

# ENVIRONMENTAL ENGINEERING

## Water Supply System

The complete layout from the source of supply to the distribution

### Sources of water

[ Aquifer - Pervious strata/layer  
Aquiclude - Impervious strata ]

#### 1. Surface Sources

The sources in which water flows over the earth's surface

eg: Rivers, Lake, Streams, natural ponds, Impounded or storage Reservoirs.

→ Surface water have suspended impurities (major), hence not considered safe for water supply without necessary treatment.

#### 2. Sub-Surface Sources: (i) Ground water source

which supply water from below the earth's surface.

eg: Springs, infiltration galleries, wells and porous pipe galleries.  
→ which is pure, but may have some hardness.

#### a) Springs:

Natural out-flow (underground passage) of water finally reaching to earth's surface is called Spring.

→ Springs discharge hot water due to presence of Sulphur (major)

#### (i) Gravity Springs (Surface & Shallow Spring)

which is due to exposed of water table

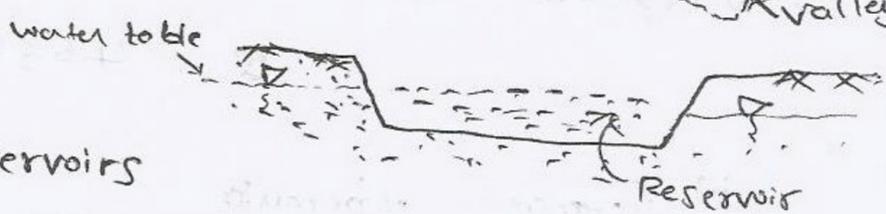
##### \* Surface Spring:

Is formed due to aquifer is exposed in a valley against vertical cut



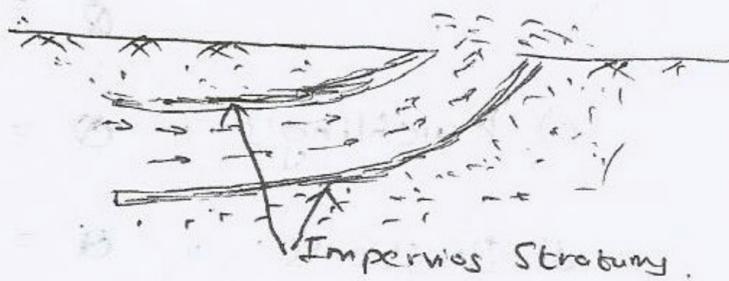
##### \* Shallow Spring:

Water collected by forming reservoirs



#### (ii) Artesian or Deep Seated Spring

Water flows out automatically through two impervious strata.



#### b) Infiltration galleries

The horizontal tunnel constructed at shallow depth along the bank of a river to intercept the ground water table

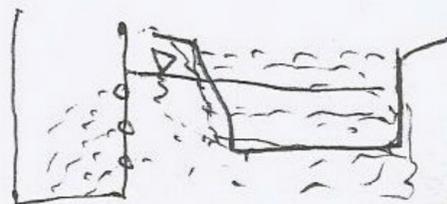
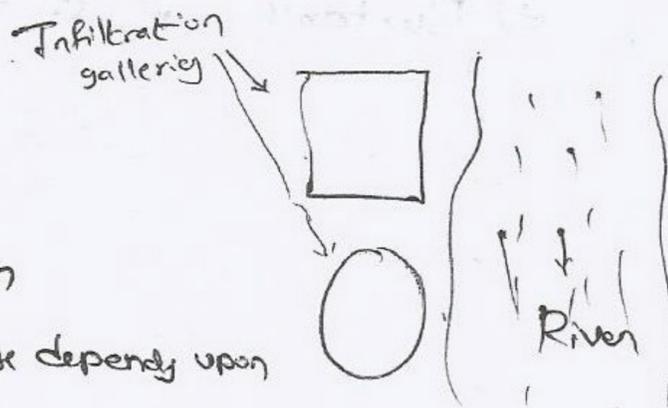
→ These are most useful in dry season

→ The quantity of water available from these depends upon

Yield of source (Rate of water percolate)

Nature of soil

Size of gallery



# Quantity of water

## 1. Per Capita Demand

Quantity of water required per person/Area per day thought out the year (capita) in a city/town. [litres per capita per day lpcd]

$$\text{Per Capita Demand} = \frac{\text{Total yearly water req of the city in litres}}{365} \times \text{Design population.}$$

$$= 270 \text{ lpcd (for an Indian city)}$$

According to (IS: 1172-1983) Water Consumption under normal conditions.

