate of supply	↑	↓	↓	↑	 ↑ - more ↓ - less
Rate of demand	↓	↑	↑	↓	 ↑* - increase ↓* - decrease
water level	↑*	-	↓*	↓*	↑*
Accumulated Supply	↑	↑	↓	↓	
Accumulated demand	↓	↓	↑	↑	
Accumulation	✓	✓	✗	✗	
Depletion	✗	✗	✓	✓	

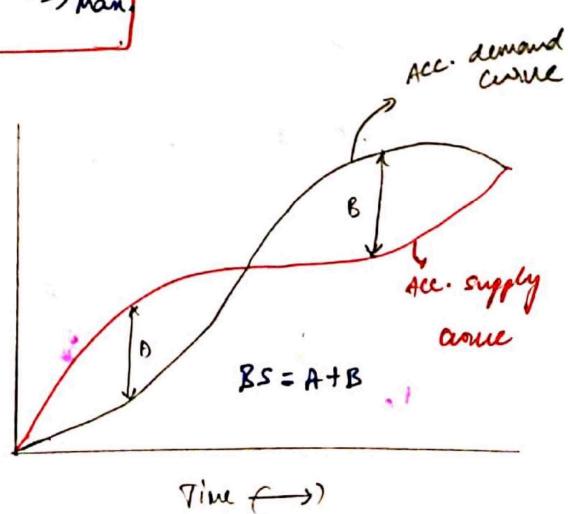
$$BS = A + B \cdot$$

= max accumulation + max depletion

2.  $BS = (CS - CD)_{\max} + (CD - CS)_{\max}$

NOTE: If supply is not constant

Accumulated Supply K  
Accumulated demand (I)



Q A town having a population of 2 lakhs is to be supplied with water at rate of 250 lpcd. The variation and the demand is as follows.

Time	% of demand
6-9 am	40%
9-12 pm.	10%
12-3 pm	10%
3-6 pm	15%
6-9 pm.	25%

Determine the minimum capacity of the reservoir when pumping is done at uniform rate from 6 am to 12 pm and 3pm-9pm.

Sol - Total demand =  $2 \times 10^5 \times 250 \times 10^{-6} = 50 \text{ MLD}$ ; total supply = 50 MLD.

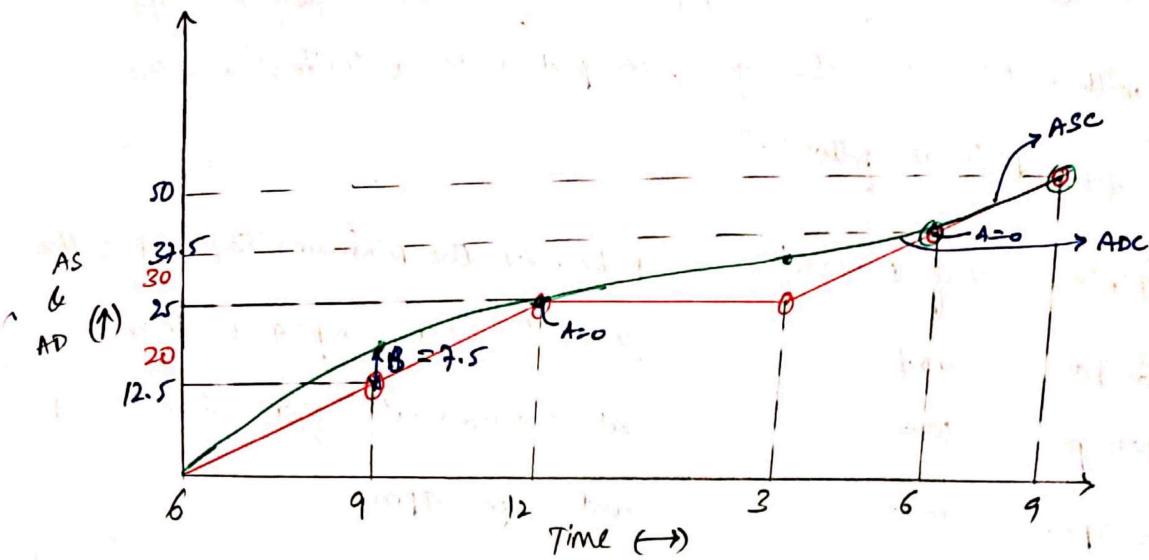
Time	% of demand	Demand (ML)	Accumulated demand	Supply (ML)	Accumulated Supply (ML)	Rate of supply = $\frac{50}{12 \text{ hr}}$
6-9	40	20	20	12.5	12.5	$\frac{50}{12 \text{ hr}}$
9-12	10	5	25	12.5	25	$\frac{50}{12 \text{ hr}}$
12-3	10	5	30	0	25	$\frac{50}{12 \text{ hr}}$
3-6	15	7.5	37.5	12.5	37.5	$\frac{50}{12 \text{ hr}}$
6-9	25	12.5	50	12.5	50	$\frac{50}{12 \text{ hr}}$

$$AD - AS = 7.5$$

$$BS = A + B = (CS - CD)_{\max} + (CD - CS)_{\max}$$

$$= 12.5 + 7.5$$

$$BS = 7.5 \text{ ML}$$



Q An overhead tank is to be provided for a city water supply, given are the following details

