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CHAPTER- 1

Water analysis and Treatments

Introduction:

Water is the most essential compound for all living matter on the earth. It plays an important role in human living, industrial and agricultural purposes. So there is no life in the earth without water. The pure water is composed of two parts of hydrogen and one part of oxygen by volume and dissolves many substances. These dissolved salts are the impurities in water. Water is a very good solvent. So it is called as universal solvent.

Sources of water:

The two important sources of water are (1) surface water and (2) underground water.

Surface water

The water available on the earth's surface is called as surface water. Surface water includes rainwater, river water, lake water and seawater.

Underground water

Underground water includes water present between the rocks in the earth crust, spring water, well water etc.

Reason for Depletion of underground Water:

The decrease in the quantum of underground water is depletion of water. Depletion of water is mainly caused by,

1. Modernization, industrialization and population growth
2. Global warming causing excess evaporation of surface water
3. Deforestation
4. Decrease in rainfall caused by seasonal changes and
5. Effluents from the industries spoiling the ground water source

To meet out this depletion of ground water sources, it is essential to find alternate plans using water management techniques to recharge the ground water sources. One of the techniques adopted is rainwater harvesting.

Testing procedures of water:

Testing procedures and parameters may be grouped into physical, chemical, bacteriological and microscopic categories.

- *Physical tests* indicate properties detectable by the senses.
- *Chemical tests* determine the amounts of mineral and organic substances that affect water quality.
- *Bacteriological tests* show the presence of bacteria, characteristic of faecal pollution.

(i) Physical tests:

Colour, turbidity, total solids, dissolved solids, suspended solids, odour and taste, temperature are recorded.

(a) Colour: Colour in water may be caused by the presence of minerals such as iron and manganese or by substances of vegetable origin such as algae and weeds. Colour tests indicate the efficacy of the water treatment system.

(b) Turbidity: Turbidity in water is because of suspended solids and colloidal matter. It may be due to eroded soil caused by dredging or due to the growth of micro-organisms. High turbidity makes filtration expensive. If sewage solids are present, pathogens may be encased in the particles and escape the action of chlorine during disinfection. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity.

(c) Odour and taste: Odour and taste are associated with the presence of living microscopic organisms; or decaying organic matter including weeds, algae; or industrial wastes containing ammonia, phenols, halogens, hydrocarbons. This

taste is imparted to fish, rendering them unpalatable. While chlorination dilutes odour and taste caused by some contaminants, it generates a foul odour itself when added to waters polluted with detergents, algae and some other wastes.

(d)Temperature: Impinging solar radiation and atmospheric temperature brings about spatial and temporal changes in temperature, setting up convection currents and thermal stratification. Temperature plays a very important role in wetland dynamism affecting the various parameters. The temperature of drinking water has an influence on its taste.

(ii)Chemical tests

pH, Electrical Conductivity (E.C), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Calcium Hardness, Magnesium Hardness, Nitrates, Phosphates, Sulphates, Chlorides, Dissolved Oxygen (D.O), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Fluorides, Free Carbon-di-oxide, Potassium and Sodium are estimated.

(a)pH is a measure of hydrogen ion concentration. It is an indicator of relative acidity or alkalinity of water. Values of 9.5 and above indicate high alkalinity while values of 3 and below indicate acidity. Low pH values help in effective chlorination but cause problems with corrosion. Values below 4 generally do not support living organisms in the marine environment. Drinking water should have a pH between 6.5 and 8.5. Harbour basin water can vary between 6 and 9.

(b)B.O.D.: It denotes the amount of oxygen needed by micro-organisms for stabilization of decomposable organic matter under aerobic conditions. High B.O.D. means that there is less of oxygen to support life and indicates organic pollution.

(iii) Bacteriological tests:

The recognition that microbial infections can be waterborne has led to the development of methods for routine examination to ensure that water intended for human consumption is free from excremental pollution. Although it is now possible to detect the presence of many pathogens in water, the methods of

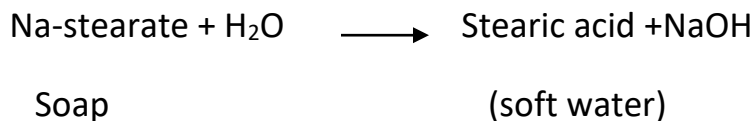
isolation and enumeration are often complex and time-consuming. It is therefore impractical to monitor drinking water for every possible microbial pathogen that might occur with contamination. A more logical approach is the detection of organisms normally present in the faeces of man and other warm-blooded animals as indicators of excremental pollution, as well as of the efficacy of water treatment and disinfection. The presence of such organisms indicates the presence of faecal material and thus of intestinal pathogens.

Conversely, the absence of faecal commensal organisms indicates that pathogens are probably also absent. Search for such indicators of faecal pollution thus provides a means of quality control. The use of normal intestinal organisms as indicators of faecal pollution rather than the pathogens themselves is a universally accepted principle for monitoring and assessing the microbial safety of water supplies. Ideally, the finding of such indicator bacteria should denote the possible presence of all relevant pathogens. In practice, these criteria cannot all be met by any one organism, although many of them are fulfilled by coliform organisms, especially *Escherichia coli* as the essential indicator of pollution by faecal material of human or animal origin.

Hardness of water: -

The water which does not give lather with soap is called Hard water. The Hard water contains dissolved calcium & magnesium salts.

Soft water: - The water which can give lather with soap easily is called as soft water.



Stearic acid + Na- stearate formation of lather



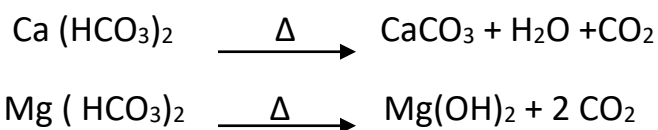
(Soluble salt)

Hard water:

Types of Hardness:- Hardness in water is of two types.

(1) Temporary hardness and (2) permanent hardness

Temporary hardness:- The hardness that can be removed simply by boiling is called the temporary hardness. It is due to the presence of boiling. On boiling $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$ are precipitated as insoluble salts.



Permanent Hardness :- Permanent hardness cannot be removed by boiling . It is due to CaCl_2 , CaSO_4 , MgCl_2 , MgSO_4 and nitrates in H_2O . These salts cannot remove this hardness. Fe^{3+} , Al^{3+} and Mn^{2+} also cause hardness in water.

The degree of hardness of drinking water has been classified in terms of the equivalent CaCO_3 concentration as follows:

Soft	0-60mg/L
Medium	60-120mg/L
Hard	120-180mg/L
Very Hard	>180mg/L

Units of Hardness :

1. Parts Per Million : Parts of CaCO_3 equivalent hardness per 10^6 parts of water

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

2. Milligrams per litre : Number of mille grams of Calcium Carbonate equivalent hardness present in 1 liter of water.

1 mg / L = 1 mg of CaCO_3 equivalent hardness present in 1 liter of water.

1 L = 1 Kg = 1000 g = 1000 x 1000 mg = 10^6 mg.

1 mg /L = 1 mg of CaCO_3 eq per 10^6 mg of H_2O = ppm

3. Clarke's degree ($^\circ\text{Cl}$): No of grains (1/700 16) of CaCO_3 equivalent hardness per 70,000 parts of water.

1°Clarke = 1 grain of CaCO_3 eq hardness per gallon of water.

= 1 part of CaCO_3 of hardness per 70,000 parts of water.

4. Degree French ($^\circ\text{Fr}$) : It is in the parts of CaCO_3 equivalent hardness per 10^5 parts of water.

1°Fr = One parts of CaCO_3 equivalent hardness per 10^5 parts of water

5. Milliequivalents per litre : - No of milli equivalents of hardness present per litre.

1 m eq/L = 1 mg of CaCO_3 per / litre of water.

= 10^{-3} x 50 g of CaCO_3 / litre

= 50 mg /L of CaCO_3 eq = 50 ppm

4.2 Estimation of hardness of water:

Hardness of water can be estimated by the following methods:

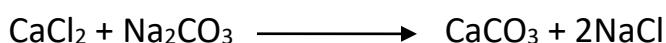
1. Hehner's method:

(A) Temporary hardness is determined by finding the alkalinity of water before boiling and that left after boiling (temporary hardness is removed by boiling).

Procedure: Pipette out 50ml of water sample in a conical flask, 2-3 drops of methyl orange indicator is added and titrated against N/50 HCl. The volume of acid used is 'V1ml. 100ml of water sample is taken in a pyrex beaker and evaporated to dryness. About 50ml of distilled water is added, warned, stirred to

dissolve the soluble portions left. The solution is filtered, washed the residue with distilled water. The solution is made up to 100mL. 50mL of this solution is taken in a conical flask and titrated against N/50HCl using methyl orange as indicator. The volume of acid used is 'V2'mL.

(B) Estimation of permanent hardness is based on the fact that it can be removed by boiling with a known excess of standard Na₂CO₃. The chloride and sulphates of calcium and magnesium form insoluble carbonates. The residual sodium carbonate is determined by titrating against a standard acid. The decrease in the amount of soda added is equivalent to permanent hardness.