1. Domestic Supply = 135 lpcd (50%)

(Home, hostels, schools... etc)

2. Industrial & Commercial purpose = 50 lpcd (25%)

3. Demand for public uses = 10 lpcd (5%)

4. Fire Demand, Commercial & Institutional = 20 lpcd (5-10%)

5. losses in waste & thefts = 55 lpcd

270 lpcd

### \* Variation in Demand

Maximum daily consumption =  $1.8 \times \text{Avg daily demand}$

Maximum hourly consumption =  $1.5 \times \text{Avg hourly demand}$

## 2. Fire Demand

a) National Board of Fire (Writers formula)

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

b) Freeman's Formula

$$Q = 1135 \left( \frac{P}{5} + 10 \right)$$

$$\left[ \begin{array}{l} Q = \text{lit/min} \\ P = \text{Population in thousand} \end{array} \right]$$

c) Kuichling's "  $Q = 3182 \sqrt{P}$

d) Buston's "  $Q = 5663 \sqrt{P}$

e) Burton's "  $Q = 900 \sqrt{P}$

## \*1) Population Forecasting methods

### 1. Arithmetical increase method (old cities)

$$P_n = P_0 + n\bar{x}$$

where

$P_n$  = Population after (n) decade from the present

$P_0$  = Population at present (ie last known census)

$n$  = No. of decade from  $P_n$  to  $P_0$  ( $\therefore n = \frac{Y_{P_n} - Y_{P_0}}{10}$ ) (1 decade = 10 years)

$\bar{x}$  = Average population increase/decade =  $\frac{P_{\text{last}} - P_{\text{first}}}{\text{No. of decade (from last - first)}}$

eg: 1930 1940 1950 1960 / 2000?

25000	28000	34000	42000	2000?
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$$P_0 = 42000, n = \frac{2000 - 1960}{10} = 4$$
$$\bar{x} = \frac{42000 - 25000}{\frac{(1960 - 1930)}{10}} = \frac{17000}{4} = 4250$$
$$P_{2000} = 42000 + 4 \times 4250$$
$$= 59000$$

### 2. Geometrical Increase method (New fast growth cities)

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

where

$r$  = Average growth rate (%)

### 3. Incremental increase method (Any type of city)

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

where

$\bar{y}$  = Average incremental increase =  $\frac{(P_L + P_R) - (P_{L-} + P_{R+})}{(\text{No. of decade} - 1)}$

(eg:  $\frac{(42000 + 25000) - (34000 + 28000)}{4-1} = \frac{5000}{3} = 1667$ )

# Impurity in water

## 1. Suspended impurity

- These are almost visible
- May settle down after long time (Cause turbidity)
- These can be removed by filtration & sedimentation
- eg: Silt, Clay, organic, inorganic, bacterial plants (algae, fungi, protozoa...)

## 2. Colloidal impurity

- These are not visible to naked eye. (but colour of water changes)
- Cannot easily removed by ordinary filters
- These can be removed by coagulation
- The Bacteria are growth & healthy easily by using colloidal impurity which makes Epidemic (fast spread disease)

## 3. Dissolved impurity

- These are chemicals react with water (Majorly these are come from suspended & colloidal impurity)

a) Salts → Major of these causes Hardness  
Some of these may remove Hardness (i.e softening)

b) Metals → Iron <sup>causes</sup> (Red colour)  
Manganese (Brown colour)  
Lead & arsenic (Poisoning)

c) Gases → Oxygen ( $O_2$ ) ————— (Corrodes metal)  
Chlorine ( $Cl_2$ ) & Ammonia ( $NH_3$ ) — (Bad taste)  
 $CO_2$  & Hydrogen sulphide ( $H_2S$ ) — (Acidity)

## 3. Living organisms in water

Living organisms in water are Bacteria, Algae, protozoa

### Bacteria:

→ Pathogenic Bacteria = Harmful or disease causing bacteria  
Non-Pathogenic " = Useful bacteria

→ Aerobic Bacteria = Bacteria requires oxygen for living

An-aerobic " = Bacteria can live without oxygen.  
Facultative Bacteria = Bacteria can live with or without oxygen

Name - Shape of Bacteria

Cocci - Sphere

Bacilli - Rod

Spirilla - Twisted rod

Algae = Related to planktons (जलजीव), responsible for (Taste & odour)

Protozoa = All unicellular animals are called protozoa

# Physical Examination of water

## 1. Temperature Test: (Thermometer)

→ Helps in determining the Density, Viscosity, Surface tension of water

## 2. Colour Test: (Platinum Cobalt Scale)

## 3. Turbidity Test: (Silica Scale)

→ Is the measure of passage of light through the water

→ Water is said to be turbid, when it contains visible matter in suspension.

