

Water supply Engineering:

Chapter 1: Introduction to water supply, quantity & quality of water

21/01/11/2021

1.1 Necessity of treated water supply

Without food human can survive for a no. of days. But ~~water~~ without water it can not possible. In ancient times human required water for drinking, bathing, cooking etc. But in this modern era, the utility of water is ~~too~~ enormously increased.

Now such stage has come that without ~~water~~ treatment water supply, it is impossible to run the present civic life & develop the towns.

Necessity of water supply are:

- drinking & cooking
- bathing & washing
- watering lawns & gardens
- growing of crops
- street washing

- fire fighting
- steam power & various industrial purposes etc.

1.2 Methods of forecasting population:

The various methods which are generally adopted for estimating future population. It can be approximate estimate only. The various methods are

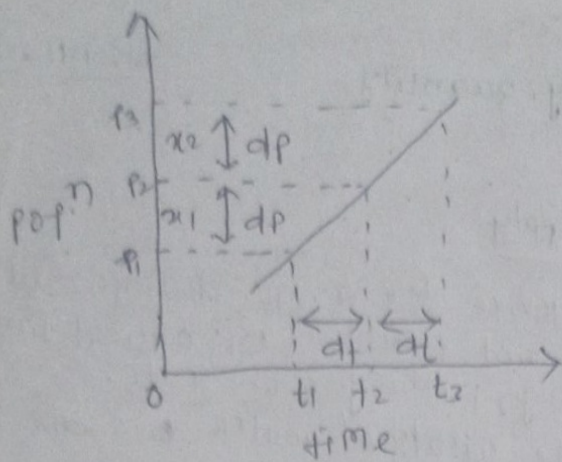
- (1) Arithmetic Increase method
- (2) Geometric Increase method
- (3) Incremental Increase method
- (4) Decreasing rate of growth method
- (5) Logistic curve method
- (6) Comparative graphical method.

(1) Arithmetic Increase method:

→ Also called as Arithmetic progression method or constant growth method.

→ ~~Arithm~~ This method is more suitable for old or settle communities.

→ This method is based on assumption that per decade increasing population as should be constant.
(popⁿ increase decade to decade is same)



where $\frac{dp}{dt} = \text{constant}$
 $x_1, x_2, \dots, x_n$ are the change of population
 $p_0 =$ population at present
 $p_n =$ forecast popⁿ after n decades
 $\bar{x} =$ Average of population increase

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

Q. population levels for 5 decades of small town given below

year $\rightarrow$	1960	1970	1980	1990	2000
pop ⁿ $\rightarrow$	2,50,000	2,80,000	3,40,000	4,20,000	4,90,000

The population of the town in the year 2020. By A.M.

Solⁿ

Year	pop ⁿ	per decade increase pop ⁿ
1960 $\rightarrow$	2,50,000	$\rightarrow$ 30,000
1970 $\rightarrow$	2,80,000	$\rightarrow$ 60,000
1980 $\rightarrow$	3,40,000	$\rightarrow$ 80,000
1990 $\rightarrow$	4,20,000	$\rightarrow$ 70,000
2000 $\rightarrow$	4,90,000	

$\Sigma x = 2,40,000$

$\bar{x} =$ Avg. of population increase

$$\bar{x} = \frac{\Sigma x}{n} = \frac{2,40,000}{4} = 60,000$$

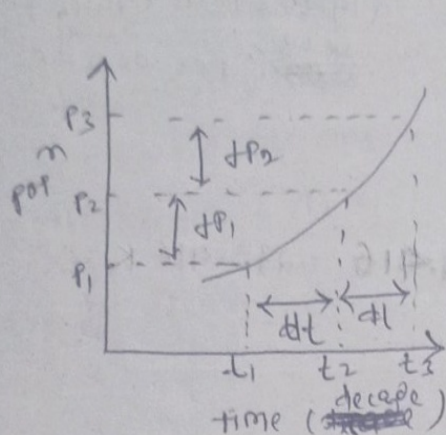
$$n = \frac{2020 - 2000}{10} = 2 \text{ decade}$$

$$\therefore p_{2020} = p_0 + n\bar{x} = 4,90,000 + 2 \times 60,000 = 4,90,000 + 1,20,000 = 6,10,000 \text{ (Ans)}$$

(2) Geometric Increase method

- This method is also called as geometric progression method or exponential growth method (or) uniform increase method (or) logarithmic growth method.
- Applicable only in rapidly growing community. (New city or younger city)
- It gives max^m value as compare to other method.

→ In this method percentage increase in population from decade to decade is assumed to be constant.



Type 1 where, $\Delta P_1 < \Delta P_2 < \Delta P_3$, $\Delta P \neq \text{constant}$

$$\begin{aligned} \frac{\Delta P}{\Delta t} &\propto P_t \\ \Rightarrow \Delta P &= K \Delta t \\ \Rightarrow \int_{P_1}^{P_2} \frac{\Delta P}{\Delta t} &= \int_{t_1}^{t_2} K \Delta t \\ \Rightarrow \ln \left[\frac{P_2}{P_1} \right] &= K \cdot (t_2 - t_1) \\ \Rightarrow P_2 - P_1 &= e^{K(t_2 - t_1)} \\ \Rightarrow P_2 &= P_1 e^{K(t_2 - t_1)} \\ \Rightarrow P_n &= P_{n-1} e^{K(t_n - t_{n-1})} \end{aligned}$$

where, K = percentage growth rate per year

Q. ^{At 100} Popⁿ of Hyderabad in the year 1990 was 20,00,000. Find the population of Hyderabad in the year 2032 if the popⁿ growth rate is 1.2% per year.

solⁿ Given data

$$P_{1990} = 20 \text{ lakh}$$

$$K = 1.2 \text{ per year} = \frac{1.2}{100} = 0.012$$

$$\begin{aligned} P_{2032} &= 20 \times 10^5 \times e^{0.012 \cdot (2032 - 1990)} \\ &= 3310658.72 \end{aligned}$$

Type 2

$$\text{Per decade \% increase} = \frac{P_n - P_{n-1}}{P_{n-1}} \times 100 = R$$

$$P_n = P_0 \left(1 + \frac{R}{100} \right)^n$$

where, P_n = projected popⁿ
 P_0 = present popⁿ

R = age geometric mean rate of increase in popⁿ per decade

$n_1, n_2, n_3, \dots, n_m \rightarrow$ be the per decade %ge increase.

Q Determine the future population of a town by geometric increase method in the year 2011.

yr	POP ⁿ in 1000	increase	%ge increase
1951	93	18	$r_1 = \frac{18}{93} \times 100 = 19.35\%$
1961	111	21	$r_2 = \frac{21}{111} \times 100 = 18.91\%$
1971	132	29	$r_3 = \frac{29}{132} \times 100 = 21.96\%$
1981	161		

$$\therefore r = \text{Geometric mean rate of increase in pop}^n = (r_1 \times r_2 \times r_3)^{1/3}$$

$$= (19.35 \times 18.91 \times 21.96)^{1/3}$$

$$= \frac{20.03}{100} \% \text{ per decade}$$

$$\therefore n = \frac{2011 - 1981}{10} = 3$$

$$\therefore P_{2011} = P_{1981} \left(1 + \frac{r}{100}\right)^n$$

$$= 161 \left(1 + \frac{20.03}{100}\right)^3 = 278.416 = 278.416 \text{ K}$$

(3) Incremental Increase method:

- Also called as method of varying increment
- growth rate is not ~~assumed~~ assumed to be constant.
- ~~but~~ because popⁿ is progressively increasing or decreasing.
- It's depending upon whether the ~~average~~ average of the incremental increase in past data is positive or negative.
- This method is an extension of arithmetic method.
- this method is more realistic method where future population forecasted based on the past growth.
- to find the future popⁿ of this method, the average of the increments over increase in population is added to arithmetical increase.

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

where: P_0 = present popⁿ
 P_n = future popⁿ (After n decade)
 n = no. of decade
 $\bar{x}$ = Average of popⁿ increase per decade
 $\bar{y}$ = avg. of the increment over increase popⁿ

$$+P_1 < +P_2 > +P_3$$

$$+P_1 > +P_2 < +P_3$$

$\therefore$ Results will be between arithmetic & geometric increase method. (so that this method is quite satisfactory method)

Q In a town, it has been decided to provide 200 lpcd in the 21st century. Estimate the domestic water requirements of this town in the year 2000 AD by projecting the population of the town by Incremental increase method.

Yr	1940	1950	1960	1970	1980
POP ⁿ	23798624	46978325	64786437	63467823	69077421

year	POP ⁿ	Increase in POP	Increment over the Incremental Increase POP ⁿ
1940	→ 23798624	→ 23179701	→ (-) 15371589
1950	→ 46978325	→ 7808112	→ (+) 873274
1960	→ 64786437	→ 8681386	→ (-) 3071788
1970	→ 63467823	→ 5609598	
1980	→ 69077421		
		total = 45278797	total = (-) 17570103
avg. per decade		$\bar{x} = \frac{45278797}{4}$ = 11319699	$\bar{y} = \frac{-17570103}{3}$ = (-) 5856701

∴ Expected population at the end of year 2000.

$$n = \frac{2000 - 1980}{10} = 2$$

$$\begin{aligned} P_{2000} &= P_{1980} + n\bar{x} + \frac{n(n+1)}{2} \bar{y} \\ &= 69077421 + 2 \times 11319699 + \frac{2 \times 3}{2} (-5856701) \\ &= 7,41,46,716 \end{aligned}$$

∴ water requirement in 2000: AD @ 200 l/head/day
= 200 × 74146716 = 14829 × 10⁶ l/day (Ans)

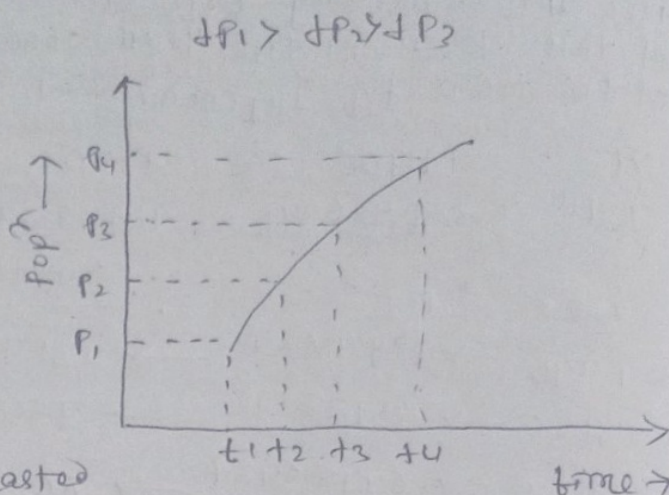
year	POP ⁿ	Increase POP per decade	Increment over increase POP ⁿ
1940	→ 250,000	→ 230,500	→ -16,700
1950	→ 480,500	→ 69,800	→ +18500
1960	→ 5,50,300	→ 88,300	→ -31,700
1970	→ 638600	→ 56,600	
1980	→ 695200		
		total = 442900	total = -1,73,900
		$\bar{x} = \frac{442900}{4}$ = 111300	$\bar{y} = \frac{-1,73,900}{3} = -57966.67$

$$\begin{aligned} P_{2000} &= P_{1980} + n\bar{x} + \frac{n(n+1)}{2} \bar{y} \\ &= 695200 + 2 \times 111300 + \frac{2 \times 3}{2} (-57966.67) = 7,43,900 \end{aligned}$$

② Decreasing growth rate method:

$$\frac{dP}{dt} \propto P_t - P_t$$

→ this method is applicable only when the rate of growth shows a down trend.



→ In this method Pop^n is forecasted by considering the average decrease in percentage rate of growth of the population:

$$P_n = P_0 \left(1 + \frac{R_0 - \bar{D}}{100} \right) \left(1 + \frac{R_0 - 2\bar{D}}{100} \right) \dots \left(1 + \frac{R_0 - n\bar{D}}{100} \right)$$

where P_n = future pop^n

P_0 = Present pop^n

R_0 = Latest known percentage increase of pop^n .

$\bar{D}$ = Avg. decreasing percentage of increase pop^n .

year	Pop^n	per decade % increase Pop^n (R)	decrease in % of increase Pop^n
1960 →	55500	$\frac{63700 - 55500}{55500} \times 100 = 14.77\%$	$14.77 - 11.93 = 2.84\%$
1970 →	63700	$\frac{71300 - 63700}{63700} \times 100 = 11.93\%$	$11.93 - 11.50 = 0.43\%$
1980 →	71300	$\frac{79500 - 71300}{71300} \times 100 = 11.50\%$	
1990 →	79500		

$$R_0 = 11.50\%, \quad \bar{D} = \frac{2.84 + 0.43}{2} = 1.635$$

$$P_{2020} = P_0 \left(1 + \frac{R_0 - \bar{D}}{100} \right) \left(1 + \frac{R_0 - 2\bar{D}}{100} \right) \left(1 + \frac{R_0 - 3\bar{D}}{100} \right)$$

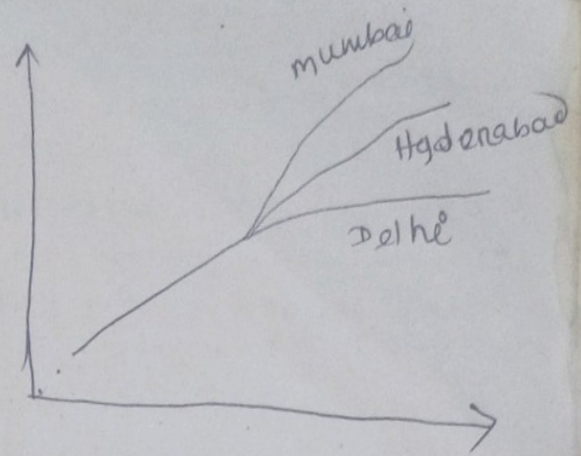
$$= 79500 \left(1 + \frac{11.50 - 1.635}{100} \right) \left(1 + \frac{11.50 - 2 \times 1.635}{100} \right) \left(1 + \frac{11.50 - 3 \times 1.635}{100} \right)$$

$$P_{2020} = 100765$$

⑤ comparative graphical method.

→ cities of similar conditions & characteristics are selected which grow in similar fashion in the past.
∴ their graph is plotted.

→ Then mean graph is also plotted.



1.3 Water Demand: (1872-1993)

→ In a water supply scheme $\xrightarrow{\text{required}}$ $\left\{ \begin{array}{l} \text{pop}^n \\ \text{water demand} \end{array} \right.$

Various Types of water Demand:

- (1) Domestic water Demand $\rightarrow$ as per IS code min^m 135-225 LPCD
- (2) Industrial " $\rightarrow$
- (3) Commercial / Institutional "
- (4) Public Demand
- (5) Fire Demand
- (6) Demand to compensate losses / theft

$$\text{LPCD} = \frac{\text{Litres per capita per Day}}{\text{per Day}}$$

$$\text{Domestic water Demand per capita water Demand} = \frac{\text{Avg. annual water consumption of a community}}{365 \times (\text{pop}^n \text{ of the community})}$$

$$\text{units: LPCD} \rightarrow \begin{array}{l} \text{lit / capita / day} \\ \text{lit / head / day} \\ \text{lit / person / day} \end{array}$$

Domestic water Demand (cooking, bathing, gardening etc)

- $\rightarrow$ as per IS code; 135-225 LPCD
- $\rightarrow$ for fully flushing system minimum 200 LPCD
- $\rightarrow$ for low income group (LIG) $\rightarrow$ 135 LPCD

Industrial $\rightarrow$ Normal city = 50 LPCD
Highly industrial = 450 LPCD (ex: paper mill, petroleum refinery etc)

Commercial / Institutional $\rightarrow$ $\left\{ \begin{array}{l} \text{Normal commercial} = 70 \text{ LPCD ex cinema} \\ \text{Highly} \quad \quad \quad = 50 \text{ LPCD} \end{array} \right.$

(Hospital - 340 LPCD - 380 LPCD)

Public Demand $\rightarrow$ 10 LPCD (includes parks, washing of roads, public drinking)

Fire Demand $\rightarrow$ $\left\{ \begin{array}{l} \text{min } 37 \text{ l/min} \\ \text{1100 l/min} \end{array} \right.$

when the popⁿ exceeds 50,000 the water required for fire demand can be computed using empirical formulae.

