

## WATER TECHNOLOGY LECTURES

LECTURE-1

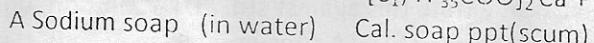
## Water Analysis

Water is the nature's most abundant and essential compound useful for lives of animals and plants. It is used for both domestic and industrial purposes. The surface sources of water contains several components and they affect our health, agriculture and industry. Some of the components in water to be studied in this chapter with regard to their sources and effects, experimental determination and calculations include:

1. Hardness
2. Nitrate content
3. Sulfate content
4. Chloride content
5. Dissolved Oxygen content

## 1. HARDNESS OF WATER

**Hard water:** "A sample of water containing soluble salts of Calcium, Magnesium, Iron, Manganese etc., which consumes a lot of soap and does not produce free lather with it is called hard water". These salts in water are derived from soils and rocks. They form insoluble white scum with sodium soap. For example:  $2 C_{17}H_{35}COONa + Ca^{2+} \rightarrow [C_{17}H_{35}COO]_2Ca + 2Na^+$



Thus hard water consumes large amount of soap. In addition hard water clogs pipes and damage boilers by forming boiler scales due to the deposition of the salts on the inner wall of the boilers.

**Hardness of water:** Hardness of water is a measure of its capacity to precipitate soap. It gives the magnitude of the presence of soluble salts responsible for making the water hard.

## Types of hardness:

There are two types of hardness-

- 1) **Temporary Hardness** (Carbonate hardness): This type of hardness is due to dissolved bicarbonates of Ca and Mg. It can be removed by boiling.

For example:  $Ca(HCO_3)_2$  (in water) (boil for 20 -30 minutes)  $\rightarrow CaCO_3$  (ppt) +  $H_2O + CO_2$ .

- 2) **Permanent Hardness** (Non-carbonate hardness): This type of hardness is due to soluble non carbonate salts of Ca, Mg etc, namely, chlorides, nitrates, sulphates, hydroxides etc. They cannot be removed by heating. They need special chemical treatments to remove them.

A water sample may contain both types of hardness and hence, Total Hardness = Temporary hardness + Permanent hardness

## Units of Hardness of water:

Hardness of water is expressed in several ways

1. **Parts per million (ppm)** : ie., parts of  $CaCO_3$  equivalents per million parts of water. For example, 1 ppm is 1 part of  $CaCO_3$  equivalent hardness in 1 million parts of water.
2. **Milligram per litre (mg/L)**: It is the number of milligrams of  $CaCO_3$  equivalent hardness in 1 litre of water.
3. **Degree of General Hardness (dGH or German degree)**: It is defined as 10 mg/L  $CaO$  or 17.848 ppm.

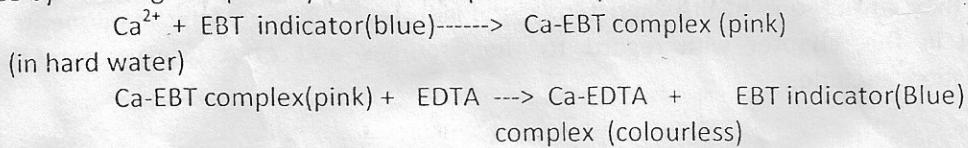
## General classification of soft and hard waters: (mg/L or ppm)

- a) Soft .... 0 - 17.1
- b. Slightly hard....17.1 - 60
- c) Moderately hard....60 - 120
- d) Hard.... 120-180

e) Very hard.... 180 and above.

#### Determination of Hardness of Water (EDTA Method)

**Principle:** To a sample of hard water containing Ca or Mg salts, when the blue coloured Eriochrome Black-T (EBT) indicator is added at pH 10, it forms a pink complex with Ca or Mg ions. However, when it is titrated against a solution of disodium salt of Ethylene diamine tetra acetic acid (EDTA), Ca and Mg ions from the EBT complex react with EDTA releasing free EBT which is blue in colour. Hence by knowing the quantity of EDTA required it is possible to find the hardness of water



#### Procedure:

##### a) Preparation of Std EDTA solution:

Dissolve a known wt. of soluble salt of EDTA in water in a 250 ml std. flask and make up to the mark with water and mixed well. Let its molarity be 'x' M.  
( $'x'$  M = Wt of EDTA salt  $\times$  1000 / Mol wt. of EDTA salt)

##### b) Determination of Total hardness:

Pipette out 25 ml of the water sample in to a clean conical flask. Add 2 ml of  $\text{NH}_3^-$ - $\text{NH}_4^+$ Cl buffer and a pinch of EBT indicator. Titrate this against std. EDTA solution, until the colour changes from pink to just blue. Note the volume of EDTA consumed, (say  $V_1$  ml).

**Calculations:** 1000 ml of 1 M EDTA = 100 g. of  $\text{CaCO}_3$

$$\begin{aligned}\text{Hence, } V_1 \text{ ml of 'x' M EDTA} &= (V_1 \times 'x' \times 100 / 1000 \times 1 \text{ M}) \\ &= 'A' \text{ g. of } \text{CaCO}_3 \text{ in 25 ml water sample.}\end{aligned}$$

$$\text{Hence, Total hardness} = [A/25] 10^6 \text{ ppm} = T_1 \text{ ppm}$$

##### c) Determination of Permanent Hardness:

Pipette out 25 ml of the same water sample in to a beaker, boil gently for 20-30 minutes, cool and filter in to a conical flask. To the filtrate add 2 ml  $\text{NH}_3^-$ - $\text{NH}_4^+$ Cl buffer and a pinch of EBT indicator. Titrate this against the same std. EDTA until the colour changes from pink to just blue. Note the volume of EDTA consumed, say  $V_2$  ml.

