

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.



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

TYPES OF HARDNESS

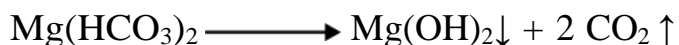
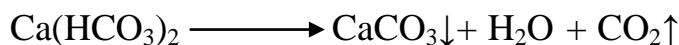
- Hardness is classified into **two** types based on dissolved salts present in water. They are: Temporary Hardness (or) Carbonate Hardness (CH)
- Permanent Hardness (or) Non-Carbonate Hardness (NCH)

TEMPORARY HARDNESS

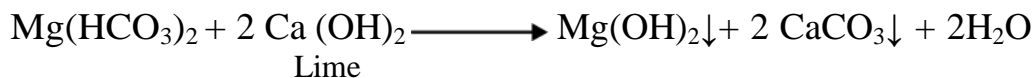
Temporary Hardness is due to the presence of dissolved bicarbonates of calcium and magnesium. Thus the salts responsible for temporary hardness are $\text{Ca}(\text{HCO}_3)_2$ and $\text{Mg}(\text{HCO}_3)_2$. Temporary hardness is otherwise known as **Carbonate Hardness (or) Alkaline Hardness**.

Temporary Hardness can be removed by following two processes:

➤ **Boiling of water**



➤ **Adding lime**



The above two processes convert the bicarbonates into insoluble carbonates and hydroxides, these are 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**



➤ **Zeolite process**



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

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 $\text{CaCO}_3 = x \times 100/\text{Molecular weight of hardness producing salt}$

(or) i.e.,

Amount equivalent to $\text{CaCO}_3 = \text{Amount of hardness producing salt} \times \frac{\text{Molecular weight of } \text{CaCO}_3}{\text{Molecular weight of hardness producing salt}}$

(or)

Amount equivalent to $\text{CaCO}_3 = \text{Amount of hardness producing salt} \times \frac{\text{Equivalent weight of } \text{CaCO}_3}{\text{Equivalent weight of hardness producing salt}}$

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 10⁵ parts of water.

Relationship between various units $1 \text{ ppm} = 1 \text{ mg/lit} = 0.1^\circ \text{Fr} = 0.07^\circ \text{Cl}$

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 $\text{MgSO}_4 = 120 \text{ mgs/lit}$

Amount equivalent to $\text{CaCO}_3 = \frac{\text{The amount of hardness producing salt} \times 100}{\text{Molecular weight of hardness producing salt}}$

We know that, the molecular weight of $\text{MgSO}_4 = 120$

$$\begin{aligned} \therefore \text{Amount equivalent to } \text{CaCO}_3 &= 120 \times 100/120 \\ &= 100 \text{ mgs/lit.} \end{aligned}$$

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

$$\begin{aligned} \therefore \text{Amount equivalent to } \text{CaCO}_3 &= 50 \times 100/40 \\ &= 125 \text{ mgs/lit} \end{aligned}$$

Problem:3

A water sample contains 204 mgs of CaSO_4 and 73 mgs of $\text{Mg}(\text{HCO}_3)_2$ 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 equivalent to CaCO_3
CaSO_4	204	136	$204 \times 100/136 = 150$ mgs/lit
$\text{Mg}(\text{HCO}_3)_2$	73	146	$73 \times 100/146 = 50$ mgs/lit

Temporary hardness = $\text{Mg}(\text{HCO}_3)_2 = 50$ mgs/lit

Permanent hardness = $\text{CaSO}_4 = 150$ mgs/lit

Total hardness = $\text{Mg}(\text{HCO}_3)_2 + \text{CaSO}_4 = 50 + 150 = 200$ mgs/lit

Problem 4

Calculate the carbonate and non-carbonate hardness of a sample of water containing the dissolved salts as given below in mgs/lit. $\text{Mg}(\text{HCO}_3)_2 = 7.3$; $\text{Ca}(\text{HCO}_3)_2 = 40.5$; $\text{CaSO}_4 = 13.6$; $\text{MgCl}_2 = 21.75$ and $\text{NaCl} = 50$.

Solution

Name of the hardness producing salt	Amount in mgs/lit	Molecular weight	Amounts equivalent to CaCO_3
$\text{Mg}(\text{HCO}_3)_2$	7.3	146	$7.3 \times 100/146 = 5$ mgs/lit
$\text{Ca}(\text{HCO}_3)_2$	40.5	162	$40.5 \times 100/162 = 25$ mgs/lit
CaSO_4	13.6	136	$13.6 \times 100/136 = 10$ 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	

$$\begin{aligned}\text{Carbonate hardness} &= \text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{HCO}_3)_2 \\ &= 5 + 25 = 30 \text{ mgs/lit}\end{aligned}$$

$$\begin{aligned}\text{Non-carbonate hardness} &= \text{CaSO}_4 + \text{MgCl}_2 \\ &= 10 + 22.9 = 32.9 \text{ mgs/lit}\end{aligned}$$

$$\begin{aligned}\text{Total hardness} &= \text{Carbonate hardness} + \text{Non-carbonate hardness} \\ &= 30 + 32.9 \\ &= 62.9 \text{ mgs/lit}\end{aligned}$$

Problem 5

A sample of water contains the following dissolved salts in mgs/lit Mg(HCO₃)₂ =73; CaCl₂=111;Ca(HCO₃)₂=81 and MgSO₄=40. Calculate the temporary and permanent hardness of the 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 equivalent to 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

$$\begin{aligned}\text{Temporary hardness} &= \text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{HCO}_3)_2 \\ &= 50 + 50 = 100 \text{ mgs/lit}\end{aligned}$$

$$\begin{aligned}\text{Permanent hardness} &= \text{CaCl}_2 + \text{MgSO}_4 \\ &= 100 + 33.33 \\ &= 133.33 \text{ mgs/lit}\end{aligned}$$

