UNIT I WATER AND ITS TREATMENT

INTRODUCTION TO HARDNESS

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UNIT I – WATER TECHNOLOGY

1.1 INTRODUCTION

Water is the most important compound essential for the survival of all living organisms. About 80% of the earth's surface is covered by water. Besides being a supporter of life, water plays a unique role in industries. Water is used in the power generation industry for the production of the electric current through steam generation. It is also used as a coolant in nuclear power plants and chemicals plants. Water is widely used in other fields such as production of steel, atomic energy, textiles, irrigation, etc.

The process of removing of all types of impurities from water and making it fit for domestic or industrial purposes is called water technology or water treatment.

SOURCES OF WATER

The main sources of water are

- Rain Water
- Surface water
- Underground water
- Sea water

The Common Impurities in Water

The common impurities present in natural waters may be classified as follows.

1. **Dissolved minerals** – mostly comprise of carbonates, bicarbonates, sulphates and chlorides of calcium, magnesium, sodium and potassium.
2. **Dissolved gases** – mostly air and carbon dioxide.
3. Suspended matter – mostly mineral matter, giving turbid or muddy water. Organic matter may also be present.
4. **Microscopic matter** – consists mostly of plant and bacterial life giving colour, taste and odour.

In general, the removal of impurities from water of classes 1, 2 and 3 form the chief problem for industrial usage, and 3 and 4 for municipal supplies.

TYPES OF WATER

On the basis of hardness, water can be classified into two types:

- Hard Water and Soft Water

HARD WATER

Water which does not produce lather easily with soap solution, but forms a white precipitate, is called **hard water**.

SOFT WATER

Water which lathers easily with soap solution, is called **soft water**.

It does not contain dissolved calcium and magnesium salts.

1.2 HARDNESS OF WATER

- **Hardness** is the characteristic property of water which "prevents **the lathering of soap**".
- This is due to the presence of certain salts of calcium, magnesium and other heavy metals dissolved in water.

How to detect hardness?

When a sample of water is treated with soap solution, if it does not produce lather, but forms a white scum or precipitate, the water contains hardness.

This is due to the formation of insoluble soaps of calcium and magnesium.

$$C_{17}H_{35}COONa + CaCl_2 \longrightarrow (C_{17}H_{35}COO)_2Ca\downarrow + 2\ NaCl$$

Sodium stearate — Hardness causing substance — Calcium stearate (Soap) (insoluble soap)

TYPES OF HARDNESS

- Hardness is classified into **two** types based on dissolved salts present in water. They are: Temporary Hardness (or) Carbonate Hardness (CH)
- Permanent Hardness (or) Non-Carbonate Hardness (NCH)

TEMPORARY HARDNESS

Temporary Hardness is due to the presence of dissolved bicarbonates of calcium and magnesium. Thus the salts responsible for temporary hardness are $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$. Temporary hardness is otherwise known as **Carbonate Hardness** (or) **Alkaline Hardness**.

Temporary Hardness can be removed by following two processes:

- **Boiling of water**

$$Ca(HCO_3)_2 \longrightarrow CaCO_3\downarrow + H_2O + CO_2\uparrow$$

$$Mg(HCO_3)_2 \longrightarrow Mg(OH)_2\downarrow + 2\,CO_2\uparrow$$

- **Adding lime**

$$Mg(HCO_3)_2 + 2\,Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + 2\,CaCO_3\downarrow + 2H_2O$$

(Lime)

The above two processes convert the bicarbonates into insoluble carbonates and hydroxides, theseare removed by filtering.

PERMANENT HARDNESS

Permanent hardness is due to the presence of dissolved chlorides and sulphates of calcium and magnesium. The salts responsible for permanent hardness are $CaCl_2$, $MgCl_2$, $CaSO_4$ and $MgSO_4$.

Permanent hardness cannot be removed by boiling.

It can be removed by the following two processes:

- **Lime – soda process**

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$$

(Soda)

- **Zeolite process**

$$CaSO_4 + Na_2Ze \longrightarrow Ca\text{-}Ze + Na_2SO_4$$

Sodium Zeolite

Permanent Hardness is otherwise known as **Non-Carbonate Hardness** (NCH) (or) **Non – alkalineHardness**.

TOTAL HARDNESS

Total hardness = Temporary Hardness + Permanent Hardness

EXPRESSION OF HARDNESS INTERMS OF EQUIVALENTS OF $CaCO_3$

The concentrations of hardness producing salts are usually expressed in terms of an equivalent amount of $CaCO_3$. $CaCO_3$ is chosen as a standard because,

- Its molecular weight (100) and equivalent weight (50) is a whole number, so the calculations in water analysis can be simplified.
- It is the most insoluble salt that can be precipitated in water treatment.