**Calculations:** 1000 ml 1 M EDTA = 100 g. of  $\text{CaCO}_3$

$$\begin{aligned}\text{Hence, } V_2 \text{ ml of 'x' M EDTA} &= (V_2 \times 'x' \times 100 / 1000 \times 1 \text{ M}) \\ &= 'B' \text{ g. of } \text{CaCO}_3 \text{ in 25 ml water boiled.}\end{aligned}$$

$$\text{Hence, Permanent hardness} = [B/25] 10^6 \text{ ppm} = T_2 \text{ ppm}$$

##### d) Calculation of Temporary Hardness:

$$\text{Total Hardness} = \text{Temporary hardness} + \text{Permanent Hardness}$$

Hence,

$$\begin{aligned}\text{Temporary hardness} &= \text{Total hardness} - \text{Permanent hardness} \\ &= T_1 - T_2 = T_3 \text{ ppm}\end{aligned}$$

## Nitrate content in water

## Nitrate content

The sources of nitrate in water are due to the use of synthetic fertilizers mostly containing nitrates, to the soil, decay of animal and vegetable products in the soil where in the nitrogenous compounds get oxidized to nitrates, and due to fixation of nitrogen in nature.

Water with more than 45 mg of nitrate per litre is bitter in taste and causes many physiological disorders like gastrointestinal cancer, alzheimer, reduces oxygen carrying capacity of blood in children causing a condition called blue-baby syndrome.

## Determination of Nitrate in Water

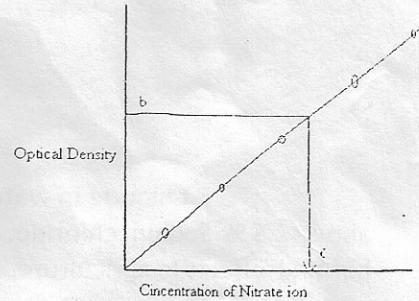
**Principle:** Nitrate reacts with Phenol Di-sulphonic Acid (PDA) to give a nitro derivative in alkaline solution, which is yellow in colour. The colour produced is proportional to the concentration of nitrate content according to Beer's law. Hence by preparing a calibration curve using standard nitrate solutions the nitrate content in water sample can be found using a colorimeter or Spectrophotometer.

**Procedure:** a) Preparation of PDA solution: Dissolve 12.5 g of Phenol in 75 ml of conc.  $H_2SO_4$ . Add further 80 ml of the acid and heat for 2 hours on a water bath and cool.

b) Preparation of Calibration curve: Take 5, 10, 15, 20 and 25 ml of standard  $KNO_3$  solution (Prepared by dissolving a known weight of about 0.367 g of  $KNO_3$ , [say 'w' g] in 500 ml of water) in separate 50 ml beakers and evaporate to dryness. Add 2 ml PDA solution to each one and dissolve the residue. Transfer each quantitatively in to separate 100 ml standard volumetric flasks. Add 10 ml conc.  $NH_3$  and dilute up to the mark with water and mix well. Measure the absorbance or optical density using 410 nm wave length filter in a colorimeter. Plot the graph to get the calibration curve.

c) Determination Nitrate content in the sample: Pipette out a known volume of the water sample (say 'a' ml) in to a 50ml beaker and evaporate to dryness. Add 2 ml of PDA and dissolve the residue. Transfer it quantitatively in to a 100 ml standard flask. Add 10 ml of conc.  $NH_3$  and dilute to the mark with water and mix well. Measure the absorbance or optical density for this sample also and find the concentration of nitrate from the graph say 'a' ml

Flask No	Volume of Nitrate solution Taken 'V' ml	Wt. of $KNO_3$ ( $w/500$ ) $\times V$ = 'A' g	Conc. Of $NO_3^-$ ( $62/101$ ) $\times A$ = 'B' g	Absorbance OD
1	5			
2	10			
3	15			
4	20			
5	25			
Test flask	Unknown volume 'a' ml		From Graph 'c'	'b'



**Calculations:** Mol. wt of  $KNO_3$  = 101, Mol. wt of  $NO_3^-$  = 62. Wt. of  $KNO_3$  in 500 ml = 'w' g. Hence, weight of  $KNO_3$  per ml =  $w/500$  g

If 'a' ml of unknown sample shows O.D value as 'b', and the corresponding concentration of Nitrate is 'c' from the calibration curve,

$$NO_3^- \text{ content in water} = c/a \times 1000 \text{ g/dm}^3$$

$$= \{c/a \times 1000\} \times 1000 = \dots \text{mg/dm}^3$$

**Sulphate content**  
**Chloride content**

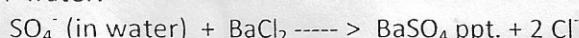
**Sulphate content in Water**

Sulphate ions usually occur in water due to sulphate rocks, the oxidation of sulphide ores, addition of gypsum in the treatment of water and air and water pollution.

Sulphate ions combine with Ca and Mg ions to form their salts which cause hardness to water and boiler scales. Water containing more than 250 mg of Sulphate per litre is objectionable. Water with more than 1000 mg of sulphate per litre may be purgative.

**Determination of Sulphate content in Water (Gravimetric method)****Principle:**

When water sample containing  $\text{SO}_4^{2-}$  is acidified, boiled and mixed with  $\text{BaCl}_2$ , it forms a ppt. of  $\text{BaSO}_4$  which is highly insoluble. From the weight of  $\text{BaSO}_4$  obtained formed it is possible to estimate Sulphate content in water.