Turbidity may be determined by turbidity content (in ppm)

a) Baylis turbidimetry < 50 ppm

b) Jacksons " > 50 ppm

## 4. Tastes & odour Test: (Osmoscope)

→ The water odour is tested at 20-25°C

→ Odour is base on PO value

PO value	0	1	2	3	4	5
Meaning	No	Very faint	Faint	Distinct	Strong	Very Strong

# Chemical Examination of water

## 1. Total Solids

Suspended Solids + Colloidal Solids + Dissolved Solids

→ Weight is taken after evaporation of water

## 2. pH Value of water (Potentiometer)

$$pH = -\log[H^+] = \log\left[\frac{1}{H^+}\right]$$

ie  $\boxed{pH \propto \frac{1}{H^+}}$  ie  $H^+ \uparrow \rightarrow pH \downarrow \rightarrow$  Acidic  
 $H^+ \downarrow \rightarrow pH \uparrow \rightarrow$  Alkaline

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

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

$$-\log[H^+] - \log[OH^-] = 14$$

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

$pH < 7$  (Acidic)  
 $pH > 7$  (Alkaline)

## Permissible Limits

<u>Physical</u>		<u>Chemical</u>	
1. Temperature	10-15°C	1. pH value	6.5-8
2. Colour	10-20 ppm	2. Total Solids	500 p.p.m
3. Turbidity	5-10 p.p.m	3. Chlorides	250 p.p.m
		4. Hardness	100 p.p.m
		5. Copper	3 p.p.m
		6. Fluorine	1.5 p.p.m
		7. Iron & Manganese	0.3 ppm
		8. Arsenic & Lead	0.05 ppm
		9. Chlorine	0.1-0.2 ppm

# Water Treatment

## 1. Screening

Process of removing large sized particles (eg: leaves, bushes, branches, debris... etc.)  
→ Filter by screens of angle  $45^\circ - 60^\circ$  to the horizontal (to increase Area & Reduce velocity)  
→ Velocity of flow  $\neq 0.75 - 1 \text{ m/s}$

## 2. Sedimentation

Particles settle down as a result of the action of gravity & forces.

Settlement of particles  $\propto$  Temperature

→ Design of Sedimentation tank

a) Flow velocity =  $\frac{\text{Discharge of water entering the basin}}{\text{Vertical cross-sectional area of the tank}} = \frac{Q}{BH}$   
( $\approx 30 \text{ cm/min}$  or  $5 \text{ mm/sec}$ )

b) overflow velocity (or) surface loading  
( $\approx 600 \text{ lit/hr/m}^2$ ) =  $\frac{\text{Discharge of water entering the basin}}{\text{Plan/surface area of the tank}} = \frac{Q}{BL}$

c) Detention time (Time req to fill tank at the given rate of flow)  
( $\approx 5 - 8 \text{ hrs}$ ) =  $\frac{\text{Volume of the tank}}{\text{Discharge of water entering the basin}} = \frac{BLH}{Q}$

### d) Dimensions

Depth =  $3 - 5 \text{ m}$

width =  $10 - 12 \text{ m}$

Length  $\neq 4 \times$  width

\* When coagulants are used  
Efficiencies are almost double

→ Rate of settling of particles in water depends upon  
viscosity of water, Density of water, Sp. gravity of particle  
and Shape & size of particle.

## 3. Sedimentation Aided with Coagulation

Certain chemical compounds called coagulants are added to water, they absorb colloidal impurities and form flocculent (like gel) precipitate called floc. These flocs settle down ~~down~~ due to gravity.

→ Coagulation is necessary, when turbidity  $> 45 \text{ ppm}$

Important coagulants (Almost all cases flocs are formed by  $[\text{OH}^-]$ )  
Hence pH value decreases

a) Alum (or) Aluminium Sulphate ( $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ )

b) Copperas (or) Ferrous Sulphate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ )

Copperas + Lime ( $\text{CaO}$ )

(or) Copperas + Chlorine ( $\text{Cl}_2$ )

## 4. Filtration:

Process of purifying water by passing through a bed of Sand or other

fine granular material.

→ It should be free from Clay, loam, lime and organic matter.

→ It should not lose weight more than 5% when placed in Hydrochloric Acid for 24 hours.

S.No	Item	Slow Sand Filters	Rapid Sand Filters
1	Pre treatment	Coagulation not Required Atmospheric pressure is enough	Coagulation is must forced more than atm pressure
2	Construction a) Skilled Supervision	Simple Not Required	Complicated, as under drainage is properly designed Essential
3	Economy	High initial cost + low maintenance cost	low initial + high maintenance it is cheaper + economical
4	Suitability	Small village + individual industries (may be)	Universally adopted, almost all Major city + towns.
5	Enclosure tank a) Depth b) Plan Area c) No. of units	2.5 - 3.5 m 100 - 2000 m <sup>2</sup> -	2.5 - 3.5 m 10 - 50 m <sup>2</sup> $N = 1.22 \sqrt{Q}$ (∵ Q = Plant Capacity, million lit/day)
6	Base Material a) Size of Gravel b) Depth of bed (layer by 150mm)	(↑) 3mm - 65mm 300mm - 750mm	3mm - 40mm 600mm - 900mm
7	Filter Sand a) Size of Sand b) Depth of bed c) Uniformity coeff (Cu)	Uniformly layered 0.2 - 0.35mm 600 - 900mm 2 - 3	Smaller grain at bottom. 0.35 - 0.55mm. 1100mm 1.2 - 1.8
8	Rate of filtration	100 - 200 lit/hr/m <sup>2</sup>	3000 - 6000 lit/hr/m <sup>2</sup>
9	Remove Turbidity	upto 50 p.p.m	upto 40 p.p.m
10	Efficiency	Bacteria removed upto 99%. less efficient in rem Colour	80-90%. very efficient in rem. Colour
11	Period of cleaning	1 - 3 months	1 - 3 days
12	Under drainage System	Laid in order to receive filtered water	Laid to receive filtered water and also to pass water for Back washing at very high rate

### \* Pressure Filters:

These are just like Small rapid Sand filters. Placed in closed steel vessels  
Cylindrical in shape.

