

भारतीय संस्कृति, शिक्षा और दर्शन

विभिन्न संकल्पनाएं

सम्पादक : डॉ. दिनेश चन्द्र शर्मा

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सम्पादक -

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आवरण -

श्रीनिवास प्रिन्टोग्राफिक्स, अजमेर

मुद्रक -

श्री श्याम ऑफसेट, किशनगढ़

Hardness of Water

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1. Introduction-

Water is essential for life, but its chemical nature can vary from place to place. Common natural impurities, hardness, determination of hardness by complexometric (EDTA method), degree of hardness. Municipal water supply, requisite of drinking water, purification of water, sedimentation, filtration, sterilization, breakpoint chlorination. Water for steam making and boiler troubles, formation of solids (Scale and Sludge formation), carryover (Foaming and Priming), boiler corrosion and caustic embrittlement, Methods of boiler water treatment (water softening) preliminary treatments, preheating, Lime-Soda process, Zeolite (Permutit) process, Deionization (Demineralization) process. Numerical problems based on hardness.

2. Sources of water -

2.1 Natural Sources of Water:

Surface Water:

- Found on the surface of the Earth.
- Includes :
 - o Rivers
 - o Lakes
 - o Ponds
 - o Streams
- Easily accessible and widely used for drinking, irrigation, and industrial use.

Groundwater :

- Stored beneath the Earth's surface in aquifers.
- Accessed through :
 - o Wells
 - o Tube wells
 - o Hand pumps
- Main source for agriculture and rural drinking water supply.

Rainwater :

- Primary and purest source of water.
- Collected directly from precipitation.
- Important for rainwater harvesting.

Glaciers and Snowfields :

- Found in polar and mountainous regions.
- Slowly melt to form rivers and streams.
- Major source of perennial rivers like the Ganges, Brahmaputra, and Indus.

Seas and Oceans :

- Cover over 70% of the Earth's surface.
- Contain saline (salt) water – not directly usable for drinking.
- Can be used after desalination.

2.2 Artificial (Man-made) Sources of Water :**Dams and Reservoirs :**

- Built across rivers to store water.
- Used for hydroelectric power, irrigation, drinking and flood control.

Canals :

- Man-made channels that carry water from rivers or reservoirs to agricultural fields.

Tanks and Artificial Ponds :

- Constructed in rural areas to store rainwater or river water.

Water Supply Systems (Municipal) :

- Includes pipelines, water tanks and treatment plants that supply water to homes, industries, and cities.

Sr. no.	Type of Source	Water Type	Usability
1.	River/Lake	Surface Water	Potable after treatment
2.	Well/Borewell	Groundwater	Generally usable
3.	Ocean	Saline Water	Needs desalination
4.	Rain	Fresh Water	Pure; used in harvesting
5.	Glacier Melt	Fresh Water	Source of rivers

Table – 1.1

3. Common Impurities of Water -

3.1 Dissolved Impurities :

These are **completely dissolved** in water and **cannot be removed by simple filtration**.

(a) Inorganic dissolved Impurities:

• **Salts of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+)**

• **Chlorides (Cl^-), sulfates (SO_4^{2-}), bicarbonates (HCO_3^-)**

• **Cause hardness in water**

(b) Gases dissolved:

• **Oxygen (O_2)**

• **Carbon dioxide (CO_2)**

• **Nitrogen (N_2)**

• **Hydrogen sulfide (H_2S) – causes foul smell**

(c) Organic dissolved substances:

• **Decomposed plant and animal matter**

• **Industrial and agricultural chemical residues (e.g., pesticides, fertilizers)**

3.2 Suspended Impurities:

These are **Insoluble solid particles** that remain suspended in water. They can be removed by **filtration or sedimentation**.

Examples :

• **Sand**

• **Clay**

• **Silt**

• **Mud**

• **Organic matter like leaves and algae**

3.3 Colloidal Impurities :

These are **very fine particles** that are neither truly dissolved nor easily filtered out. They remain **evenly distributed** throughout the water and form a **colloidal solution**.

Examples:

• **Microorganisms (e.g., bacteria, protozoa)**

• **Fine clay or soil particles**

• **Decaying organic matter**

- Emulsified oils and fats

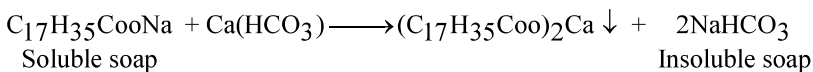
Colloidal particles are usually **negatively charged** and require **coagulation** for removal (e.g., using alum or activated carbon).