**Procedure:**

Pipette out 100 ml of the water sample in to a beaker and add conc. HCl drop wise till acidic. Test it by adding a drop of methyl red till colour changes to pink. Boil the sample until the volume is reduced to half. Add hot  $\text{BaCl}_2$  (10 %) solution slowly with constant stirring until all the sulphate is precipitated. Digest for an hour on a water bath and filter either through a weighed sintered glass crucible or through a Watmann filter paper No 42. Wash the ppt. with water until the washings are free from chlorides. Dry the ppt. or ignite the ppt. as the case may be, cool and weigh as  $\text{BaSO}_4$  ('w' g.)

**Calculations:**

$$\text{Volume of water sample taken} = 100 \text{ ml},$$

$$\text{Weight of } \text{BaSO}_4 = 'w' \text{ g.}$$

$$233.3 \text{ g of } \text{BaSO}_4 \text{ contains } 96.0 \text{ g of } \text{SO}_4^{2-}$$

$$\text{Hence } 'w' \text{ g. of } \text{BaSO}_4 \text{ contains } (96.0 \times w)/233.3 \text{ g. of } \text{SO}_4^{2-} \\ = 'm' \text{ grams of } \text{SO}_4^{2-} \text{ in } 100 \text{ ml of water.}$$

$$\text{Hence, } \text{SO}_4^{2-} \text{ content in water per litre in mg} = (m/100) \times 1000 = 10 m \text{ g. dm}^{-3} \times 1000 \\ = ..... \text{ mg dm}^{-3}$$

**Chloride Content in Water**

Chloride in water is due to the soluble salts in soil or mixing of sea water as it contains about 2.5 % Sodium chloride. It causes metallic corrosion of structures, pipes etc in industry besides harmful effects in agriculture. More than 250 mg of chloride per litre of water is objectionable.

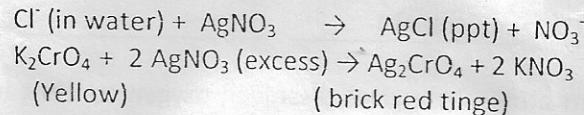
**Determination of Chloride content in Water (by Argentometry)**

This method is based on the precipitation titration of Silver compounds and hence it is called argentometry.

**Principle:**

When silver nitrate is treated with the sample of water containing chloride, it forms  $\text{AgCl}$  ppt. But when  $\text{K}_2\text{CrO}_4$  is used as indicator, the excess of  $\text{AgNO}_3$  beyond the end point reacts with

$\text{K}_2\text{CrO}_4$  to give a brick red ppt of  $\text{Ag}_2\text{CrO}_4$ . By knowing the quantity of  $\text{AgNO}_3$  consumed, chloride content can be determined.



### **Procedure:**

Pipette out 100 ml the water sample in to a conical flask , add 2-3 drops of potassium chromate indicator and titrate against standard  $\text{AgNO}_3$  until the colour changes from yellow to brick red tinge. Note the volume of  $\text{AgNO}_3$  consumed,  $V_1$  ml.

(Note that water sample for titration should be nearly neutral. In acidic condition solubility of silver chromate increases while in basic condition  $\text{AgOH}$  and  $\text{Ag}_2\text{O}$  will be formed, and interfere in accuracy of the results.

## Calculations:

Volume of water taken = 100 ml,

Volume of  $\text{AgNO}_3$  =  $V_1$  ml

Concentration of  $\text{AgNO}_3 = N_1$

Normality of Chloride in water =  $(N_1 \times V_1 / 100) \equiv N_2$

Hence, Chloride content in water in mg =  $N_2 \times 35.5 \times 1000 = \dots \text{mg dm}^{-3}$

## ( Dissolved Oxygen Content )

Dissolution of oxygen from atmosphere gives dissolved oxygen content in water. Algae and rooted aquatic plants also give out oxygen in to water through photosynthesis.

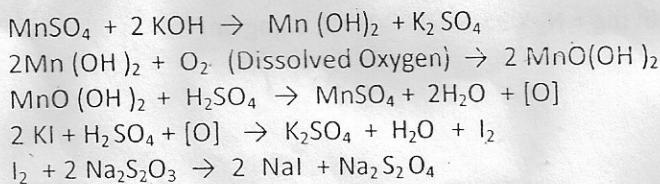
Dissolved oxygen is required for biological oxidation of pollutants. However oxygen being an oxidizing agent it causes corrosion in industry.

**Determination of Dissolved Oxygen content in water (Winkler's Method)**

Dissolved oxygen cannot be directly estimated by titration, but however oxygen being an oxidizing agent it can be estimated in an indirect way.

**Principle:**

When a strong alkaline solution of  $MnSO_4$  (divalent) is added to a water sample containing dissolved oxygen , it picks up oxygen to form basic  $MnO(OH)_2$  ( tetravalent) which is used to oxidise  $KI$  to  $I_2$ . The liberated Iodine is found by titrating against a standard  $Na_2S_2O_3$  thereby oxygen content is estimated.

**Procedure :**

In a stoppered bottle containing 300 ml of water sample add 3 ml  $MnSO_4$  and 3 ml alkaline  $KI$ . Stopper the bottle and shake well for 10 to 15 minutes . Allow to stand for 2 minutes. Then add 1 ml conc.  $H_2SO_4$  and mix well to dissolve  $MnO_2$  ppt and to liberate  $I_2$ .

Pipette out 100 ml of the above solution in to a conical flask and titrate against standard Sodium thiosulphate solution using 2 ml of starch solution as indicator near the end point until the blue colour is just discharged. Note the volume of  $Na_2S_2O_3$  required (say  $V_1$  ml ).