→ Water is forced into filter by pressure (Rate of filtration ≈ 6000-15000 lit/hr/m<sup>2</sup>)

→ Hence less efficient than slow + rapid sand filters in removing bacteria + turbidity

→ They are best suited for swimming pools, railway stations ... etc  
(i.e other than drinking + Municipal water usage)

## 5. Disinfection:

The process of killing pathogenic bacteria from water and making it safe to the public use. (i.e. No infection)

- Most commonly used disinfectant for drinking water throughout the world is Chlorine
- The process of applying Chlorine or Chlorine Compounds in small quantity to water to disinfect is known as Chlorination

### Notes:

Sterilization - Removal of all bacteria (i.e. Pathogenic + Non-Pathogenic)

\* Some Minor methods of Disinfection (other than Chlorination)

#### 1. Boiling: of water:

- Most of bacteria is destroyed when temp reaches  $80^{\circ}\text{C}$ .
- In case of large scale it is impracticable

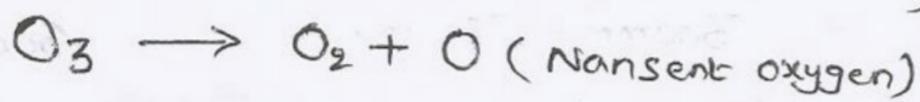
#### 2. Excess Lime Treatment

- Generally Lime used for Softening,
- But excess lime may kill bacteria also.
- But it also increases pH value of water (main disadvantage)

#### 3. Broming:

- It possess less eye irritation than residual chlorine
- Hence it is largely used as disinfectant for Swimming Pools.

#### 4. Ozone: ( $\because 3\text{O}_2 \xrightarrow[\text{Arc voltage}]{\text{under high electric}} 2\text{O}_3$ )



##### Advant

- Nascent oxygen, produced is powerful to remove organic matter as well as Bacteria from water
- Ozone is unstable (nothing remain in water), by the time it reaches to distribution system

##### Dis

- It also remove colour, taste & odour from water
- It tastes become bitter to tongue.
- More over it is costly.

## \* Chlorination:

In fact direct Chlorine ( $\text{Cl}_2$ ) kill's bacteria when ( $\text{pH} < 5$ )

- Although other compounds made by Chlorine (called Chlorine Compounds) are more efficient than direct Chlorine

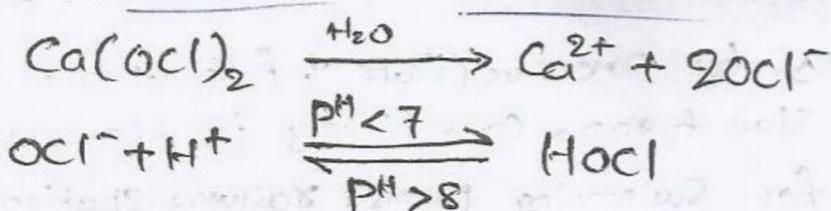
Various forms in which Chlorine can be applied

#### 1. In the form of Chlorine dioxide ( $\text{ClO}_2$ ) (It is powder)

- $2\frac{1}{2}$  times stronger than Chlorine, but is very useful & costly.

#### 2. In the form of "Hypochlorites or Bleaching powder"

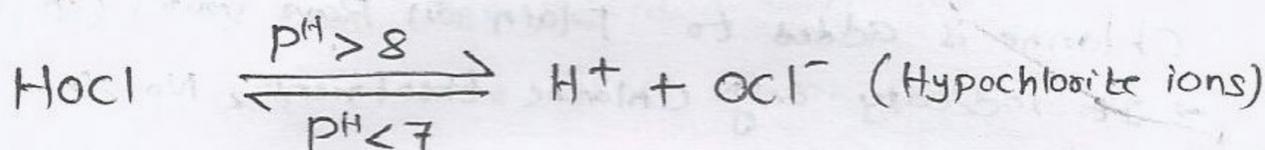
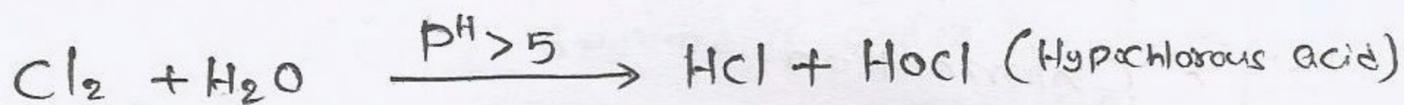
In bleaching,  
Chlorine content  
= 30-35%