(1) Kuichlings formula $Q = 3182 \sqrt{P}$

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

(3) National Board of fire underwriters formula

(a) $\text{pop}^n \leq 2 \text{ lakh}$, $Q = 4637 \sqrt{P} (1 - 0.01 \sqrt{P})$

$> 2 \text{ lakh}$, $Q = 54600 \text{ l/min}$

(4) Buston formula $Q = 5663 \sqrt{P}$

$$\begin{array}{l} Q = \text{l/min} \\ P = \text{thousand} \end{array}$$

Q. compute the fire demand for a city having population of 140,000 as per the formula.

- ① Kuichlings formula $Q = 3182 \sqrt{P} = 3182 \times \sqrt{140} = 37650 \text{ lit/min}$
- ② freeman " $Q = 1136 \left(\frac{P}{5} + 10 \right) = 1136 \left(\frac{140}{5} + 10 \right) = 43168 \text{ lit/min}$
- ③ National ~~fire~~ board of fire under water formula $Q = 4637 \sqrt{P} (1 - 0.01 \sqrt{P})$
 $= 4637 \sqrt{140} (1 - 0.01 \sqrt{140}) = 48371 \text{ lit/min}$
- ④ Buston formula $Q = 5663 \sqrt{P} = 5663 \times \sqrt{140} = 6700 \text{ lit/min}$

Per capita demand:

→ It is annual avg. amount of daily water required by ~~person~~ one person.

$$q = \frac{\text{Total yearly water requirement of city}}{\text{population} \times 365}$$

Factors affecting per capita demand.

- size of city
- climatic condition
- quality of water supply
- pressure in distribution system
- system of supply. $\left\{ \begin{array}{l} \text{continuous} \\ \text{intermediate} \end{array} \right.$
- water meter
- cost of water

Variation of in water Demand for Design.

- (1) Average daily water Demand (Q)
 $= \text{population} \times \text{per capita water demand}$
- (2) Max^m daily water Demand $= 1.8 \times q$
 $= 1.8 \times \text{avg. daily consumption}$
- (3) Max^m hourly demand of max^m day
 $= \text{hourly variation factor} \times \frac{\text{max^m daily consumption}}{24}$
 $= 1.5 \times \frac{1.8 \times q}{24} = 2.7 \times \frac{q}{24}$
 $= 1.5 \times \text{avg. hourly consumption of the max^m day}$
 $= 1.5 \times \left(1.8 \times \frac{q}{24} \right)$
 $= 2.7 \times \text{avg. hourly demand}$

① coincident Draft = max daily water demand + fire Demand

③ total Demand = Total Draft = $\max^m$ hourly demand
or
coincident draft } $\max^m$

Note total water requirement of a city is generally expressed in on the basis of total Demand.

1.4 Impurities in water:

Note

(1) pure water $\rightarrow$ drinking water

(2) potable water $\rightarrow$ fit for drinkable

(3) palatable " $\rightarrow$ aesthetically looking good.

(4) wholesome " $\rightarrow$ chemically may not be pure, but does not contain anything harmful to human being.

(5) polluted " $\rightarrow$ it contains undesirable substance
 $\rightarrow$ not fit for drinkable & domestic use.

(6) contaminated " $\rightarrow$ it contains pathogenic bacteria
 $\rightarrow$ unfit for drinking.

(7) mineral " $\rightarrow$ contains useful minerals, calcium, magnesium & iron, ~~etc~~ (in required proportion)

The common impurities in water:

(1) Based on size of impurities:

macro $\left\{ \begin{array}{l} \text{a) suspended impurities} \quad (10^1 \text{ mm} - 10^3 \text{ mm}) \text{ or } (100 \mu\text{m} - 1 \text{ mm}) \\ \text{b) colloidal} \quad " \quad (10^3 \text{ mm} - 10^6 \text{ mm}) \text{ or } (1 \mu\text{m} - 10^3 \mu\text{m}) \\ \text{micro c) dissolved} \quad " \quad (10^6 \text{ mm} - 10^8 \text{ mm}) \text{ or } (10^3 \mu\text{m} - 10^5 \mu\text{m}) \end{array} \right.$

(2) Based on ~~Nature~~ Nature of impurities

a) organic impurities

b) inorganic "

organic matter in water causes increase of micro organism

(3) Based on state of matter

a) physical impurities

$\rightarrow$ suspended solid
 $\rightarrow$ Temp
 $\rightarrow$ colour
 $\rightarrow$ odour/taste
 $\rightarrow$ Turbidity

b) chemical impurities

$\rightarrow$ TDS
 $\rightarrow$ Alkalinity
 $\rightarrow$ acidity
 $\rightarrow$ pH
 $\rightarrow$ Hardness
 $\rightarrow$ chloride
 $\rightarrow$ sulphate

$\rightarrow$ DO
 $\rightarrow$ Nitrogen compounds
 $\rightarrow$ Iron & manganese
 $\rightarrow$ toxic chemicals

Nitrogen
 $\rightarrow$ Ammonia
 $\rightarrow$ Organic Nitrogen
 $\rightarrow$ Nitrite
 $\rightarrow$ Nitrate

c) Biological

" $\rightarrow$ pathogens, microbial organism
 $\rightarrow$ Bacteria, virus, protozoa etc.

1.5 analysis of water:

→ It can be done by ^{testing} ~~test~~ of water ^{on the basis} ~~on the basis~~ to physical, chemical & biological impurities.

1.5.1 physical impurities

defines those characteristics which respond to senses, touch, smell, taste, feel

97 suspended solids

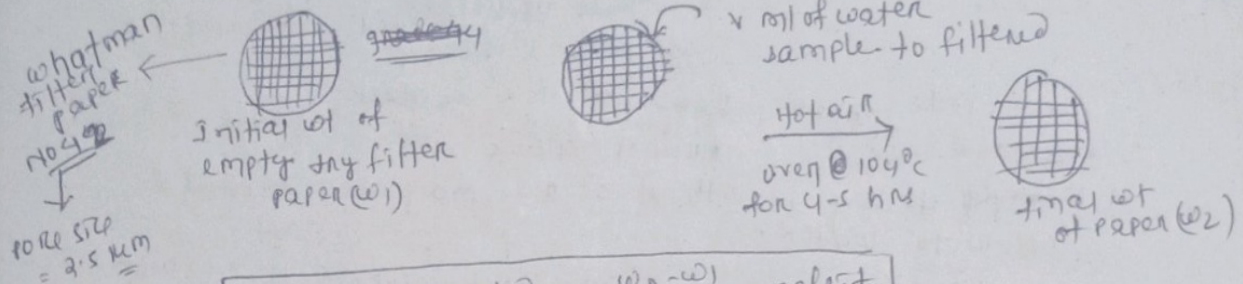
→ It comes only in surface water not in gw.
suspended + dissolved solid.

→ total solid = suspended + dissolved solid.
non filtered filtered

mon $\frac{1}{2}$ liter

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→ measured by : gravimetric = by weight measurement



$$\therefore \text{ suspended solid} = \frac{\omega_2 - \omega_1}{r} \text{ mg/Lt}$$

Q. A 100cc of water sample passed through a empty dry filter paper of 1.236 gm after oven and drying its final weight measured to 1.264 gm. find TS in sample.

$w_1 = 1.236 \text{ gm}$
 $w_2 = 1.264 \text{ gm}$
 $v_1 = 100 \text{ cc} = 100 \text{ ml}$

$\text{SS} = \frac{w_2 - w_1}{v_1} = \frac{(1.264 - 1.236) \text{ gm}}{100 \text{ ml}}$
 $= \frac{0.028 \text{ gm}}{100 \times 10^{-3} \text{ l}} = \frac{0.28 \text{ gm}}{\text{lit}}$
 $= \frac{280 \text{ mg}}{\text{lit}} \text{ (ans)}$

The permissible limit for SS is 20 mg/lit } as per EPA

Note Permissible limit for SS, i.e. 30 mg/lit } as per EPA (Environmental protection Agency)

(b) Temperature

- If temperature increases, it promotes growth of micro-organisms
- $T \uparrow$ chemical reaction rate $\uparrow$
 $T \uparrow$ viscosity $\downarrow$
- Temperature should be between $10-25^{\circ}\text{C}$ (IS: 10500:2012)
- Temperature affects chemical & biological reaction.

(c) colour is caused by $\left\{ \begin{array}{l} \text{suspended} \rightarrow \text{leads to apparent colour} \\ \text{dissolved matter} \rightarrow \text{leads to true colour} \end{array} \right.$

Iron oxide gives reddish color ~~asbestos~~
Manganese oxide " brown colour

→ ~~Heavy~~ Heavy growth of algae may also impart color to water.

Measurement: → by color machine Technique (Tintometer)
→ expressed in terms of TCU (True Color Unit)

→ 1 TCU = 2mg of platinum as a chloroplatinate ions ~~mixed~~ in 1 lit ~~mixed~~ of distilled water. Then colour produced is taken as one standard color unit.

Also Hazen unit

→ Also this scale is presented by Burgess, which is called Burgess scale.

Permissible limit = 5 TCU } IS: 10500:2012
Rejection " = 15 TCU

(d) Taste & odour:

→ Taste & odour are caused by dissolve gases like H_2S (Hydrogen sulphide), methane, ~~then~~ decomposing of organic matter, dead organism body, industrial liquids, ammonia, agricultural chemicals, etc.

Measurement by device

odour (TON)

→ by osmoscope
→ in terms of TON
(Threshold Odour Number)

$$\text{TON} = \frac{A+B}{4}$$

A = vol of water sample in ml
B = vol of distilled water used in dilution in ml

permissible limit = 1-3

Taste

→ taste is expressed in terms of FTN
(Flavoured Threshold Number)

* the odour scale is graduated with p^0 values from 0-5.
 $p^0 < 0 \rightarrow$ no perceptible odour
 $p^0 > 5 \rightarrow$ extremely strong odour.

→ turbidity: (5-10 TU)

→ No turbidity = clear water = if allow ~~eye~~ to see side by side through water.

→ it is the measure of resistance offered by the particles present in water to the passage of light through water is called turbidity.

→ caused by two particles { suspended impurities
{ ~~colloidal~~ impurities

(why not dissolved particles?)

→ they are extremely dissolved in the water & become water ~~molecule~~ molecules.

→ Turbidity is a surface phenomenon.

Turbidity $\propto \frac{1}{\text{size of the particle}}$
 $\propto$ Surface area

→ Turbidity is expressed in terms of turbidity units.

→ standard (1 TU): 1mg of finely divided silica mixed in 1l of distilled water, then turbidity produced is taken as 1 standard turbidity unit.

→ This was produced by Jackson

→ Therefore it is also known as ~~Jackson~~ Jackson Turbidity unit (JTU)

→ turbidity is measured by the device which works on the principle of
(1) light absorbance
(2) light scattering.

(A) Device working on the principle of light absorbance

(a) Jackson turbidity rod → used for field measurement

(b) Jackson Turbidity meter → for highly turbidity (1)
(Turbidity ≥ 25 JTU
(≤ 25 cannot use))

(c) Baylis turbidity meter → low turbidity 0-5 JTU

(d) Hellige " " → 0 to 50 JTU

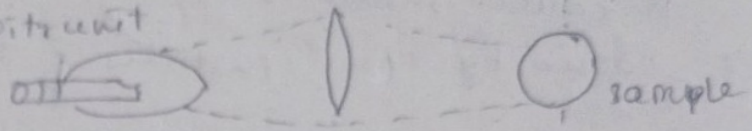
(2) Device on principle of scattering of light

- device is Nephelometer
- mostly used device for domestic water supplies
- it measures turbidity in terms of NTU (Nephelometric Turbidity Unit)

1 NTU = 1 mg of formazine polymer mixed in 1 litre of distilled water then the turbidity produced is taken as 1 NTU.

- In this device light intensity is measured at right angles to the incident ray.

- FTU also called formazine turbidity unit



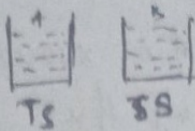
- Acceptable limit for rejection " 1 NTU to 5 NTU " IS: 10500:2012

Photometer

1.5.2 Chemical Impurities

(1) Total Dissolved Solids:

$$TS = SS + TDS$$



sample B

1) After filter from filter paper NO 42, paper should oven at $104^{\circ}-105^{\circ}\text{C}$ for 1-4 hr $\rightarrow$ find ~~the~~ suspended solids.

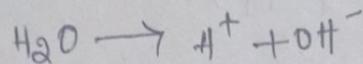
(2) Then take sample 4 & get oven dry at 600°C for 1-4 hr & get calculated total solid.

$$\therefore TDS = TS - SS$$

Permissible limit $\rightarrow 500 \text{ mg/lit}$ as per IS: 10500:2015
 Rejection " $\rightarrow 2000$

(2) pH

$\rightarrow$ It stands for potential of Hydrogen concentration



$\rightarrow$ Ionization eqⁿ of water, $\frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]} = K$

for water at Temp $= 4^{\circ}\text{C}$, $[\text{H}_2\text{O}] = 1$

$K = 10^{-14} \text{ mol/lit}$
 $=$ self ionization constant

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

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

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

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

$$\Rightarrow \log \left[\frac{1}{[\text{H}^+]} \right] + \log \left[\frac{1}{[\text{OH}^-]} \right] = 14$$

$$\Rightarrow \boxed{\text{pH} + \text{pOH} = 14}$$

$$\rightarrow \text{where } \text{pH} = \log_{10} \left(\frac{1}{[\text{H}^+]} \right) = -\log_{10} \text{H}^+$$

↑
alkaline
indicator

Measurements: (a) colorimetric = By using pH paper

(b) Titrimetry = By using titration

(Methylorange & phenolphthalein)

acidic indicator $\leftarrow$ 2.8-4.4
 True colour is red
 changed to yellow

8.6-10.3
 colourless
 changed to red

(c) potentiometry =

→ permissible limit $pH = 6.5 - 8.5$

Notes concentration of x in $mg/lit = (\text{conc. of } x \text{ mol/lit}) \times \frac{\text{molecular wt of } x}{x} \times 1000$
~~conc. of x mol/lit~~
 $= x \text{ eq/lit} \times \text{equivalent wt of } x \times 1000$
 $= x \text{ m.eq/lit} \times \text{equivalent wt of } x$

Ex $pH = 9.25$ then find out $[OH^-]$ in mg/lit

Ans $pH = 9.25$ $pOH = 14 - 9.25 = 4.75$

$$pOH = 4.75 \Rightarrow \log_{10} \left[\frac{1}{[OH^-]} \right] \Rightarrow 4.75 = 0.475 = \log_{10} \left[\frac{1}{[OH^-]} \right]$$

$$\Rightarrow 10^{4.75} = 10^{(-\log_{10} [OH^-])} \Rightarrow 10^{4.75} = [OH^-]^{-1}$$

$$\Rightarrow 10 [OH^-] = 10^{4.75} \text{ mol/lit}$$

$$\therefore [OH^-] \text{ mg/lit} = 10^{4.75} \text{ mol/lit} \times \frac{\text{molecular wt}}{1} \times 1000$$
$$= 10^{4.75} \times 17 \times 1000 = 0.302 \text{ mg/lit}$$

Notes pH value is important due to

- the amount of chemical required in treatment of water depends on pH .
- By knowing pH , nature of water can be found.

③ Acidity:

- it is measure of the ability of water to neutralise $[OH^-]$ ^{↑ Alkalinity}
- it is also defined as quantity of ions in water that will react to neutralize hydroxide (OH^-) .
- Acidity ~~causes~~ increased corrosion problems.

→ Acidity $\leq 50 \text{ mg/lit}$ of $CaCO_3$

→ measured by Titrimetric method or volumetric method.

Titrants are → $NaOH$

Indicator → methyl orange (pink-yellow)

→ phenolphthalein (yellow-pink)

→ mainly caused by 1) carbon dioxide
2) sulphate of iron & aluminium

→ methyl orange indicator for mineral acid ($pH = 0-4.2$)
phenolphthalein 1) for carbonic acid ($pH = 6.2-8.3$)

→ permissible acidity $\leq 50 \text{ mg/lit}$ as CaCO_3

$$\text{conc. of } x \text{ in mg/lit} = \frac{V \times N \times \text{equivalent wt of } x}{\text{vol. of water sample in terms of ml}} \times 1000$$

$$\text{conc. of } x \text{ in terms of } y \text{ in mg/lit} = \frac{V \times N \times \text{equivalent wt of } y}{\text{vol. of water sample in terms of ml}} \times 1000$$

→ total acidity = methyl orange + phenolphthalein

$$\text{acidity due to methyl orange} = \frac{V \times N \times \text{eq. wt of } \text{CaCO}_3}{\text{vol. of water sample in ml}} \times 1000$$

$$\text{acidity due to phenolphthalein} = \frac{V \times N \times \text{eq. wt of } \text{CaCO}_3}{\text{vol. of water sample}} \times 1000$$

(5) Alkalinity

→ Alkalinity is defined as quantity of ions in water that will react to neutralize hydrogen ions H^+ .

→ measure of ability of water to neutralize the acid.