**Calculations:**

$$\text{Volume of water sample taken} = 100 \text{ ml}$$

$$\text{Volume of } Na_2S_2O_3 \text{ consumed} = V_1 \text{ ml}$$

$$\text{Normality of } Na_2S_2O_3 \text{ used} = N_1$$

$$\text{So, Normality of D.O in water} = (N_1 \times V_1) / 100 = N_2$$

$$\begin{aligned} \text{Hence, Dissolved Oxygen content} &= N_2 \times 8 \times 1000 \\ &= \dots\dots\dots \text{mg/dm}^3. \end{aligned}$$

**Biological Oxygen Demand (B.O.D)**

Sewage water contains a lot of organic pollutants which undergo anaerobic oxidation to give products with stinking smell. Such waste water requires oxygen for the oxidation.

**Definition:** "The amount of oxygen required in milligrams for the biological oxidation of organic matters under aerobic condition, present in one litre of waste water over an incubation period of five days at 20°C, is called biological oxygen demand".

Oxygen present in water is capable of oxidizing the biologically oxidizable pollutants, with the help of bacteria and in this way the oxygen in water is consumed.

**Determination of B.O.D :**

**Principle:** When a sample of water containing dissolved oxygen is treated with  $MnSO_4$  and alkaline KI solutions, dissolved oxygen oxidizes  $Mn^{2+}$  to  $Mn^{4+}$ . On acidification  $Mn^{4+}$  liberates  $I_2$  from KI which is estimated by standard  $Na_2S_2O_3$ . By determining the dissolved  $O_2$  content in water before and after incubation period it is possible to find B.O.D

**Procedure:**

a) **Preparation of Two separate diluted waste water sample :** Pipette out a known volume of sewage water sample ('A' ml) and dilute it to a known volume ('B' ml) by adding dilution water containing free oxygen and nutrients. Fill in two bottles.

b) **Blank titration:** In bottle -1 find D.O immediately as follows: Add 2 ml  $MnSO_4$  + 3 ml alkaline KI. Stopper the bottle and mix well for 10-15 minute. Wait for 2 minutes and then add 1 ml conc.  $H_2SO_4$  to dissolve  $MnO_2$  ppt and to liberate  $I_2$ . A known volume of this solution ('V' ml) is titrated against std.  $Na_2S_2O_3$  using 2 ml of starch as indicator near the end point. Note the volume of  $Na_2S_2O_3$  required (say  $V_1$  ml).

c) **Back titration :** Bottle -2 is incubated for 5 days at 20°C. After 5 days, add 2 ml  $MnSO_4$  + 3 ml alkaline KI. Stopper the bottle and mix well for 10-15 minutes. Wait for 2 minutes and then add 1 ml of conc.  $H_2SO_4$  to dissolve  $MnO_2$  ppt and to liberate  $I_2$ . Pipette out same known volume of this solution ('V' ml) and titrate against the same std.  $Na_2S_2O_3$  as above. Note the volume  $Na_2S_2O_3$  required (say  $V_2$  ml ).

**Calculations:** 1) D.O from Blank titration: Volume of water sample taken = V ml,

$$\text{Volume of } Na_2S_2O_3 = V_1 \text{ ml}$$

$$\text{Normality of } Na_2S_2O_3 = N_1$$

$$\text{Normality of D.O in water} = (N_1 \times V_1) / V = N_2$$

$$\text{Hence, Amount of D.O in mg} = N_2 \times \text{Eq. wt of } O_2 \times 1000 = D_1 \text{ mg/dm}^3$$

2) D.O from back titration:

(After 5 days)

$$\text{Volume of water sample} = V \text{ ml}$$

$$\text{Volume of } Na_2S_2O_3 = V_2 \text{ ml.}$$

$$\text{Normality of } Na_2S_2O_3 = N_1$$

$$\text{Normality of D.O in water} = (N_1 V_2) / V = N_3$$

$$\text{Hence, Amount of D.O in mg} = N_3 \times \text{Eq. Wt of } O_2 \times 1000 = D_2 \text{ mg/dm}^3$$

Therefore,

$$\text{B.O.D of the sample} = (D_1 - D_2) (B/A) = \dots \text{mg dm}^{-3}$$

$$\text{Chemical Oxygen Demand (C.O.D)}$$

Effluent coming out of domestic and industrial areas contain both biologically oxidizable organic pollutants and chemically oxidizable organic and inorganic pollutants. For oxidation of such pollutants a strong oxidizing agent such as  $K_2Cr_2O_7$  which can release a large amount of oxygen is required.

**Definition:** "The amount of oxygen in milligrams used in the chemical oxidation of biologically oxidizable, organic and inorganic pollutants present in one litre of waste water is called chemical oxygen demand".

COD gives the total oxidizable impurities including biologically oxidizable, and chemically oxidizable organic and inorganic matters in the sewage.

#### Determination of C.O.D :

##### Principle:

A known volume of waste water sample is taken and refluxed with a known quantity of  $K_2Cr_2O_7$  solution in  $H_2SO_4$  in presence of  $Ag_2SO_4$  (to catalyse the oxidation of straight chain organic compounds) and  $Hg SO_4$  (to avoid the interference of chloride by forming a soluble complex). The amount of  $K_2Cr_2O_7$  unconsumed and thereby the amount of  $K_2Cr_2O_7$  consumed is determined by using Std. F. A. S, which corresponds to C.O.D of the sample.