Calculate the min. capacity of the reservoir without any free storage  
have water q  $(8 \cdot 4 \times 10^4)$

Assuming the tank to be full  $\uparrow$  12-15 hrs; Compute the

water level in the reservoir at diff time intervals.

Time -	0-4	4-6	6-10	10-12	12-15	15-16	16-20	20-23	23-24
water pumped	0	$5 \times 10^4$	$10 \times 10^4$	$5 \times 10^4$	0	$2.5 \times 10^4$	$10 \times 10^4$	$2.5 \times 10^4$	0
Water consumed	$1.3 \times 10^4$	$4 \times 10^4$	$12 \times 10^4$	$2 \times 10^4$	$2.5 \times 10^4$	$5.9 \times 10^4$	$10 \times 10^4$	$1 \times 10^4$	$0.3 \times 10^4$

Soln

Time	Supply ( $10^4$ )	Demand ( $10^4$ )	CS ( $10^4$ )	CD ( $10^4$ )	CS - CD ( $10^4$ )	Water level
0-4	0	10.3	0	10.3	-1.3	9.9
4-6	5	4	5	5.3	-0.3	5.9
6-10	10	12	15	17.3	-2.3	8.9
10-12	5	3	20	20.3	-0.3	5.9
12-15	0	2.5	20	22.8	-2.8	8.4*
15-16	2.5	5.9	22.5	28.7	$\frac{-6.2}{8}$	0
16-20	10	10	32.5	38.7	$\frac{-6.2}{8}$	0
20-23	7.5	1	40	39.7	$\frac{0.3}{1}$	6.5
23-24	0	0.3	40	40	0	6.2