This process is known as  
Hypochlorination

- Hypochlorination is less efficient than Chlorine

### 3. In the form of Chlorine with ammonia



So Chlorine only available in the form of

Hypochlorous acid (HOCl), Hypochlorite ions (OCl<sup>-</sup>) and

Molecular Chlorine (Existing in sample of water)

Hence

Hypochlorous acid + Hypochlorite ions + Molecular Chlorine = Free available Chlorine

Although

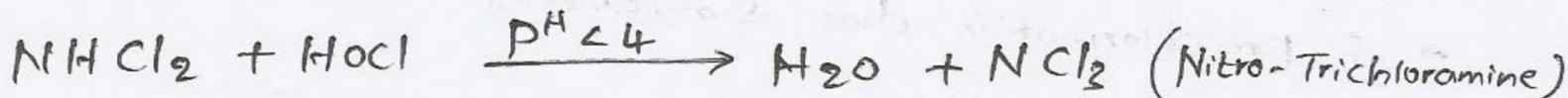
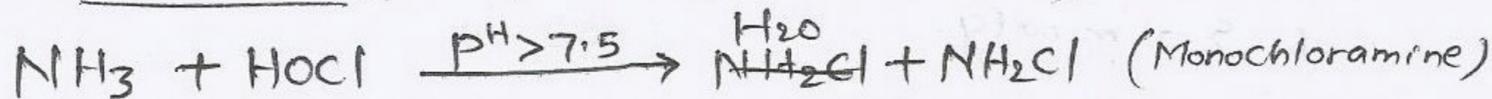
(i.e. 80%) Hypochlorous acid (HOCl) is most predominant than other two

Hence

Maintain pH value less than 7 while chlorination

Moreover

HOCl is immediately reacts with ammonia (present in water) and form chloramines (more predominant than HOCl)

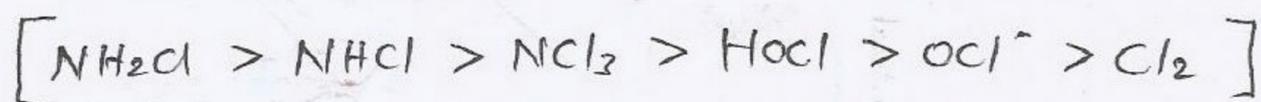


Depending on the pH value these chloraming kills bacteria more efficiently (∵ we maintain pH < 7, hence NHCl<sub>2</sub> is highly formed)

→ To get efficient results add enough additional ammonia to water, in case of less ammonia

→ Treatment with chloraming is less irritation to nose & eyes.

Hence, pathogen killers are



∴ Time of Contact of Chlorination = 20 - 30 minutes

(i.e. Time from adding chlorine - start killing)

Contact period  $\propto \frac{1}{\text{Temperature}}$

# Types of Chlorination

## 1. Plain Chlorination

- Chlorine is added to Plain (or) Raw water (in Tanks + Reservoirs)
- It indicates only Chlorine treatment, No other treatment has been given
- Amount of Chlorine Required = 0.5 p.p.m

## 2. Pre-Chlorination

- Chlorine is added to raw water before Sedimentation
- It reduces the bacterial load on filters thereby increasing their efficiency.
- The normal doses are 5-10 mg/L, so that at least 0.2-0.5 p.p.m of residual Chlorine come to filter plant.

## 3. Post-Chlorination

- Chlorine is added after filtration
- It is also known as Disinfection
- The amount of Chlorine added should be such that a residual Chlorine of about 0.2 p.p.m appears in water after a contact period of 20 minutes.

## 4. Double Chlorination

- Chlorine is added twice (Generally Pre + Post Chlorination)
- If pre chlorination done, simultaneously Double Chlorination happens.

## 5. Break-point Chlorination

### a) Curve AB

- By addition of Chlorine from A-B Chloramines are formed.
- Although some  $Cl_2$  consumed for killing bacteria, hence AB curve slightly less than Imaginary curve

### b) Curve BC

- From B, Chloraming starts killing bacteria more rapidly.
- From B-C, the applied Chlorine <sup>may</sup> also participated in oxidation (killing bacteria)