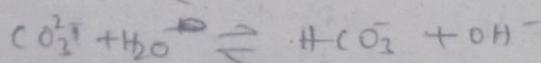
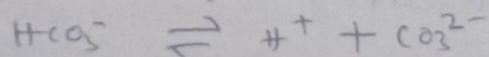
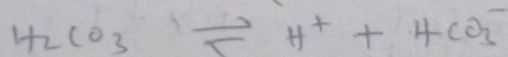
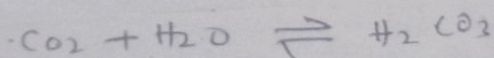
→ Alkalinity in water caused by

(1) $\text{OH}^- \rightarrow \text{pH} = 14 \text{ to } 10.2 \rightarrow \text{caustic alkalinity}$

(2) $\text{CO}_3^{2-} \rightarrow \text{pH} = 10.2 \text{ to } 8.3 \rightarrow \text{carbonate}$

(3) $\text{HCO}_3^- \rightarrow \text{pH} = 8.3 \text{ to } 4.3 \rightarrow \text{bicarbonate}$

→ Alkalinity comes due to atmospheric CO_2 mixed in water & ~~microbial~~ ^{microbial} decomposition of organic matter



→ Alkalinity imparts bitter taste to water.

→ Measurement

$$\text{total alkalinity} = \text{OH}^- (\text{mg/lit}) \times \frac{\text{eq. wt. of } \text{CaCO}_3}{\text{eq. wt. of } \text{OH}^-} + \text{HCO}_3^- (\text{mg/lit}) \times \frac{50}{61}$$

$$\text{total alkalinity} = \text{CO}_3^{2-} (\text{mg/lit}) \times \frac{\text{eq. wt. of } \text{CaCO}_3}{\text{eq. wt. of } \text{CO}_3^{2-}} + \text{HCO}_3^- (\text{mg/lit}) \times \frac{\text{eq. wt. of } \text{CaCO}_3}{\text{eq. wt. of } \text{HCO}_3^-}$$

$$= \text{CO}_3^{2-} (\text{mg/lit}) \times \frac{50}{30} + \text{HCO}_3^- (\text{mg/lit}) \times \frac{50}{61}$$

→ permissible acidity $\leq 50 \text{ mg/lit}$ as CaCO_3

→ conc. of x in $\text{mg/lit} = \frac{V \times N \times \text{equivalent wt of } x}{\text{vol of water sample in terms of ml}} \times 1000$

→ conc. of x in terms of y in $\text{mg/lit} = \frac{V \times N \times \text{equivalent wt of } y}{\text{vol of water sample in terms of ml}} \times 1000$

→ total acidity = methyl orange + phenolphthalein

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acidity due to phenolphthalein = $\frac{V \times N \times \text{eq. wt of } \text{CaCO}_3}{\text{vol of water sample}} \times 1000$

(5) Alkalinity

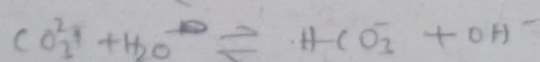
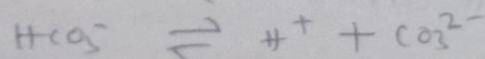
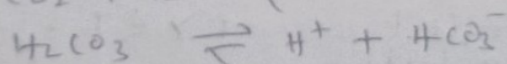
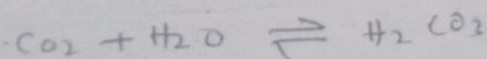
→ Alkalinity is defined as quantity of ions in water that will react to neutralize hydrogen ions H^+ .

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→ Alkalinity in water caused by

- (1) $\text{OH}^- \rightarrow \text{pH} = 14 \text{ to } 10.2 \rightarrow \text{caustic alkalinity}$
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→ Alkalinity comes due to atmospheric CO_2 mixed in water & ~~microbial~~ ^{microbial} decomposition of organic matter



→ Alkalinity imparts bitter taste to water.

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total alkalinity = $\text{OH}^- (\text{mg/lit}) \times \frac{\text{eq. wt of } \text{CaCO}_3}{\text{eq. wt of } \text{OH}^-} + \text{HCO}_3^- (\text{mg/lit}) \times \frac{50}{61}$

total alkalinity = $\text{CO}_3^{2-} (\text{mg/lit}) \times \frac{\text{eq. wt of } \text{CaCO}_3}{\text{eq. wt of } \text{CO}_3^{2-}} + \text{HCO}_3^- (\text{mg/lit}) \times \frac{\text{eq. wt of } \text{CaCO}_3}{\text{eq. wt of } \text{HCO}_3^-}$

= $\text{CO}_3^{2-} (\text{mg/lit}) \times \frac{50}{30} + \text{HCO}_3^- (\text{mg/lit}) \times \frac{50}{61}$

Alkalinity in water estimated by titrimeter

→ titrants : H_2SO_4

Indicators: ~~phenolphthalein~~

Phenolphthalein

methyl orange

(pink - colourless)

(yellow - pink)

→ P alkalinity

→ M alkalinity

or T "

(total alkalinity)

Relation bet ⁿ P & T	OH^-	CO_3^{2-}	HCO_3^-
$P = 0$	0	0	T
$P < \frac{1}{2}T$	0	2P	T - 2P
$P = \frac{1}{2}T$	0	2P	0
$P > \frac{1}{2}T$	2P - T	2T - 2P	0
$P = T$	T	0	0

* Alkalinity in water causes following problem

(1) ~~bitter~~ taste

1) water becomes bitter taste

(2) causes scaling problems (create a layer in pipe so that dia of pipe decreases)

* permissible limit → ~~at least~~

Total alkalinity $\leq 200 \text{ mg/L}$ as $CaCO_3$

Q If P-alkalinity in water is 200 mg/L as $CaCO_3$ & T-alkalinity is 300 mg/L as $CaCO_3$ then find Hydroxide alkalinity, CO_3^{2-} , HCO_3^- .

Given data

$P = 200 \text{ mg/L}$
 $T = 300 \text{ mg/L}$

$P > \frac{1}{2}T = 200 > \frac{1}{2} \times 300$

consequently

$OH^- = 2P - T$
 $CO_3^{2-} = 2T - 2P$
 $HCO_3^- = 0$

⑤ Hardness:

→ Hardness = carbonate Hardness + non carbonate Hardness

Temporary
↓
 $\text{CaHCO}_3, \text{CaCO}_3$
of calcium & magnesium
↓
easy to remove by boiling.

permanent
↓
 $\text{Fe}^{2+}, \text{Mn}^{2+}$
 $\text{Al}^{3+}, \text{Sr}^{2+}$
↓
strontium

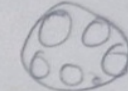
→ Hardness is defined as concentration of multivalent metallic cations in solution.

→ practically / mainly → Hardness is represented by Ca^{2+} & Mg^{2+}

$\frac{40}{100}$
(Atomic wt)

$\frac{24}{100}$
(Atomic wt)

→ calcium Hardness leads to → laxative effects to health
magnesium " leads to → laxative "

- Hardwater leads to lesser foam formation & soap ~~would be more~~ consumption ~~of~~ would be more.
- it causes incrustation of pipes  → 
- it makes food tasteless.

~~measured by~~ spectrophotometry

Notes

total hardness (TH) expressed in terms of mg/l as CaCO_3 .

$$\therefore \text{TH as CaCO}_3 = \text{Ca}^{2+} \text{ mg/l} \times \frac{\text{eq}^{\text{wt}} \text{ wt of CaCO}_3}{\text{eq}^{\text{wt}} \text{ wt of Mg}^{2+}}$$

$$\therefore \boxed{\text{TH} = \text{Ca}^{2+} \times \frac{50}{20} + \text{Mg}^{2+} \times \frac{50}{12}}$$

Relation betⁿ TA & TH

if (1) $\text{TH} > \text{TA}$

$$\Rightarrow \text{CH} = \text{TA}$$

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

(2) $\text{TH} \leq \text{TA}$

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

$$\text{NCH} = 0$$

measured by glycine method or EDTA method
(2) spectrophotometric method.

EDTA method:

Titrant: EDTA (Ethylenediamine Tetraacetic Acid)

Indicator: EBT (Erichrome Black T)

colour: comes from pink to blue

Hardness in water causes

- (1) Bitter taste (unpalatable)
- (2) Increased soap consumption
- (3) Corrosion
- (4) Scaling problem.

Total Hardness
mg/lit as CaCO_3

Type of water

< 75	→	Soft
75-150	→	Moderate hard
150-200	→	Hard
> 200	→	Very Hard

* Acceptable limit of: 200 mg/lit as CaCO_3

- (6) chlorides: chlorides along with sodium present in high concentration cause
- (1) Kidney
 - (2) cardio. (heart) problem

→ chlorides in water are derived mostly from

- (1) Natural mineral deposit
- (2) Agricultural or irrigation discharge
- (3) Sea water ~~intrusion~~ intrusion.

→ chlorides in water ^{expressed} measured by "Mohr method"

→ Titrimetric measurement

Titrimetric method process

Titrant: silver Nitrate (AgNO_3)

Indicator: potassium chromate (K_2Cr_2)

color: yellow to brick red.

Ag = 107.

→ permissible limit: $\leq 250 \text{ mg/lit}$
rejection " : $> 1000 \text{ mg/lit}$ } as per IS: 10500: 2012

- (7) sulphates: → sulphates in high concentration in water cause laxative problem. (loose motion)

→ ~~not~~ estimated by turbidimetry using barium. ^{Diarrhea}

→ Drinking water standard of sulphate $< 200 \text{ mg/lit}$ (permissible)

→ rejection limit = 400 mg/lit

⑧ Dissolved oxygen (DO)

- DO keep water fresh for long period.
- If sufficient DO present in water then water is odourless & taste good.
- DO is estimated by Winkler's method, with the help of titrimetry.

titration: sodium thiosulphate
Indication: starch solution
colour: Blue to colourless

Note:

By adding magnesium sulphate, alkali iodide azide, SnCl_2 in water sample, if it shows brown colour then we know DO is present.

"Brown precipitate is form" → DO present in water
"No brown" → DO is not present.

- But high level of DO present in water even causes corrosion.
- permeable limit: 3 to 4 mg/lit
rejection limit: ≥ 10 mg/lit

⑨ fluorides

(i) $f < 1 \text{ mg/lit}$ → Dental cavities

(ii) $f + \text{Enamel}$ → strong, durable, hard, resistant teeth

(At the age of formation of permanent teeth)

(iii) $f > 1.5 \text{ mg/lit}$ → mottling of teeth (yellow colour teeth)

→ Decolouration of teeth

↪ fluorosis

new teeth
discolour
(yellow)

Bone -
abnormalities

→ fluorides are estimated by colorimetry.

→ Reagent: Zirconium spears

→ Drinking water standard → $f \leq f \leq 1.5 \text{ mg/lit}$

⑩ Nitrogen compounds:

→ It is found when water contaminated by sewage waste water, organic substance are found in water.

→ Following compounds found in water

- (a) Ammonia Nitrogen } Kjeldahl Nitrogen
- (b) organic Nitrogen }
- (c) Nitrites
- (d) Nitrates

→ Knowing the form of nitrogen compound it is possible to know state & condition of the pollution or contamination

→ Ammonia Nitrogen = just polluted or recently polluted
organic Nitrogen = contaminated by vegetable & animal waste.

Nitrites

(Before decomposition of pollution)

Nitrates

= Intermediate state of pollution

= oxidized organic matter (old pollution)

→ Nitrogen compound in water is estimated by colorimetry

→ Drinking water standard

(1) Ammonia Nitrogen $< 0.15 \text{ mg/lit} \rightarrow (\text{NH}_3)$

(2) ~~Ammonia~~ organic " $< 0.30 \text{ mg/lit}$

(3) Nitrites (NO_2) ≈ 0 (zero)

mg (4) Nitrates (NO_3) $< 45 \text{ mg/lit}$

Note if Nitrate concentration $> 45 \text{ mg/lit}$, it caused infantile disease known as methemoglobinemia or Bluebaby disease.

(11) Iron & Manganese:

Drinking standards: Fe (Iron) $< 0.3 \text{ mg/lit}$
Mn (Manganese) $< 0.05 \text{ mg/lit}$

⑫ Toxic chemical substance:

caused due to toxic chemical substances

(1) Damage central nervous system

(2) Damage Blood cell / Blood vessel

(3) Carcinogenic disease (cancer)

Phenols $< 0.001 \text{ mg/l}$

Mercury $< 0.001 \text{ mg/l}$

Artenic $< 0.05 \text{ mg/l}$

Chromium $< 0.05 \text{ mg/l}$

Cyanide $< 0.05 \text{ mg/l}$

Boron $< 0.01 \text{ mg/lit}$

Cadmium $< 0.01 \text{ mg/lit}$

Lead $< 0.1 \text{ mg/lit}$

Barium $< 1 \text{ mg/lit}$

These substance in water trace by AAS

(Atomic Absorption Spectrophotometer)

1.5.3 Biological water quality parameters (microbial test of water)

- the most important organisms are called pathogens.
- these are capable of transmitting diseases.
- examples are Bacteria, virus, protozoa etc.
- very difficult to count & test in laboratory on the daily basis.
- so, to detect & count, the presence of coliforms is generally tested.
 - ↓
 - harmless (non pathogenic bacteria)
 - ↓
 - aerobic lactose fermenters
- its presence or absence indicates the presence & absence of pathogenic bacteria.
- coliform called Bacteria coli, ex E. coli = Escherichia coli, B. coli = ~~Bacillus coli~~ ^{Bacillus coli}
- E. coli organisms are excreted (discharge) through human or animal body by fecal matter.
- if E. coli is found → indicates water is contaminated by fecal matter.
 - ↳ other pathogens may be the presence.
- therefore E. coli is known as indicator of organisms.

Tests for coliforms:

- (1) membrane filter technique (~~is not used~~)
- (2) MPN test (most probable number) →
- (3) coliform index.

MPN test (E. coli test)

- This test is conducted by multiple tube fermentation test.
- It has three stages.

- (i) presumptive test → +ve results indicates presence
- (ii) confirmed test → confirmation about coliform
- (iii) completed test → examined under microscope & confirmed the coliform.

E. coli test results expressed in terms of

- (1) E. coli index.
- (2) MPN (most probable number)

incubator
@ 37° for 24 hours

↓
gas +ve
no gas -ve

MPN $\rightarrow$ st represents bacteria densities which is most likely to be present in the given water sample for the given test results.

from thomas eqⁿ:

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

* Drinking water with respect to microbial water quantity

(1) E-coli index = 0

(2) MPN $\leq$ 1 no/100ml

Size of sample	No. of +ve	number of -ve
1	4	1
0.1	3	2
0.01	2	3
0.001	0	5

Determine the MPN using thomas eqⁿ.

solⁿ

Number of positive tube = $4 + 3 + 2 = 9$

ml of sample in negative tube = $(1 \times 1) + (2 \times 0.1) + (3 \times 0.01) + (5 \times 0.001) = 1.235$

ml of sample in all tube = $(5 \times 1) + (5 \times 0.1) + (5 \times 0.01) + (5 \times 0.001) = 5.555$

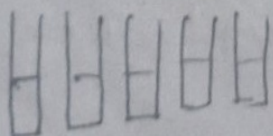
MPN/100mg = $\frac{9 \times 100}{\sqrt{1.235 \times 5.555}} = 344$

Notes

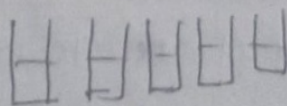
10 ml sample

1 ml sample

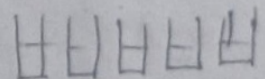
0.1 ml sample



10 ml $\times$ 10 Lactose broth



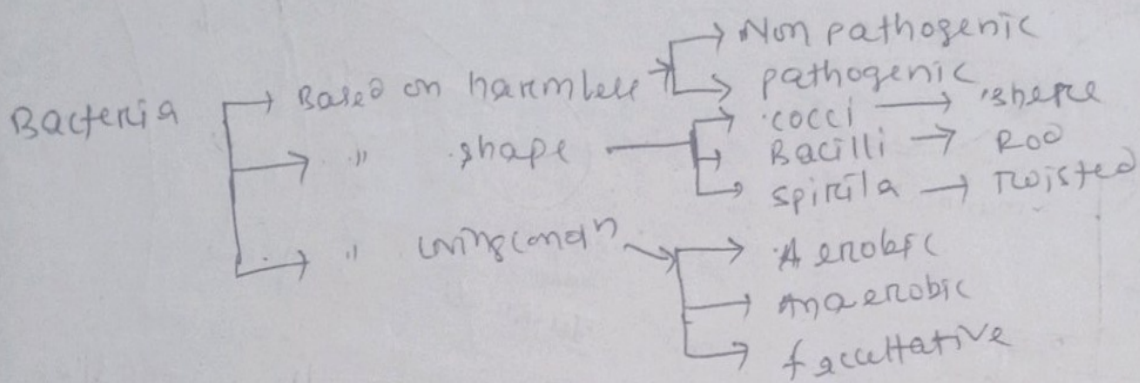
10 ml $\times$ 10 Lactose broth



10 ml $\times$ 10 Lactose broth

Water Borne Diseases

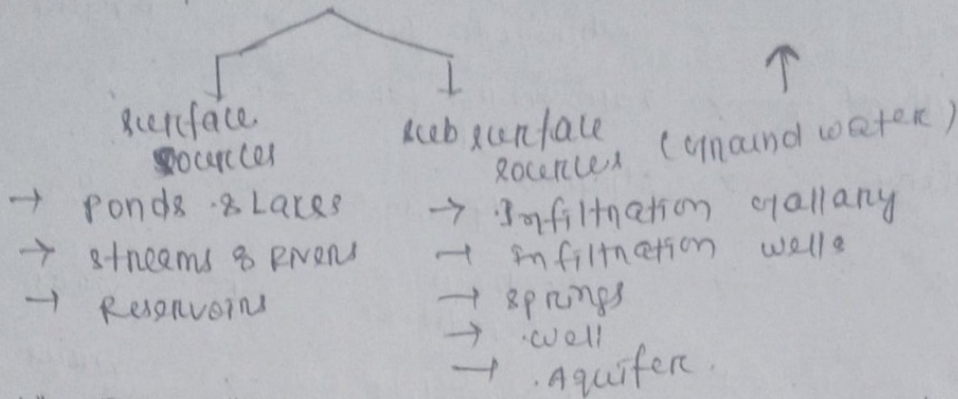
<u>Name of disease</u>	<u>organism</u>	<u>category</u>
(1) cholera	vibrio cholera	Bacteria
(2) Typhoid	salmonella Typhi	Bacteria
(3) paratyphoid	salmonella para Typhi	"
(4) Dysentery	shigella dysentria	"
(5) jaundis	infectious hepatitis	virus
(6) polio	polio myelitis	virus
(7) malaria	plasmodium parasite	protozoa