Sr. No.	Type of Impurity	Nature	Examples	Removal Methods
1.	Dissolved Impurities	Soluble in water	Salts, gases, chemicals	Distillation, RO, ion exchange
2.	Suspended Impurities	Insoluble solids	Sand, silt, clay	Filtration, sedimentation
3.	Colloidal Impurities	Very fine particles	Microbes, fine clay, organic matter	Coagulation, advanced filtration

Table – 1.2

4. Hardness of Water and it's Type –

When soap trodum and potaseun salts of higher fatty acids like stearic, palmatic does not produce lathet, swoth water, but form an insoluble soap of cafetom and maarom white ppt or scurn, then that water is said to be a hard water and a water which produce lather with soap easily is called soft water.



Thus a large amount of soap is wasted in this process and no lather is formed until all these hardness producing ions are completely removed.

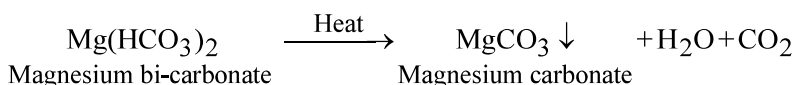
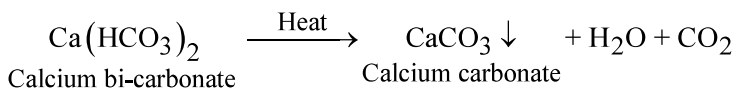
Hard water contain calcium and magnesium salts in it. Whereas soft water dose not contain dissolve calcium and magnesium salt.

5. Type Of Hardness—

5.1 Temporary or Carbonate Hardness –

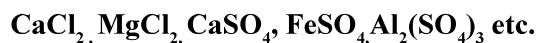
This types of hardness occurs due to the presence of soluble bicarbonates and carbonates of calcium, magnesium and other heavy metals in water. It can be removed easily by simple boiling when

dissolved bicarbonates are decomposed, yielding insoluble carbonates and hydroxides, which are collected as a crust at the bottom of vessel.



5.2 Permanent or Non-Carbonate Hardness –

This type of hardness occurs due to the presence of sulphates, chlorides, nitrates salts of calcium, magnesium, iron and other heavy metals. It cannot be removed by simple boiling. Hence, the salts responsible for permanent hardness are-



6. Degree of Hardness –

Although hardness of water is never present in the form of CaCO_3 , because it is insoluble in water, it is always calculated in terms of CaCO_3 .

The reason for choosing CaCO_3 as the standard for reporting hardness of water is the easy in calculations as its molecular weight is exactly 100 (and equivalent wt. is exactly 50) and it is the most insoluble salt that can be precipitated in water treatment. Thus, equivalent of CaCO_3 for hardness producing substance can be calculated by formula.

6.1 Equivalents of CaCO_3

$$\begin{aligned} & \left[\text{Mass of hardness producing substance} \left(\text{in } \frac{\text{mg}}{\text{lit}} \right) \right] \\ &= \frac{[\text{Chemical equivalent of } \text{CaCO}_3]}{\text{Chemical equivalent of hardness producing substance}} \\ &= \frac{\left[\text{Mass of hardness producing substance} \left(\text{in } \frac{\text{mg}}{\text{lit}} \right) \right] \cdot 50 \times 2}{\text{Chemical equivalent of hardness producing substance} \times 2} \end{aligned}$$

$$\begin{aligned}
&= [\text{mass of hardness producing substance in mg/lit.}] \times \\
&\quad \frac{100}{2 \times \text{Chemical Eq. of hardness producing substance}} \\
&= [\text{Mass of hardness producing substance in mg/lit.}] \times \\
&(\text{multiplication factor in mg/lit.}) \\
&= \text{multiplication factor} - \\
&\quad \frac{\text{Mol.wt of CaCO}_3}{\text{Mol.wt of hardness causing substance}}
\end{aligned}$$

Total hardness = (Temporary hardness + Permanent hardness)

