WATER POLLUTION

HARDNESS OF WATER : Water which not lather easily with soap is called 'Hard water',It is due to the presence of Ca^{+2} & Mg^{+2} ions .Sodium salts of long-chain fatty acids (Oleic acid , palmitic acid, stearic acid) presents in the soap ,react with Ca^{+2} & Mg^{+2} ions of water to form insoluble scums of Ca & Mg soaps which do not have any detergent value.

$C_{17}H_{35}COOH$ + $C_{17}H_{35}COONa$ -------→ Lather
Stearic acid soap

$2\,C_{17}H_{35}COONa + CaCl_2$ -------→ $(C_{17}H_{35}COO)_2Ca\downarrow + 2\,NaCl$
Sodium stearate calcium stearate (insoluble)

$2\,C_{17}H_{35}COONa + MgSO_4$ -------→ $(C_{17}H_{35}COO)_2Mg\downarrow + Na_2SO_4$
Magnesium stearate (insoluble)

The hardness of water can be classified into two types—
1. Temporary hardness /Carbonate hardness 2. Permanent hardness /Bicarbonate hardness

1. Temporary hardness of water: The presence of carbonates (CO_3^{-2}) and bicarbonates (HCO_3^-) of Mg & Ca in water makes it temporary hardness. In this case, the hardness in water can be removed by boiling of water.

2. Permanent hardness of water : The presence of chlorides and sulphates of Mg & Ca in water are called permanent hardness .This cannot be removed by boiling.

UNITS OF HARDNESS:

1. **Parts Per Million (ppm)** : It is no. of parts of $CaCO_3$ equivalent hardness per 10^6 parts of water.

1ppm = 1 part of $CaCO_3$ eq. hardness in 10^6 parts of water.

2. **Milligrams per litre (mg/l)** : The no. of milli grams of $CaCO_3$ equivalent hardness present per litre of water.

1mg / lit. = 1mg of $CaCO_3$ eq. hardness in 1 lit. of water.

CONVERSION OF TEMPORARY HARD WATER INTO SOFT WATER :

Temporary hardness of water: The presence of carbonates (CO_3^{-2}) and bicarbonates (HCO_3^-) of Mg & Ca in water. There are 3 types-----

1. By adding soap : By adding sufficient quantity of soap i.e. enough stearate ions are added to precipitate all the Ca^{+2} ions , leaking the excess soap to carry out the cleaning action.

2. By Boiling of water: By boiling of hard water , the soluble HCO_3^- of Ca & Mg decompose and ppt. as insoluble CO_3^{-2} ,which are removed by filteration.

$Ca(HCO_3)_2$ -------Boil----→ $CaCO_3\downarrow + CO_2 + H_2O$
Calcium bicarbonate (soluble) Calcium carbonate (insoluble)

$$Mg(HCO_3)_2 \xrightarrow{\text{-------Boil----}} \underset{\text{(insoluble)}}{MgCO_3\downarrow} + CO_2 + H_2O$$
(soluble)

3. Clarks process / By addition of Lime : In this process add calcium hydroxide (CLARK'S REAGENT) to water. It removes the hardness of water by converting soluble bicarbonates into insoluble carbonates.

$$\underset{\text{Calcium bicarbonate (soluble)}}{Ca(HCO_3)_2} + \underset{\text{calcium hydroxide}}{Ca(OH)_2} \xrightarrow{\text{----------}} \underset{\text{Calcium carbonate (insoluble)}}{2\,CaCO_3\downarrow} + 2H_2O$$

$$\underset{\text{(soluble)}}{Mg(HCO_3)_2} + Ca(OH)_2 \xrightarrow{\text{----------}} \underset{\text{(insoluble)}}{2\,MgCO_3\downarrow} + 2H_2O$$

CONVERSION OF PERMANENT HARD WATER INTO SOFT WATER :

Permanent hardness of water : The presence of chlorides and sulphates of Mg & Ca in water are called permanent hardness. There are 3 methods .

1.Washing soda process
2. Zeolite / permutit process
3. Ion-exchange process.