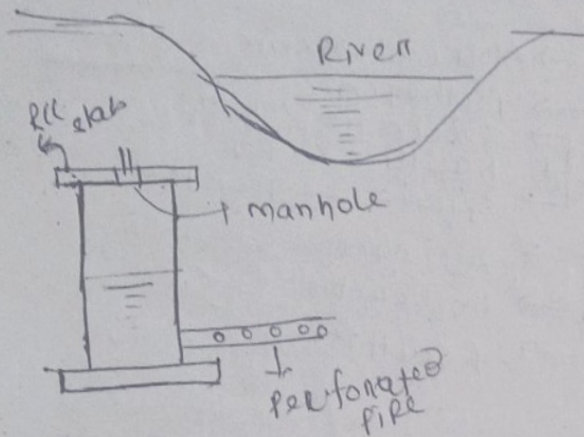
Chapter-2:

Sources & conveyance of water

2.1 sources of water

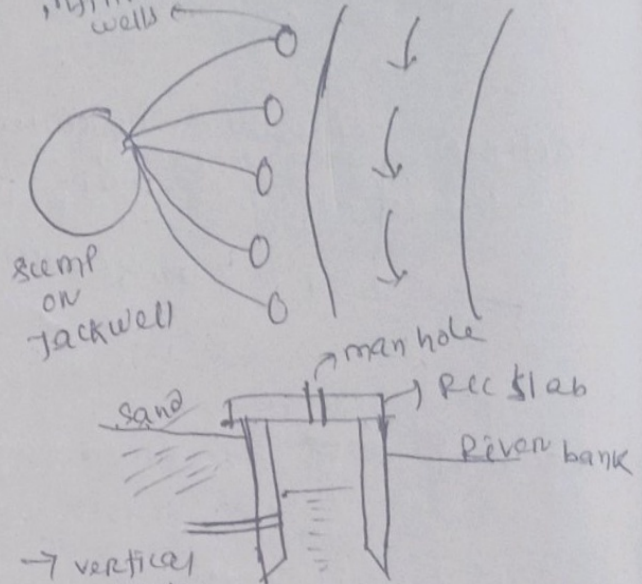


Infiltration gallery:



- ~~Horizontal~~ Horizontal wells
- These are horizontal tunnel constructed at shallow depth (3 to 5 meters) along the banks of river
- water collect through perforated pipe or open joints of brick

Infiltration wells



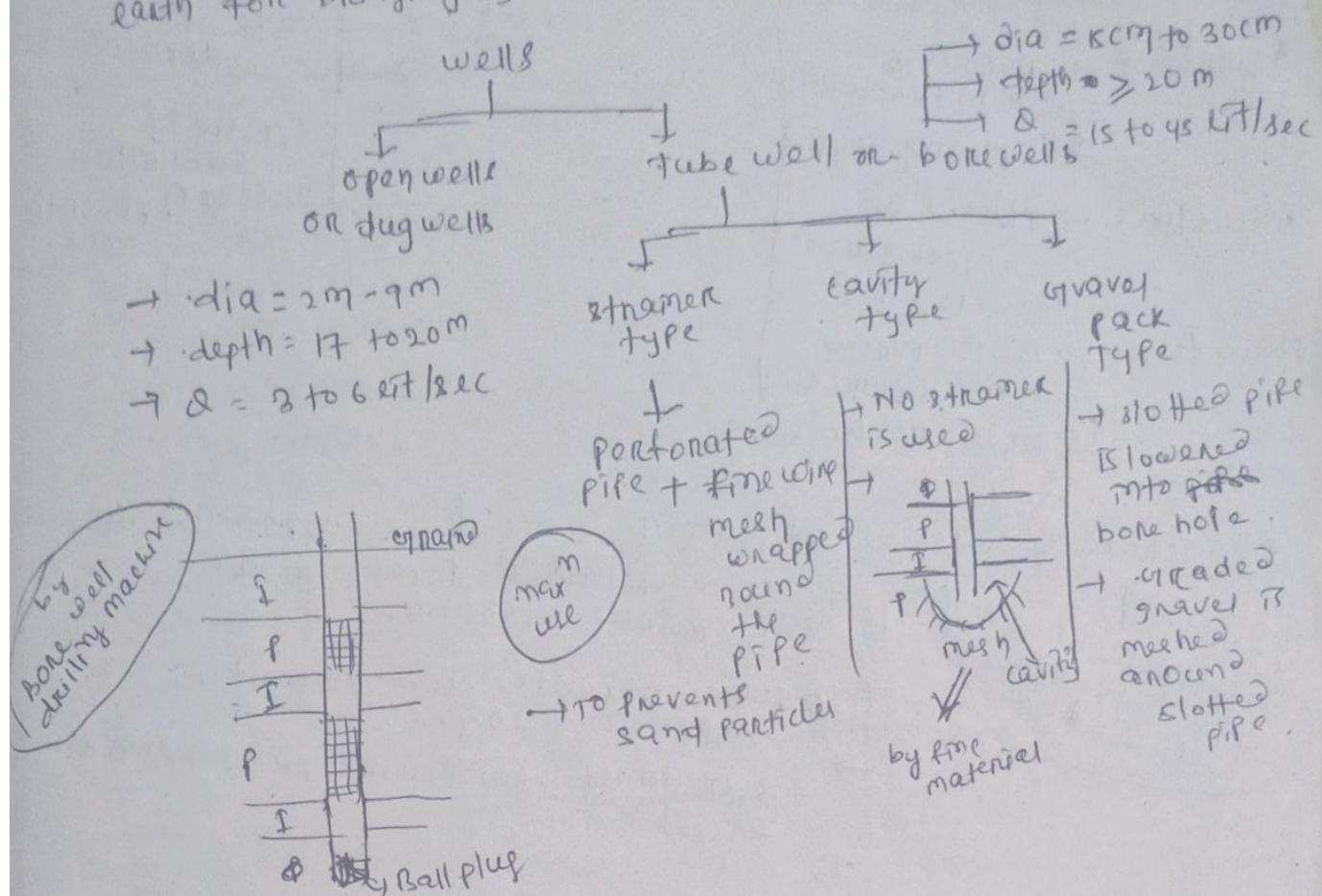
- vertical wells
- These are shallow wells constructed in series along the bank of river.
- water collect through bottom of wells.

springs

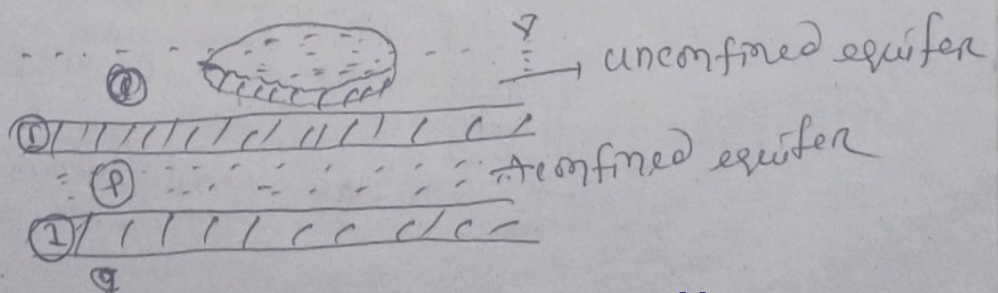
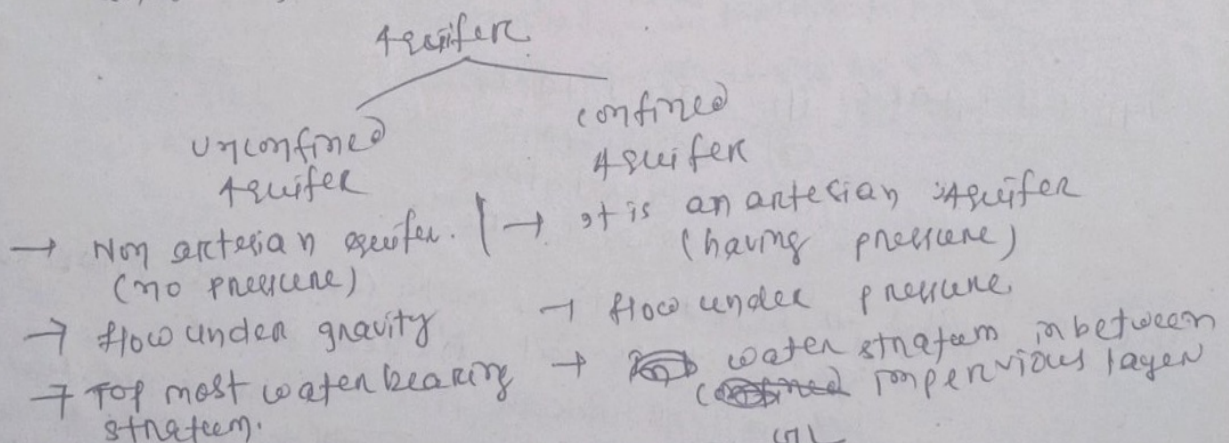
- Natural outflow of ground water at the earth's surface = springs
- Types
 - Artesian springs → due to pressure, water ~~is~~ outflow
 - Gravity springs → due to overflow of groundwater table
 - surface springs →
- certain springs sometimes discharge hot water due to the presence of sulphur in them.

Wells

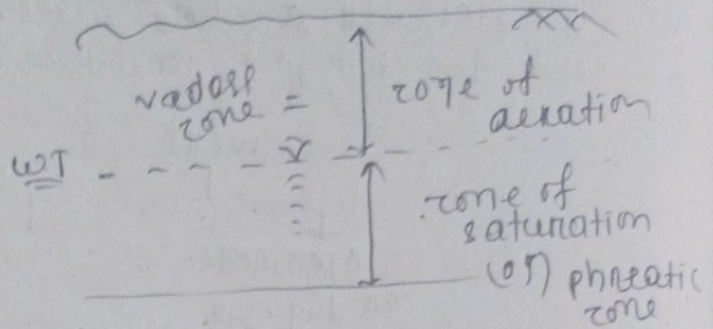
→ A water well is a hole usually vertical, excavated in the earth for bringing ground water to the surface.



Aquifer : A permeable stratum which is capable of yielding appreciable quantities of groundwater under gravity.



Aquifer → ex sandy soil
 stored water
 porous &
 permeable soil
 Aquitard → porous &
 semi permeable
 ex sandy clay soil
 Aquiclude → porous &
 impermeable
 ex clay soil
 Aquifuge → neither porous
 & nor permeable
 ex granite rocks strata



Perched aquifer → if within zone of saturation, the water table is retained locally in the impervious stratum.

after sometime
 it is refilled
 the water

→ some saturated soil present in impervious layer.
 → sometimes it is found in unconfined aquifer.

Intakes for collecting surface water:

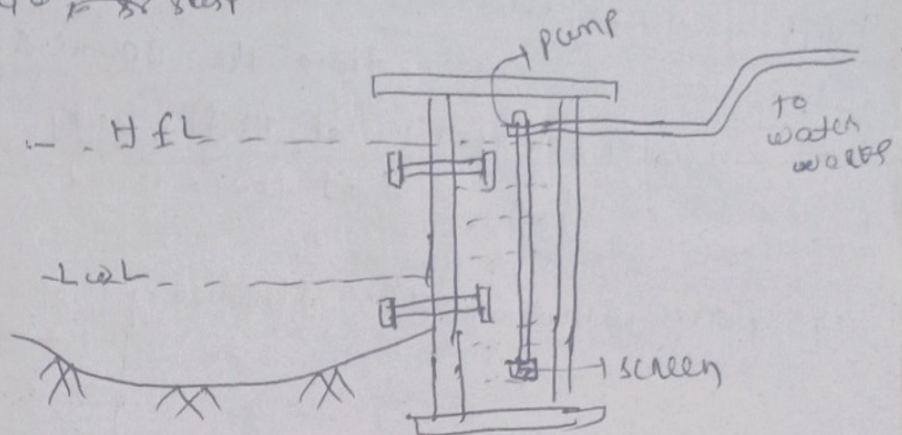
Intake → to collect the water from ^{surface} source & then discharge ~~water~~ by means of pumps to the water treatment plants.

Types of Intakes
 (1) Lake Intakes
 (2) Reservoir
 (3) River Intake
 (4) Canal Intake

(1) Lake intakes → To collect water, mostly submersible intakes are used.
 → construct at the bed of lake
 → A bell mouth pipe will be connected at ~~to pump out~~ inlet & it by gravity water collect at sumpwell.
 → These water is pumped to treatment plant.
 → It draw small amount of water

② River Intake

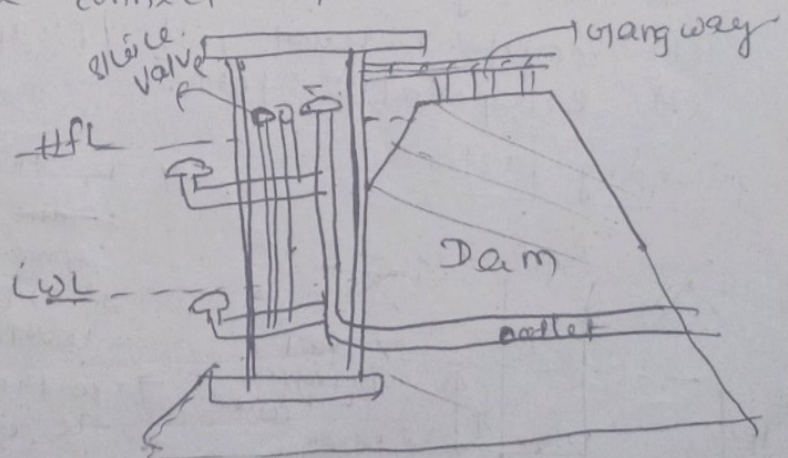
- water drawn from ϕ up stream side always (free from contamination water disposed)
- ~~can~~ ~~circulatory~~
- circular masonry tower of 4-7 m dia.
- constructed along the river, such that even dry period, water will be available.
- sump well is connected from penstocks
- screens are used at inlet to prevent floating ~~particulate~~ solid ~~from~~ ~~stop~~.



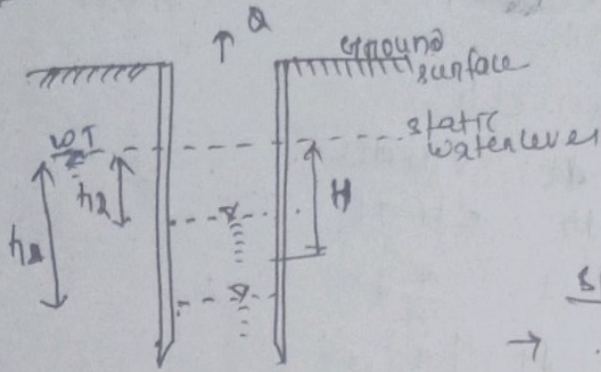
~~wet~~ Intake → collect + store + discharge
~~dry~~ Intake → collect + discharge

③ Reservoir Intake

- Both monsoon & summer, water can be used.
- some of river dries up in summer, at that time Reservoir Intake meet the hot weather demand.
- Intake constructed at slope side of Dam
- Intakes pipes are connected at different level HFL, LWL,



Recuperation test: measure the performance of well.



→ this test is find the specific capacity wells.