7. Multiplication factor for various compounds equivalent to CaCO₃ –

Sr. No.	Dissolved/ Salt/Ion	Molar Mass	Chemical Equivalent	Multiplication Factor for Converting into Equivalent of CaCO ₃
1.	Ca(HCO ₃) ₂	162	81	100 / 162
2.	Mg(HCO ₃) ₂	146	73	100 / 146
3.	CaCO ₃	100	50	100 / 100
4.	MgCO ₃	84	42	100 / 84
5.	CaSO ₄	136	68	100 / 136
6.	CaCl ₂	111	55.5	100 / 111
7.	MgSO ₄	120	60	100 / 120
8.	MgCl ₂	95	47.5	100 / 95
9.	Mg(NO ₃) ₂	148	74	100 / 148
10.	CO ₂	44	22	100 / 44
11.	Ca ²⁺	40	20	100 / 40
12.	Mg ²⁺	24	12	100 / 12
13.	CO ₃ ²⁻	60	30	100 / 60
14.	H ⁺	1	1	100 / 100
15.	HCO ₃ ⁻	61	61	100 / 61

16.	OH ⁻	17	17	100 / 136
17.	NaAlO ₂	164	82	100 / 111
18.	Al, (SO ₄) ₃	342	57	100 / 120
19.	FeSO ₄ ·7H ₂ O	278	139	100 / 95

Table – 1.3

8. Units of Hardness -

There are four units in which hardness can be expressed:

(a) Parts Per Million (ppm) :

- Defined as the number of parts by weight of **CaCO₃** present per million (10⁶) parts of water.

- Example: 1 ppm = 1 part of CaCO₃ equivalent hardness in 10⁶ parts of water.

(b) Milligrams Per Litre (mg/lit.):

- Defined as the number of milligrams of **CaCO₃** present in one litre of water.

1 mg/lit. = 1 mg of CaCO₃ equivalent hardness per litre of water
= 1 mg of CaCO₃ equivalent hardness per 10⁶ mg of water
= 1 part of CaCO₃ per 10⁶ parts of water

(c) Degree Clarke (°Cl)

It is defined as the parts of **CaCO₃ equivalent hardness per 70,000 parts of water.**

It is the number of grains of CaCO₃ equivalent hardness per gallon (10 lb) of water.

$1 \text{ grain} = 17000 \text{ lb} \quad \text{1 grain} = \frac{1}{70000} \text{ lb}$

i.e., **1°Cl = 1 part of CaCO₃ per 70,000 parts of water**

(d) Degree French (°Fr)

It is defined as the parts of **CaCO₃ equivalent hardness per 10⁵ parts of water.**

i.e., **1°Fr = 1 part of CaCO₃ equivalent per 10⁵ parts of water**

9. Relationship Between Various Units of Hardness:

- 1 ppm = 1 mg/lit. = 0.1 °Fr = 0.07 °Cl**
- 1 °Fr = 10 ppm = 10 mg/lit. = 0.7 °Cl**
- 1 °Cl = 14.3 ppm = 14.3 mg/lit. = 1.43 °Fr**

- **Summary :**

Water is vital for life but contains various impurities that affect its quality. Hardness, determined by EDTA method, affects usage in domestic and industrial settings.

- **Sources of Water :**

Water comes from natural sources (rivers, lakes, groundwater, rain, glaciers, oceans) and artificial sources (dams, reservoirs, canals, municipal systems).

- **Impurities in Water :**

Impurities are categorized as dissolved (salts, gases, organic matter), suspended (sand, silt), and colloidal (microbes, fine particles), each needing different purification methods.

- **Types of Hardness :**

- **Temporary hardness :** Caused by bicarbonates; removable by boiling.

- **Permanent hardness :** Caused by sulfates, chlorides, etc.; not removed by boiling.

- **Degree of Hardness :**

Hardness is measured in terms of CaCO_3 equivalents due to its simplicity in calculations (molar mass = 100 g/mol).

- **Multiplication Factors :**

Various salts have specific multiplication factors to convert their concentration into CaCO_3 equivalents based on molecular weights.

- **Units of Hardness :**

Hardness is expressed in:

- ppm (mg/L)
- °Cl (Clarke)
- °Fr (French)

These units help standardize water hardness measurements.

- **Unit Conversions :**

- $1 \text{ ppm} = 1 \text{ mg/L} = 0.1^\circ\text{Fr} = 0.07^\circ\text{Cl}$
- $1^\circ\text{Fr} = 10 \text{ ppm} = 0.7^\circ\text{Cl}$
- $1^\circ\text{Cl} = 14.3 \text{ ppm} = 1.43^\circ\text{Fr}$