### c) At 'C' (Break point)

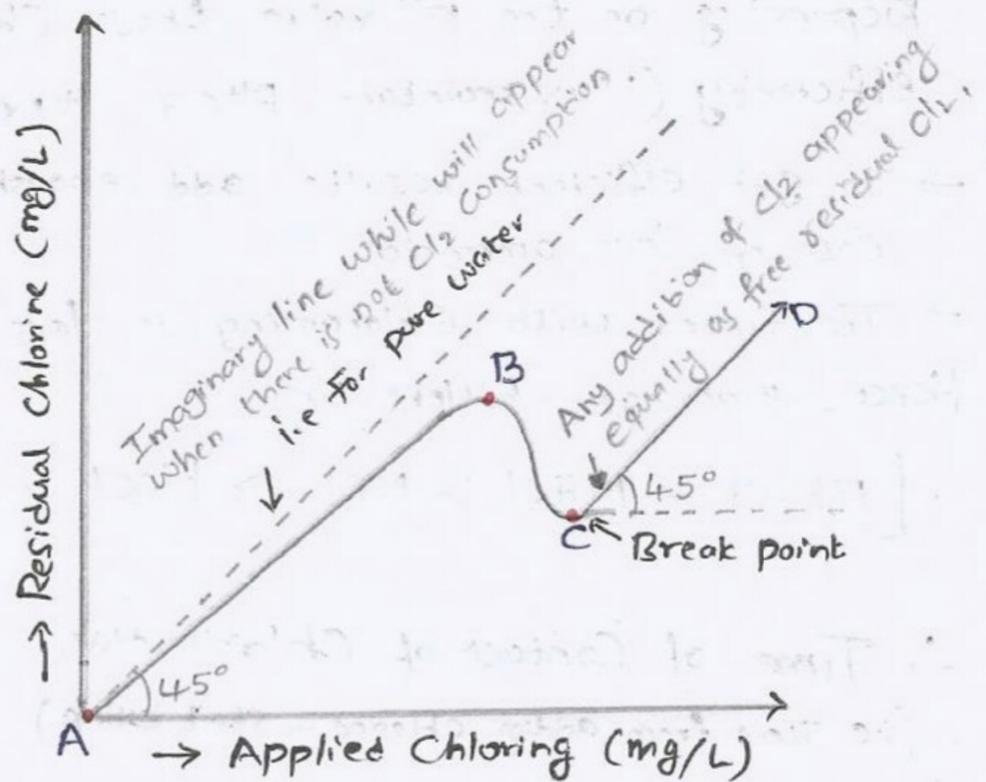
- The oxidation is finished (ie There is no bacteria)
- ∴ Residual Chlorine will Reappear.

### d) Straight line CD (→)

- After Break point (C), There is no bacteria, hence further addition of ~~add~~ of  $Cl_2$  will appear equally as free Chlorine

→ The phenomenon from A-C is called Break point Chlorination (or) (Post-Chlorination)

→ The phenomenon after 'C' is called Super Chlorination



## 6. Super Chlorination:

- A high dose of Chlorine (i.e 2-3 p.p.m) is added to water beyond Break point, (So that Res residue will left)
- If not satisfied, may add Chlorine after Break point
  - This may be done in some special cases, like highly polluted water, during epidemics of water born diseases.

## 7. Dechlorination

The removal of unwanted/Excess Chlorine in water by Chemical or physical (Simple Aeration) treatment is known as dechlorination.

Most Common Dechlorinating agents

- (i) Activated Carbon
- (ii) Ammonia ( $\text{NH}_4\text{OH}$ )
- (iii) Sulphur dioxide Gas ( $\text{SO}_2$ )
- (iv) Sodium sulphate ( $\text{Na}_2\text{SO}_3$ )

Sodium Bisulphate ( $\text{NaHSO}_3$ )

Sodium Metabisulphate ( $\text{Na}_2\text{S}_2\text{O}_5$ )

Sodium thiosulphate ( $\text{Na}_2\text{S}_2\text{O}_3$ ) → Cheapest agent.

## \* Testing of Chlorine Residuals

- Chloro-tex test
- D.P.D test
- Orthotolidine test
- Starch iodine test.

## Hardness of water

Hard (karskato) waters are undesirable, because they may lead to Soap consumption, Feeling rough while bathing, making food tasteless, Causing Corrosion (by wear + tear), Friction losses in pipes...etc.  
→ Underground waters are generally Harder than the Surface waters.  
→ Hardness of water can be measured by EDTA method.

a) Temporary Hardness  $(Ca^{2+})$   $(Mg^{2+})$   $(CO_3^{2-})$   $(HCO_3^-)$   
Due to the presence of Calcium & Magnesium Carbonates or Bicarbonates  
ie Calcium carbonate  $(CaCO_3) \downarrow$  | Calcium bicarbonate  $(Ca(HCO_3)_2)$   
Magnesium carbonate  $(MgCO_3)$  | Magnesium bicarbonate  $(Mg(HCO_3)_2)$

b) Permanent Hardness

Due to the presence of Calcium and Magnesium Sulphates or Chlorides or Nitrates

ie  $Ca \begin{cases} SO_4 \\ NO_3 \\ Cl_2 \end{cases}$  and  $Mg \begin{cases} SO_4 \\ NO_3 \\ Cl_2 \end{cases}$