##### Procedure:

- Preparation of Std. F.A.S solution:** Dissolve a known weight of F.A.S in water with a drops of dil.  $H_2SO_4$  in a 250 ml Std. volumetric flask and make up to the mark with water and mix well. Let its Normality be = Wt. of F.A.S  $\times 4$  / Equivalent wt. of F.A.S
- Back Titration :** A known volume of waste water sample is taken ( $V$ ) ml in to a conical flask and 1 g. of  $Ag_2SO_4$  and 1 g. of  $Hg SO_4$  are added, followed by a known volume of  $K_2Cr_2O_7$  acidified by  $H_2SO_4$ . The solution is refluxed for 2 hours. Cooled and titrated it against a standard F. A. S solution using ferroin as indicator till the wine red colour is just obtained. Note the volume of F.A.S required (say,  $A$  ml).
- Blank titration :** The above procedure is repeated by taking the same volume of distilled water instead of waste water sample. Note the volume of F.A.S required after titration (say,  $B$  ml)

##### Calculations :

$$\text{Volume of waste water sample taken} = V \text{ ml}$$

$$\text{Normality of F.A. S used} = N$$

$$\text{Volume of F. A. S for back titration} = A \text{ ml}$$

$$\text{Volume of F. A. S for blank titration} = B \text{ ml}$$

So, the amount of  $K_2Cr_2O_7$  consumed in terms of 'N' normal F.A.S =  $(B - A)$  ml

$$\text{Hence, normality of oxygen in waste water } N_1 = [(B - A)/V] \times N$$

$$\text{Hence, C.O.D of the sample} = N_1 \times \text{Equiv. wt. of Oxygen in mg.}$$

$$= N_1 \times 8 \times 1000$$

$$= \dots \text{mg dm}^{-3}$$

**Sewage Treatment**

Sewage is water-carried waste, in solution or suspension. It includes household waste liquid from toilets, baths, kitchen and also from industry and commercial establishments.

**Definition of Sewage:** "Sewage is the effluent coming out of domestic and industrial areas, containing a lot of solids, mud, clay, biologically oxidizable matters, organic and inorganic matters and pathogenic bacteria, giving annoying smell"

Domestic waste water treatment is the process removing contaminants from waste water. Its objective is to produce environmentally-safe fluid and solid wastes suitable for disposal or reuse.

- Effects of Sewage:**
1. It seeps in to potable water
  2. Causes destruction of aquatic life,
  3. Gives bad smell
  4. Causes water-borne diseases.

**Stages of Treatment for Domestic Sewage :** It involves removal of solids, suspended matters, organic compounds and bacteria. This is carried out in three stages :

- 1) Primary treatment
- 2) Secondary treatment
- 3) Tertiary treatment

**Primary treatment:** This treatment is meant for removal of all solids. It consists of

- 1) Screening: By passing sewage water through bar screens and mesh screens. Large floating and suspended particles are removed.
- 2) Silt and Grit removal: Silt and grit (broken glass sand etc) are removed by settling down in a grit chamber
- 3) Removal oils and grease: By adding soap they are converted in to soapy mixture and by blowing air to form foams and then skimmed off.
- 4) Sedimentation: Fine suspended particles are removed by sedimentation with coagulants like alum, Ferrous sulphate etc., in 1-2 hours.

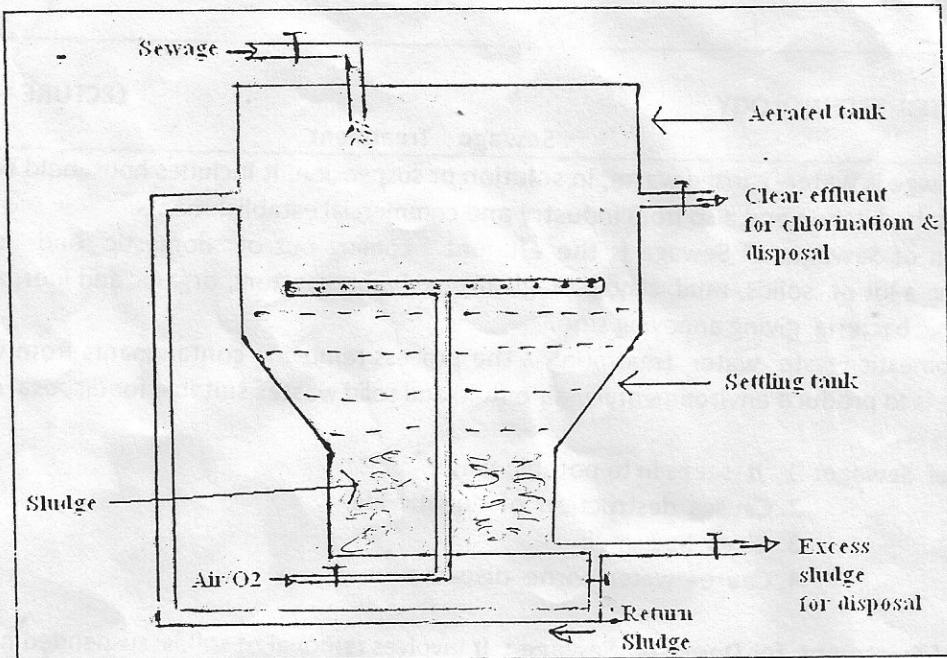
**Secondary Treatment:** This treatment is meant for biological oxidation of organic pollutants with the help of oxygen and bacteria so that they are converted in to  $\text{CO}_2$  and nitrates and sludge. There are two different methods: 1) Trickling filter process 2) Activated sludge process.