$$BS = A + B.$$

$$A = (CS - CD)_{\text{max}}$$

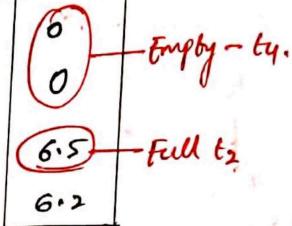
$$= 0.3 \times 10^4$$

$$B = (CD - CS)_{\text{max}}$$

$$= 6.2 \times 10^4$$

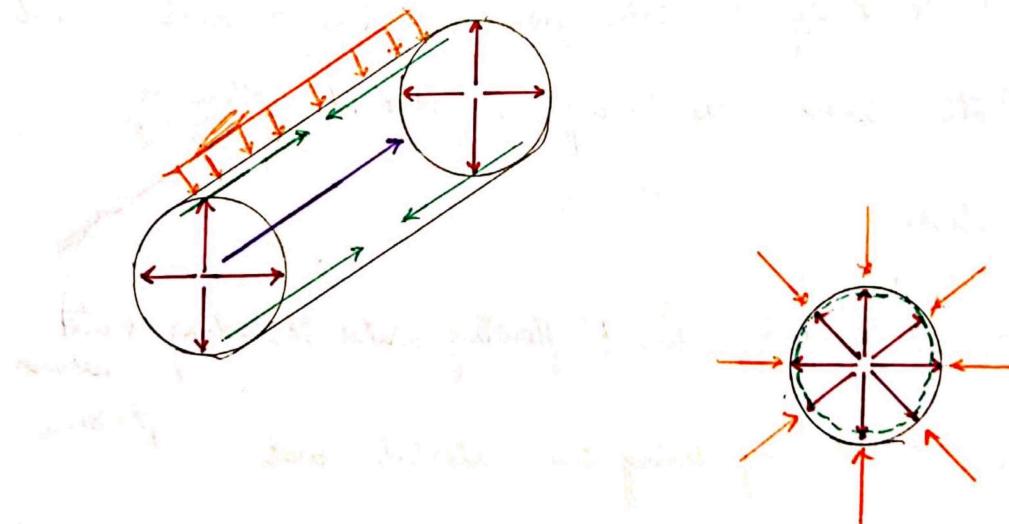
$$BS = (0.3 + 6.2)$$

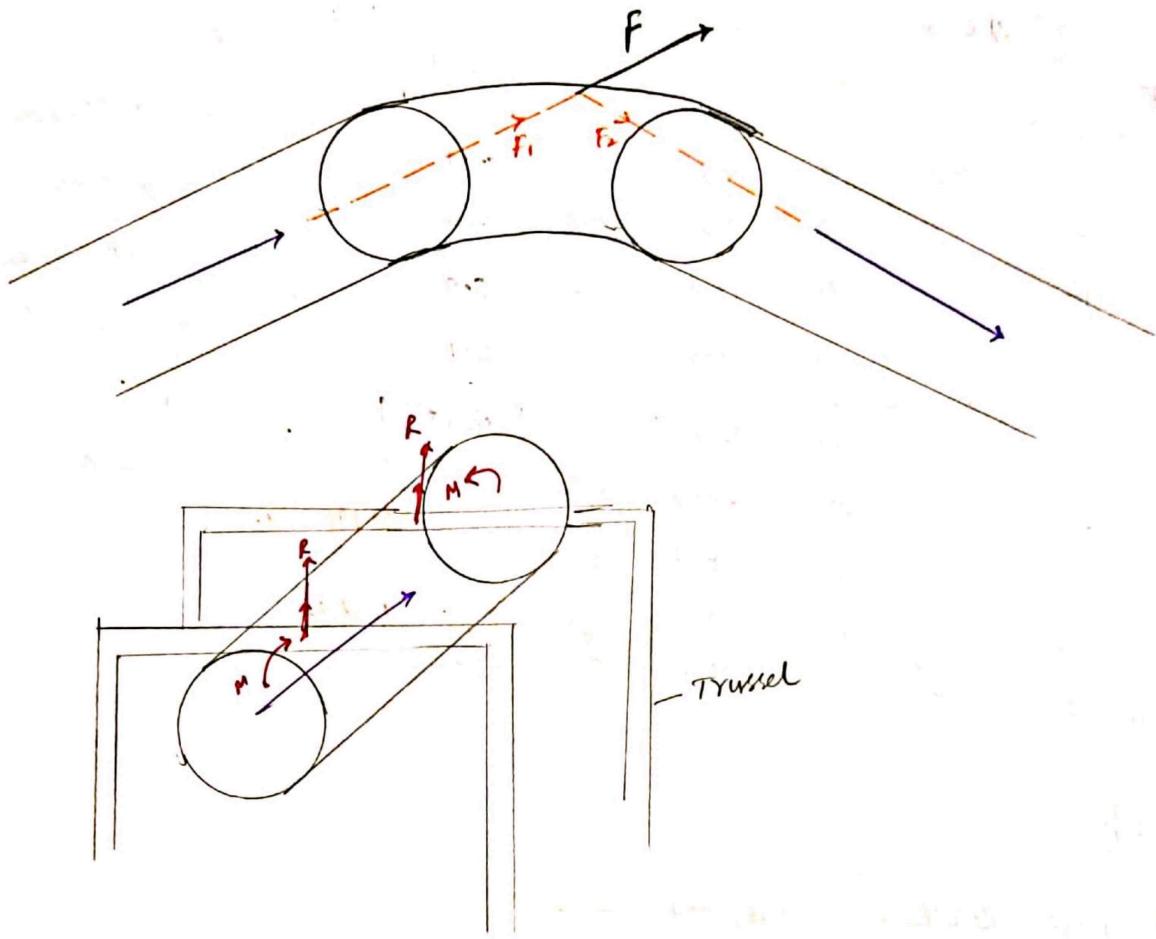
$$= 6.5 \times 10^4 \text{ l/s}$$



LBC-42

# PIPES REQUIRED TO CARRY THE WATER!





- Pipes used to carry the water from one point to another point in raw water scheme are being subjected to following types of stresses.
  - ① Internal pressure due to flowing water including water hammer pressure [It is resisted by using the material that is strong in tension].

EXTERNAL

- (b) ↑ Pressure due to backfill and vehicular load  
[It is to be resisted by using the material that is strong in compression].
- (c) longitudinal thermal stresses which are developed due to variation in temperature, when pipes are laid above the ground  
[It is to be resisted by using a material having low co-efficient of thermal expansion and by providing Expansion joints].
- (d) longitudinal stress developed due to unbalanced force at the bend & at change of cross-section  
[It is to be resisted by holding & anchoring pipes in heavy concrete blocks & stone masonry blocks].
- (e) Bending (or) flexural stresses due to reaction offered by structural members of TRESTLES.  
[It is to be resisted by providing some soft material below it].