→ this test conclude how much time it take to recuperate on re-yielding after final depressing of water head

specific capacity of wells

→ Discharge per unit drawdown in the well

The ~~specific capacity~~ specific capacity of a wells in recuperation test can be determined by the following formula

$$\text{specific capacity per unit area of the well} = \frac{1}{t} \ln \left(\frac{h_1}{h_2} \right) = \frac{1}{t} 2.303 \log_{10} \left(\frac{h_1}{h_2} \right)$$

$$C = \frac{c'}{A}$$

c' = specific capacity of well

where, t = time required of wells yielding of water to water table level.

h_1 = ~~initial~~ depression head
 h_2 = final depression head

$$\therefore Q \text{ (discharge of well)} = c A H$$

$$Q = \frac{1}{t} \ln \left(\frac{h_1}{h_2} \right) \times A \times H$$

where, A = cross sectional area of well
 H = depression head

Q In a recuperation test, the following results were obtained:

Initial depression head = 10 m

final depression head = 8 m

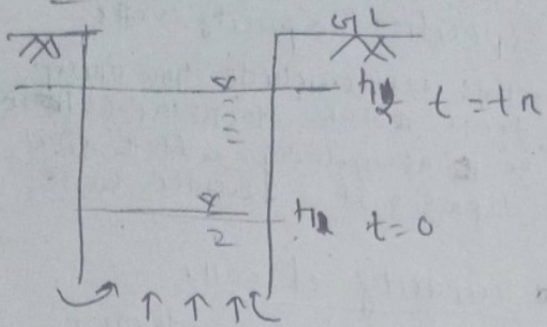
time of recuperation = 6 hrs

Dia of well = 4 m

calculate the specific capacity of well & yield under the head of 3 m,

$$\text{sol}^n \quad c = \frac{1}{t} \ln \frac{h_1}{h_2} = \frac{1}{6 \times 60 \times 60} \ln \frac{10}{8} =$$

derivation



$Q = \frac{Q}{h} = \text{specific capacity of well}$

$$\Rightarrow Q = c' h$$

$$\Rightarrow Q dt = c' h dt$$

$$\Rightarrow A dh = c' h dt$$

$$\Rightarrow c' dt = \frac{A}{h} dh$$

$$\Rightarrow \int_0^t c' dt = \int_{h_2}^{h_1} \frac{A}{h} dh$$

$$\Rightarrow c'(t-0) = A \ln h \Big|_{h_2}^{h_1}$$

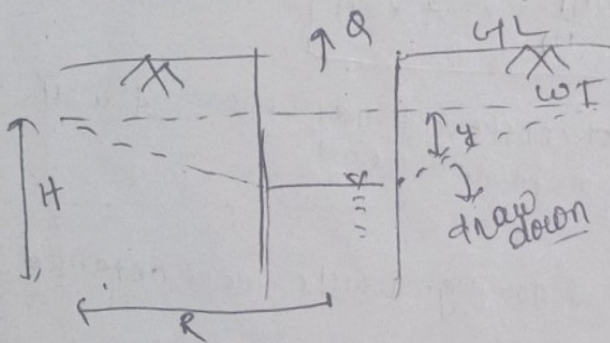
$$\Rightarrow c' t = A \ln (h_1) - \ln h_2$$

$$= \ln \left(\frac{h_1}{h_2} \right)$$

$$\Rightarrow \boxed{c' = \frac{A}{t} \ln \left(\frac{h_1}{h_2} \right)}$$

$$\Rightarrow \boxed{\frac{c'}{A} = \frac{1}{t} \ln \frac{h_1}{h_2}}$$

Cone of depression



A depression of water table is occurred during pumping into a confined cone shape. ~~It is~~
 → it is called cone of depression.

Properties

① Porosity (η) = $\frac{V_v}{V}$

$\eta > 20\% \rightarrow$ Adequate water
 $5\% < \eta < 20\% \rightarrow$ moderate "
 $\eta < 5\% \rightarrow$ very less water

② specific yield (s_y): → vol^m of water extracted by force of gravity from unit vol^m of aquifer is known as specific yield.

$$s_y = \frac{\text{vol}^m \text{ of water extracted}}{\text{vol}^m \text{ of aquifer}}$$

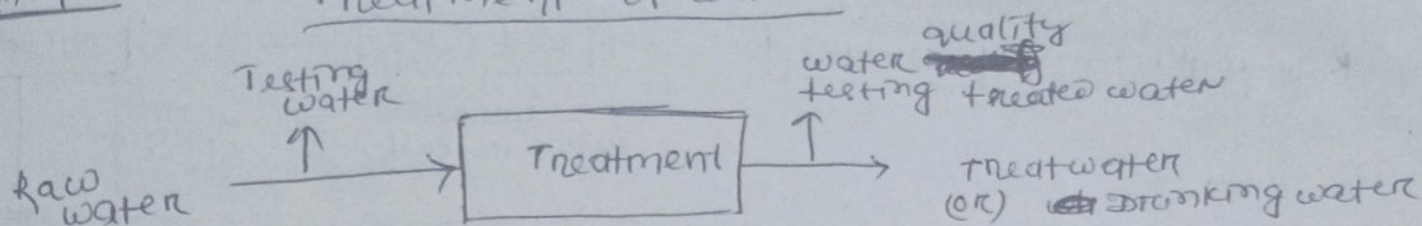
③ specific Retention (S_r) → Fraction of water retained by the soil against force of gravity is known as specific Retention.

$$S_r = S_y + S_{re}$$

* Permeability of soil → $K > 10^{-1} \text{ cm/sec}$
 semi permeable → $10^{-4} \text{ cm/sec} < K < 10^{-1} \text{ cm/sec}$
 impermeable soil → $K < 10^{-4} \text{ cm/sec}$.

chapter-3

Treatment of water



Treatment is removal process which removes excess amount of anything beyond limits.

→ Method of treatment & Nature of raw water constituent & standard of water quality.

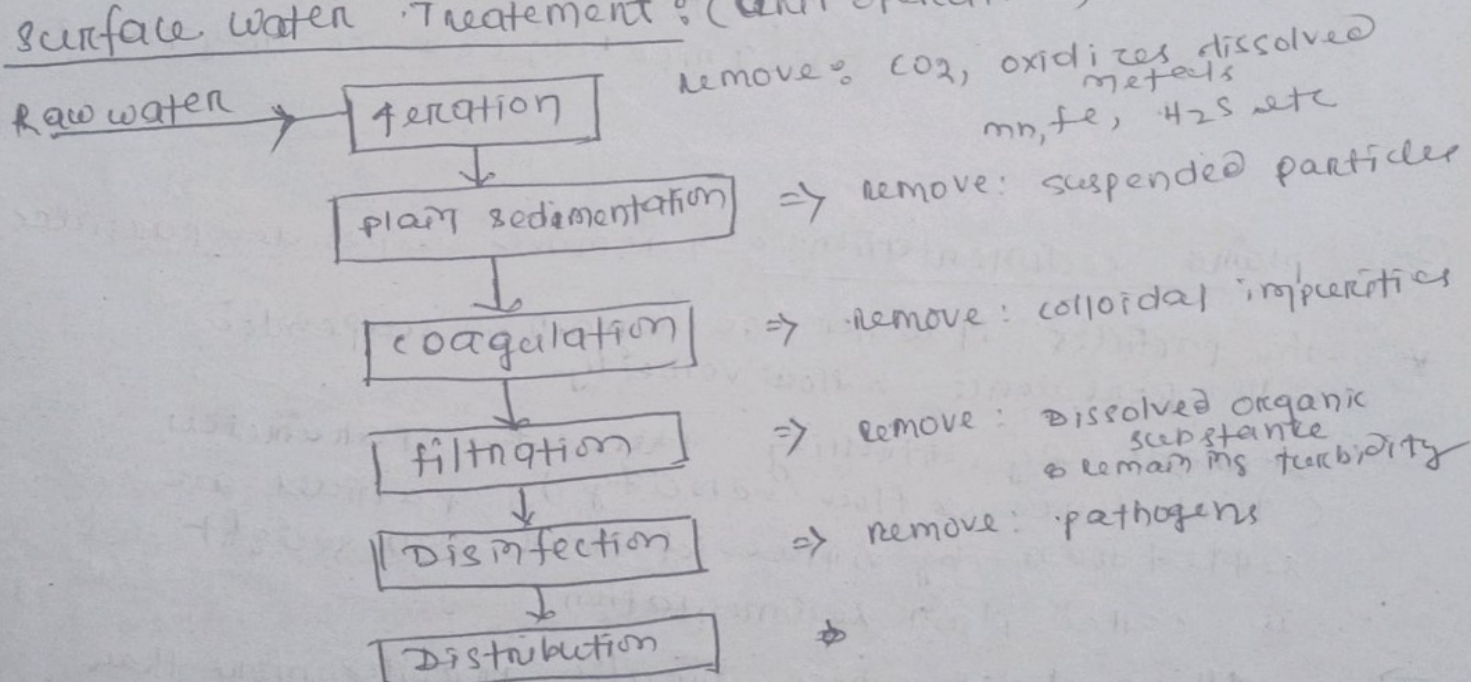
→ Treatment of water is given to water by two method

- (1) Unit operation
- (2) Unit process

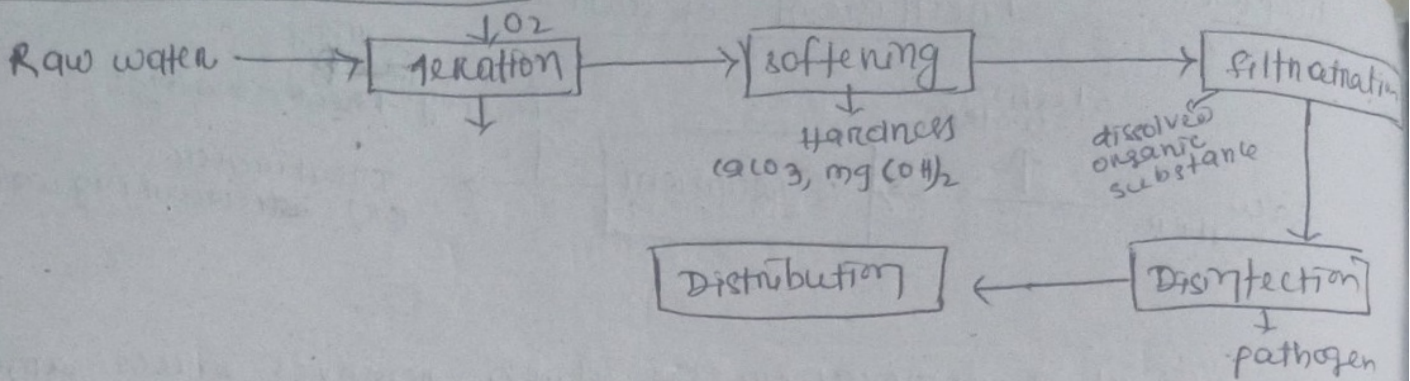
Unit operation → excess impurities are removed by physical process operation.

Unit process → excess impurities are removed by chemical or biological force.

Surface water Treatment: (Unit operation)



Ground water treatment:



softening → use to remove hardness
hardness causes incrustation in pipe
→ food become tasteless

Surface water treatment:

- (1) Aeration: water is brought in intimate contact with air
→ used to remove undesirable gases dissolved in water like CO₂, H₂S, FeO, MnO

~~process~~ process of aeration

- (1) spray nozzle (remove CO₂ = 90%, H₂S = 99%)
- (2) cascade aerator
- (3) diffused air aerator
- (4) trickling bed or tray tower

- (2) plain sedimentation: → remove suspended particles

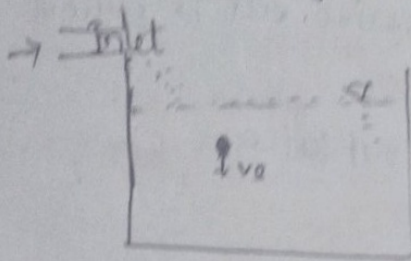
* the particles in water is remain in suspended due to turbulence & flow velocity.

→ ~~at least~~ By controlling these two parameters (turbulence & flow velocity), particles are settled down by virtue of their own weight is called plain sedimentation.

→ All particles whose specific gravity more than specific gravity of water have tendency to settle down.

→ plain sedimentation operation follows type 1 settling.

Type-I settling → it deals with discrete particles settlement



The particles which do not change ~~his~~ size wt, specific gravity with respect to time

→ settling velocity will be calculated by Stokes law

$$v_s = \frac{(v_s - v_w) d^2}{18\mu} \quad \text{--- (1)}$$

✓ applicable for discrete particles settling

$$Re < 1$$

$$Re = \frac{v_s d}{\mu}$$

for open Stokes law is valid

where, v_s = settling velocity of suspended particles

v_w = unit wt of particles

v_w = unit wt of water

d = dia. of particles

μ = viscosity dynamic viscosity

(P.A.S)

$$= \frac{N \cdot sec}{m^2}$$

eqn (1) can be written as

$$\begin{aligned} v_s &= \frac{(v_s - v_w) d^2}{18\mu} = \frac{v_w \left(\frac{v_s}{v_w} - 1 \right) d^2}{18\mu} \\ &= \frac{v_w (s-1) d^2}{18\mu} = \frac{v_w g (s-1) d^2}{18\mu} = \frac{g (s-1) d^2}{18\mu} \end{aligned}$$

$$\Rightarrow \boxed{v_s = \frac{g (s-1) d^2}{18\mu}} \quad \text{--- (2)}$$

if $d < 0.1 \text{ mm}$

Note

$$d < 0.1 \text{ mm} \rightarrow v_s = \frac{g (s-1) d^2}{18\mu} = \frac{(v_s - v_w) d^2}{18\mu}$$

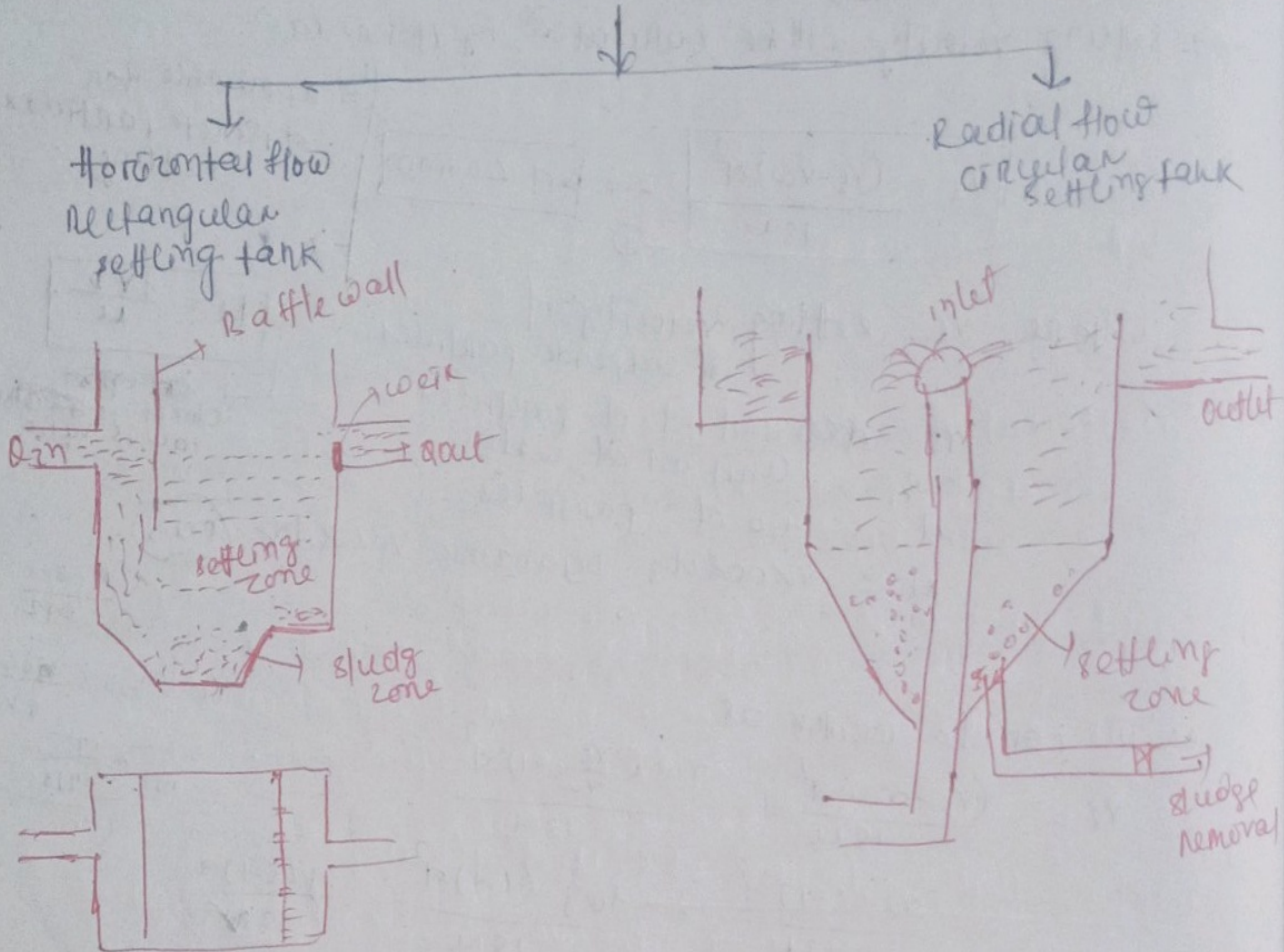
$$d > 1 \text{ mm} \rightarrow v_s = 1.8 \sqrt{g (s-1) d}$$

Q A particle is having a size of 0.025 mm with specific gravity of 2.65. if the kinetic viscosity of water is 0.01 cm²/sec, the settling velocity of the particles as per Stokes law is?