Procedure: 50ml of the given water sample is taken in the beaker and 50ml of N/50 Na₂CO₃ solution is added. Boiled the solution for 15 minutes. Cooled the solution, filtered the precipitate and the filtrate is collected in a conical flask. Titrated the unused Na₂CO₃ present in the flask against N/50 HCl. Using methyl orange as an indicator. The titre value is 'V'

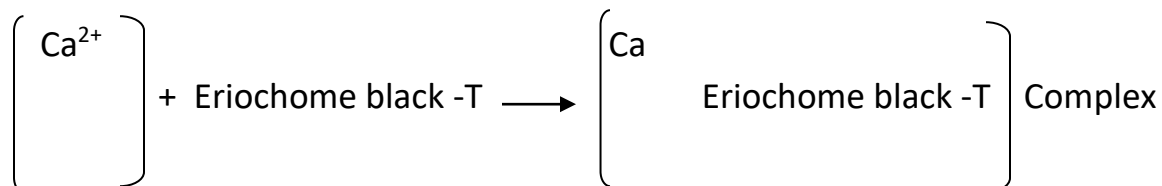
2. Estimation of hardness of water by EDTA Method:

This is a complexometric method. Ethylene diamine tetraacetic acid (EDTA) in the form of its sodium yields the anion.

Principle of EDTA titrations:

The quick, complete and 1:1 interaction of metal ions with EDTA leading to the formation of stable complex is the basis for complexometric titrations.

Theory: The hard water is buffer to a P^H value of 10 using NH₄OH-NH₄Cl buffer and few drops of EBT(Eriochrome Black T) indicator solution are added. EBT forms a weak complex with metal ions that has a wine-red colour. During the course of titration of water sample against EDTA, first EDTA combines with free Ca²⁺ or Mg²⁺ ions to give very stable and colour less metal-EDTA Complex. After all the free metal ions are consumed, the next drop of added EDTA solution displaces the indicator to form Metal-EBT complex.

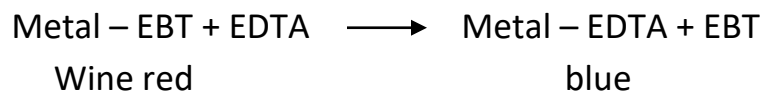
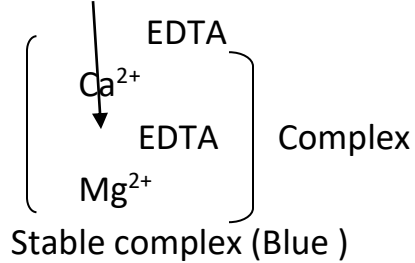




Mg

Unstable complex

(Wine Red)



At the equivalence point, there is change in colour from wine-red to blue.

Procedure:

Step – 1: Standardisation of EDTA solution:

The burette is filled with EDTA solution after washing and rinsing. Pipette out 50mL of standard hard water (1mL of it must contain 1mg of $CaCO_3$) into a 250mL conical flask, 10mL of buffer solution and 2-3 drops of EBT indicator are added and titrated against EDTA solution until the wine-red colour changes to blue. Let the volume of EDTA solution consumed be V_1 mL.

Step – 2: Determination of total hardness of water:

As per the same procedure (Step-1), 50mL of the unknown water sample is titrated against EDTA. Let the volume of EDTA solution consumed be V_2 mL.

Step -3: Determination of permanent hardness of water:

250mL of the water sample is taken in a 500mL beaker and boiled it till the volume is reduced to about 50mL. [The step causes all the bicarbonates to decompose respectively into insoluble $CaCO_3$ and $Mg(OH)_2$]. Filter and wash the

precipitate with distilled water and quantitatively collect the filtrate and washings in a 250mL conical flask and made up the volume to 250mL with distilled water. 50mL of this water sample is titrated against EDTA solution as in Step-1. Let the volume of EDTA solution consumed be V_3 mL.

Calculations:

Step – 1: *Standardisation of EDTA Solution:*

V_1 mL of EDTA = 50mL of standard hard water
= 50mg of CaCO_3 (1mL contains 1mg of CaCO_3)
1mL of EDTA = $50 / V_1$ mg of CaCO_3 equivalent hardness.

Step -2: *Determination of total hardness of water:*

50mL of unknown hard water sample = V_2 mL of EDTA
= $V_2 \times 50 / V_1$ mg of CaCO_3 eq.

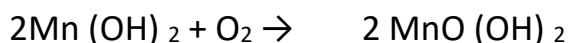
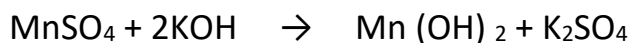
Step-3: *Determination of permanent hardness of water:*

50mL of boiled water = V_3 mL of EDTA
= $V_3 \times 50 / V_1$ mg of CaCO_3 eq.

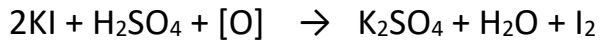
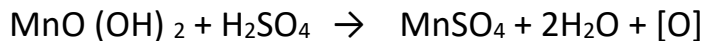
Step-4: *Determination of temporary hardness*

3. Determination of Hardness of Water by Winkler's method (Dissolved Oxygen):

The determination of dissolved oxygen is to bring about the oxidization of potassium iodide with the dissolved oxygen present in the water sample after adding MnSO_4 , KOH and KI . The basic manganese oxide formed acts as an oxygen carrier to enable the dissolved oxygen in the molecular form to take part in the reaction. The liberated iodine is titrated against standard hypo Solution using starch indicator.



Basic manganese oxide (Brown precipitate)



Experimental Procedure:

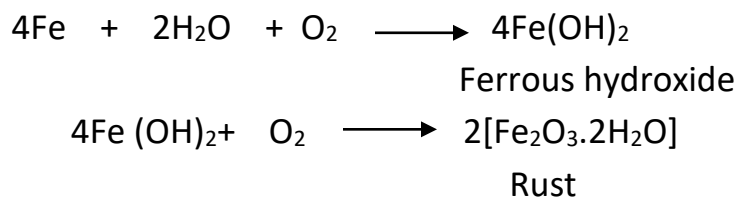
Take the standard flask with 200 ml of water to that add 2ml of MnSO_4 and 2ml of $\text{KI} + \text{KOH}$ (alkali potassium iodide). Light brown precipitate forms, to this add 2ml of conc. H_2SO_4 precipitation dissolved into brown colour. Take 100 ml of solution which is in the standard flask and pour it into conical flask. To the conical flask add 1–2ml of starch needed immediately colour changed to blue. Then titrate the solution with hypo solution until the solution becomes colourless. Note down the readings and repeat it. Amount of dissolved oxygen content is obtained in mg/ lit (or) ppm.

FORMULAE:

$$\text{D.O} = \text{Normality of Hypo} \times V \times 8 \times 1000$$

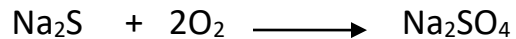
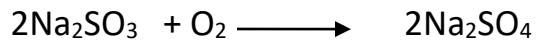
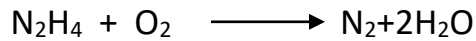
Volume of the sample

Dissolved oxygen: This is the most usual corrosion causing factor., water usually contains about 8ppm of dissolved oxygen at room temperature. Dissolved oxygen reacts with iron of boiler in the presence of water and under prevailing high temperature to form ferric oxide (rust).



Removal of dissolved oxygen:

(i) By adding calculated quantity of hydrazine or, sodium sulphite or, sodium sulphide.



(ii) **By mechanical deaeration:** The process consists of spraying water over preheated perforated plates stacked in a tower. Removal of dissolved oxygen is ensured by applying high temperature and vacuum.

Softening of water:

Definition: The process of removing hardness-causing salts from water is known as “Softening of water”.

Internal treatment:

Internal treatment means treating the raw water inside the boiler. In this process (sequestration), an ion is prohibited to exhibit its original character by ‘complexing’ or converting it into other more soluble salt by adding appropriate reagent. This can be done by two processes.

A) Appropriate chemicals are added to the boiler water to precipitate the scale-forming impurities in the form of ‘sludges’ which can be removed by blow-down operation.

B) Problem causing cations are converted into compounds that will stay in “dissolved form” in water and thus do not cause any harm.

Internal treatment methods are –

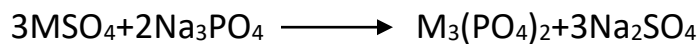
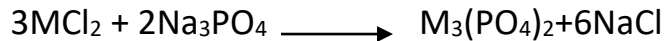
1) Colloidal conditioning:

Scale formation can be avoided in low-pressure boilers by adding organic substances like kerosene, tannin, agar-agar etc., that get adsorbed over the scale

forming precipitates, thereby yielding non-sticky and loose deposits, these can be removed easily by blow-down operation.

2) Phosphate conditioning:

It is applicable to high-pressure boilers. Formation of scales is avoided by adding sodium phosphate, that reacts with magnesium and calcium salts to form non-adherent and easily removable, soft sludge of calcium and magnesium phosphate. This can be removed by blow-down operation.



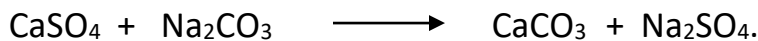
Where $M = Mg^{2+}$ or Ca^{2+}

The main phosphates employed are –

- a) NaH_2PO_4 – sodium dihydrogen phosphate (acidic)
- b) Na_2HPO_4 – disodium hydrogen phosphate (weakly alkaline)
- c) Na_3PO_4 – trisodium phosphate (alkaline)

3) Carbonate conditioning:

In low-pressure boilers, scale formation can be avoided by adding sodium carbonate to boiler water, when salts like $CaSO_4$ are converted into $CaCO_3$ in equilibrium.



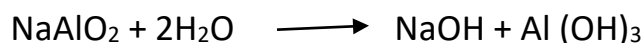
Deposition of $CaSO_4$ as scale does not take place and calcium is precipitated as loose sludge of $CaCO_3$ that can be removed by blow-down operation.