## # Different type of pressure pipes used to carry the water:

### ② CAST IRON (CI) / GALVANISED PIPE : <sup>IRON(GI)</sup>

- These pipes are Moderate in cost
- They are easy to join
- They are strong in compression and are highly durable
- They are resistant against corrosion
- They possess long life upto 100 yrs.
- Service connections can be made very easily in them
- Their water carrying capacity decreases with time due to "TUBERCULATION" [Ref- WTP].
- They cannot resist water pressure beyond  $700 \text{ kN/m}^2$
- They are bulky hence uneconomical to transport
- They are very likely to break during transportation
- Hence, these pipes are suitable to be used as distribution MAIN

NOTE: In order to increase resistance of these pipes against corrosion, Coating of zinc is applied over them termed as "GALVANISATION".

### (ii) STEEL PIPE / HUME STEEL PIPES:

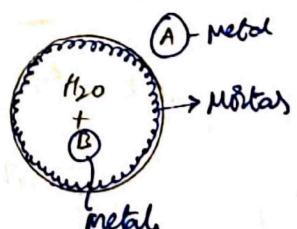
- These pipes can resist high water pressure as they are strong in Tension, but cannot withstand heavy compressive load.
- These are susceptible to corrosion.
- These are light in weight hence, offers low transportation cost. However, their maintenance cost is more.
- It is difficult to make service connection in these pipes.
- These possess comparatively short life of 25 to 30 yrs.
- Hence these pipes are suitable to be used as "pumping main".

#### NOTE:

In order to increase the resistance against corrosion, a layer of Mortar is applied over these pipes by the process is

termed as "Centrifugation"

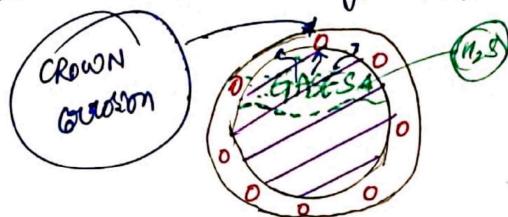
→ This pipe is formed as "HUME STEEL PIPE"



LEC - 43

(III) REINFORCED CEMENT CONCRETE PIPE :  
(RCC)

- It can resist heavy compression load and high water pressure.
- These pipes do not get corroded by water from inside & by soil from outside, But may undergo " $H_2S$ " corrosion at "CROWN"



- These pipes are easy to construct both at site & at yard
- They possess long life upto 75 yrs.
- As they possess low co-efficient of thermal expansion they do not require expansion joints.
- These pipes are suitable to be laid underwater
- These pipes are heavy and bulky, hence have high transportation cost.
- They are difficult to be repaired
- Making connections is difficult in these pipes & they tend to leak due to shrinkage.

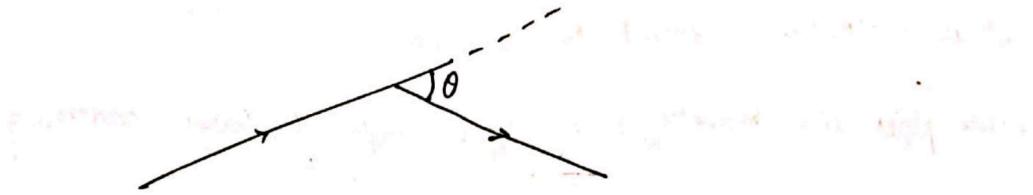
IV CLAY VITRIFIED PIPE [VC]

- It is virtually resistant to corrosion
- These pipes are smooth, hence offers high discharge carrying capacity
- These are brittle, weak in tension hence breaks easily
- It is difficult to provide joints in them
- They are not used as pressure pipes but are used as gravity pipes to carry the flow at partial depth.

V ASBESTOS CEMENT [AC] PIPE!

- These are virtually resistant to corrosion
- These are light in weight, hence is to transport
- These are flexible pipes, can bend upto angle of  $120^\circ$ , Hence requirement of the joints is comparatively less in these pipes.
- These pipes can be assembled very easily without skilled labour
- These pipes are smooth hence offers high discharge carrying capacity

- These pipes are costly, soft, weak, brittle <sup>hence</sup> can break easily



### # PIPES APPURTENANCES!

- Additional accessories required for proper functioning of the pipes is termed as pipe appurtenances like
  - a) Valves
  - b) Joints
  - c) Anchorage.

