

## **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.

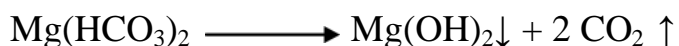
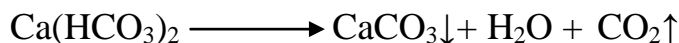
*In general, the removal of impurities from water of classes 1, 2 and 3 form the chief problem for industrial usage, and 3 and 4 for municipal supplies.*

### TYPES OF WATER

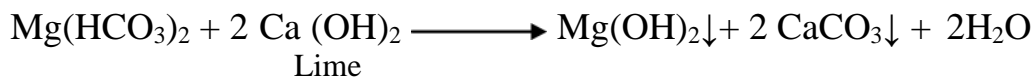
On the basis of hardness, water can be classified into two types:



➤ **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  $\text{CaCl}_2$ ,  $\text{MgCl}_2$ ,  $\text{CaSO}_4$  and  $\text{MgSO}_4$ .

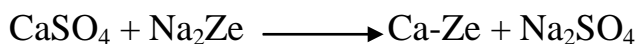
Permanent hardness cannot be removed by boiling.

It can be removed by the following two processes:

➤ **Lime – soda process**



➤ **Zeolite process**



Sodium Zeolite

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 $\text{CaCO}_3$

The concentrations of hardness producing salts are usually expressed in terms of an equivalent amount of  $\text{CaCO}_3$ .  $\text{CaCO}_3$  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  $\text{CaCO}_3 = \text{Amount of hardness producing salt} \times \frac{\text{Molecular weight of CaCO}_3}{\text{Molecular weight of hardness producing salt}}$

(or)

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

## UNITS OF HARDNESS

### i. PARTS PER MILLION (PPM)

It is defined as the number of parts of  $\text{CaCO}_3$  equivalent hardness per 10<sup>6</sup> parts of water.

### ii. MILLIGRAMS PER LITRE (mg/L)

It is defined as the number of milligrams of  $\text{CaCO}_3$  equivalent hardness per 1 litre of water.

### iii. CLARKE'S DEGREE (°Cl)

It is defined as the number of parts of  $\text{CaCO}_3$  equivalent hardness per 70,000 parts of water.

### iv. FRENCH DEGREE (°Fr)

It is defined as the number of parts of  $\text{CaCO}_3$  equivalent hardness per 10<sup>5</sup> 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  $\text{MgSO}_4$  per litre. Calculate the hardness in terms of  $\text{CaCO}_3$  equivalents.

#### Solution:

##### Given:

The amount of  $\text{MgSO}_4 = 120$  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  $\text{Ca}^{2+}$  ions per litre, calculate its hardness in terms of  $\text{CaCO}_3$  equivalent?

Solution Given:

The amount of  $\text{Ca}^{2+}$  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  $\text{CaSO}_4$  and 73 mgs of  $\text{Mg}(\text{HCO}_3)_2$  per litre. What is the total hardness in terms of  $\text{CaCO}_3$  equivalent?

### Solution

Name of the hardness producing salt	Amount in mgs/lit	Molecular weight	Amounts equivalent to $\text{CaCO}_3$
$\text{CaSO}_4$	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 $\text{CaCO}_3$
$\text{Mg}(\text{HCO}_3)_2$	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
$\text{CaSO}_4$	13.6	136	$13.6 \times 100/136 = 10$ mgs/lit

MgCl <sub>2</sub>	21.75	95	21.75X100/95=22.9 mgs/lit
NaCl	50	NaCl does not contribute any hardness to water hence it is ignored	

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

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

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

### Problem 5

A sample of water contains the following dissolved salts in mgs/lit Mg(HCO<sub>3</sub>)<sub>2</sub> =73; CaCl<sub>2</sub>=111;Ca(HCO<sub>3</sub>)<sub>2</sub>=81 and MgSO<sub>4</sub>=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 <sub>3</sub>
Mg(HCO <sub>3</sub> ) <sub>2</sub>	73	146	73x100/146=50 mgs/lit
CaCl <sub>2</sub>	111	111	111X100/111=100 mgs/lit

Ca(HCO <sub>3</sub> ) <sub>2</sub>	81	162	81X100/162=50 mgs/lit
MgSO <sub>4</sub>	40	120	40X100/120=33.33 mgs/lit



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

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

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