1. WASHING SODA PROCESS : Hard water is treated with a calculated amount of washing soda when chlorides and sulphates of Ca & Mg present in hard water get ppted. as insoluble Ca & Mg carbonates which can be filtered off. This is the way to removal of permanent hardness.

$$\underset{\text{(Hardness)}}{CaCl_2} + \underset{\text{sodium carbonate}}{Na_2CO_3} \xrightarrow{\text{----------}} \underset{\text{ppt.}}{CaCO_3\downarrow} + 2\,NaCl$$

$$MgCl_2 + Na_2CO_3 \xrightarrow{\text{----------}} \underset{\text{ppt.}}{MgCO_3\downarrow} + 2\,NaCl$$

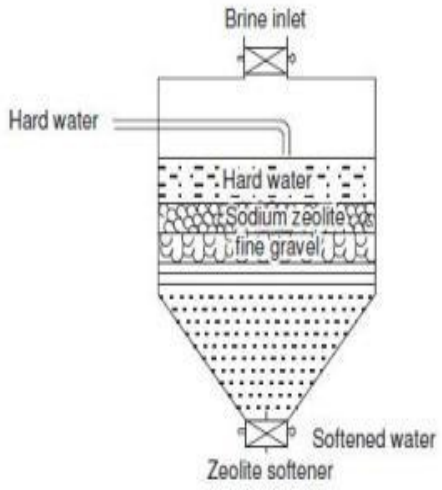
$$CaSO_4 + Na_2CO_3 \xrightarrow{\text{----------}} \underset{\text{ppt.}}{CaCO_3\downarrow} + Na_2SO_4$$

$$MgSO_4 + Na_2CO_3 \xrightarrow{\text{----------}} \underset{\text{ppt.}}{MgCO_3\downarrow} + Na_2SO_4$$

2. ZEOLITE / PERMUTIT PROCESS :

- Zeolite in Greek (Zein + lithos) = **" Boiling stone ".**
- Sodium alumina silicate is known as Zeolite (or) permutit .
- Its formula is $Na_2O.Al_2O_3.xSiO_2.y\,H_2O$. **x= 2 to 10 ; y = 2 to 6** .It is written as Na_2Z.
- In this process hard water is pumped through the zeolite bed and sand racks at a specified rate. Insoluble substances remain on the sand shelf.
- As water travels through the zeolite bed , the hardening ions Ca^{+2} & Mg^{+2} reacts with zeolite to form CaZ & MgZ respectively.
- Outgoing water contains equivalent amount of sodium salts.
- Thus using this method the cation can be removed and the hardness removed.
- The NaCl solution is pumped through a hose for about 12 hours to restore the Zeolite capacity after a while for reuse.

- The chemical reactions taking place in Zeolite softner ,are-------



$Ca(HCO_3)_2 + Na_2Z \rightarrow CaZ + 2\,NaHCO_3$

$Mg(HCO_3)_2 + Na_2Z \rightarrow MgZ + 2\,NaHCO_3$

$CaCl_2 + Na_2Z \rightarrow CaZ + 2\,NaCl$

$MgCl_2 + Na_2Z \rightarrow MgZ + 2\,NaCl$

$CaSO_4 + Na_2Z \rightarrow CaZ + Na_2SO_4$

$MgSO_4 + Na_2Z \rightarrow MgZ + Na_2SO_4$

- Small quantities of Fe & Mn bicarbonates are also removed simultaneously.
- $Fe(HCO_3)_2 + Na_2Z \rightarrow FeZ + 2\,NaHCO_3$

  $Mn(HCO_3)_2 + Na_2Z \rightarrow MnZ + 2\,NaHCO_3$

➢ **REGENERATION OF ZEOLITE : It can be regenerated & reused by treating with 10% Brain soln.**

➢ $CaZ + 2NaCl \rightarrow Na_2Z + CaCl_2$

$MgZ + 2NaCl \rightarrow Na_2Z + MgCl_2$

brain

3. ION- EXCHANGE PROCESS / DEIONIZATION/DEMINERALIZATION PROCESS :

This method is superior to all other methods because it eliminates both cation and anion which responsible for permanent hardness. In this method consists of two tanks and explain of 3 steps.

STEP-1 : When the hard water is passed through the bed of the **cation exchange resin (RCOOH or R-SO_3H)** in the first tank, Ca^{+2} & Mg^{+2} can be exchanged with the H+ in the resin to remove the hardness caused by the cation. But this water contains Cl^-, SO_4^{-2}, HCO_3^- anions.