**Activated Sludge Process:**

**Principle:** When sewage is treated with air or oxygen in presence of a part of the sludge from previous oxidation process, the oxidation reaction will be much faster as the sludge containing microorganisms will act as an activator.

**Process:** It consists of an aeration tank and a settling tank connected to each other and provided with pipes for aeration, removal of clear effluent and settled sludge.

The sewage containing activated sludge is mixed, agitated and aerated vigorously with required amount of oxygen for 4-10 hours and then allowed to settle down in the settling tank. The bacteria present in the activated sludge multiply rapidly as a result of which organic solids present in the sewage are readily oxidized and the suspended as well as colloidal matter coagulate and precipitate. A part of the settled sludge is sent for recirculation as activated sludge and the rest is used as fertilizer. The residual water is chlorinated to remove bacteria and finally discharged in to the sea or river or spread over an open land.



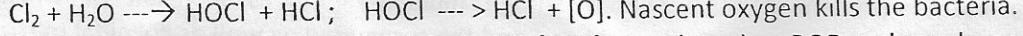
- Advantages:**
- 1) It gives clear effluent.
  - 2) Effluent is free from bad smell.
  - 3) Degree of purity can be varied depending on the purposes of the effluent.

- Disadvantages:**
- 1) Skilled supervision and check on return sludge is required
  - 2) Not suitable for industrial wastes as they contain inorganic wastes.
  - 3) Large volume of sludge creates a disposal problem

#### Tertiary Treatment

The aim of tertiary treatment of sewage is for further purification as well as its recycling as pure water. It is the most advanced phase of sewage treatment which is provided to only about 2% of the sewage. The main steps involved in this treatment are:

- 1) **Removal of phosphates and nutrients:** This is done by adding  $\text{Ca}(\text{OH})_2$  at pH 10 to 11. Flocculant precipitate of phosphates will be formed.  $\text{NH}_4$  salts will be converted into  $\text{NH}_3$  gas at that pH.
- 2) **Coagulation and Sedimentation:** Suspended fine particles are removed by sedimentation in presence of coagulants like alum,  $\text{FeSO}_4$ , etc.. The coagulants trap the suspended particles and settle down at the bottom.
- 3) **Filtration:** The waste water is passed through sand and filter beds to remove the last traces of suspended matter.
- 4) **Removal of gases:** Degasification of  $\text{NH}_3$ ,  $\text{CO}_2$ , and  $\text{H}_2\text{S}$  are done in a degasifier where hot water is allowed to trickle down through perforated plates. Hot temperature promotes the removal of gases.
- 5) **Disinfection:** The pathogenic bacteria are destroyed by disinfection. Chlorine is the most effective and cheap disinfectant used.



Thus the treated waste water has high clarity, free from odour, low BOD and nearly equivalent to drinking water.

**Potable Water**

**Definition:** "Water that is fit for human consumption and meets all the safe microbiological and chemical standards of quality is called potable water."

Water that is fit for drinking should be i) reasonably soft ii) have high degree of clarity iii) free from smell and colour iv) should have agreeable taste v) free from pathogenic bacteria vi) pH should be around 7 to 7.2 vii) should not contain minerals like lead, arsenic, chromium etc.,

**Purification of water****Reverse Osmosis Process**

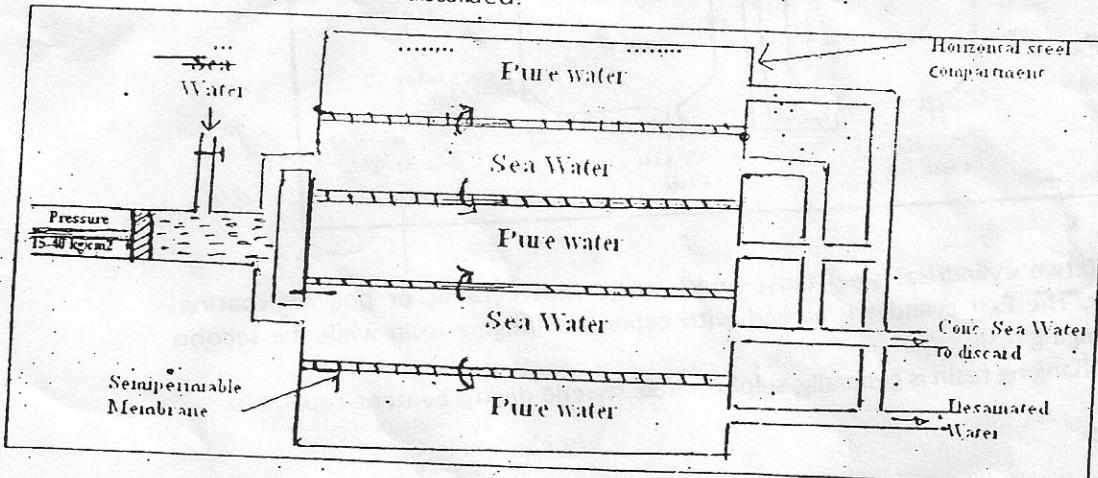
Reverse Osmosis (RO) is the most economical and highly effective method of removing several impurities from water such as total dissolved solids, turbidity, toxic metals, organic compounds, pesticides etc.

**Principle:** When pure water and a solution of a salt are separated by a semi permeable membrane, which can permit only water molecules to pass through, pure water will flow in to the salt solution by a natural tendency called osmosis. This natural tendency can be reversed by applying an opposite pressure more than the osmotic pressure, to the salt solution so that water from the salt solution tends to flow out as pure water. This is the basis of reverse osmosis.