## Softening of water

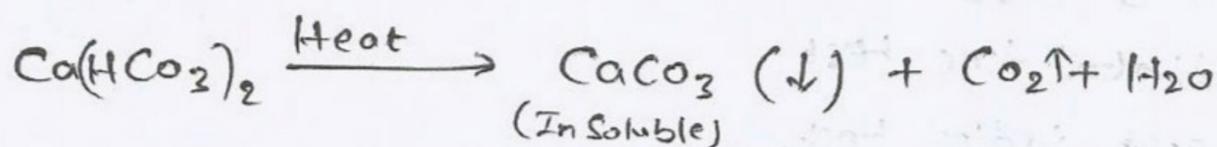
The Reduction or Removal of hardness from water

a) Removal of Temporary hardness

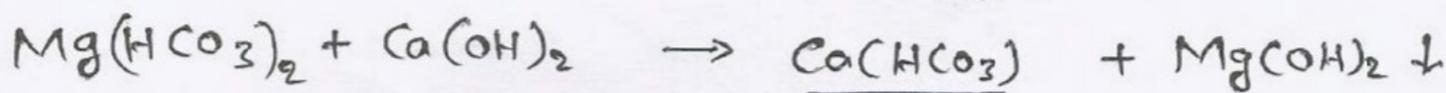
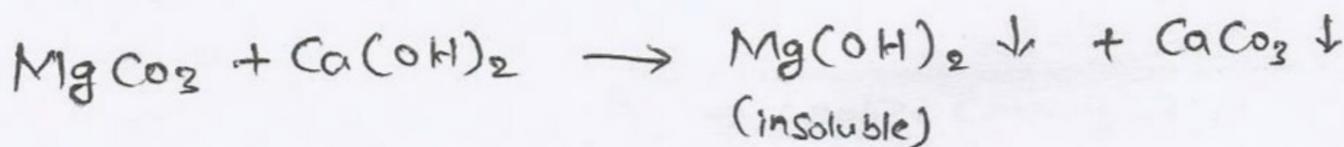
By sedimentation by forming insoluble precipitations.  
→  $CaCO_3$  is insoluble precipitation, can be sedimented

(i) Boiling:

only  $CaHCO_3$  can be effected ( $\because Mg[HCO_3]$  is soluble in water)



(ii) Addition of Lime



→ Temporary hardness also known as Carbonate Hardness.

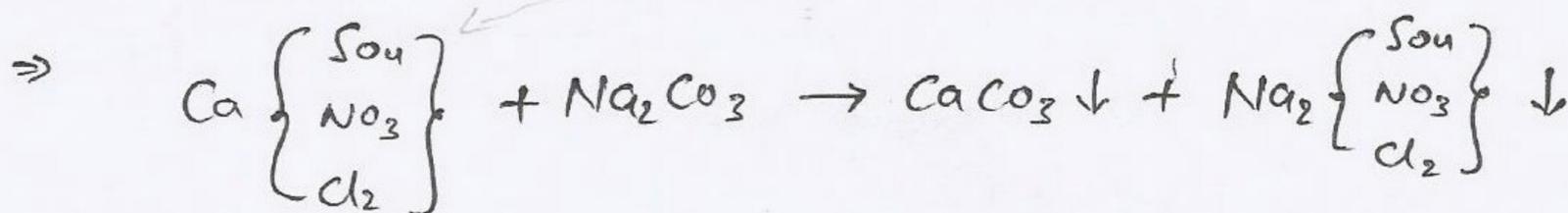
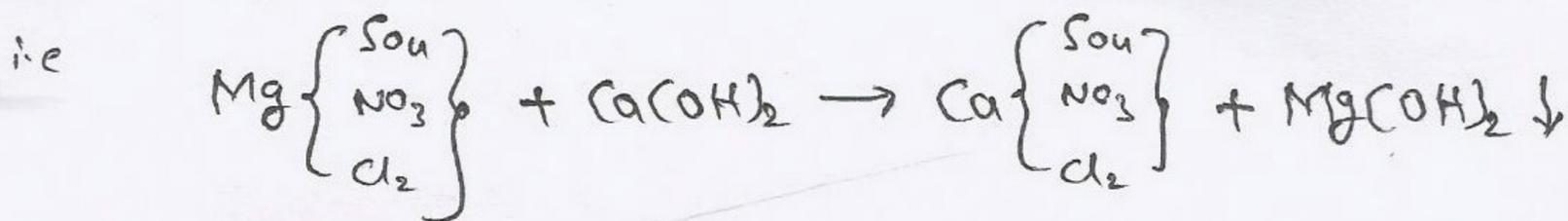
Carbonate hardness = Total hardness  
(or)  
Alkalinity } whichever is less