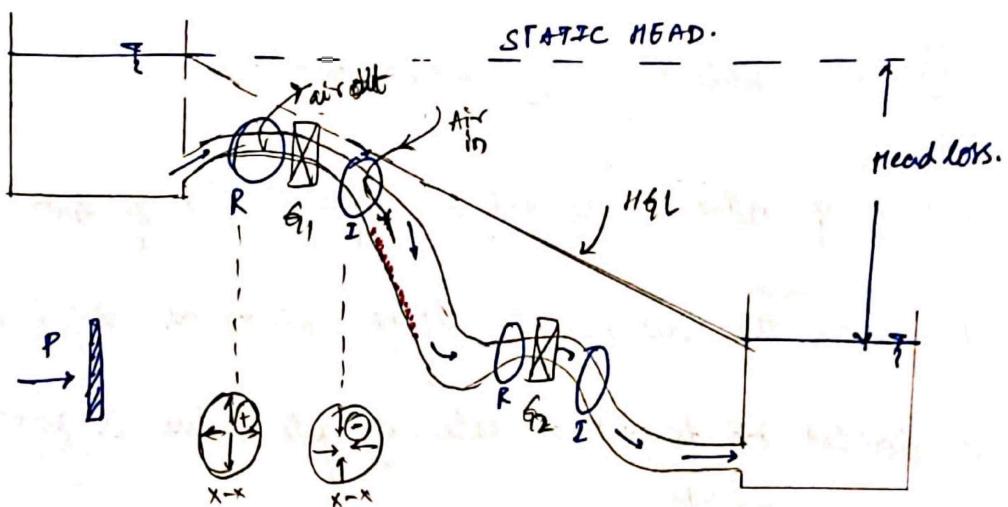
#### a) VALVES:

- Now there are several type of valves provided for the proper functioning of the pipes as follows.

##### i) GATE/CUTOFF/SERVICE VALVE

##### SHUTOFF

- These valves are provided to regulate the flow of water in pipes, by dividing them into no. of sections



- These valves are placed at summit points in these pipes, as the pressure to be generated by these valves is least at these points, thereby reducing the cost of these valves.
- These valves are manually operated.
- These are made up of cast iron with bronze, brass or stainless steel mountings.

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**(ii) AIR VALVE:**

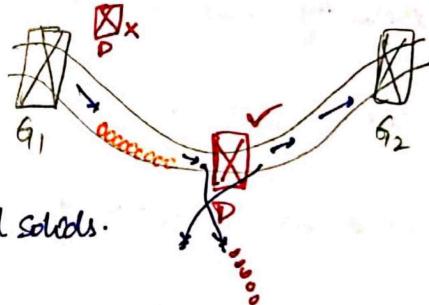
- It is automatic valve which is provided to ensure the safety of pipes against failure.
- These valves are also provided at summit points on either side of gate valve.

- These are further classified as
  - (a) AIR RELIEF
  - (b) AIR INLET.
- Air Relief valve is provided on upstream side of gate valve to release the air out from pipe whereas Air inlet valve is provided on downstream side of gate valve to permit the air into the entry of the pipe

### (iii) DRAIN / Blow off / SCOUR VALVE!

**b)**

- These valves are provided to drain the water out from the pipe and to carry out scouring of settled suspended solids.
- These are placed at lower most point in the pipe network, to ensure the gravity drainage from the pipe



### (iv) PRESSURE RELIEF VALUE!

- Water hammer pressure in the pressure pipes can be reduced by using pressure relief valves.

- Such type of valves are adjusted to open out automatically as soon as the pressure in the pipe becomes more than pre determined design pressure.