Reactions :

$2RCOOH + Ca^{+2} \dashrightarrow (RCOO)_2Ca + 2H^+$

$2RCOOH + Mg^{+2} \dashrightarrow (RCOO)_2Mg + 2H^+$

STEP-2 : The anion exchanges the Cl^-, SO_4^{-2}, HCO_3^- containing water with the OH^- in the Cl^-, SO_4^{-2}, HCO_3^- anion resin as it passes through the anion exchange resin (R-OH or R-NH_2) bed in the second tank. In this way the Cl^-, SO_4^{-2}, HCO_3^- anions can be eliminated.

Reactions :

$2\,R\text{-}OH + Cl^- \rightarrow 2\,R\text{-}Cl + 2\,OH^-$

$2\,R\text{-}OH + SO_4^{-2} \rightarrow R_2\text{-}SO_4 + 2\,OH^-$

$2\,R\text{-}OH + CO_3^{-2} \rightarrow R_2\text{-}CO_3 + 2\,OH^-$

STEP-3 : H^+ & OH^- formed in the above two stages together we can get as soft water. In this method , both cation & anion ,which cause hardening are removed and converted into soft water.

Reaction :

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

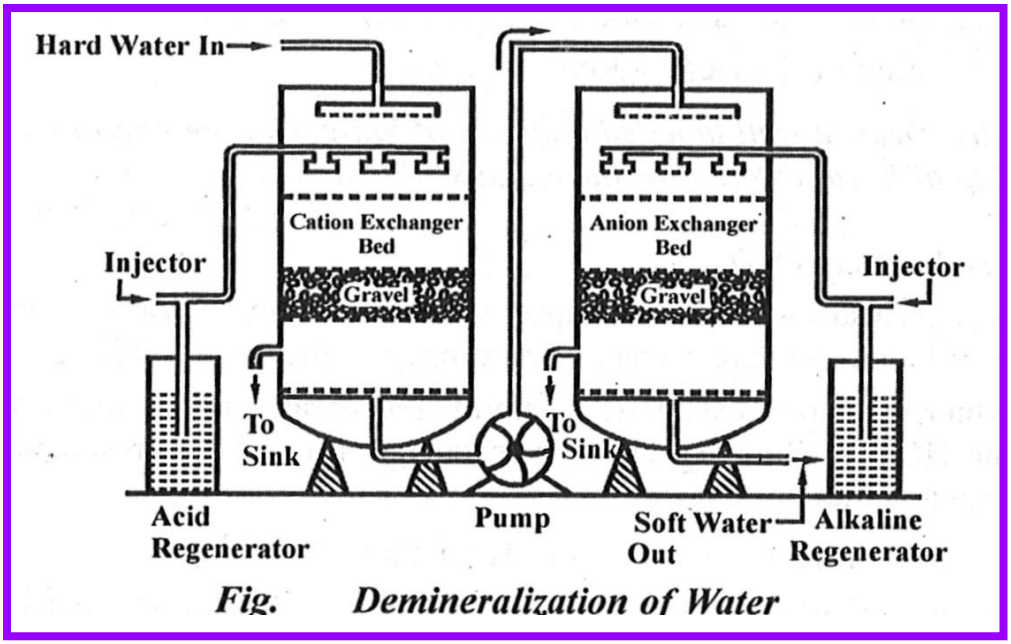


Fig. Demineralization of Water

Definitions of DO, BOD & COD :

DISSOLVED OXYGEN (DO) :

- ***"The amount of oxygen dissolved in water is known as 'Dissolved oxygen '.***
- Healthy water should generally have DO value above 6.5- 8 mg/ lit .
- ***The optimum value of good quality water has been 4-6 mg/lit. of DO,*** which is able to maintain aquatic life in a water body.
- If DO value are lower than this value, then the water is expected to be polluted.
- ***Water pollution increases as the DO value decreases***.
- DO in natural water is determined by ------a) Winkler's method b) Polarographic method .

BOD (Bio Chemical Oxygen Demand):

- ***Definition :*** "The amount of oxygen required by micro –organisms to decomposition of organic matter in water sample over a period of 5 days at 20^0C ," is called BOD .
- It is expressed in ppm (or) mg/lit.
- ***Reaction :*** **Organic matter + Bacteria + DO → CO_2 + H_2O + New bacteria**
- ***Pure drinking water BOD < 1 ppm.***
- BOD is standardized measurement of water quality.
- BOD values are useful in process design and loading. Calculation, measurement of treatment efficiency and operation, stream pollution control.
- It is also useful in determination of self purifying capacity of a stream.