Settlement tank:

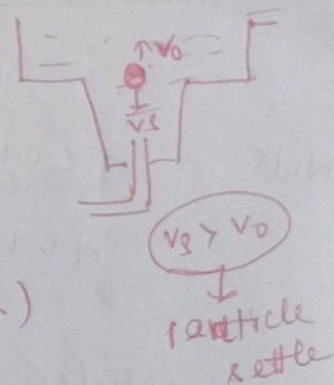
→ the place where settling operation is carried out is called settling tank or sedimentary tank.

→ Two types (1) fill & draw type → outdated
(2) continuous type



Design parameters of plain sedimentation.

- ① overflow velocity
- ② detention time / retention time
- ③ horizontal flow velocity
- ④ weir loading rate
- ⑤ particle removal efficiency.



① overflow velocity (v_o)

→ Also called as surface loading rate (CLR)
or surface overflow rate (SOR)
or hydraulic loading rate (HLR)
or overflow velocity (v_o)

→ It is defined as volume of water overflow per unit time per unit surface area is known as SOR.

② Detention time

- it is also called as Retention time or hydraulic detention time.
- it is defined as the average theoretical time taken by the water to travel from inlet to outlet of settling tank or called detention time.

$$\text{Detention time} = \frac{\text{Vol}^m \text{ of settling tank}}{\text{flow rate}}$$

→ 4-shas

$$= \frac{V}{Q} = t \text{ in hr}$$

③ Horizontal flow velocity (V_H)

- speed with which the water travels from inlet to outlet of settling tank is called horizontal flow velocity.

$$V_H = \frac{\text{Distance travel}}{\text{Time of travel}} = \frac{L}{t} = \frac{\text{Distance of travel}}{\text{Detention time}}$$

$$= \frac{Q}{B \times H} = \frac{Q}{\text{Area of 4/8 of settling tank}}$$

④ Weir loading rate (WLR)

$$WLR = \frac{Q}{\text{unit length of weir}} \quad \text{Dis charge per unit weir.}$$

⑤ Particles removal efficiency

$$\eta = \frac{v_s}{v_o} \times 100 \quad \text{if } v_s > v_o, \text{ then } \eta \text{ should be taken partially } 100\%.$$

- if settling time $\leq$ detention time, the particles are capture 100%.

$$\frac{H}{v_s} \leq \frac{L}{V_H}$$

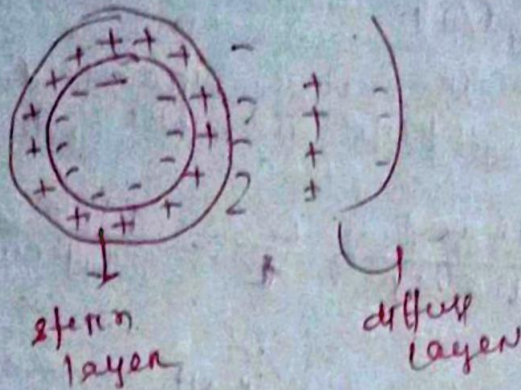
WSS ⇒ say $\frac{H}{v_s} = \frac{L}{V_H}$ ($\because Q = V_H \times B \times H$)

$$\Rightarrow v_s = V_H \times \frac{H}{L} = \frac{Q}{B \times H} \times \frac{H}{L} = \frac{Q}{B \times L} = v_o$$

$$\Rightarrow \boxed{v_s = v_o}$$

③ coagulation:

- After ^{plain} sedimentation, some of the suspended & colloidal impurities are ~~come~~ still in water.
- that particles are suspended due to having ~~less~~ specific gravity than water.
- Also, colloidal particles are charge particles. They usually carry -ve charges.



- Because of the electronic double layers surrounding the particles, colloids attain stability in water.
- Colloidal particles present in water is measured by "Zeta potential".

→ To destabilize colloidal particles in water, certain chemical are used known as coagulant.

- Addition of coagulant to the water to ~~destabilize~~ destabilize colloidal particles is known as coagulation or chemical conditioning.

- chemical conditioning leads to physical conditioning is known as flocculation (growth of particle).
↓
floc formation is occurred.

Mechanism of coagulation / principles:

- ① Ionic layer compression $\rightarrow$ compress the colloidal layer, Introduce van der Waals force
- ② Adsorption and charge neutralization $\rightarrow$ neutralise the double layer
- ③ sweep coagulation $\rightarrow$ flocs is making
- ④ Inter particle Bridging $\rightarrow$ Large particles may be formed

floc = gelatinous precipitate (flop)

Common coagulants

* trivalent Aqua metallic cationic substances have very high coagulating power. These chemical substance known as coagulants.

$\rightarrow$ commonly found coagulants

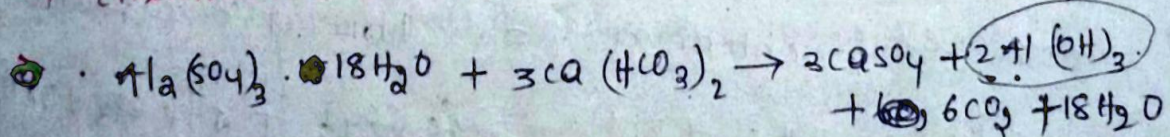
- (1) Aluminium sulphate (Alum)
- (2) ferric sulphate (copperas)
- (3) ferric sulphate & ferric chloride (chlorinated copperas)
- (4) sodium aluminate ($\text{NaAlO}_2 \cdot 2\text{H}_2\text{O}$)
- (5) lime (when phosphorous, ammonia is more in water)

① Aluminium sulphate (Alum)

$\rightarrow$ This is also known as universal coagulant.
 $\rightarrow$ This is very effective when pH should be between 6.5 to 8.5.

• Alum + Alkalinity $\rightarrow$

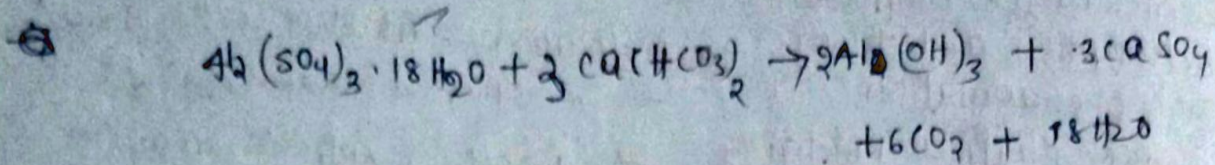
$\rightarrow$ chemical formula is $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$



* $\rightarrow$ Alum attracts other fine particles & suspended matter, thus grow in size & finally settle.

$\rightarrow$ Amount of Alum (coagulant) $\propto$ turbidity & color of raw water

→ Alum also reduce colour, taste & odour.



1 mole of alum gives 2 mole of $Al(OH)_3$

⇒ 666 gm of alum gives $2 \times 78 = 156$ gm of $Al(OH)_3$

⇒ 1 gm of alum = 0.234 gm of $Al(OH)_3$ ppt

* → Normal dose is 10-30 mg/lit of water.

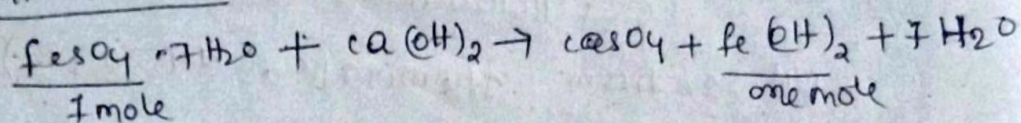
② Copperas: (Ferrous sulphate: $FeSO_4 \cdot 7H_2O$) = Hydrated copperas

→ It is works in the pH of 8.5 & above

→ Its form heavy flocs.

→ Copperas is used for water which not coloured. because it cannot remove colour.

→ Chemical Reaction:



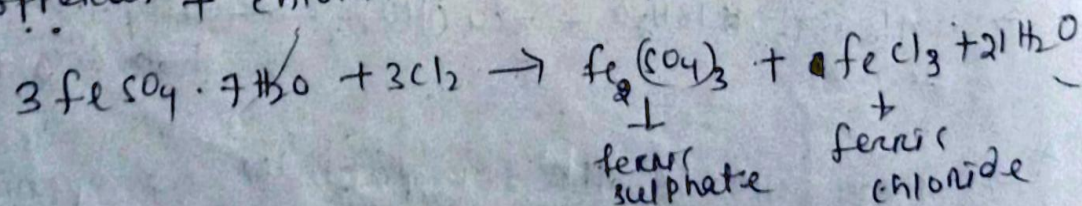
→ 1 mole copperas will form one mole of ferric hydroxide
 $56 + 24 + 16 \times 4 + 7(16+2) \rightarrow 56 + 2 \times 17$
 $= 270 \text{ gm} \rightarrow 90 \text{ gm}$
 ⇒ 1 gm of copperas gives $\frac{90}{270} = 0.33 \text{ gm}$ of flocs.

→ dose of copperas 10-30 mg/lit

③ ferric sulphate & ferric chloride.

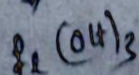
→ Also called as chlorinated copperas

→ copperas + chlorinated = chlorinated copperas



→ It remove colour.

→ These are produced floc, when pH 6.5 & pH 8.5



④ sodium aluminate ($\text{Na}_2(\text{Al}_2\text{O}_4)$)

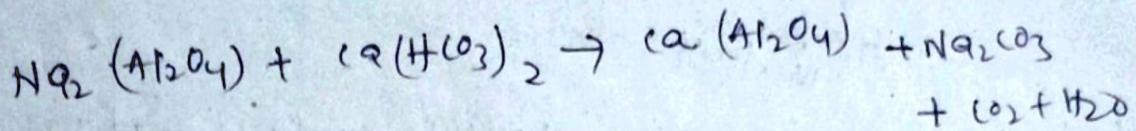
→ it is costly coagulant.

→ the advantage of this coagulant ~~is~~ ~~are~~ are

(1) it is completely independent of pH

(2) any water can be treated.

(3) ~~it is not~~

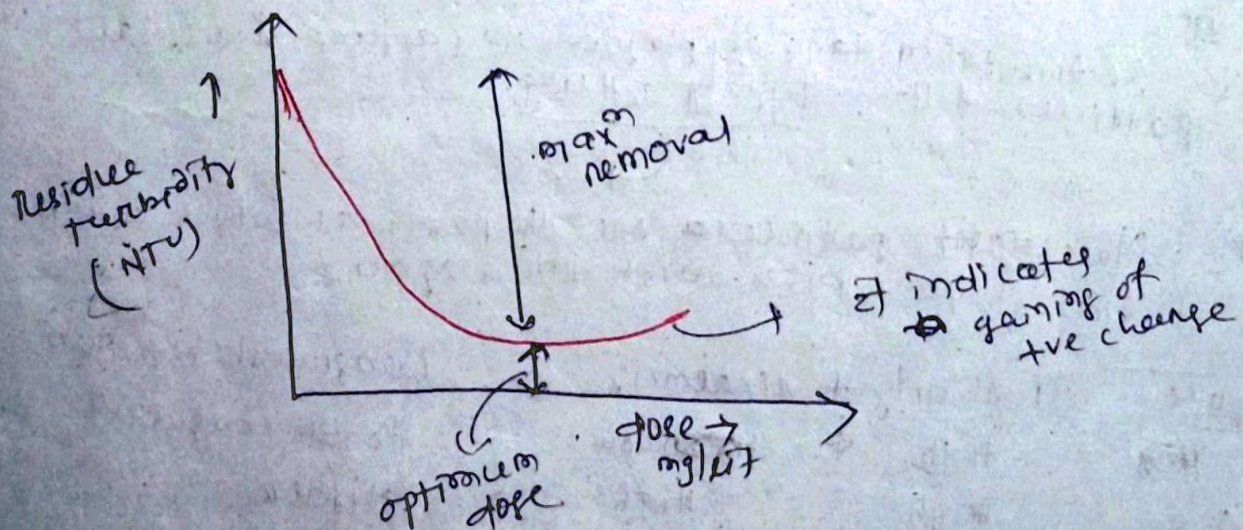
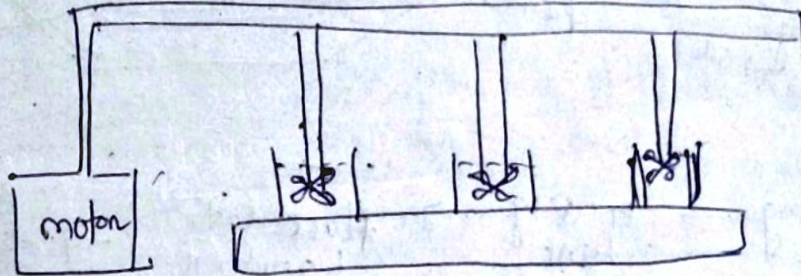


→ less dose → no removal
more dose → no removal

→ no alkalinity required

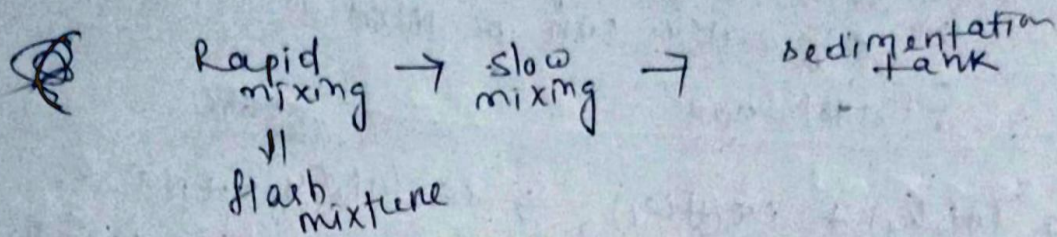
Optimum dose of coagulant: By JARTEST.

→ minimum dose & maximum removal of particles is known as optimum dose.

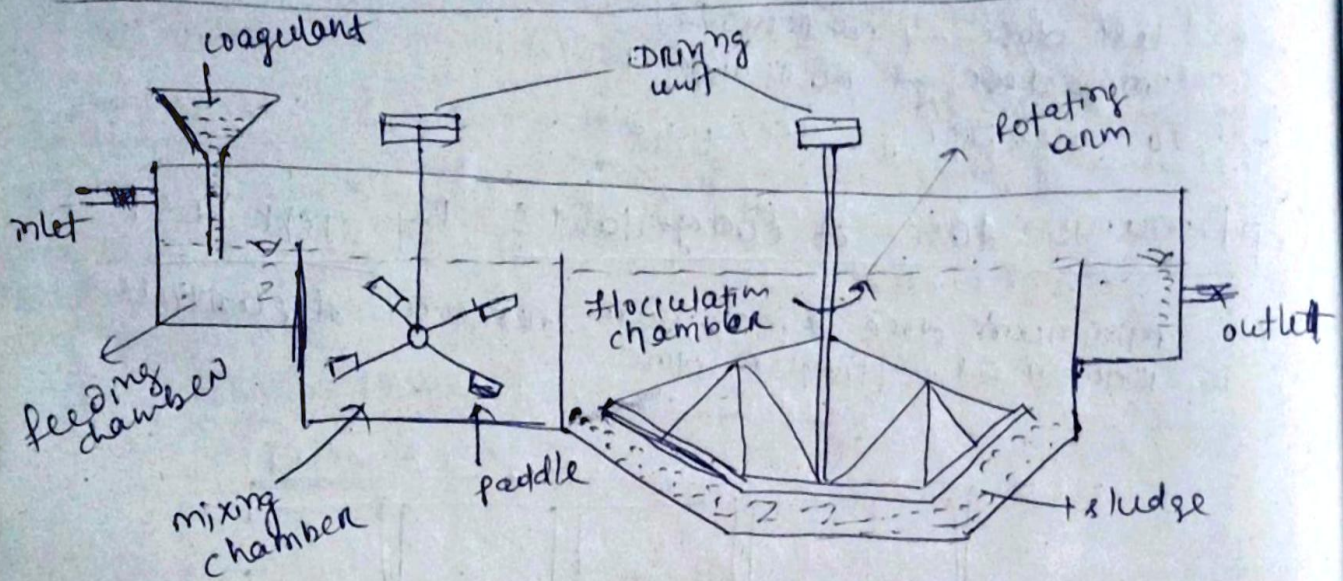


clariflocculation:

- This is a type of reactor.
- The unit employed to carry out coagulation, flocculation & sedimentation is known as clariflocculation.



flow diagram for coagulation sedimentation:



feeding → mixing tank → flocculation chamber → sedimentation tank

* Sedimentation tank employed to capture flocculant particles follow type II setting.

