Lecture-1

Water treatment is the process of removing all types of impurities from water, making it suitable for domestic and industrial use.

Impurities in water

Once water has fallen on the earth as rain, it will either start to penetrate the soil, remain on the surface in puddles, or run off into rivers or lakes - depending largely on the type of rock strata found immediately below the earth's surface. Therefore, the main source of impurities is the mineral and organic constituents which make up the upper layers of the earth's crust, and which are dissolved or held in suspension by the water. Surface waters are especially prone to seasonal changes in quality caused mainly by varying levels of organic contaminants. For instance, during the autumn and winter months, dead leaves and decaying plants release large quantities of organic matter into streams, lakes and reservoirs.

Water has been called both 'the matrix of life' and 'the universal solvent'. So in addition to providing a life-support system for a broad range of living organisms, it can dissolve virtually every chemical compound, though not necessarily to a detectable degree. It normally contains < 500 mg/l total dissolved solids TDS - equivalent to a purity of 99.95%. Even so, minute quantities of impurities can have a profound effect on industrial and laboratory processes - hence the need for purification.

The various impurities present in raw waters can be classified as follows:

A. **Dissolved impurities:** It is of three types: (**1).** ***Inorganic salts*** (due to presence of dissolved salts like carbonates, bicarbonates, nitrates, chlorides and sulphates of calcium (Ca), magnesium (Mg), iron (Fe),sodium (Na), etc. (**2).** ***Organic matters*** (due to presence of humic and fulvic Acids) (3) ***Dissolved gases*** **(**includes O_2, CO_2). Dissolved impurities causes corrosion in boilers and imparts hardness to water.

B. **Suspended & Colloidal impurities:** (1) **Suspended Impurities:** *Organic* (includes vegetable & animal matters, industrial & domestic by-products, oil globules, etc.); *Inorganic* (includes clay/silica/sand particles); (3) ***Colloidal*** *(*organic and inorganic)- includes finely divided silica, clay, sand, products from organic wastes, etc. Such impurities impart turbidity, colour and odour to water.

C. **Living Matters:** It is of two types: (1) *Micro-organisms* (include bacteria, fungi, protozoa, and algae); (2) *Macro-organisms* (includes fish, worm, larvae, etc.). Living matters brings health related issues upon consumptions.

Hardness- A water quality parameter of water

Hardness in water is a characteristic by virtue of which it prevents lathering/foaming of soap solution. It is also defined as the soap consuming capacity of water. Higher is the hardness of water larger is the consumption of soap. Hardness is due to presence of dissolved salts of calcium (Ca), magnesium (Mg) and other heavy metals like iron (Fe), manganese (Mn), and aluminum (Al). In other words hardness in water is due to bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{3-}), and nitrate (NO_3^-) of Ca, Mg, Fe, Mn, Al, etc.

Salts like $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $CaCl_2$, $MgCl_2$, $CaSO_4$, $MgSO_4$, $Ca(NO_3)_2$, $Mg(NO_3)_2$, $FeSO_4$, $Al_2(SO_4)_3$, $MnSO_4$, $Mn(HCO_3)_2$, $Fe(HCO_3)_2$, etc. are responsible of hardness of water. **The major contributor towards hardness is Ca and Mg-salts.

N.B.: Chemical constituents like $NaHCO_3$, NaCl, KCl, K_2SO_4, Na_2SO_4, $NaNO_3$, KNO_3, Fe_2O_3, etc. are treated as ***non-hardness constituents***.

Soap consuming tendency of hard water *(Why is hard water consumes more soap?)*

Soaps are sodium (Na) or potassium (K) salt of higher fatty acids (e.g.; Stearic acid $C_{17}C_{35}COOH$, oleic acid $C_{17}C_{33}COOH$, palmitic acid $C_{15}C_{31}COOH$). For example, $C_{17}C_{35}COONa$ (Sodium stearate).