COD (Chemical Oxygen Demand) :

- **Definition** : The amount of oxygen required by organic matter in a sample of water for its oxidation by a strong oxidising agent such as potassium dichromate solution **($K_2Cr_2O_7$).**
- It is expressed as ppm of oxygen taken from a $K_2Cr_2O_7$ solution in 120 minutes.
- ***Reaction :*** **Organic matter + 16 H^+ + 2 $Cr_2O_7^{-2}$ → $4Cr^{+3}$ + $3CO_2$ + $11H_2O$**
- COD has been found to be more scientific than the BOD.
- COD is used in calculating the efficiency of treatment plants and proposing standards for discharging domestic effluents in various types of water bodies.

EUTROPHICATION :

DEFINITION : It may defined as "the nutrients (N,P etc,)enrichment of natural water ,leading to on increased **production of algae and macrophytes** and decrease the dissolved oxygen" is known as eutrophication.

Causes : Chemical fertilizers ; Detergents ; poor sewage treatment.

TYPES OF EUTROFICATION :

1. Natural Eutrophication : The process of lake ageing characterized by nutrient enrichment is called "Natural Eutrophication."

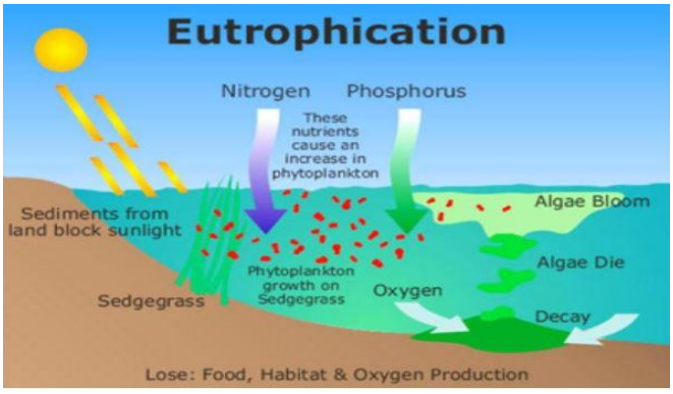
2. Cultural Eutrophication : Due to human activities as increase of nitrogen & phosphorous takes place to lakes & streams are called "Cultural Eutrophication."

Effects of Eutrophication :

- Increasing biomass of phytoplankton resulting in 'algal blooms'. These algal blooms releases toxic chemicals which kill fish and other aquatic animals.
- It causes **HYPOXIA (oxygen shortage condition**).
- Loss of species biodiversity.
- Some phytoplankton species produce toxins that cause severe symptoms such as diarrhoea, memory loss, paralysis and in severe cause's death.

Control methods :

- The use of house hold sewage , industrial waste & agricultural fertilizers should be prevented from entering the reservoirs.
- The waste should be cleaned and left out.
- Inhibit bacteria in water.
- 'Algal blooms' should be removed from the water.



Physical & chemical properties of water :

Physical properties of water :

It is essential to monitor the physical aspects of water quality to determine if the water is polluted or not. Physical characteristics can be determined by:

- **Colour** – pure water is colourless; coloured water can indicate pollution. Colour can also show organic substances. The maximum acceptable level for the ***colour of drinking water is 15 TCU (True colour unit).***
- **Turbidity** – pure water is clear and does not absorb light. If turbidity appears in the water, it may indicate water pollution.
- **Taste and odour** – pure water is always tasteless and odourless. If any type of taste and smell is present, it may indicate water pollution.
- **Temperature** – the temperature is not directly used to evaluate whether water is drinkable or not. However, in natural water systems like lakes and rivers, the temperature is a significant physical factor that determines water quality.
- **Total dissolved Solids (TDS)** – If water is filtered to remove suspended solids, the remaining solid in the water indicates the total dissolved solids. ***If the dissolved solids in the water exceed 300 mg/l, it adversely affects living organisms as well as industrial products.***
- **PH :** The PH of water is measured with a simple PH sensor.PH of water is measured between 0 and 14.If the reading PH =7 i.e. water is neutal ; PH < 7 that the water is in acidic ; ph > 7 water is in alkaline . ***Pure drinking water PH=7 is in neutral.***

Chemical properties of water :

- **Amphoteric Nature of Water** - Water can act as both an acid and a base which means water can act as both a proton donor and a proton acceptor.