**Method:**

It consists of several horizontal steel compartments separated by semi permeable membrane made out of Cellulose acetate or poly methyl methacrylate.

A pressure of 15 to 40 kg cm<sup>-2</sup> is applied to the brackish water or sea water to force its pure water to pass out through the semi permeable membrane in to the neighbouring compartments leaving behind concentrated sea water. The pure water passed in to the different compartments are collected while the concentrated sea water left out is discarded.

**Advantages of the method:**

- 1) This method can remove ionic, non ionic, colloidal and high molecular weight impurities.
- 2) The life time of the membrane is very high- about 2 years
- 3) It has low capital cost
- 4) Membrane can be replaced easily
- 5) Maintenance is low

Purification of Water  
Nano materials for Water purification – Nano filters

Water used for industrial purpose should be sufficiently pure and free from all hardness producing salts. There are several methods by which water can be softened. Among them Ion exchange method is most important as it can remove all ions from water.

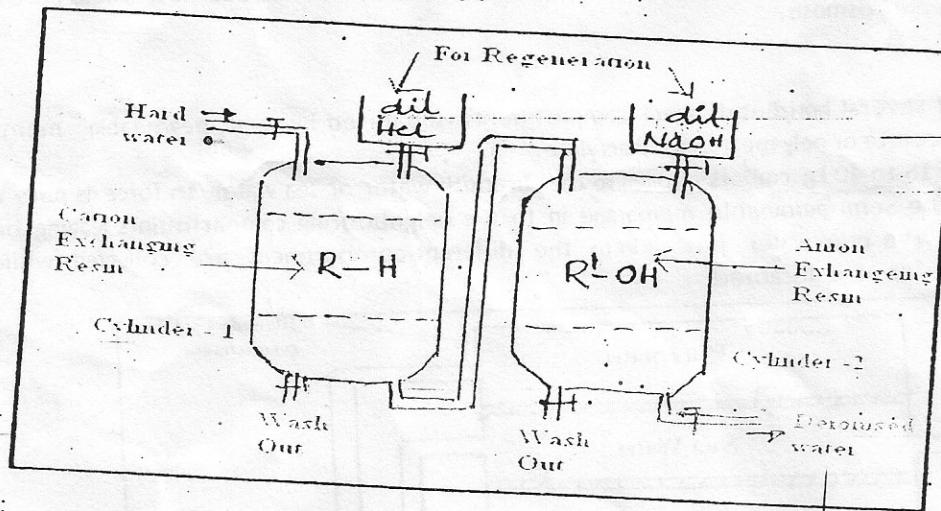
**Ion Exchange Method**

(De-ionization Process, Demineralization Process)

This method makes use of some organic resins capable of replacing cations and anions from water. When water is passed through these resins, the ions are exchanged for  $H^+$  and  $OH^-$  ions respectively giving de-ionised water. Since water is free from all minerals it is also called de-mineralization process.

**Principle:**

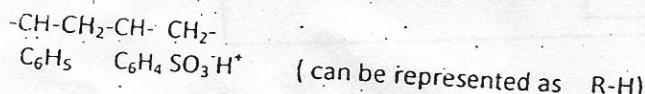
When a sample of hard water is passed through a Cation exchanging resin bed, the  $H^+$  ions replace all cations, and then through an anion exchanging resin bed, the  $OH^-$  ions replace all anions from water, thus giving de-ionised water.



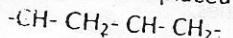
**Construction:**

It consists of two cylindrical steel tanks lined inside with ceramic or polymer coating, connected to each other. The first cylinder is packed with cation exchanging resin while the second cylinder with anion exchanging resin.

The cation exchanging resin is generally, sulphonated styrene divinyl benzene copolymer with replaceable  $H^+$  ions.



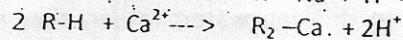
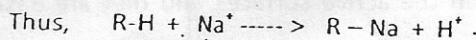
The anion exchanging resin is generally, styrene divinyl benzene copolymer with quaternary amino group with replaceable  $OH^-$  ions.



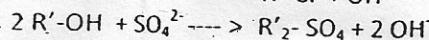
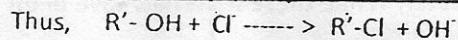
These resins are characterized by the fact that i) they are solid in state ii) insoluble in water iii) they replace cations and anions respectively iv) they can be regenerated and used again.

**Process:**

Hard water is passed through the first cylinder containing cation exchanging resin where all cations such as  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  etc., are removed and  $\text{H}^+$  ions are released into the water.

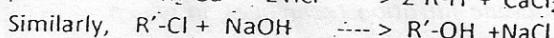
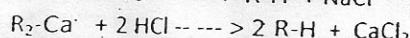
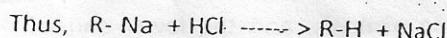


Water coming out of the first cylinder is then passed through the second cylinder containing anion exchanging resin where all anions such as  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$  etc., are removed and  $\text{OH}^-$  ions are released into the water.



$\text{H}^+$  and  $\text{OH}^-$  thus released combine to produce water molecules,  $\text{H}^+ + \text{OH}^- \longrightarrow \text{H}_2\text{O}$

**Regeneration:** The exhausted cation exchanging and anion exchanging resins are regenerated by passing dil.  $\text{HCl}$  and dil.  $\text{NaOH}$  through the respective resin beds.



The resin beds thus obtained are washed with de-ionised water and used again.