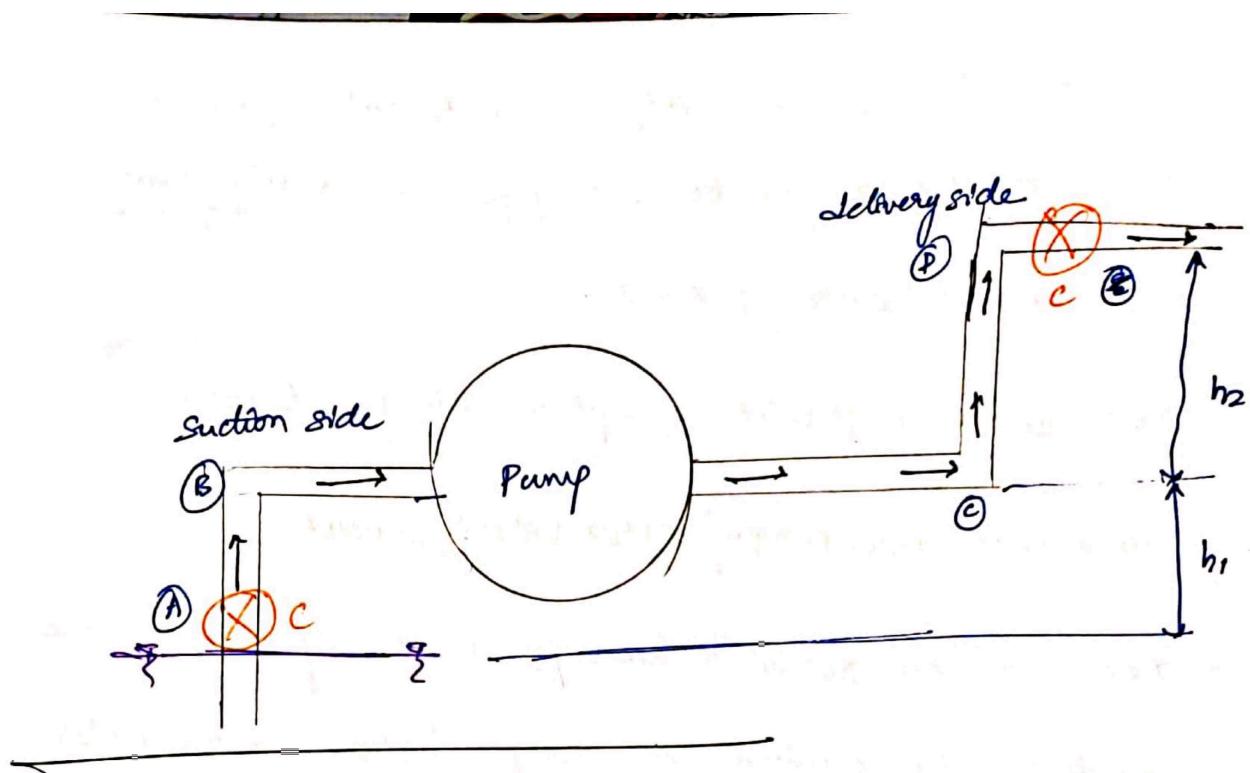
- These valves are provided on upstream side of gate valve

#### ⑤ CHECK VALVE / NON-RETURN / REFLUX VALVE / FOOT VALVE

- These valves are provided to ensure/check flow of water in one direction, by avoiding the backflow/return of the water
- These valves are provided on suction and delivery side of the pump

- If these valves are provided at the end of suction line, these are termed as foot valves

- They are also provided at the inter connection between a polluted water system and a potable water system so as to prevent the entry of polluted water into the treated water



### (B) JOINTS:

- For the proper functioning of the pipes following types of joints are being provided in it.
- i) SOCKET & SPIGOT JOINTS!**
- Cast iron pipes are being joined with the help of socket & spigot type of joints.
- It is used on very large scale in today's time also.
- These joints are made in such a way that one end of pipe is enlarged termed as 'socket' and other

end is kept normal termed as "SPIGOT"

- Once the ~~spigot~~ end of the pipe is inserted into socket and SPIGOT the remaining space is filled with jute and finally with molten lead which solidifies to give perfect joint.

### ii) FLANGED JOINTS:

- These joints are provided for ~~indoor~~ works where the deflection and vibrations are not expected and there is a need to disjoin pipe occasionally.

Ex FILTER pumps, PUMPING STATION.

- For cast iron pipes these joints are provided by casting ~~these~~ both the end of pipes as flanged.
- For steel pipes, flanges are separately screwed & welded over the ends of pipes.
- These joints are strong, rigid and expensive, hence not suitable to be used where deflections & vibrations are expected to occur.

### (iii) MECHANICAL / DRESSER COUPLING : JOINTS

- this type of joint provided when straight end of the pipes are to joined
- in this case special type of metallic collar is fitted and tightened over the abutting ends of the pipes, thus forming a mechanical joint
- these joints are strong and are capable of withstanding vibrations, hence are generally used ~~to carry~~ <sup>in</sup> the pipes ~~over the bridge~~ which are carried over the bridge

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### (iv) FLEXIBLE JOINT :

- the joints are provided where large scale flexibility is required
- in order to provide this joint, one end of the pipe is enlarged termed as "SOCKET END". which is in turn cast in spherical and the other end of the pipe

is kept normal with "Bead" being provided @ the <sup>tip</sup> end

- A retainer ring is placed over the bead which keeps the special rubber gasket in position
- This spigot end of this joint can move/deflected with respect to the socket end of the pipe around the bead.

#### ⑤ EXPANSION JOINTS:

- These joints are provided to overcome thermal stresses induced in the pipe due to temperature variation
- These joints are provided at regular interval in the pipes
- For providing the expansion joints one end of the pipe is enlarged (socket) and other is kept normal.
- Here since socket end is flanged it is connected rigidly with the annular ring provided over the spigot end

- For these joints small space is being kept b/w both the faces of the pipes.
- In order to avoid the leakage of water rubber gasket is also provided around the ~~flat~~ joint.