  $H_2O\ (l) + NH_3(aq) \Leftrightarrow NH_4^+\ (aq) + OH^-(aq)$ ------- **Acidic Behaviour**

  $H_2O\ (l) + HCl\ (aq) \Leftrightarrow H_30^+(aq) + Cl^-(aq)$ ---------- **Basic Behaviour**

- **Alkalinity :** The alkalinity of water is its acid-neutralizing capacity comprised of the total of all titratable bases. The measurement of alkalinity of water is necessary to determine the amount of lime and soda needed for water softening. Alkalinity of water is mainly caused by the presence of OH^- , CO_3^{-2-} , HCO_3^- ions or a mixtutre of two of these ions in water.
- **Hardness :** The bicarbonate salts of Ca & Mg have a give temporary hardness in water, while the chloride and sulphate of Ca & Mg have a gives permanent hardness in water.

s.no.	Amount of CaCO3 mg/ lit.	Hardness of water
1.	0- 40	Soft water
2	40-100	Average
3	100-300	Hard
4	300-500	High hardness
5	500-1000	Very high hardness

INDUSTRIAL WASTE WATER TREATMENT :

- The procedures used to treat waste water produced as an unwanted by product by industry are referred to as industrial waste water treatment. The treated industrial waste water (or effluent) can be reused.
- The method of industrial waste water treatment depends on various factors, mainly....
  1. Nature of industrial waste
  2. BOD & COD of the effluent
  3. PH value of the water
  4. Suspended solid particles present (SSP)
  5. Total solids present (TSP)
  6. Toxic chemical substances present.
  7. Pollutants present .
- There are many methods to treat industrial waste water. Important 4 of them are...
- **1. Adsorption method (Filteration by activated charcoal)**
- **2. Physical treatment (sedimentation & Floatation)**
- **3. Chemical treatment (Reverse Osmasis & Electro dialysis)**
- 4. Biological treatment

1.ADSORPTION METHOD (Filteration by activated charcoal):

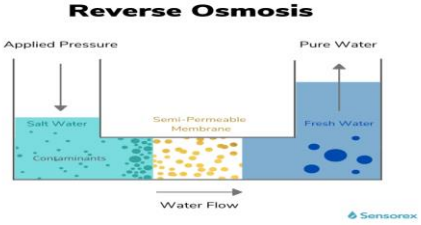
- Industrial waste water contains highly toxic biodegradable and non- biodegradable organic and inorganic chemicals, such waste water is discharged into a room or vessel impregnated with activated charcoal .
- **Here activated charcoal acts as an adsorbent.**
- As a result, about 99% of chlorinated hydrocarbons such as aldrin , endrin and DDT are absorbed over coal and removed from the water.
- In this way the pure water comes out through an open passage fitted to the bottom of the vessel.

2.PHYSICAL TREATMENT : It consists of separating the suspended inorganic matter by---

- **i) Sedimentation :** Separate the heavier settleable solids in a sedimentation tank.
- **ii) Floatation :** In this method air injected in such a way that small air bubbles (< 0.1 mm) should be formed. This is necessary due to the small size low density solid particles to be removed.

3.CHEMICAL TREATMENT ;

- The chemical treatment **is used to remove the dissolved organic matter from waste water. By two methods.....**
- **i) Reverse Osmosis :** In this method water molecules moves from *higher concentrated to lower concentrated solution through semipermeabale membranes* at a pressure higher than the Osmatic pressure. It is a simple ,low expensive process.



- **ii) electro dialysis** : In this process, dissolved salts from waste water are separated by passing an electric current through the waste water tank,fitted with "Ion-exchange membranes".

4. Biological treatment :

- When the waste water ***contains large quantity of biodegradable substances*** its biological treatment is need.
- Biological treatment may be used either with or without acclimatisation (increasing con. To the micro- biological population under a controlled condition).
- **Acclimatisation depends upon its BOD/COD ratio.**
- If BOD/COD > 0.6 → waste water required biological treatment without acclimatisation
- If BOD/COD < 0.6 → waste water required biological treatment with acclimatisation
- If BOD/COD < 0.3 → no biological treatment for waste water is required.

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