If the concentration of hardness producing salt is x mgs/lit, then

Amount equivalent to $CaCO_3$ = x × 100/Molecular weight ofhardness producing salt

(or) i.e.,

Amount equivalent to $CaCO_3$ = Amount of hardness producing salt × Molecular weight of $CaCO_3$/ Molecular weight of hardness producing salt

(or)

Amount equivalent to $CaCO_3$ = Amount of hardness producing salt × Equivalent weight of $CaCO_3$/Equivalent weight of hardness producing salt

UNITS OF HARDNESS

i. PARTS PER MILLION (PPM)

It is defined as the number of parts of $CaCO_3$ equivalent hardness per 106 parts of water.

ii. MILLIGRAMS PER LITRE (mg/L)

It is defined as the number of milligrams of $CaCO_3$ equivalent hardness per 1 litre of water.

iii. CLARKE‟S DEGREE (°Cl)

It is defined as the number of parts of $CaCO_3$ equivalent hardness per 70,000 parts of water.

iv. FRENCH DEGREE (°FR)

It is defined as the number of parts of $CaCO_3$ equivalent hardness per 10^5 parts of water.

Relationship between various units 1 ppm = 1 mg/lit = 0.1° Fr = 0.07° Cl

PROBLEMS BASED ON HARDNESS

Problem 1

A sample of water contains 120 mgs of $MgSO_4$ per litre. Calculate the hardness in terms of $CaCO_3$equivalents.

Solution:

Given:

The amount of $MgSO_4$ = 120 mgs/lit

Amount equivalent to $CaCO_3$ = The amount of hardness producing salt x100/Molecular weight of hardness producing salt

We know that, the molecular weight of $MgSO_4$ = 120

∴ Amount equivalent to $CaCO_3$ = 120 × 100/120

= 100 mgs/lit.

Problem 2

If a sample of water contains 50 mgs of Ca^{2+} ions per litre, calculate its hardness in terms of $CaCO_3$ equivalent?

Solution Given:

The amount of Ca^{2+} ions = 50 mgs/lit

The molecular weight of calcium = 40

∴ Amount equivalent to $CaCO_3$ = 50 × 100/40

= 125 mgs/lit

Problem:3

A water sample contains 204 mgs of $CaSO_4$ and 73 mgs of Mg $(HCO_3)_2$ per litre. What is the total hardness in terms of $CaCO_3$ equivalent?

Solution

Name of the hardness producing salt	Amount in mgs/lit	Molecular weight	Amounts equivalentto $CaCO_3$
$CaSO_4$	204	136	204 × 100/136 = 150 mgs/lit
Mg $(HCO_3)_2$	73	146	73 × 100/146 = 50 mgs/lit

Temporary hardness = Mg $(HCO_3)_2$ = 50 mgs/lit

Permanent hardness = $CaSO_4$ = 150 mgs/lit

Total hardness = Mg $(HCO_3)_2$ + $CaSO_4$ = 50 + 150 = 200 mgs/lit

Problem 4

Calculate the carbonate and non-carbonate hardness of a sample of water containing the dissolvedsalts as given below in mgs/lit. $Mg(HCO_3)_2$ = 7.3; $Ca(HCO_3)_2$ = 40.5; $CaSO_4$ = 13.6; $MgCl_2$ =21.75 and NaCl = 50.

Solution

Name of the hardness producing salt	Amount in mgs/lit	Molecular weight	Amounts equivalentto CaCO3
$Mg(HCO_3)_2$	7.3	146	7.3x100/146=5 mgs/lit
$Ca(HCO_3)_2$	40.5	162	40.5X100/162=25 mgs/lit
$CaSO_4$	13.6	136	13.6X100/136=10 mgs/lit

$MgCl_2$	21.75	95	21.75X100/95=22.9 mgs/lit
NaCl	50	NaCl does not contribute any hardness to water hence it is ignored	

Carbonate hardness = $Mg(HCO_3)_2 + Ca(HCO_3)_2$

= 5 + 25 = 30 mgs/lit

Non-carbonate hardness = $CaSO_4 + MgCl_2$

= 10 + 22.9 = 32.9 mgs/lit

Total hardness = Carbonate hardness + Non−carbonate hardness

= 30 + 32.9

= 62.9 mgs/lit

Problem 5

A sample of water contains the following dissolved salts in mgs/lit $Mg(HCO_3)_2$ =73; $CaCl_2$=111;$Ca(HCO_3)_2$=81 and $MgSO_4$=40.Calculate the temporary and permanent hardness ofthe water.

(At. Wts. of Ca, Mg, O, C, Cl, S, H are 40,24,16,12,35.5,32,1)

Solution

Name of the hardness producing salt	**Amount in mgs/lit**	**Molecular weight**	**Amounts equivalentto $CaCO_3$**
$Mg(HCO_3)_2$	73	146	73x100/146=50 mgs/lit
$CaCl_2$	111	111	111X100/111=100 mgs/lit
$Ca(HCO_3)_2$	81	162	81X100/162=50 mgs/lit
$MgSO_4$	40	120	40X100/120=33.33 mgs/lit

Temporary hardness = $Mg(HCO_3)_2 + Ca(HCO_3)_2$

= 50+50 = 100 mgs/lit

Permanent hardness = $CaCl_2 + MgSO_4$

= 100 + 33.33

= 133.33mgs/lit