4) Calgon conditioning:

The method involves the addition of sodium hexameta phosphate (Calgon) to boiler water to prevent the formation of scale and sludge. Calgon converts the scale forming impurity like $CaSO_4$ into soluble complex compound.

5) Treatment with sodium aluminate ($NaAlO_2$):

Sodium aluminate gets hydrolysed yielding $NaOH$ and a gelatinous precipitate of aluminium hydroxide.



Sodium aluminate gelatinous precipitate. The sodium hydroxide formed precipitates some of the magnesium as $Mg(OH)_2$.



The flocculent precipitate of $Mg(OH)_2$ and $Al(OH)_3$ produced inside the boiler, entraps finely suspended and colloidal impurities. The loose precipitate can be removed by blow-down operation.

6)Electrical conditioning:

Sealed glass bulbs having mercury connected to a battery are set rotating in the boiler. When water boils, mercury bulbs emit electrical discharges, that prevents scale forming particles to adhere/stick together to form scale.

7) Radioactive conditioning:

Tablets having radioactive salts are placed inside the boiler water at a few minutes. The energy radiations emitted by these salts prevent formation of scales.

8) Complexometric method:

The method involves 1.5% alkaline(pH8.5) solution of EDTA to feed water. The EDTA binds the scale forming cations to form stable and soluble complex. As a result, the sludge and scale formation.

The treatment-

- a) Prevents the deposition of iron oxides in the boiler,
- b) Reduces the carryover of oxides with steam,
- c) Protects the boiler units from corrosion by wet steam

Methods used for softening of water:

- 1) Lime-soda process
- 2) Zeolite or, permutit process
- 3) Ion exchange process

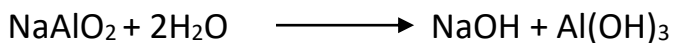
(1)Lime-soda process:

In this method, the soluble calcium and magnesium salts in water are converted chemically into insoluble compounds by adding calculated amounts of lime

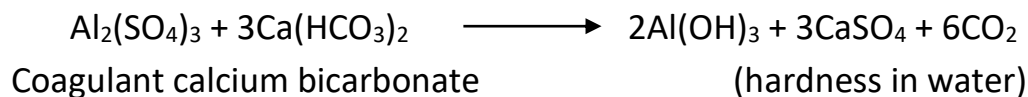
[Ca(OH)₂] and soda [Na₂CO₃]. Precipitates of calcium carbonate [CaCO₃] and magnesium hydroxide [Mg(OH)₂] formed are filtered off.

(i) Cold lime-soda process:

In this method, calculated quantity of lime and soda are mixed with water at room temperature. At room temperature, the precipitates formed are finely divided so they do not settle down easily and cannot be filtered easily. Hence, small amounts of coagulants like alum, aluminium sulphate, sodium aluminate etc, that hydrolyse to flocculent, gelatinous precipitate of aluminium hydroxide and entraps the fine precipitates. Sodium aluminate as a coagulant helps the removal of silica as well as oil. Cold Lime-soda process provides water having a residual hardness of 50-60ppm.



Sodium aluminate



Method:

Raw water and calculated quantities of chemicals (lime+soda+coagulant) are fed from the top into the inner vertical circular chamber fitted with a vertical rotating shaft carrying a number of paddles. As the raw water and chemicals flow down, there is a vigorous stirring and continuous mixing, there by softening of water takes place. As the softened water comes into the outer co-ocial chamber, it rises upwards, the heavy sludge settles down in the outer chamber. Then the softened water passes through a filtering media to ensure the complete removal of sludge. Finally filtered soft water flows out continuously through the outlet at the top Sludge settled at the bottom of the outer chamber is drawn off.

ii) Hot Lime-soda process:

The process involves in treating water with softening chemicals at a temperature of 94-100°C. since hot process is operated at a temperature close to the boiling point of the solution. So-

- The reaction proceeds faster.
- The softening capacity of hot process is increased to many fold.
- No coagulants are needed as the precipitate and sludge formed settle down rapidly.
- Most of the dissolved gases are driven out of the water.
- Filtration of water becomes much easier as the viscosity of softened water is lower. This in turn increases the filtering capacity of filters.

Hot lime-soda process produces water of comparatively lower residual hardness of 15-30ppm. Hot lime-soda plant consists of mainly 3 parts.

- a) a “reaction tank” in which raw water, chemicals and steam are thoroughly mixed.
- b) a “Conical sedimentation vessel” in which the sludge settles down.
- c) a “ sand filter” that ensures complete removal of sludge from the softened water.

Advantages of Lime-soda process:

- i) Lime-soda process is economical.
- ii) Treated water is alkaline and hence has less corrosion tendencies.
- iii) Due to alkaline nature of treated water, amount of pathogenic bacteria in water is considerably reduced.
- (iv) It removes not only hardness causing salts but also minerals.
- (v) Iron and manganese are also removed from the water to some extent.
- (vi) If the process is combined with sedimentation with coagulation, lesser amounts of coagulants shall be needed.

Disadvantages:

- (i) The process requires careful operation and skilled supervision for economical and efficient softening.

(ii) Sludge disposal is a problem.

(iii) The process can remove hardness only upto 15ppm, which is not good for high pressure boilers.

Zeolite or, permutit process:

Zeolites are naturally occurring hydrated sodium alumino silicate minerals (like Na_2O , Al_2O_3 , $x\text{SiO}_2 \cdot y\text{H}_2\text{O}$ where $x = 2-10$ and $y=2-6$) capable of exchanging reversibly its sodium ions for hardness-producing ions in water. Zeolites are known as permutits and in greek it means “boiling stone”.

Zeolites are of two types-

(i) Natural zeolites: These are non-porous, amorphous and durable.

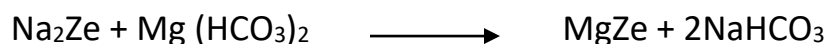
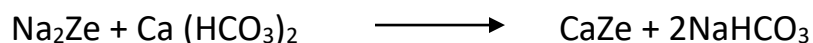
Ex: Natrolite, $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$

(ii) Synthetic zeolites: These are porous and possess a gel structure. Prepared by heating together sodium carbonate (Na_2CO_3), alumina (Al_2O_3) and silica (SiO_2) Synthetic zeolites possess higher exchange capacity per unit weight compared to natural zeolites.

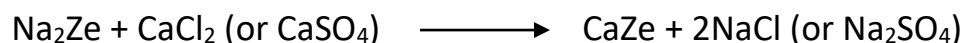
Process:

For softening of hard water by zeolite process, hard water is percolated at a specified rate through a bed of zeolite. Zeolite holds sodium ions loosely and can be represented as Na_2Ze . Where Ze=insoluble radical frame work. The hardness causing ions (Ca^{2+} , Mg^{2+}) are retained by the zeolite as CaZe and MgZe respectively, while the outgoing water contains sodium salts. During this process, the water becomes free from Ca^{2+} and Mg^{2+} ions.

Reactions taking place during the softening process –



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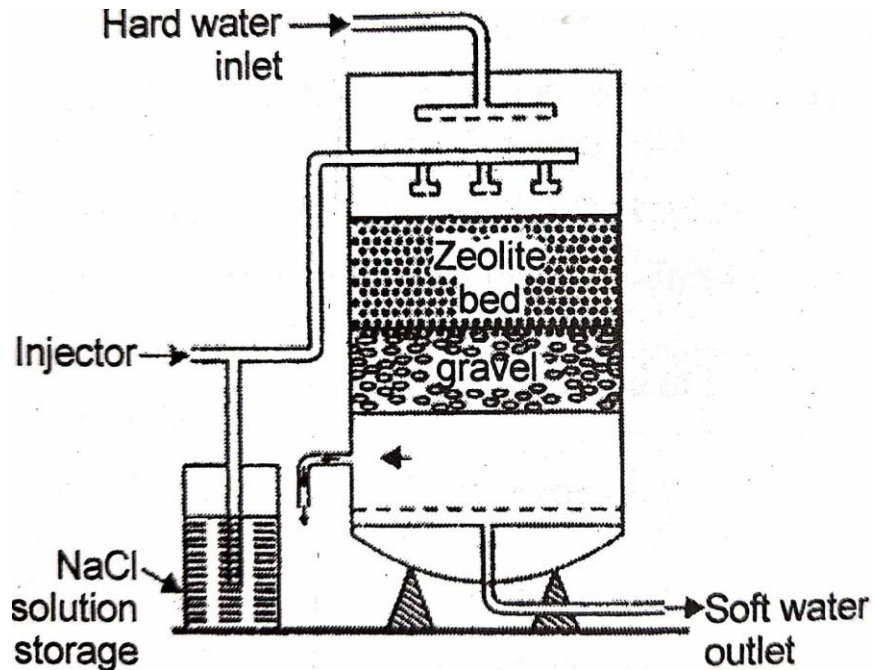
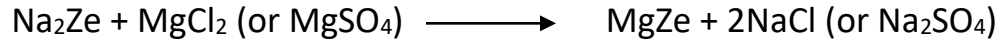
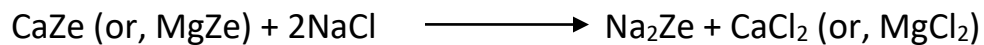


Fig: Zeolite process water softening

Regeneration:

After some time, the zeolite is completely converted into calcium and magnesium zeolites. Hence the bed ceases to soften water i.e, it gets exhausted, at this stage, the supply of hard water is stopped and the exhausted zeolite is reclaimed by treating the bed with a concentrated solution of sodium chloride(brine). The reaction taking place is



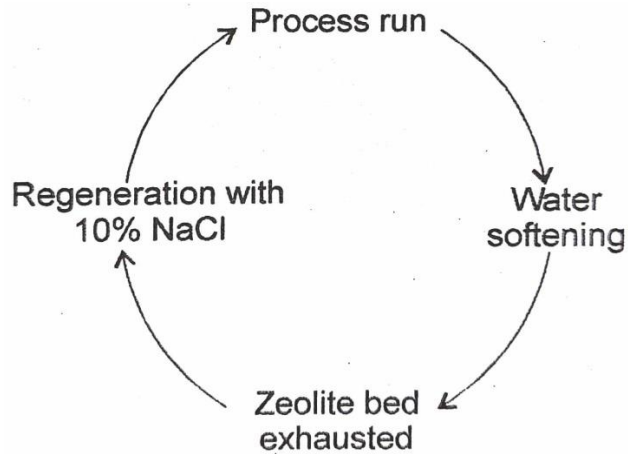


Fig: Working cycle of zeolite process

Exhausted zeolite brine reclaimed zeolite washings .The washings are led to drain and thus the regenerated zeolite bed is used again for softening purpose. The working of zeolite softeners involve alternate cycles of softening run and the regeneration run. The scheme for softening and regeneration processes are represented as below.

Limitations of zeolite process:

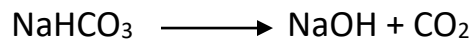
(i)The supplied water is turbid, the suspended matter must be removed before the water is fed to the zeolite bed. Otherwise the pores of the zeolite bed will get clogged by the turbidity, thereby making it inactive.

(ii) If water contains large quantities of coloured ions like Mn^{2+} and Fe^{2+} ,they must be removed because these ions produce manganese and iron zeolites that cannot be regenerated easily.

(iii) If mineral acids are present in water, they destroy the zeolite bed and hence they must be neutralized with soda in advance, before feeding the water into the zeolite bed.

(iv) The water to be softened should not be hot as the zeolite tends to dissolve in it.

(v) Anions are not removed by this process. The bicarbonates present in hard water get converted to NaHCO_3 that goes into soft water effluent. If it is used as boiler feed, under the boiler conditions NaHCO_3 disso



(vi) Both the products are not desirable. Since NaOH may lead to caustic embrittlement and CO_2 makes the condensed water into acidic and corrosive. Thus, it is desirable to remove temporary hardness before subjecting the raw water to zeolite process.

(vii) Compared to ion-exchange process, water treated by zeolite process contains 25% or dissolved salts. The higher cost of the plant and materials are also limiting factors.

Advantages:

- (i) The hardness is nearly completely removed and water of about 10ppm hardness is produced.
- (ii) The equipment used is compact and occupies less space.
- (iii) It is quite clean and rapid process that requires less time for softening.
- (iv) Less skill is needed for maintenance as well as operations.
- (v) Impurities are not precipitated, so there is no danger of sludge formation.
- (vi) The process automatically adjusts itself to waters of different hardness.

Ion-exchange process: (or) Deionization or Demineralization:-

Ion exchange resins: Ion exchange is “a process in which ions held on a porous, essentially insoluble solid are exchanged for ions in solution that is brought in contact with it”.

The ion exchange resins are insoluble, cross-linked, high molecular weight organic polymers with a porous structure. The functional groups attached to the chains are responsible for ion-exchange properties.

Classification:

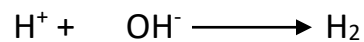
The ion-exchange resins may be classified as –

(a) Cation exchange resins ($R-H^+$): These resins are mainly styrene divinyl benzene copolymers, which on sulphonation or carboxylation, become capable to exchange their hydrogen ions with the cations in the water. Such resins have acidic functional groups like $-SO_3H$, $-COOH$, $-OH$ (phenolic) capable of exchanging the cationic portion of minerals by their hydrogen ions and hence they are termed as cation exchangers. Ex: Amberlite IR-120, Dowex – 50.

(b) Anion exchange resins (R^+OH^-): These resins are styrene-divinyl benzene or amine-formaldehyde copolymers that contain basic functional groups like amino or quaternary ammonium ($-NR_3$) or quaternary phosphonium or tertiary sulphonium groups an integral part of the resin matrix. These resins after treatment with dilute NaOH solution, become capable of exchanging their OH^- ions with anions in water and therefore known as anion exchangers.

Ex: Amberlite – 400, Dowex-3.

The hard water is first passed through cation exchange column, when all the cations like Ca^{2+} , Mg^{2+} are removed from it and the equivalent amount of H^+ ions are released from the column to water. After passing through cation exchange column, the hard water is passed through anion exchange column, when all the anions like SO_4^{2-} , Cl^- present in the water are removed and equivalent amount of OH^- ions are released from the column to H^+ and OH^- ions released from cation exchange and anion exchange columns respectively combine to form water molecule.



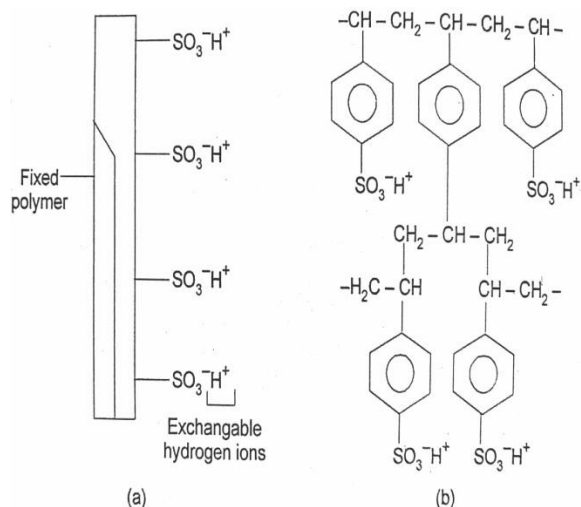


Fig: Sulphonate form of cation exchange resin

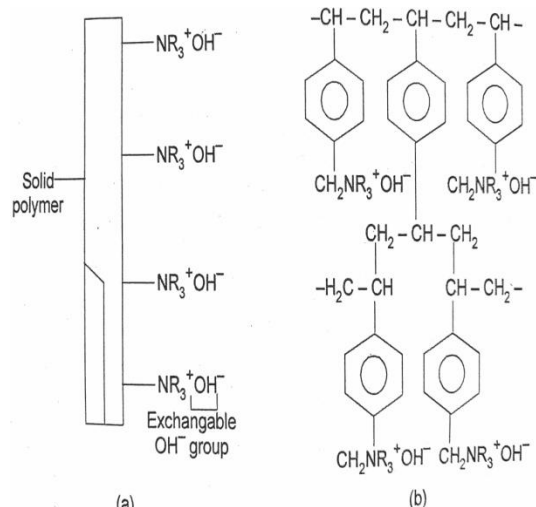


Fig: Hydroxide form of anion exchange resin

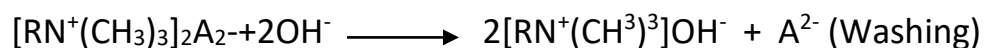
Thus, the water coming out from the exchanger is free from cations as well as anions. Ion-free water is known as deionized or demineralized water. It is also free from acidity or alkalinity. Thus it is as pure as distilled water. Finally, the demineralized water is passed through a degasifier, a tower whose sides are heated and which is connected to a vacuum pump, High temperature and low pressure reduces the amount of dissolved gases like CO₂ and O₂ in water.

Regeneration:

When capacities of cation and anion exchangers to exchange H⁺ and OH⁻ ions respectively are lost, then they are said to be exhausted. The exhausted cation exchange column is regenerated by passing a solution of dilute HCl or H₂SO₄. The regeneration can be represented as-



The column is washed with deionized water and washing is passed to sink or drain. The exhausted anion exchange column is regenerated by passing a solution of dilute NaOH solution. The regeneration can be represented .



The column is washed with deionized water and washing is passed to sink or drain. Then the regenerated ion exchange resins are used again.

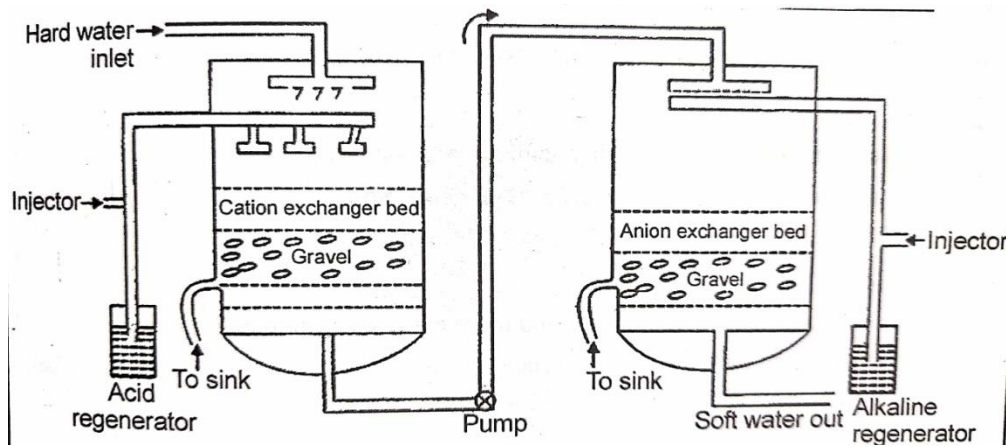


Fig: Ion exchanger process

Advantages:

- i) The process can be used to soften highly acidic or, alkaline waters.
- ii) The process produces water of very low hardness (2ppm), SO, the treated water is very good for use in high pressure boilers.