- Advantages:**
1. Can be used to soften acidic and alkaline water
  2. Water is free from all ions and hence can be used for high pressure boilers
  3. Resins can be regenerated and used again
  4. Process is simple to operate

**Disadvantages:**

1. Equipment is costly
2. Water with turbidity cannot be treated
3. Water containing heavy metals should not be passed since regeneration of resins becomes difficult

### Nanomaterials for water purification – Nano filters (NF)

#### Introduction

There is a significant need for novel advanced water technologies, in particular to ensure a high quality of drinking water, eliminate micropollutants, and intensify industrial production processes by the use of flexibly adjustable water treatment systems. Nano engineered materials, such as nano adsorbents, nanometals, nanomembranes, and photocatalysts, offer the potential for novel water technologies that can be easily adapted to customer-specific applications.

The new approaches based on nanotechnology are continually being used in water purification methods. These need to be lower in overall cost, durable and more effective than current options for the removal of water pollutants. It is in this context, the nano-enabled technologies (nano filtration) fare being considered. These consist of filtration materials that have enhanced performance arising

from their smaller size and high specific surface area. These nano filters will play a significant role in water treatment in the future.

Nanomaterials used for nano filtration have smaller size (nm) and high surface areas, however, because of the fine pores, not all the water can easily reach the active surfaces and they are easily plugged. These fine particles fibers cannot just be added to drinking water; rather, they must be incorporated into filtration media that allow for the contaminants to readily come in contact with the active media. Attention is being given to the development of filters that can take advantage of the properties of nanomaterials for removal of contaminants from water. While these materials have been shown to be extremely effective, cost is still a major issue.

**Q- What is nano filtration? Write advantages and applications.**

Nano filtration (NF) is a fairly recent development in the range of membrane separation processes, which takes in the upper end (in separation size terms) of reverse osmosis, and the lower end of ultrafiltration. Nano filtration is defined as 'It is one of the membrane filtration techniques, in which water is passed over a membrane which acts almost like a sieve to separate out impurities. The membrane blocks impurities in the water sample, allowing only the water and certain monovalent ions to pass through while trapping undesirable materials on the other side'.

**Design of nano membranes:** The membranes are key to the performance of nano filtration systems. Nanomaterials like activated materials like carbon or alumina, metal oxides, porous silicates, etc. are embedded into filtration media like cellulose derivatives and synthetic polymers, from inorganic materials, ceramics or from organic/inorganic hybrids. The nano filtration is essentially a liquid phase one, because it separates a range of inorganic and organic substances from water. This is done by diffusing water through a membrane, under pressure differentials that are considerably lesser than those for reverse osmosis, but still significantly greater than those for ultrafiltration. Membranes are designed in the form of plate, spiral wound, tubular, capillary or hollow fibre formats.

**Working of NF:** it can work on lower pressure than RO. When pressure is applied on contaminated water, monovalent and water molecules pass through the membrane. The divalent ions like calcium, magnesium, iron (micronutrient, required for the body) are partially arrested, while virus, bacteria, suspended solids are completely arrested by nano membrane. The Figure below shows how water is purified by nano filter membrane by showing what it will let through and what it will not allow to pass through.

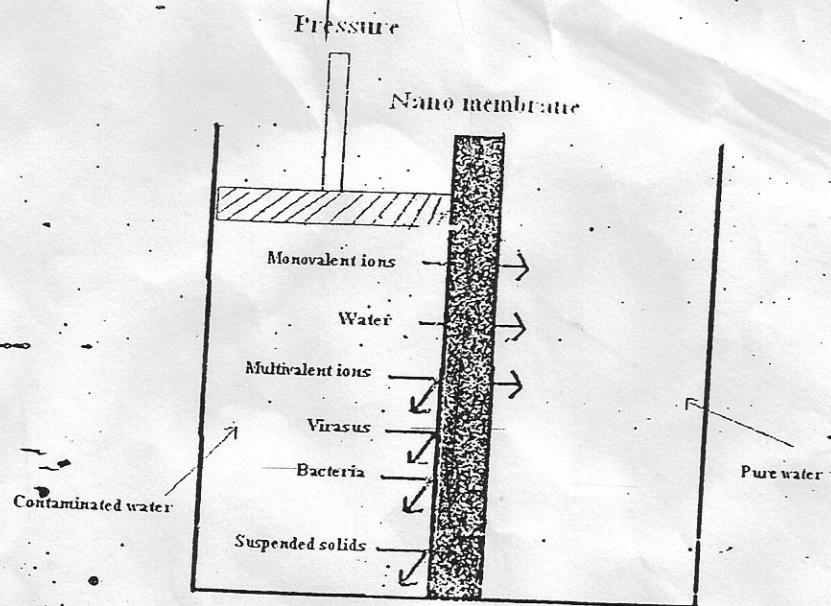


Figure: Nano filter

#### Advantages of NF

- Works on lower pressure than RO and so requires much less energy
- Recovery in NF water purifiers is more than RO and so NF does not waste as much water as an RO
- Ideal for drinking water purification of any water source with TDS less than 1000ppm
- NF also used for the removal of natural organic matter from water, toxic heavy metals, odours, colours, and in the removal of trace herbicides from large water flows.
- NF can also be used for the removal of residual quantities of disinfectants in drinking water
- NF will remove upto 60% of hardness salts of calcium and magnesium in water
- Nano filter water purifiers have a lesser tendency of fouling of its membranes.

#### Applications

- The conversion of sea water into potable water (desalination) is another prosperous field of application since comparable desalination technologies are very cost-intensive.
- One of the main uses of NF membranes in industrial applications is to soften water or remove water hardness.
- Applications in the food and dairy sector, in chemical processing, in the pulp and paper industry, and in textiles, although the chief application continues to be in the treatment of fresh, process and waste waters.

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