* flocculant particles are the particles which changes its size, shape & mass with time & space.

Note		Turbidity & Alkalinity		Coagulant required	
High	Low	High	Low	⇒	Lower coagulant
High	High	High	High	⇒	Higher "
Low	High	Low	High	⇒	"
Low	Low	Low	Low	⇒	Difficult to add

Settling time:

Q. A continuous flow sedimentation tank is 3.5 m deep & 65 m long. The flow velocity observed is 1.22 cm/sec. What is the size of the particles of 2.07 g/cm³ may be effectively removed. Assume $T = 25^\circ\text{C}$ & $\nu = 0.01 \text{ cm}^2/\text{sec}$.

Given data, $T = 25^\circ\text{C}$ $v_H = 1.22 \text{ cm/sec}$
 $H = 3.5 \text{ m}$ $\nu = 0.01 \text{ cm}^2/\text{sec}$
 $L = 65 \text{ m}$

Settling time $\leq$ Detention time

$$\Rightarrow \frac{H}{v_s} = \frac{L}{v_H}$$

$$\Rightarrow v_s = v_H \times \frac{H}{L} = 1.22 \times \frac{3.5 \times 100}{65 \times 100} = 0.065 \text{ cm/sec}$$

$$v_s = \frac{g(s-1)d^2}{18\nu} = \frac{9.81(2.65-1) \times d^2}{18 \times 0.01} = 0.065 \text{ cm/sec}$$
$$= 0.065 \times 10^{-2} \text{ m/sec}$$

$$\Rightarrow d^2 = \frac{18 \times 0.01 \times 0.065}{9.81 \times 1.65} = 0.0268 \text{ cm}^2$$

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

$$\Rightarrow d^2 = \frac{v_s \times 18 \nu}{g(s-1)} = \frac{0.065 \times 10^{-2} \times 18 \times 0.01 \times 10^{-4}}{9.81(2.65-1)}$$

$$= 0.0722 \times 10^{-8} = 2.68 \times 10^{-5} \text{ m}$$

$$= 2.68 \times 10^{-2} = 0.0268 \text{ mm}$$

$$d^2 = \frac{0.065 \times 18 \times 0.01}{9.81 \times 100 \times 1.65} =$$

Filtration:

The colloids which escape from coagulation & dissolved organic substances present in water are removed by filtration.

Defⁿ: Filtration is the method or operation of passing water through a stationary bed of granular media. Media retain particles & yield particle free water.

→ It may remove fine flow particles, colour, dissolved mineral & micro-organisms.

→ Filters are classified into several categories based on several criteria:

(a) Based on force used while filtration

- (i) pressure filtration
- (ii) gravity "

(b) Based on rate of filtration

- (i) slow ~~and~~ filter (100 to 200 lit/hr/m^2)
- (ii) rapid filter (3000 to 6000 lit/hr/m^2)

(c) Based on number of filter media use:

- (i) single media filter
- (ii) dual media filter
- (iii) multi media filter or mixed media filter.

media
eg sand, anthracite, garnet etc.

Mechanism of filtration:

(1) mechanical straining

(2) sedimentation

(3) biological action

(4) electrolytic changes

→ Attached impurities on the top of the media & forms a mat on it. Particles finer than void are removed by sedimentation due to gelatinous mass in the pores.

→ Schmutz deck

yellowish layer due to micro-organism

Note Filter: → the place where filter media is packed & water is passed through media is called as filter.

slow sand filter:

→ single media gravity type ^{slow filter} ~~slow media~~
(use only sand or anthracite or garnet)

→ Rate of filtration is slow.

$$Rof = 100 \text{ to } 200 \text{ lit/hr/m}^2$$

→ particle removal efficiency is 98 to 99%.

→ it is highly effective & efficient filtration.

Notes

→ pretreatment is not required, ~~only~~ post treatment may not require.
→ capable of removing bacteria & colloidal particle.

(→ after coagulation, slow sand filtration is not done due to operation problem.)

components

(1) filter box (open water rectangular tank)

size :- 100 - 2000 m²

Depth :- 2.5 to 3 m

bed slope :- 1 in 100

(2) filter media: sand is used as filter media

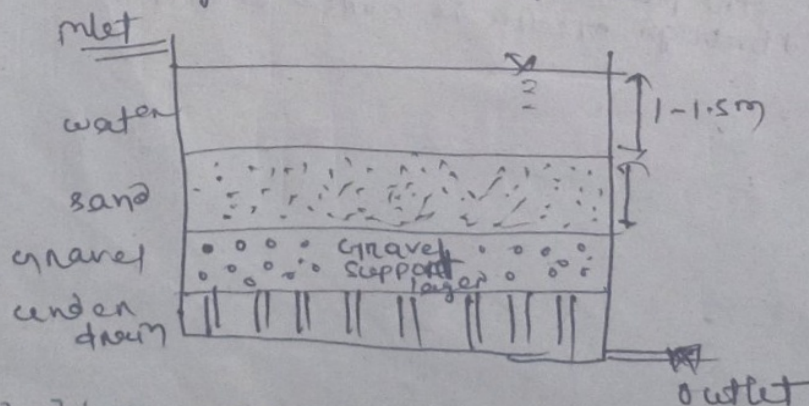
thickness :- 90 - 110 cm

effective size D_{50} :- 0.2 to 0.35 mm

↳ 10%

(3) gravel bed: it supports sand bed & prevents escape of sand grain along water

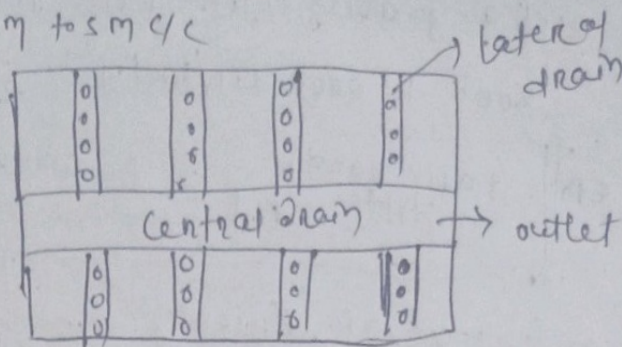
thickness of gravel bed = 30 - 75 cm



well graded: 3 - 6 mm

④ under drainage system:

spacing of lateral = 2m to 5m/c

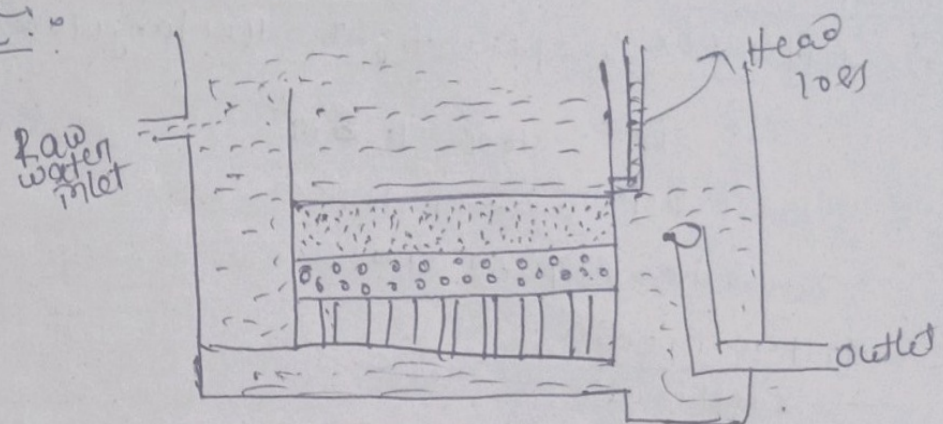


⑤

inlet :- to apply water uniformly without disturbing sand bed.

outlet :- to collect water & constant rate.

⑥ Piezometer:



→ If Head loss is 70 to 90 cm (70% to 90% of thickness of filter), then filter is not working properly. Then cleaning is required.

→ Normally filter reach to this condition once in every one month to 3 months.

→ While cleaning, top 1.5 cm - 3 cm layer of sand should be removed due to captured particles or settle down on the top of sand layer.

→ slow sand filter is washed by scraping 1.5 to 3 cm top layer of sand.

→ If total scraping ^{upto} 50 cm of the media, then ~~the~~ replaced by new ^{sand} media should be done.

Rapid sand filter

→ single media gravity type rapid filter.

→ $R_{of} = 3000 \text{ to } 6000 \text{ Lt/hr/m}^2$

$$\left(\text{rapid sand filter} \right)_{R_{of}} = 30 \text{ times } \left(\text{slow sand filter} \right)_{R_{of}}$$

→ particle removal efficiency is 80-90%.

→ Both pretreatment and post treatment are required. (compulsory)

Components

① filter BOX : open tight rectangular box

size : $10 \text{ m}^2 \text{ to } 8 \text{ m}^2$

depth : 2.5 m to 3.5 m

bed slope : 1 in 100

② filter-media :

→ sand is used as media

thickness : 60-90 cm

d_{10} : 0.35 to 0.55 mm

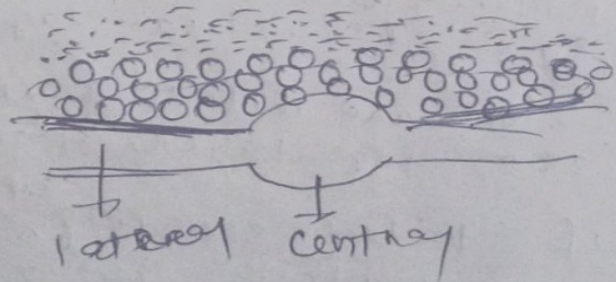
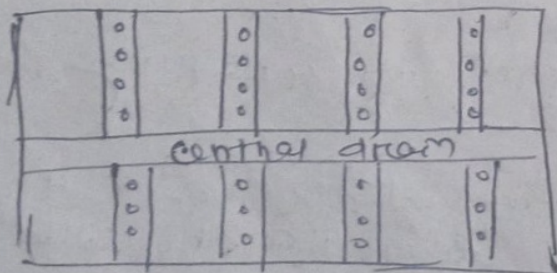
C_u : 1.2 to 1.8

③ Gravel Bed :

thickness of gravel bed 60 to 90 cm

well graded size : 3 mm to 40 mm

④ Under drainage system (closed drain)

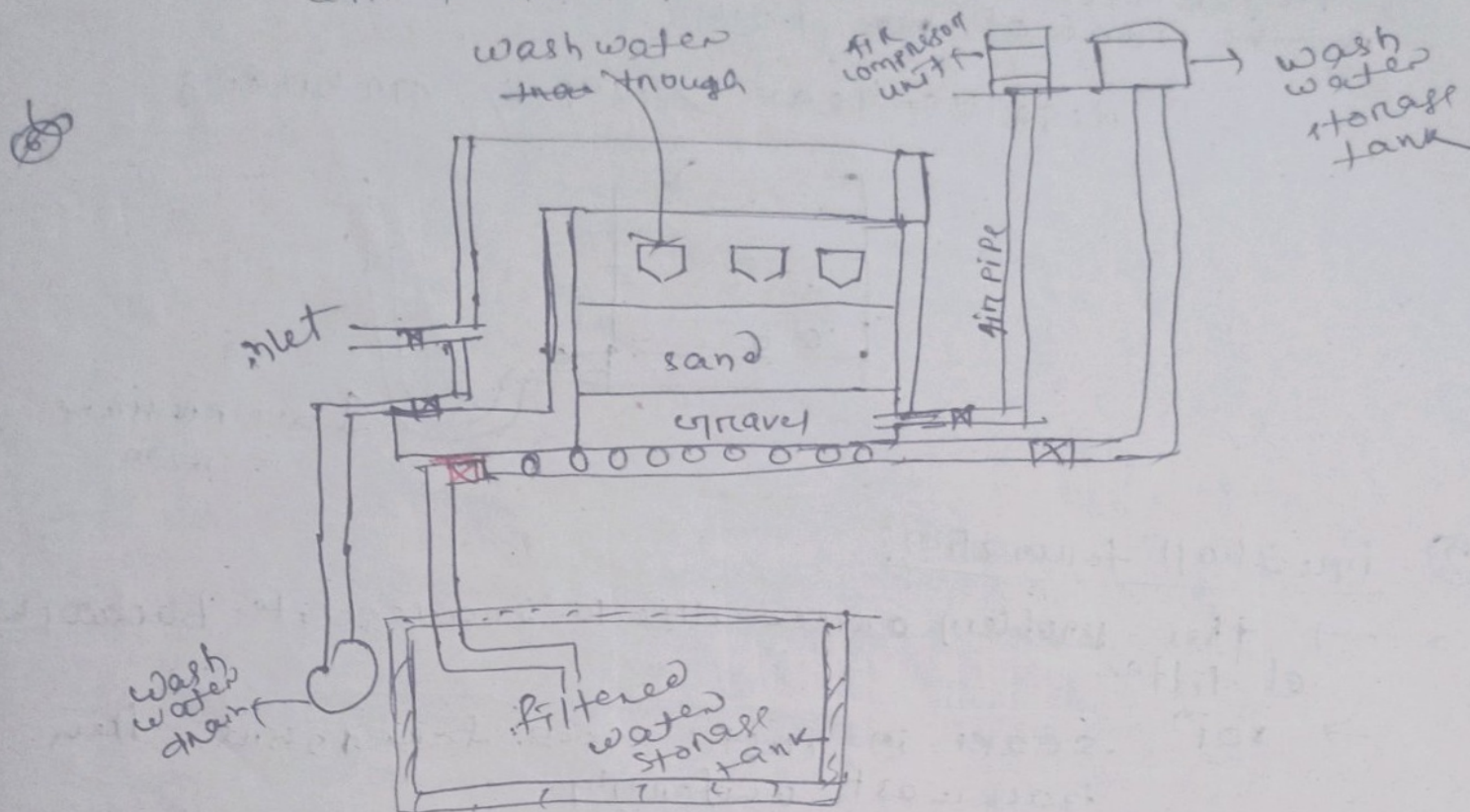


lateral = 30 cm max centre to centre

hole of perforated pipe = 5 mm

⑤ Inlet & outlet

Inlet $\rightarrow$ to apply water uniformly without disturbing sand bed
 outlet $\rightarrow$ there is no special outlet.
 $\rightarrow$ central drain is the outlet of this filter.



⑥ Piezometer : Terminal Head $\neq 3m$.

⑦ Replaced condⁿ of filter

① Terminal Head loss $\geq 3m$

② turbidity break through ≥ 2.5 NTU

due to $\rightarrow$ Rate of flow velocity
 turbidity break through

Notes

$\rightarrow$ ~~Replaced~~ Replaced the filter once in a day
 (Back washing)

$\rightarrow$ 2 to 6% of filter water

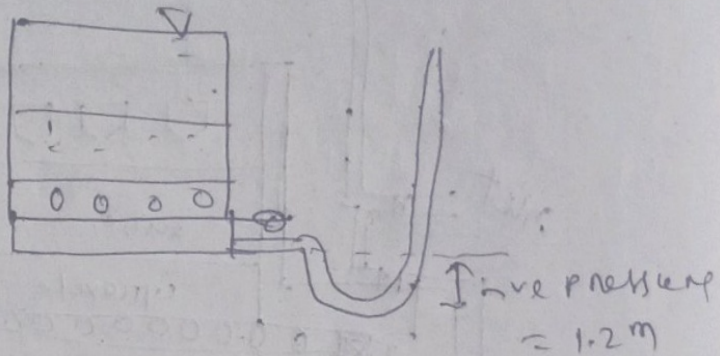
$$\boxed{\text{No of filter} = 1.22 \sqrt{Q}} \quad Q \text{ in MLD}$$

operation problem associated with rapid sand filter

① Air Binding (Air lock)

→ this occurs when filters are operated beyond a -ve head of 1.2 m

Negative head $> 1.2 \text{ m} \Rightarrow$ Air binding



② mud ball formation

→ this problem arises due to inadequate backwashing of filter.

→ solⁿ : soaks in caustic soda for 2 hrs then backwash uniformly.

③ cracking of filtration

→ this forms at the top of the mud layer, extends into sand bed.