Disadvantages:

- i) Capital cost is high since chemical and equipment both are costly.
- ii) If water contains turbidity then the efficiency of the process is reduced.

Disadvantages of hard water in domestic and Industrially use:-

Domestic use:

(a)Washing: Hard water, when used for washing purposes, does not produce lather freely with soap. As a result cleaning quality of soap is decreased and a lot of it is wasted. Hard water reacts with soap it produces sticky precipitates of calcium and Mg soaps. These are insoluble formations.

(b) Bathing: Hard water does not produce lather freely with soap solution, but produces sticky scum on the bath-tub and body. Thus, the cleaning quality of soap is depressed and a lot of it is wasted.

(c) Cooking: The boiling point of water is increased because of presence of salts. Hence more fuel and time are required for cooking.

(d) Drinking: Hard water causes bad effects on our digestive system. Moreover, the possibility of forming calcium oxalate crystals in urinary tracks is increased.

Industrial use:-

(a) Textile industry:- Hard water causes wastage of soap. Precipitates of calcium and magnesium soaps adhere to the fabrics and cause problem.

(b) Sugar Industry:- Water containing sulphates, nitrates, alkali carbonates etc. if used in sugar refining, causes difficulties in the crystallization of sugar. Moreover, the sugar so produced may be de-liquiscent.

(c) Dyeing industry:- The dissolved salts in hard water may reacts with costly dyes forming precipitates.

(d) Paper Industry:- Calcium, magnesium, iron salts in water may affect the quality of paper.

(e) Pharmaceutical Industry:-Hard water may cause some undesirable products while preparation of pharmaceutical products.

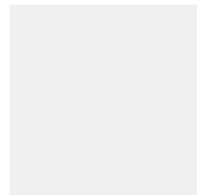
(f) Concrete making:- water containing chlorides and sulphates, if used for concrete making, affects the hydration of cement and the final strength of the hardened concrete.

(g) Laundry:- Hard water, if used in laundry, causes much of the soap used in washing to go as waste iron salts may even causes coloration of the cloths.

Alkalinity:

Theory: Alkalinity is an aggregate property of the water sample which measures the acid-neutralizing capacity of a water sample. It can be interpreted in terms of specific substances only when a complete chemical composition of the sample is also performed. The alkalinity of surface water is due to the carbonate, bicarbonate and hydroxide content and is often interpreted in terms of the concentrations of these constituents. Higher the alkalinity, greater is the capacity of water to neutralize acids. Conversely, the lower the alkalinity, the lesser will be the neutralizing capacity.

Alkalinity of sample can be estimated by titration with standard H_2SO_4 or HCl solution. Titration to pH 8.3 or decolourisation of phenolphthalein indicator will indicate complete neutralization of OH^- and $1/2$ of CO_3^{2-} , while to pH 4.5 or sharp change from yellow to orange of methyl orange indicator will indicate total alkalinity.



To detect the different types of alkalinity, the water is tested for phenolphthalein and total alkalinity, using Equations:

$$\text{Phenolphthalein alkalinity } \left(\frac{\text{mg}}{\text{L}}\right) \text{ as } \text{CaCO}_3 = \frac{A \times \text{Normality of acid} \times 50,000}{\text{mL of sample}}$$

$$\text{Total alkalinity } \left(\frac{\text{mg}}{\text{L}}\right) \text{ as } \text{CaCO}_3 = \frac{B \times \text{Normality of acid} \times 50,000}{\text{mL of sample}}$$

Where,

A = titrant (mL) used to titrate to pH 8.3

B = titrant (mL) used to titrate to pH 4.5

N = normality of the acid (0.02N H_2SO_4 for this alkalinity test)

50,000 = a conversion factor to change the normality into units of CaCO_3

Chemical Oxygen Demand (COD):

Theory: COD is used as a measure of oxygen equivalent to organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. For samples from a specific source, COD can be related empirically to BOD. COD determination has advantage over BOD determination in that the result can be obtained in about 5 hours as compared to 5 days required for BOD test.

The organic matter gets oxidized completely by $K_2Cr_2O_7$ in the presence of H_2SO_4 to produce CO_2 and H_2O . The excess of $K_2Cr_2O_7$ remained after the reaction is titrated with ferrous ammonium sulphate. The dichromate consumed gives the O_2 required for oxidation of organic matter.

$$COD \left(\frac{mg}{L} \right) = \frac{\text{Vol. of FAS for sample} \times \text{Normality of FAS} \times 8000}{\text{Vol. of sample}}$$

DRINKING WATER QUALITY STANDARDS:

Sl. No.	Characteristic/Parameter	BIS	ICMR	WHO
1	Colour	5	2.5	-
2	Odour	Agreeable	Unobjectionable	Unobjectionable
3	Turbidity	10 NTU	5 NTU	2.5 NTU
4	pH	6.5-8.5	7.0-8.5	7.0-8.5
5	TDS	500 mgl	500 mgl	500 mgl
6	Hardness	300 mgl	300 mgl	200 mgl
7	Ca	75 mgl	75 mgl	75 mgl
8	Mg	30 mgl	50 mgl	30 mgl
9	CL	250 mgl	200 mgl	200 mgl
10	Sulphate	200 mgl	200 mgl	200 mgl
11	Fe	0.3 mgl	0.1 mgl	0.1 mgl
12	Nitrate	45 mgl	20 mgl	45 mgl
13	Phenolic compounds	0.001 mgl	0.001 mgl	0.001 mgl
14	Cd, Sc	0.01 mgl	-	0.01 mgl
15	Cu, As	0.05 mgl	0.05 mgl	0.01 mgl

16	Cyanides	0.05 mgl	-	0.01 mgl
17	Pb	0.1 mgl	-	0.01 mgl
18	Anionic detergents	0.2 mgl	-	-
19	PAH	-	-	-
20	Residual Chlorine	0.2 mgl	-	-
21	Pesticides	Absent	-	-

BIS- Beaurau of Indian Standards.

ICMR- Indian Council for Medical Research.

WHO- World Health Organization.

BIOCHEMICAL OXYGEN DEMAND (BOD):

Biochemical oxygen demand, or BOD, measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. BOD also measures the chemical oxidation of inorganic matter (i.e., the extraction of oxygen from water via chemical reaction). A test is used to measure the amount of oxygen consumed by these organisms during a specified period of time (usually 5 days at 20 C). The rate of oxygen consumption in a stream is affected by a number of variables: temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and inorganic material in the water.

BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die.

Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff.

Apparatus :

(i) BOD bottles, 300 mL, narrow mouth, flared lip, with tapered and pointed ground glass stoppers.

(ii) Air incubator or water bath, thermostatically controlled at $27 \pm 1^\circ\text{C}$. Light entry must be prevented in order to avoid photosynthetic oxygen production.

(iii) Accessories: plastic tube, screw-pin and a 5-10 L water container.

Reagents :

(i) Phosphate buffer solution. Dissolve 8.5 g KH_2PO_4 , 21.75 g K_2HPO_4 , 33.4 g $\text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}$ and 1.7 g NH_4Cl in 1L distilled water.

(ii) Magnesium sulphate solution. Dissolve 22.5 g $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ in 1L distilled water.

(iii) Calcium chloride solution. Dissolve 27.5 g CaCl_2 in 1L distilled water.

(iv) Ferric chloride solution. Dissolve 0.25 g $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ in 1L distilled water.

(v) Acid and alkali solution. 1N NaOH and 1N H_2SO_4 . Use for neutralising samples.

(vi) Glucose-glutamic acid solution (prepare fresh). Dissolve 150 mg dry reagent grade glucose and 150 mg dry reagent grade glutamic acid in 1L distilled water

(vii) Sample dilution water. Add 1 mL each of phosphate buffer, MgSO_4 , CaCl_2 and FeCl_3 solutions per litre distilled water.

Procedure:

(i) Prepare required amount of dilution water at the rate of 1000 to 1200 mL per sample per dilution. Bring the diluted water temperature to 27°C . Saturate with air by shaking in a partially filled bottle, by bubbling with organic free filtered air or by storing in cotton-plugged bottles for a day.

(ii) Some samples do not contain sufficient microbial population (for example, some industrial wastes, high temperature wastes, or wastes with extreme pH

values). For such wastes, the dilution water is seeded using effluent from a biological treatment system processing the waste. Where this is not available, use supernatant from domestic wastewater after settling for at least 1 h but not more than 36 h. Seed from a surface water body receiving the waste may also be suitable. Add enough seed volume such that the DO uptake of the seeded dilution water is between 0.6 and 1.0 mg/L. For domestic wastewater seed, usually 4 to 6 mL seed / L of dilution water is required. Surface water samples usually do not require seeding.

(iii) Dilution of sample. Dilutions must result in a sample with a residual DO (after 3 days of incubation) of at least 1 mg/L and a DO uptake of at least 2 mg/L. Make several dilutions using the Table and experience with the particular sample source. Polluted surface waters may have 5 to 25 mg/L BOD For preparing dilution in graduated cylinders, siphon dilution water, seeded if necessary, into a 1 to 2 L capacity cylinder. Siphoning should always be done slowly without bubbling, use a screw-pin on the tube to regulate the flow. Keep the tip of the tube just below the water surface as it rises. Fill cylinder half full, add desired quantity of sample and dilute to appropriate level, mix with plunger type mixing rod. Siphon mixed diluted sample in three BOD bottles, stopper without entraining any air. Determine initial DO on one bottle and incubate the other two at 27°C. Determine final DO in duplicate after 3 days. For direct pipetting, siphon the desired sample volume to individual bottles and fill with enough dilution water. Complete the test as in the earlier case.