A sample of hard water (let say contains hardness constituent as $CaCl_2$) when treated with soap does not produce enough lather, but on the other hand forms a white scum or precipitate. The precipitation process continues till all the hardness constituents are removed as white scum. After this, soap generates enough foam with water. The chemical reactions involved during this process are as follows:

1. $2C_{17}C_{35}COONa$ (soap) + $CaCl_2$ → $(C_{17}C_{35}COO)_2Ca$ (*Calcium Stearate, White scum*) + 2NaCl
2. Soap + water → Produces enough foam

Hard Water and Soft Water

The water which does not produce lather with soap solution readily, but forms a white curd is called hard water. In fact any cations which produce soft precipitate with soap solution will contribute to hardness. Examples include Ca^{+2}, Mg^{+2}, etc. On the other hand, water which lathers easily on shaking with soap solution is called soft water. Soft water is free from dissolved Ca and Mg-salts. The difference between the two is summarized in the following table.

Sl. No.	**Hard Water**	**Soft Water**
1	Water which does not readily produce lather with soap solution, but forms a white curd, is called "Hard Water".	Water which readily form foam on shaking with soap solution, is called "Soft Water".
2	It contains dissolved Ca, Mg, Fe, Mn-salts.	It does not contain dissolved Ca, Mg, Fe, Mn-salts.
3	Cleansing quality of soap is depressed and a lot of soap is wasted during washing and bathing.	Cleansing quality of soap is not depressed and a little amount of soap is wasted during washing and bathing.
4	B. Pt. of water is elevated.	Water boils at 104 ^{0}C.
5	Hair and skin becomes hard and dull.	Hair and skin becomes soft.
6	It is not a plumbosolvent	**Plumbo-solvency** occurs

***A residual hardness 100-200 ppm as $CaCO_3$ equivalent is needed for drinking purposes.

***Plumbosolvency*: Plumbosolvency** is the ability of a solvent like water to dissolve lead (Pb latin name-Plumbum). Soft water is a plumbo-solvent. Permissible limit of Pb in water is 0.01 ppm.

Why shouldn't drinking water be too soft?

The reason is that soft water is plumo-solvent and helps in dissolution of Pb as per the following reaction: **$2Pb + 2H_2O + O_2 \rightarrow 2Pb(OH)_2$**

N.B: The solubility of Pb in water is diminished in the presence of HCO_3^- (i.e., in hard water)

Also minerals like Calcium is needed *for strong teeth and healthy bones in children.*

Q.2. Which of the following salts are non-hardness constituents?

Na_2SO_4, $NaNO_3$, $Al_2(SO_4)_3$, $MnSO_4$, $Mn(HCO_3)_2$

Ans. Na_2SO_4 and $NaNO_3$

Q. 3. What is plumbo-solvency?

Ans: Plumbosolvency is the ability of a solvent like water to dissolve lead (Pb stands for plumbum in Latin)

$2Pb + 2H_2O + O_2 \rightarrow 2Pb(OH)_2$

Q. 4. Give reason that hard water is not a plumbo-solvent.

Ans. 1. The solubility of Pb (plumbum) in water is diminished in the presence of HCO_3^- , SO_4^{2-} (i.e., in hard water), 2. bicarbonates and sulphates provide a protective layer on the surface of the pipe.

Q. 5. Give reason that hard water consumes a lot of soap.

Ans. A sample of hard water (let say contains hardness constituent as $CaCl_2$) when treated with soap does not produce enough lather, but on the other hand forms a *white scum or precipitate*. The precipitation process continues till all the hardness constituents are removed as white scum. After this, soap generates enough foam with water. The chemical reactions involved during this process are as follows:

3. $2C_{17}C_{35}COONa$ (soap) + $CaCl_2 \rightarrow (C_{17}C_{35}COO)_2Ca$ (*Calcium Stearate, White scum*) + 2NaCl
4. After some time, Soap + water (Free from hardness)→ Produce enough foam

Q. 6. Write the chemical reactions involved when hard water reacts with soap.

Ans. The chemical reactions involved during this process are as follows:

1. $2C_{17}C_{35}COONa$ (soap) + $CaCl_2 \rightarrow (C_{17}C_{35}COO)_2Ca$ (*Calcium Stearate, White scum*) + 2NaCl
2. Soap + water → Produce enough foam

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