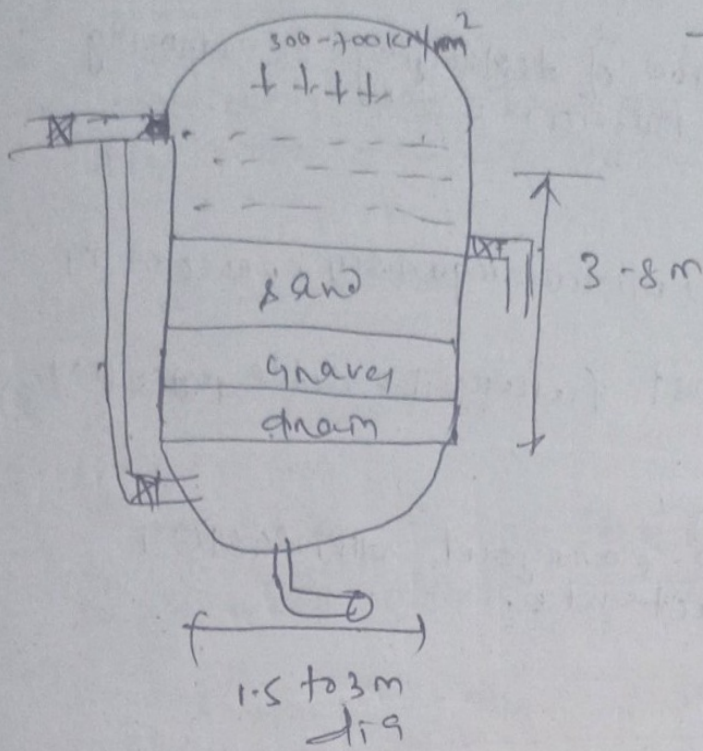
pressure filters :

→ these are rapid sand filter where filtration is carried out under pressure head of 30 to 70 m of water ($300 \text{ to } 700 \text{ kN/m}^2$)

→ $\text{Por} = 6000 \text{ to } 15000 \text{ Gt/hr/m}^2$

→ $\eta = 60-70\%$

→ It is used for small scale works such as houses, swimming pool, small scale industries etc.



→ this filter is widely used in swimming pool, private building, colony etc.

→ pressure applied on filter is more than atmospheric pressure

→ operation is done by closed vessels.

→ pressure filter
 ↙ horizontal
 ↘ vertical

Disinfection:

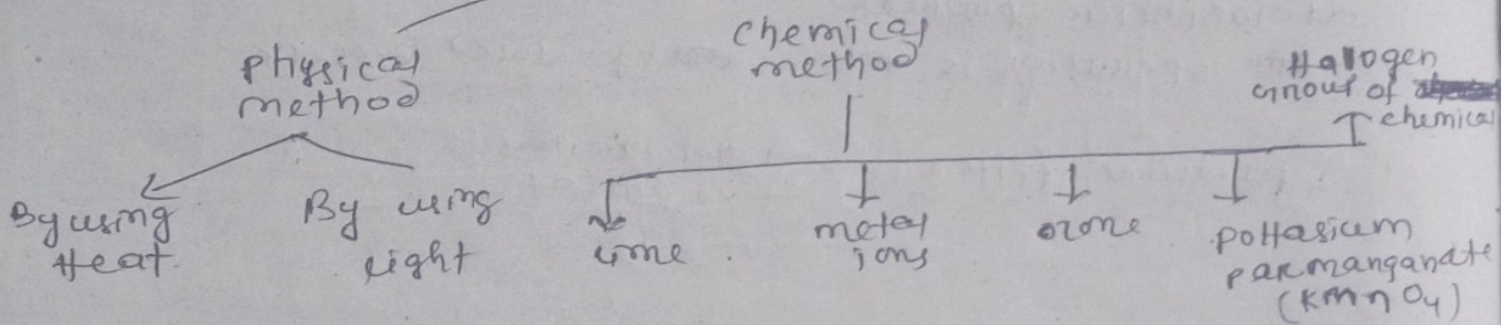
Disinfection is the method of destroying or removing of diseases causing organism present in water.

Object:

- To kill existing germs (micro-organism) present in water.
- To protect water against future possible potential contamination.

* The substance ^{or chemical} used to carry out disinfection is called ~~disinfectant~~ disinfectants.

Methods of Disinfection:



Physical method:

① ~~By using heat~~

① By using heat

- efficient & effective kill of pathogens
- fast kill ~~cell~~ cell wall
- No toxic to human beings

Draw Back:

- No residual power
- formation of CaCO_3
- very expensive & large scale is not practiced.

② By using light

- By means of uv rays, disinfection is carried out
- they have very high destructive power
- uv rays penetrates & damage the protoplasm

Draw Back:

- No residual power
- ~~cost~~ costly, as UV rays are generated by quartz bulb, which is not available easily.

Chemical method:

① ~~UV ray~~ treatment:

① Lime

- Alkalinity of water increased by adding excess lime to the water & that way the organism can be destroyed.
- $pH > 9.5 \rightarrow 90\%$ of organisms destroyed.

drawback

- ~~color~~ colour problem
- taste changes ~~with~~ & odour is formed

② metal ions:

- silver & copper ion having capacity to kill ~~organism~~ micro-organism.

③ potassium permanganate ($KMnO_4$)

- it is widely used to disinfectant of water in rural area.
- it is very slow. $\rightarrow$ 24-48 hrs take to disinfection of water.
- After disappeared the pink colour in water, water is able to drink.

④ Ozone: ozone is more powerful than chlorine.

- Ozone is treating in water is known as ozonisation.
- it instantly removed the micro-organism, colour, odour.
- it increase taste of water.
- Also remove high concentration of Fe & Mn.
- Any amount of ozone can use in water; no chance to harm human body.
- but it has ~~some~~ little residual.

Drawbacks:

- ozone is more costly than chlorine.
- less residual protection ~~against~~
- cannot be stored.

Use in swimming pool

⑤ Halogens group of chemicals

- these are strong oxidant
- substances which are used as halogens group of chemicals are

- (1) chlorine
- (2) Bromine
- (3) Iodine

} these are available only in the form of tablet or pills

Chlorination:

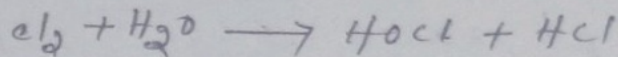
→ The method of addition of chlorine & its compound to the water to disinfectant to the micro-organism is called chlorination.

- this is ^{the} cheapest substance so it is widely using.
- it has more capacity of disinfection.
- Advantage of using chlorine is that it does not lose power until the water is used.
- it has high residual power.
- it destroyed micro-organism in reasonable time & maintain disinfectant capabilities for long period.

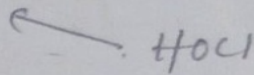
✓ chlorination with water:

when chlorine added to water, then it forms hydrolysis (forming acid) & ionises (forming ions).

Hypochlorous
acid



Hydrolysis



(ionisation)

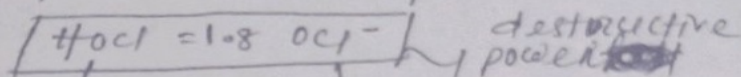
↳ Hypochlorite ion

→ HOCl & OCl⁻ release in water, these substance is diffuse into cell wall of micro-organism along with foods & form chloroformic substances & destroy the organism.

→ HOCl & OCl⁻ release in water & together is known as free chlorine or freely available chlorine.

→

HOCl is more power than OCl⁻

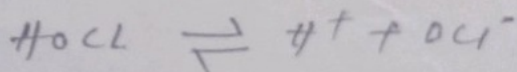


destructive
power

Natural compound
has more power
to kill micro-organism

whereas OCl⁻ having -ve
charge so it has less power

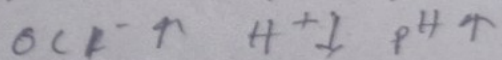
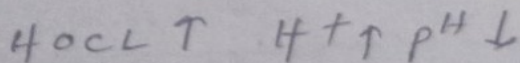
→ HOCl formation of HOCl & OCl⁻ is depends on pH.



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

Rate of reaction
mole/lit/sec

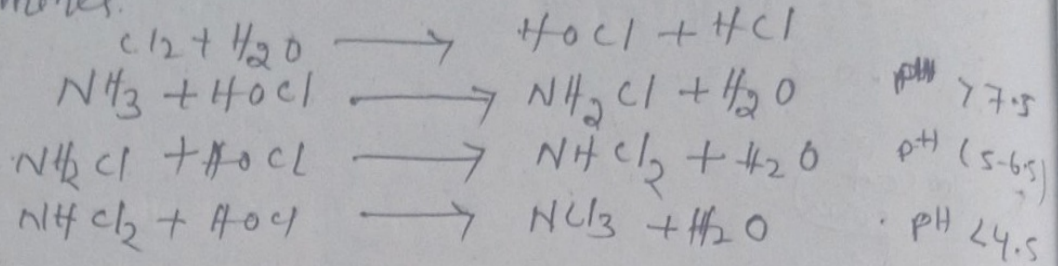
$$\Rightarrow \frac{[\text{OCl}^-]}{[\text{HOCl}]} = \frac{K}{[\text{H}^+]}$$



only HOCl is formed when $\text{pH} < 5$
only OCl^- is formed when $\text{pH} > 10-14$

Chloramines:

* more over chlorine will immediately react to with ammonia present in water to form chloramines.



pH
8.5 $\text{NH}_2\text{Cl} \rightarrow$ monochloramine
8-4.4 $\text{NHCl}_2 \rightarrow$ Dichloramine
4.4 $\text{NCl}_3 \rightarrow$ trichloramine

High powerful as compared to NCl_3

→ The chlorine in the form of chloramine present in water is known as combine chlorine or combinely available chlorine.

Advantage:

- It produce long & persistent Residual power
- for any dosage of chloramine is not harmful.

Note But HOCl is react to micro-organism present in water & form THM (Tri-Halomethanes) such as chloroform.

→ THM are carcinogenic, causes cancer.

(2) free chlorine residual in water should not be more than 0.2 mg/lit. & should not be less than 0.1 mg/lit.

✓ free chlorine = 0.1 - 0.2 mg/lit

~~if free chlorine~~

if free chlorine $< 0.1 \text{ mg/lit} \rightarrow$ No residual power or No protection

if free chlorine $> 0.2 \text{ mg/lit} \rightarrow$ produced THM

chlorine demand of water:

I → As soon as chlorine is added to water, chlorine reacts with iron & manganese present in water.

→ Hence some chlorine is consumed.

II → then chlorine reacts with ammonia present in water in doing so some more chlorine is consumed

III → lastly chlorine is reacts with micro-organism & destroy ~~the~~ all the organism. In doing so some chlorine is consumed.

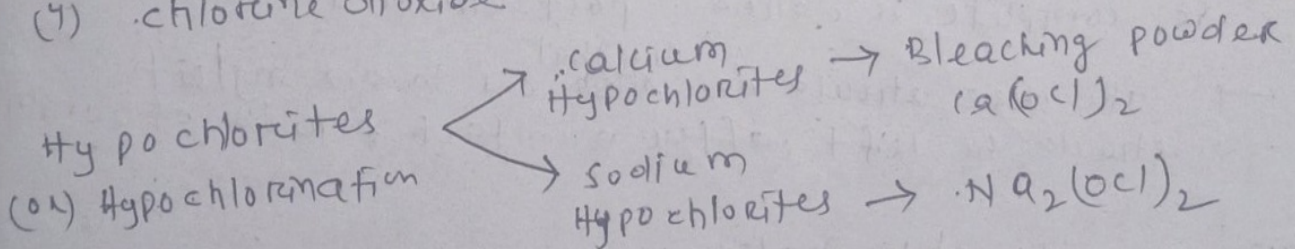
→ After finishing all the above job, if any chlorine is remain in water. then it is called Residual chlorine present in water.

$$\text{Cl}_2 \text{ demand of water} = \text{amount of Cl}_2 \text{ added to water} - \text{Residual Cl}_2 \text{ in water}$$

$$\Rightarrow \boxed{\text{Cl}_2 \text{ demand of water} = \text{Cl}_2 \text{ dose} - \text{Residual dose of Cl}_2}$$

forms of chlorine: chlorine is found in market in following forms.

- (1) Hypo chlorites
- (2) chloramines
- (3) chlorine gas
- (4) chlorine dioxide



* Bleaching powder contains ~~30 to 35%~~ 30 to 35% of Cl_2 & remain is lime.

$$\text{Cl}_2 \text{ dose} = \text{Bleaching powder} \times \% \text{Cl}_2 \text{ in Bleaching powder}$$

Types of chlorination:

- ① plain chlorination
- ② pre chlorination
- ③ post chlorination
- ④ double chlorination
- ⑤ super chlorination
- ⑥ Break point chlorination
- ⑦ De chlorination

① plain chlorination:

- only chlorination & no other treatment is given to water.
- it removes bacteria, colour etc.
- dose = 0.5 mg/lit

② pre-chlorination:

- pre chlorination is the chlorination is done before filtration or sedimentation & coagulation.
- dose is 0.1 to 0.5 mg/lit

③ post chlorination:

- Applying chlorine at the end when all treatment is complete is called post chlorination.
- the dose should be ^{such that} 0.1 to 0.2 mg/lit should be left after a contact period of 20 min.

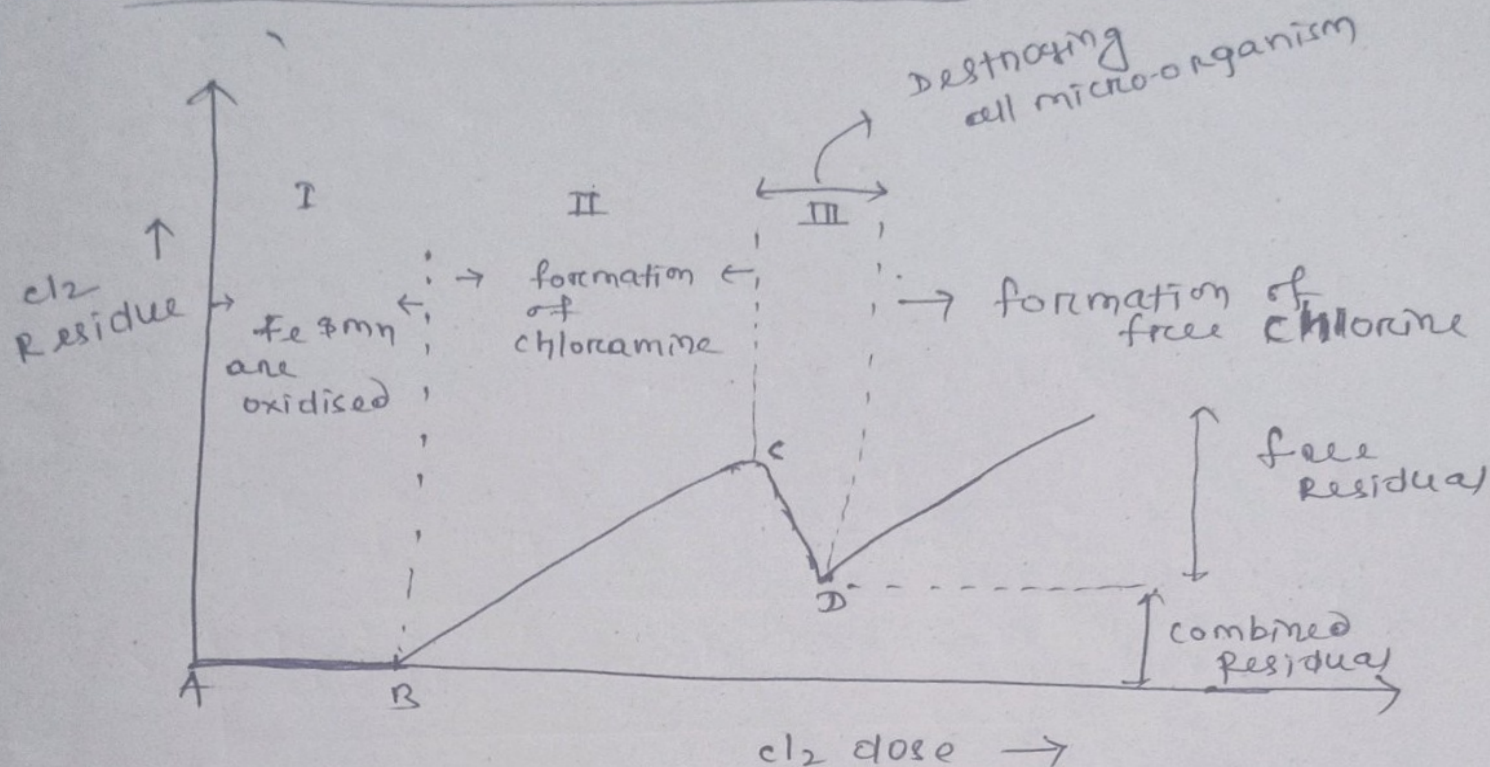
④ Double chlorination:

- pre chlorination & post chlorination combinedly is called double chlorination.

⑤ super chlorination

→ It is a process in which the addition of excess amounts of chlorine to a water supply for speed of chemical reaction or more disinfection within a short contact time beyond the break point is called super chlorination.

⑥ Break point chlorination



In the above graph, 'D' point is the Break point chlorination.

→ 'D' point is the Break point ~~where~~ after which free chlorine & residual chlorine is appear for further protection of water from micro-organism.

⑦ Dechlorination: It is the process of removing excess chlorine present in water by adding sodium thiosulphate, Activated carbon & sulphur dioxide etc. (separately).

Note Testing of chlorine residue:

(1) Orthotolidene test
(2) starch Iodide test

(3) chlorotex test
(4) DPD test