(iv) Dilution water blank. Find the DO consumption of unseeded dilution water by determining initial and final DO as in c above. It should not be more than 0.2 mg/L

(v) Seed control. Determine the DO uptake by seeding material according to the procedure in c above.

Calculation:

a. When dilution water is not seeded

$$\text{BOD, mg.l}^{-1} = D_0 - D_T / P$$

(b) When dilution water is seeded:

$$\text{BOD, mg.l}^{-1} = (D_0 - D_T) - f x (B_0 - B_T) / P$$

where: D_0 = DO of diluted sample initially, mg/L

D_T = DO of diluted sample after 3 day incubation at 27°C, mg/L

P = decimal volumetric fraction of sample used

B_0 = DO of seed control initially, mg/L

B_T = DO of seed control after incubation, mg/L

f = ratio of %seed in diluted sample to %seed in seed control

Disinfection of water

The process of destroying/killing the disease producing bacteria, micro organisms, etc, from the water and making it safe are, is called Disinfection.

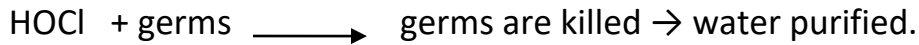
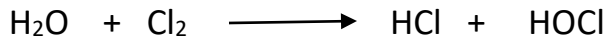
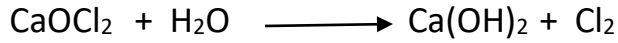
Disinfectants:- The chemicals or substances which are added to water for killing the bacteria. The disinfection of water can be carried out by following methods.

(a) Boiling:- Water for 10 -15 min.boiled,all the disease producing bacteria are killed and water become safe for use.

(b) Bleaching powder:-

It is used to purify the drinking water from micro organisms. The purification process is achieved by dissolving 1 kg of bleaching powder in 1000 kilo litres of water. This dissolved water solution is left undisturbed for many hours when bleaching powder is mixed with water, the result of chemical reaction produces a

powerful Germicide called Hypochlorous acid. The presence of chlorine in the bleaching powder produces disinfection action, kills germs and purifies the drinking water effectively.



(c) Chlorination:-

Chlorination is the process of purifying the drinking water by producing a powerful Germicide like hypochlorous acid. When this chlorine is mixed with water it produces Hypochlorous acid which kills the Germs present in water.

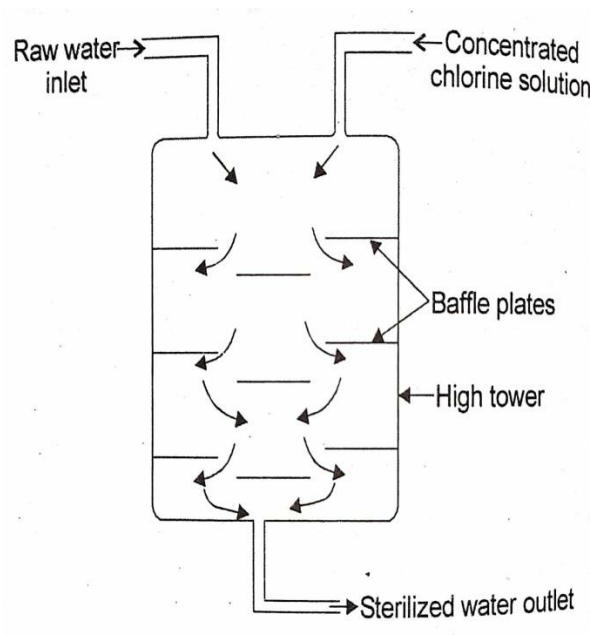
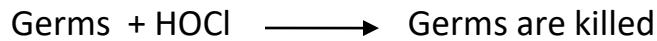
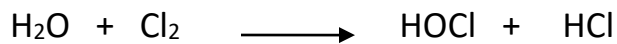


Fig: Chlorinator

Chlorine is basic (means PH value is more than 7) disinfectant and is much effective over the germs. Hence chlorine is widely used all over the world as a powerful disinfectant. Chlorinator is an apparatus, which is used to purify the water by chlorination process.

Break- Point Chlorination:-

Break Point Chlorination is a controlled process. In this process suitable amount of chlorine is added to water. In order to kill all the bacteria present in water, to oxidize the entire organic matter and to react with free ammonia the chlorine required should be appropriate. Break point determines whether chlorine is further added or not. By chlorination, organic matter and disease producing bacteria are completely eliminated which are responsible for bad taste and bad odour in water. When certain amount of chlorine is added to the water, it leads to the formation of chloro-organic compounds and chloramines. The point at which free residual chlorine begins to appear is terms as “Break-Point”.

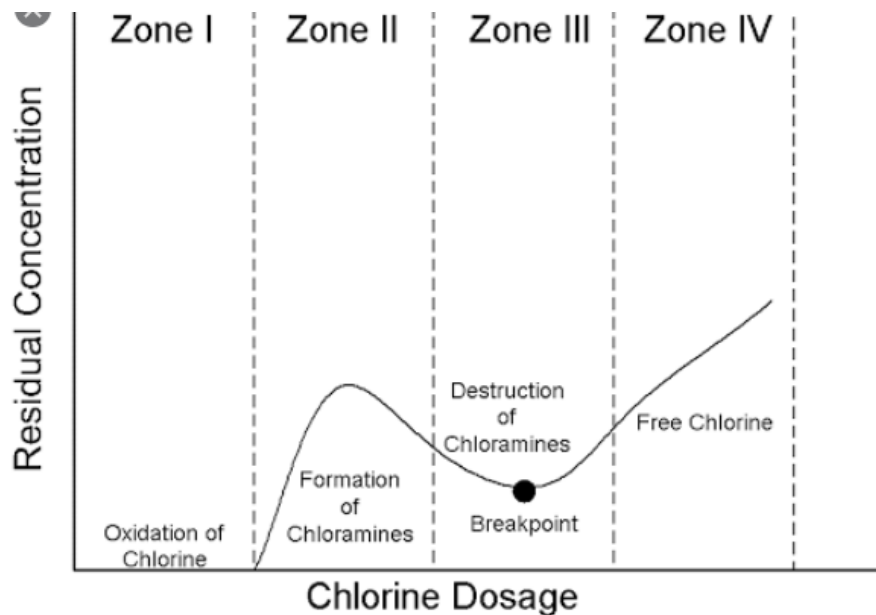
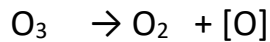


Fig : Break Point Chlorination

(d) Ozonisation:-

Ozone is powerful disinfectant and is readily dissolved in water. Ozone being unstable decomposes by giving nascent oxygen which is capable of destroying the Bacteria. This nascent oxygen removes the colour and taste of water and oxidizes the organic matter present in water.



(e) Desalination

The removal of dissolved solids (NaCl) from water is known as desalination process. It can be carried out by (1) Reverse osmosis and (2) electro dialysis.

1. Reverse osmosis process:-

The membrane process used in the water purification system has been of much use now a days. Electro dialysis and reverse osmosis are part of the membrane process. In osmosis, if a semi-permeable membrane separates two solutions, solvent from the lower concentration passes to the higher concentration to equalize the concentration of both. But in the reverse osmosis, pressure higher than osmotic pressure is applied from the higher concentration side so that the path of the solvent is reversed, i.e. from higher concentration to lower concentration.

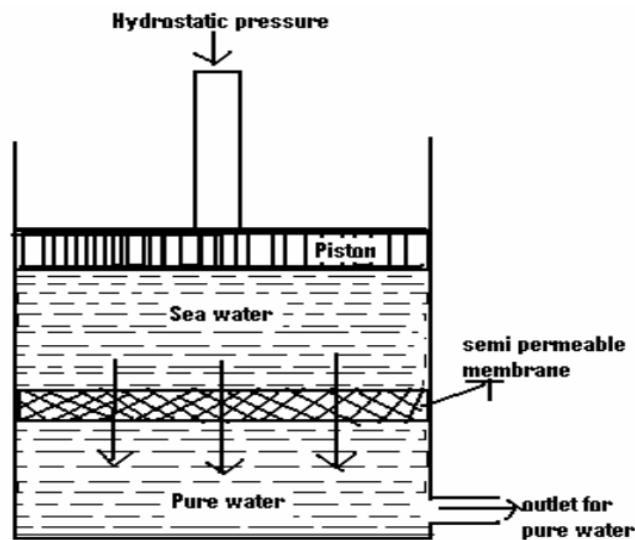


Fig : Reverse Osmosis

This method is applicable mainly for the desalination of sea water. Sea water and pure water are separated by a semi-permeable membrane made up of cellulose acetate fitted on both sides of a perforated tube. Inventions are in progress to search for better membrane. Cellulose acetate Polymethyl acrylate and polyamides have been proved to be better membranes.

The process is very easy. It is used to make pure water. It removes the ionic and non ionic substances in the water. It also can remove suspended colloidal particles. The life of a membrane is nearly 2 years and it should be replaced after this period. By this process, sea water is made to fit for drinking water obtained after being treated by this process is used in boilers.