#### (VI) INSULATION JOINT:

- These joints are provided at regular interval along the length of the pipe, so as to insulate pipe against the flow of electric current & to avoid electrolysis.
- Rubber gasket & rings can also be provided for the same purpose
- In some cases rubber covering is also provided to resist the flow of covering.

## ④ ⑤ "MAN HOLES"

- They are provided at regular intervals along the length of the pipe so as to help in laying, inspecting, repairing and maintaining the pipe.
- There are generally provided ~~on~~ <sup>on</sup> the large pipes.  
Ex pipes carrying the water from source upto the treatment plant.
- Spacing varying between. (300 - 600 m).

## ⑥ ⑦ ANCHORAGE:

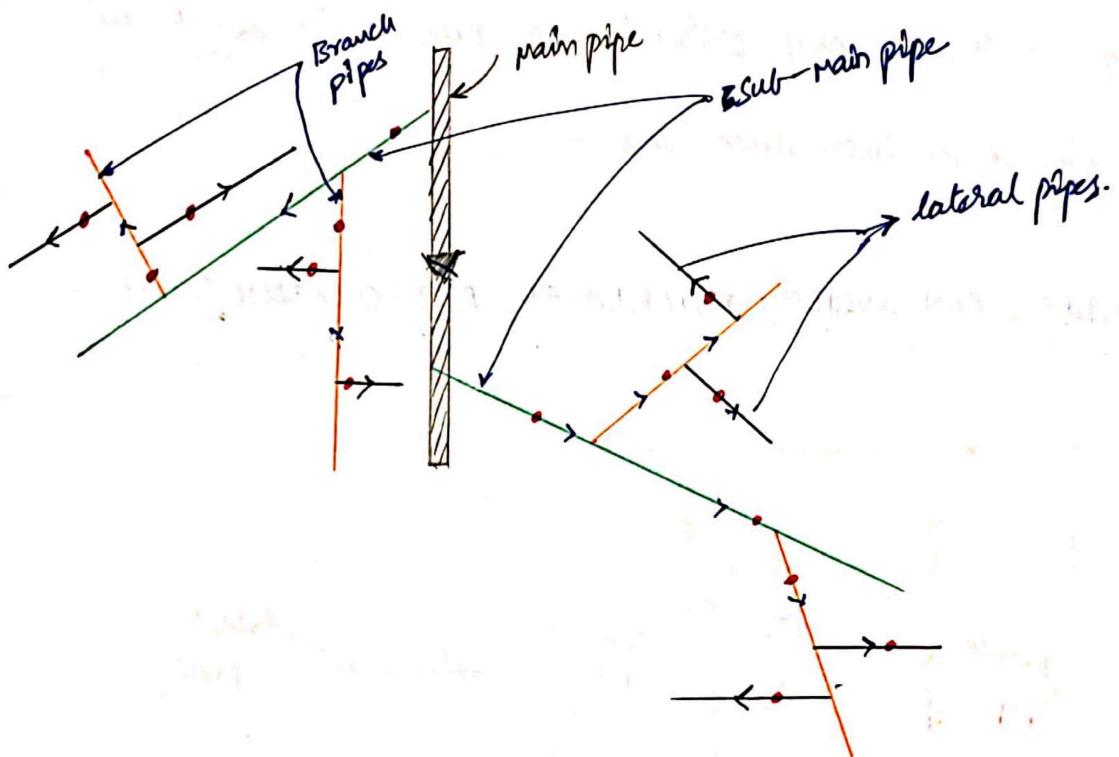
- The pipe try to pull apart & get out of alignment at bends and other points of unbalanced pressure
- To hold these pipes in to positions at these points they are embedded into heavy concrete blocks (R) stone masonry blocks.
- They are also provided in the case where the pipe is to be laid on sloping surface

## # DISTRIBUTION SYSTEM

- It is the network of pipe being provided to carry the water upto the consumer
- This distribution system consists of water pipes, valves, joints, pumps, fire hydrant, water meters etc for effective working
- This distribution system must possess the following properties
  - (a) Capable of supplying the water as per the demand at desired location
  - (b) capable of supplying the water in case of fire breakout.
  - (c) It should be simple to design, economical, easy to repair and maintain
  - (d) It should be safe against theft and leakages.
  - (e) It should be safe against entry of polluted water.