## b) Removal of permanent Hardness

### (i) Lime-Soda Process

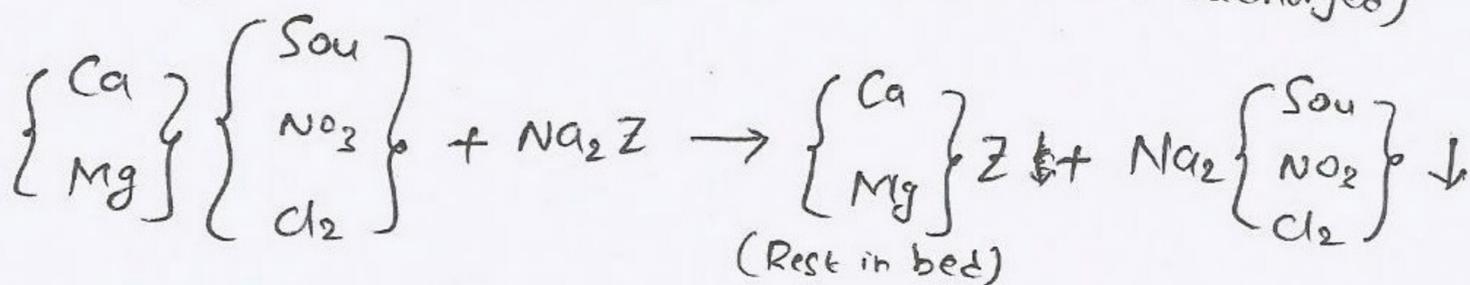
Lime -  $\text{Ca(OH)}_2$  & Soda -  $\text{Na}_2\text{CO}_3$

→ Although Mg reacts with <sup>lime</sup>soda & Ca reacts with <sup>soda</sup>lime



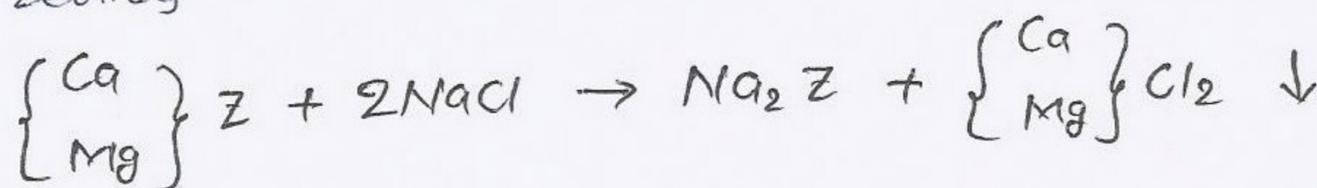
### (ii) Zeolite or Base exchange or Cation Exchange process.

In this process hard water is passed through Bed of Zeolite Sand ( $\text{Na}_2\text{Z}$ ). While passing the cations  $\begin{Bmatrix} \text{Ca}^+ \\ \text{Mg}^+ \end{Bmatrix}$  can be replaced by Sodium [ $\text{Na}_2^+$ ] (ie cations are exchanged)



→ After softening of water, The zeolite bed loses the Zeolity ( $\text{Na}_2\text{Z}$ ). Hence these can be charged by passing Sodium Chloride ( $\text{NaCl}$ ).

Charging of Zeolity



→ It is observed that  $\begin{Bmatrix} \text{Ca} \\ \text{Mg} \end{Bmatrix} \text{Cl}_2$  are not in water,

Hence easily separated (by manual)

→ Rate of filtration is about 18000 lit/hr/m<sup>2</sup>

Zeolite Process	Lime Soda process
1. Process is Costlier	1. Process is economical
2. Compact & Small	2. Bulky & Large
3. No Sludge is formed	3. Large quantity of Sludge is formed
4. pH value not affected	4. Increased pH value
5. Can economically treat Hardness < 800 mg/L	5. Excessively hard water can be treated Hardness > 500 mg/L

1) Given data for...

2) Given data for... (continued)

$$\begin{pmatrix} 200 \\ 100 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix} \rightarrow \begin{pmatrix} 300 \\ 200 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 200 \\ 100 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix} \rightarrow \begin{pmatrix} 300 \\ 200 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix}$$

3) ... (faded text describing a process or calculation)

$$\begin{pmatrix} 200 \\ 100 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix} \rightarrow \begin{pmatrix} 300 \\ 200 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix}$$

4) ... (faded text)

$$\begin{pmatrix} 200 \\ 100 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix} \rightarrow \begin{pmatrix} 300 \\ 200 \\ 0 \end{pmatrix} + \begin{pmatrix} 100 \\ 100 \\ 0 \end{pmatrix}$$

5) ... (faded text)

6) ... (faded text)

## Water Distribution System

1. Dead End System (or Tree System)
2. Grid Iron System (City or Town having Rectangular pattern Improvement over Dead end System)
3. Ring System (Well Planned City only)
4. Radial System (Opposite to Ring System)

## Sanitary Engineering

Combined Sewage = (Surface + Storm) Sewage water

Infiltration = Water leaky from Ground to Sewers

Ex-filtration = Water leaky from Sewers to Ground.

\* Design of Sewers:

Internal diameter  $\geq 15\text{cm}$

Self Cleaning velocity  $\geq 0.75\text{ m/s}$

land disposal of Sewage req large area of Sandy or Alluvial Soil

\* Sewage treatment:

Primary treatment:

Screening  $\rightarrow$  Grit Chamber  $\rightarrow$  Sedimentation  $\rightarrow$  Coagulation

Secondary treatment

Secondary treatment or Biological treatment of Sewage is done by

Sewage filter and activated Sludge process unit

Mostly used filter are Trickling filter.