For practical purposes, semi-permeable membrane based on thin films of cellulose acetate, polymethyl acrylate and polyamide polymers are used, a pressure of the order of $15\text{-}40\text{kg/cm}^2$ is applied for separating the water (pure solvent) from its contaminants. The process is also known as super filtration or hyper filtration.

Advantages:

1. Reverse osmosis possesses a distinct advantage of removing ionic as well as non-ionic, colloidal and high molecular weight organic matter.
2. Colloidal SiO_2 can be removed by reverse osmosis which even cannot be removed by demineralization.
3. It is a simple and reliable process.
4. Capital and operating expenses are low.
5. The life of semi-permeable membrane is about 2 years and it can be easily replaced within few minutes, thereby nearly uninterrupted water supply can be provided.

Disadvantage :

1. Periodical cleaning of membrane is needed.
2. Pretreatment for bacterial removal is needed.

2. Electro dialysis:

Electro dialysis is based on the fact that the ions present in saline water migrate towards their respective electrodes, through ion-selective membranes under the influence of applied EMF. The unit consists of electrodes (cathode and anode) and thin, rigid ion selective membranes which are permeable to either cation or anion. The anode is placed near the anion-selective membrane while the cathode is placed near the cation-selective membrane. Under the influence of an applied emf across the electrodes, the cations (Na^+) move towards the cathodes through cation selective membrane and anions (Cl^-) move towards the anode through anion selective membrane. The net result is the depletion of ions in the central compartment while it increases in the two side compartments. Desalinated water is periodically drawn out from the central compartment while the concentrated brackish water is replaced by fresh samples. For practical purposes, an electro dialysis cell is used. It consists of large number of paired sets of ion-selective membranes. Under a pressure of about 5-6kg/m², saline water is passed in and we get alternate streams of pure water and concentrated brackish water.

Advantages of desalination of electro dialysis:

- (i) The process is economical as per the capital cost and operational expenses are concerned.
- (ii) The unit is compact and the method is best suited.

MUNICIPAL WATER TREATMENT

WATER FOR DRINKING PURPOSE (Potable water):

The treatment of water for domestic supply will depend to a large extent on the quantity of the source water.

Water used for drinking should be-

1. Colourless and odourless
2. Free from colloidal and suspended impurities and
3. Free from microorganisms and bacteria.

The three stages involved in purifying a water sample for drinking purpose are-

- (i) Sedimentation
- (ii) Filtration
- (iii) Sterilization

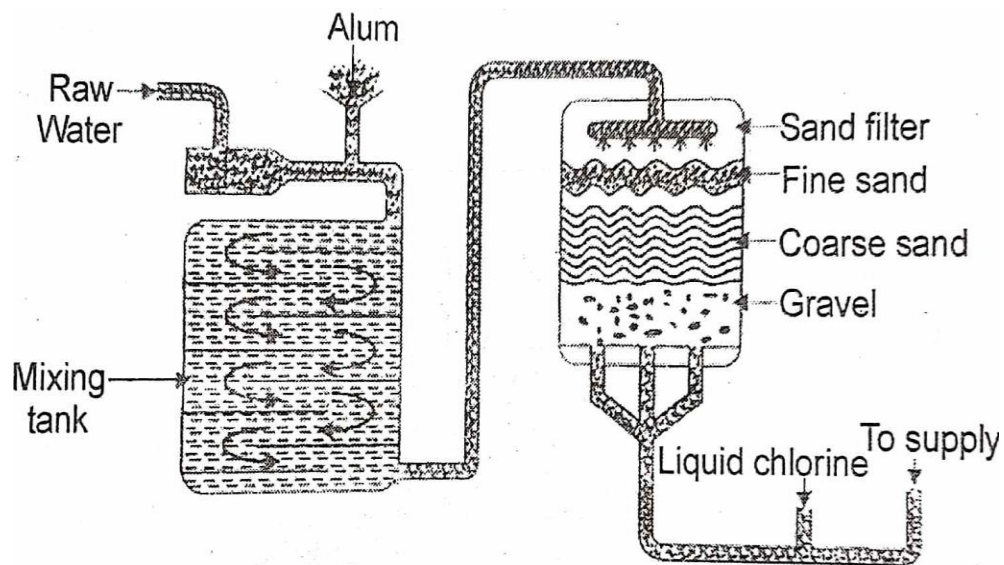


Fig: Flow diagram of drinking water treatment plant

(i) SEDIMENTATION

Water from river or lake is taken in the big tank called sedimentation tank. Here the insoluble matter settles down at the bottom of the tank as sediments. In this tank, the colloidal impurities are converted into precipitate by adding Alum. The clear water from the top layer is sent to the next tank called Filtration tank.

A few commonly used sedimentation with coagulants are-

(a) Potash Alum [$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$]

(b) Sodium Aluminate ($NaAlO_2$)

(c) Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$)

(ii) FILTRATION TANK:

In filtration tank, the suspended impurities and the microorganisms are removed. In all types of filtration, the filter bed used is constructed as follows. The filter bed consists of a layer of fine sand followed by the layer of coarse sand, which is then followed, by a layer of gravel. There is a drain at the bottom to remove the filtered water. The layer of fine sand acts as the filtering unit and the other two beds support the fine sand layer. Generally filtration is done due to the gravitational force. The filtered water is then taken to the sterilization tank.

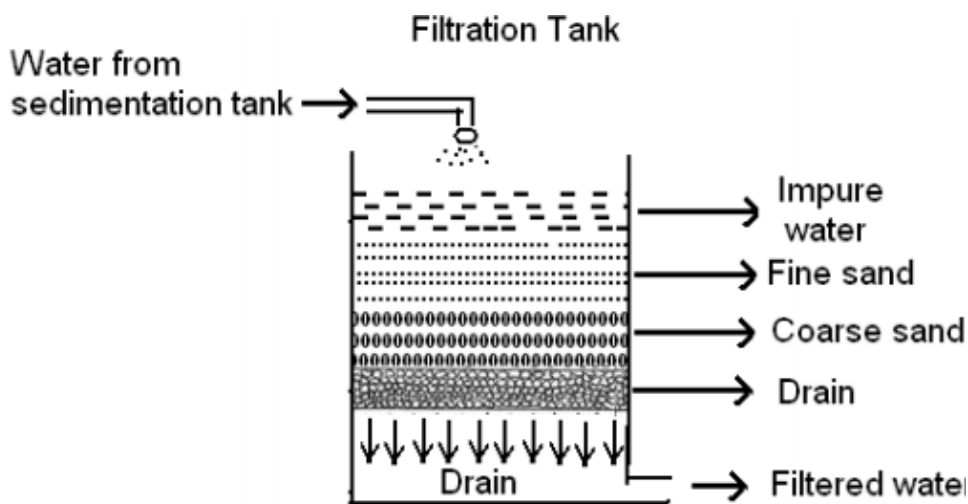


Fig: Filtration Tank

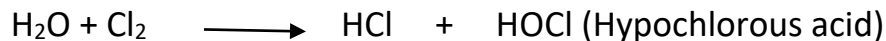
In drinking water supply schemes, generally gravity filters are used. However, in industrial areas where large amount of drinking water is required in short period, pressure filters are used in which water is sent through filter beds using external pressure. In gravity filtration, there are two types namely slow sand filtration and rapid sand filtration. The difference between these two methods is mainly in the recovery of filter beds used.

(iii) STERILIZATION:

Sterilization is the process of killing the bacteria. It is done by Chlorination, Ozone treatment, Ultraviolet irradiation treatment etc.

(a)Chlorination:

Chlorination is addition of chlorine. Chlorine is added to water in the acidic pH range of 6.5 to 7. When chlorine is added to water, it forms HCl and HOCl. The hypochlorous acid molecule enters into the living cells of bacteria and kills them.



Other sterilizing agents used apart from chlorine are chloramines, bleaching powder etc. The advantage of using chloramines is that it does not evaporate out easily and can be carried over to a longer distance along with the water.

The main advantages of using chlorine gas are:

- (i) It is the most efficient method of making free chlorine available to raw water.
- (ii) It lowers the pH of the water slightly.
- iii) Control is simple; testing simple; and it is not an expensive method.

The main disadvantages are:

(i) Chlorine gas is toxic and can combine with other chemicals to form combustible and explosive materials.

(ii) Automatic control systems are expensive.

(iii) Chlorine cylinders may not be readily available at small centres.

(iv) Chlorine expands rapidly on heating and hence the cylinders must have fusible plugs set at 70°C. It also reacts with water, releasing heat. Water should not therefore be sprayed on a leaking cylinder.

(b) Ozone treatment: The principle is relatively simple, this method needs special equipment, supply of pure oxygen and trained operators. Ozone is generated by passing pure oxygen through an ozone generator. It is then bubbled through a gas diffuser at the bottom of an absorption column, in a direction opposite to the flow of raw water. Retention or contact time is critical and the size of the absorption column depends on the water flow.