# TYPES OF DISTRIBUTION SYSTEM!

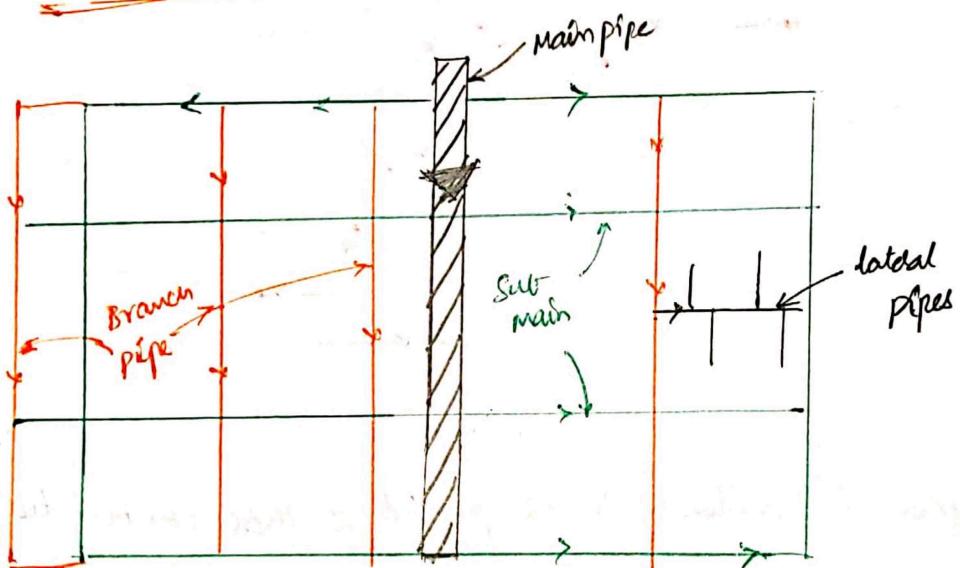
- Distribution system are of following types.

(1) DEAD END / TREE SYSTEM:

- This system is suitable to be provided for those communities where development is unplanned
- It can be designed very easily.
- Here length of the pipes and requirement of no. of valves is less, so it is economical

- It can be expanded very easily
- It consists of no. of dead ends, so chances of recontamination of water is maximum.
- In case of fire breakout demand cannot be met
- In case of any obstruction in pipe water cannot be supplied in downstream section

## (ii) GRID IRON SYSTEM / INTERLACED / RETICULATION SYSTEM:

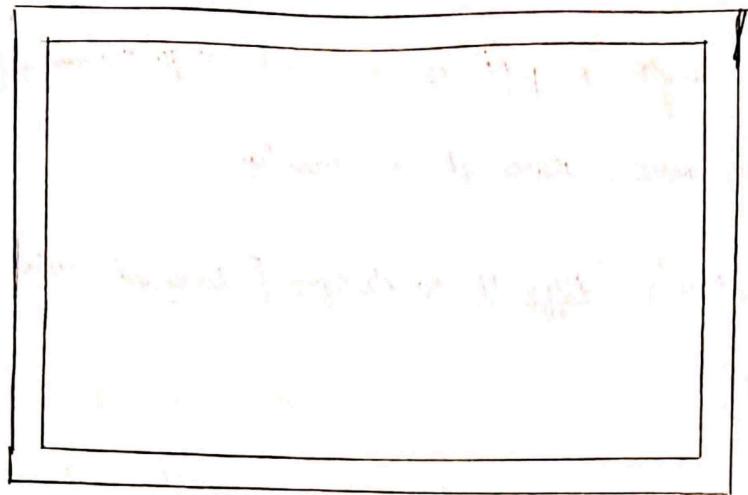


- This system is provided for those communities where development is highly planned

- In this system all the pipes are interconnected with each other
- In this case length of pipe is more and requirement of no. of valves is also more, hence it is costly
- It is comparatively difficult to design [designed using Hardy Cross method].
- In this system fire demand can be easily met
- It is difficult to expand
- As in this case water continuously recirculates, chances of recontamination of water is least.
- In case of any obstruction in pipes, flow of water is not disturbed.

### (iii) RING / CIRCULAR SYSTEM:

- It is similar to the grid iron system, will only change that it consists of main pipe which encircles an area of high water demand & does not possess



iv) RADIAL / STAR SYSTEM:

- This is also similar to grid form system with the only change that water is supplied in Radial direction in this case.

**F**NOTE! In order to install water supply plumbing system in any building, first and main step is to obtain water supply connection from the municipal body.

- A typical water supply connection connecting the service pipe line with the Municipal water mains consists of following.

- (i) FERRULE: - It is a right angled sleeve made up of sleeve.
- (ii) GOOSE NECK - It is a small sized curved pipe, usually of lead.
- (iii) service pipe - It is a  $\frac{3}{4}$  inch pipe, size of which is comparative.
- (iv) stop cock - It is provided just before water enters.
- (v) water meter - It is provided inside the boundary of the individual household.