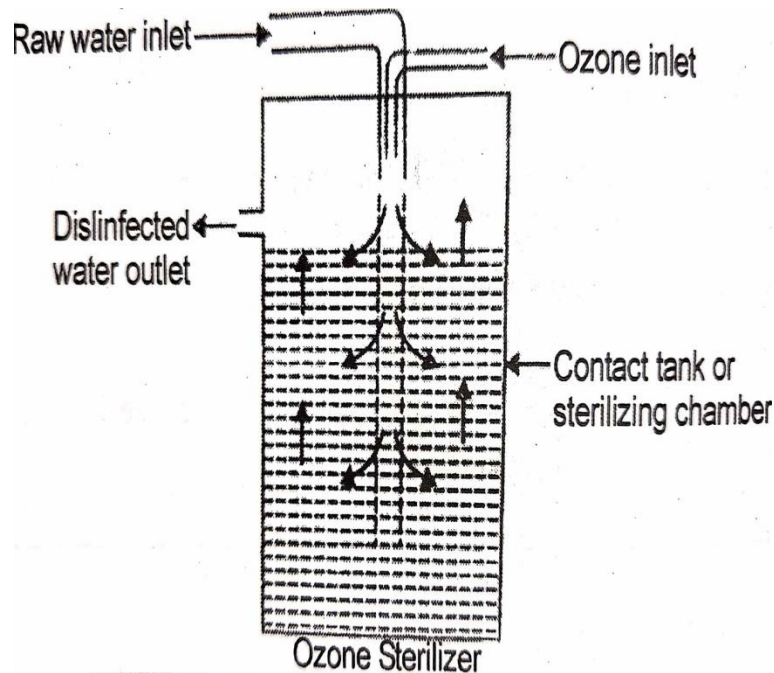
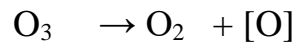


Fig: Ozone Sterilizer

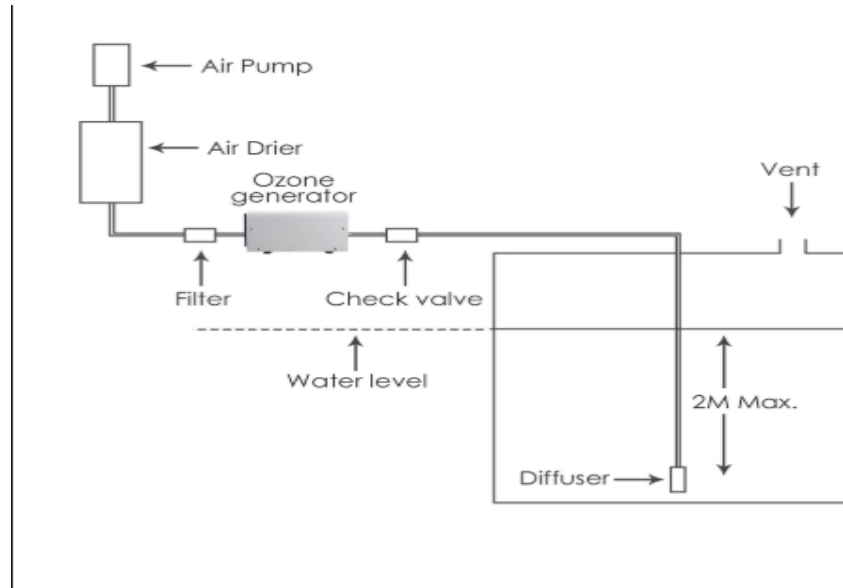


Fig: Ozone Treatment

The main advantages of ozone treatment are:

- (i) Ozone is a much more powerful germicide than chlorine especially for faecal bacteria.
- (ii) It reduces turbidity of water by breaking down organic constituents.
- (iii) The process is easily controlled.

The disadvantages are:

- (i) Pure oxygen may not be readily available locally.
- (ii) Ozonized water is corrosive to metal piping.
- (iii) Ozone decomposes rapidly into oxygen.
- (iv) Water has to be aerated prior to use to remove the ozone.

(c) Ultraviolet irradiation treatment: This method is often used to treat drinking water. Successful commercial installations have been made to purify sea water in large fish processing plants. Ultra-violet rays can also be used for sterilizing purpose.

The main advantages of U-V treatment are:

- (i) U-V rays in the range of 2500-2600 Angstrom units are lethal to all types of bacteria.
- (ii) There is no organoleptic, chemical or physical change to the water quality.
- (iii) Overexposure does not have any ill effects.

The main disadvantages are:

- (i) Electricity supply should be reliable.
- (ii) Turbidity reduces efficiency.
- (iii) Water may require prior treatment like filtration.
- (iv) The unit requires regular inspection and maintenance.
- (v) Thickness of the water film should not exceed 7.5 cm.

QUESTIONS

PART – A

1. Define hard and soft waters.
2. List the salts that cause Carbonate and non-carbonate hardness in a water sample.
3. What is rain water harvesting?
4. Mention any two problems caused by using hard water sample.
5. List any two methods of softening of hard water.
6. What is osmosis?
7. What is osmotic pressure?
8. Explain reverse osmosis.
9. Name the membranes used in R.O.method of softening of hard water
10. What is ppm?
11. What is sedimentation?
12. What is sterilization of water?
13. Explain the reaction that takes place when chlorine is added to water.
14. What are boiler scales?
15. What is caustic embrittlement?
16. What is priming?
17. What is foaming?
18. Give any one problem caused by boiler scale.

PART – B

1. List the problems caused by hard water?
2. What is rainwater harvesting? What are its goals?

PART-C

1. Explain Ion Exchange method of softening a hard water sample.
2. What is regeneration of Ion-exchange plant? How is it carried out?
3. Explain Reverse Osmosis method of softening a hard water sample.
4. Explain EDTA method of estimating hardness of a sample of water.
5. Describe the method used in water supply schemes to get potable water.
6. Describe the total dissolved solid and alkalinity.
7. Explain the biological oxygen demand and chemical oxygen demand.

Multiple choice questions:

1. Which of the following is a source of surface water -
(a) Rain water (b) river water (c) sea water (d) **all**
2. Hard water is
(a) Gives lather with soap (b) **does not give lather with soap**
(c) Hard to touch (d) solid
3. Equivalent weight of CaCO_3
(a) 100 (b) **50** (c) 10 (d) 1000
4. Indicator in EDTA method is -
(a) Fast sulphon (b) **Eriochrome Black T** (c) methyl orange (d) phenolphthalein
5. Break point chlorination refers to -
(a) Titration (b) coagulation (c) sedimentation (d) **disinfection**
6. Caustic embrittlement is -

- (a) **Boiler corrosion**
- (b) Method of softening
- (c) Internal treatment
- (d) External treatment

7. Zeolite is known as

- (a) Calgon
- (b) **Permutit**
- (c) Alum
- (d) Salt

8. In reverse osmosis -

- (a) **Water gets separated**
- (b) Contaminants are separated
- (c) Both of these
- (d) None of these

9. The process of removing extra common salt is called -

- (a) deionization
- (b) softening
- (c) **desalination**
- (d) disinfection

10. A semi permeable membrane allows

- (a) **only solvent particle**
- (b) only solute particle
- (c) both solute and solvent particles
- (d) neither of them

11. Hard water is water containing (a)

- (a) **Ca²⁺, Mg²⁺, Fe³⁺**
- (b) Na⁺ & K⁺
- (c) NO₃⁻ and PO₄³⁻
- (d) dissolved gases

1. Define hardness of water. What are the units of hardness of water. Give the relationship between different units.

2. Explain the EDTA method for the determination of hardness of water.

3. Discuss briefly the boiler troubles and their treatment.

4. Write short note on the following

- (a) Scale formation
- (b) Sludge formation
- (c) Caustic embrittlement

5. Give a brief note on the following

- (a) priming
 - (b) foaming
 - (c) electro dialysis
6. Explain the following
- (a) Reverse osmosis
 - (b) Colloidal conditioning
 - (c) Calgon conditioning
7. Discuss the lime soda process for softening of hard water.
8. How can you differentiate scale and sludge formation of hard water?
9. Describe the ion-exchange process used for softening of water.
10. How can you differentiate the following.
- a. Temporary hardness and permanent hardness
 - b. Scales and sludges
11. a) What is meant by “hardness” of water. And what are the disadvantages of hard water?
- b) Distinguish between temporary and permanent hardness of water.
- c) What are its units?
- d) How do you express the hardness of water?
12. (a) What is the principle of EDTA method? Explain the estimation of hardness of water by complex metric method.
- (b) Mention the dis-advantages of using hard water for industrial purpose.
13. (a) Explain the terms temporary and permanent hardness of water.
- (b) How do you estimate the temporary hardness of water by EDTA method?
- (c) 50 ml of a sample of hardwater was titrated against 0.01 M EDTA, required 48 ml of EDTA for titration. 50 ml of the same hardwater after boiling and filtering etc. required 35ml of the EDTA for titration. Calculate the total and temporary hardness of water in degree Clark.
14. (a) Estimation of free chlorine in water samples.
- (b) Discuss the impurities in water and their effects.
- (C) Explain the sedimentation process for the treatment of municipal water
15. Write a short notes on the following:

- a) Break - point chlorination
- (b) Dissolved oxygen
- (c) Hardness of water
- (d) Sedimentation and coagulation.

16. Distinguish the following:

- (a) Hard water and soft water
- (d) Sedimentation and filtration

21. Distinguish between the following:

- (b) Soft water and dematerialized water.
- (c) Lime soda process and demineralization of water.

22. What are boiler scales? How their compositions effect the boiler? What are their ill effects? Discuss the measures for their prevention.

23. Compare the lime soda process with zeolite process of water softening.

24. (a) Describe the demineralisation of water by ion - exchange method.

(b) Mention the disadvantages of using hard water for any two industries

25. Explain the Ion-exchange method for the removal of dissolved impurities and its advantages over lime soda process

26. (a) Explain the cold lime soda process and hot lime soda process. What are the advantages of lime soda process?

27. Explain the Ion-exchange method for the removal of dissolved impurities and its Advantages over lime soda process.