3. Water pollution

Water : Water is the chemical substance with chemical formula H_2O, one molecule of water has two hydrogen atoms covalently bonded to a single oxygen atom.

2. Physical properties of water Water is colourless and tasteless liquid. The molecules of water have extensive hydrogen bonds resulting to unusual properties in the condensed form. This also leads to high melting and boiling points. As compared to other liquids, water has a higher specific heat, thermal conductivity, surface tension, dipole moment etc. These properties form the reason for its significance in the biosphere. Water is an excellent solvent and therefore it helps in the transportation of ions

Chemical properties of water Water reacts with a lot of substances to form different compounds. Some significant reactions are as follows:

• Amphoteric nature:

- Water can act as both acid and base, which means that it is amphoteric in nature.

Example: Acidic Behaviour: H_2O (l)+NH_3 (aq) ⇌ H_3O^+ (aq)+ NH^+_4(aq)

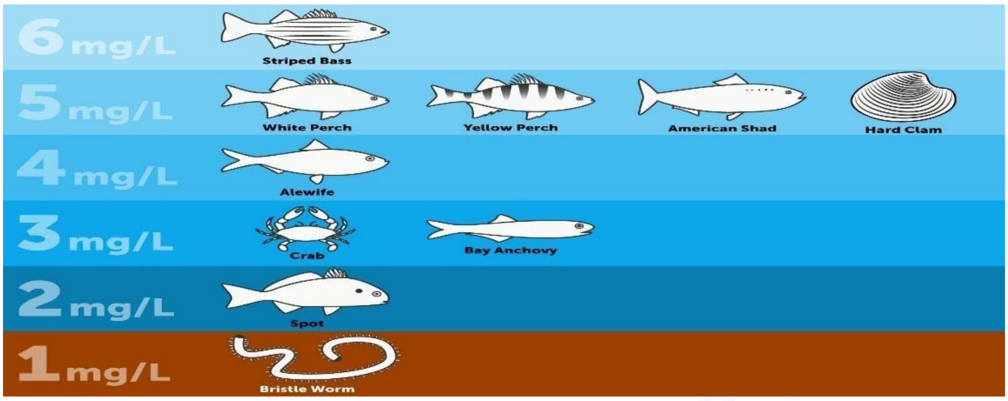
Basic Behaviour: H_2O (l)+ H_2S(aq) ⇌ H_3O^+ (aq) + HS^- (aq)

Properties

Chemical formula	H2O
Molar mass	18.01528(33) g/mol
Odour	None
Density	**Solid**: 0.9167 g/ml at 0°C **Liquid:** 0.961893 g/mL at 95°C 0.9970474 g/mL at 25°C 0.9998396 g/mL at 0°C
Boiling point	99.98 °C (211.96 °F; 373.13 K)
Melting point	0.00 °C (32.00 °F; 273.15 K)
Solubility	Miscible with acetonitrile, dimethyl sulfoxide, dimethoxymethane, dimethylformamide, acetaldehyde, sulfonate, tetrahydrofuran, 1,4- dioxane, glycerol, acetone, isopropanol, propanol, ethanol, methanol. Partially miscible with Bromine, Ethyl Acetate, Diethyl ether, Dichloromethane
Vapor pressure	3.1690 kilopascals or 0.031276 atm
Refractive index(nD)	1.3330 (20°C)
Thermal conductivity	0.6065 W/m·K
Viscosity	. 0.890 cP
Structure	
Crystal structure	Hexagonal Molecular
shape	Bent
Point group	C_2v
Dipole moment	1.8546 D
Specific heat capacity (C)	75.375 ± 0.05 J/mol·K
Std enthalpy of formation	-285.83 ± 0.040 kJ/mol
Std molar entropy	69.95 ± 0.03 J/mol·K
Gibbs free energy	-237.24 kJ/mol

3. Dissolved Oxygen

Dissolved Oxygen is the amount of gaseous oxygen (O2) dissolved in the water. Oxygen enters the water by direct absorption from the atmosphere, by rapid movement, or as a waste product of plant photosynthesis. Water temperature and the volume of moving water can affect dissolved oxygen levels. Oxygen dissolves easier in cooler water than warmer water. Adequate dissolved oxygen is important for good water quality and necessary to all forms of life. Dissolved oxygen levels that drop below 5.0 mg/L cause stress to aquatic life. Lower concentrations cause greater stress



Dissolved Oxygen and Water

water molecules contain an oxygen atom, this oxygen is not what is needed by aquatic organisms living in natural waters. A small amount of oxygen, up to about ten molecules of oxygen per million of water, is actually dissolved in water. Oxygen enters a stream mainly from the atmosphere and, in areas where groundwater discharge into streams is a large portion of stream flow, from groundwater discharge.

Dissolved oxygen and water quality. Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, whereas stagnant water contains less. Bacteria in water can consume oxygen as organic matter decays. Thus, excess organic material in lakes and rivers can cause eutrophic conditions, which is an oxygen-deficient situation that can cause a water body to "die." Water near the surface of the lake– the epilimnion– is too warm for them, while water near the bottom–the hypolimnion– has too little oxygen.

4. Biological Oxygen Demand (BOD) and Water Biochemical oxygen demand (BOD) represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature.

When you look at water in a lake the one thing you don't see is oxygen. we think that water is the opposite of air, but the common lake or stream does contain small amounts of oxygen, in the form of dissolved oxygen. Although the amount of dissolved oxygen is small, up to about ten molecules of oxygen per million of water, it is a crucial component of natural water bodies; the presence of a sufficient concentration of dissolved oxygen is critical to maintaining the aquatic life and aesthetic quality of streams and lakes.

Determining how organic matter affects the concentration of dissolved oxygen (DO) in a stream or lake is integral to water- quality management. The decay of organic matter in water is measured as biochemical or chemical oxygen demand.

5. COD - Chemical Oxygen Demand

The COD value indicates the amount of oxygen which is needed for the oxidation of all organic substances in water in mg/l or g/m^3 .

The COD (Chemical Oxygen Demand) is closely related to the laboratory standard method named Dichromate-Method. With this method the chemical oxygen demand is determined during chromic acid digestion of organic loads in waste water. Based on this method the COD became a commonly used sum parameter in waste water analysis. It is used for planning of waste water treatment plants, for controlling the cleaning efficiency and for the calculation of waste water taxes.

Common Detection Methods

Dichromate Method (Wet Chemical Oxidation)

The dichromate method needs about 2 hours for oxidation and it uses hazardous chemicals such as chromic acid, mercury sulphate, sulphuric acid and titration reagents, it is not suitable for online analysis. Also due to the heavy usage of toxic chemicals this method is not acceptable for laboratory personal. High operational and subsequent costs are the result and consequently industries and operators are looking for online sum parameters and 'clean' methods, without a second pollution due to the chemicals involved.

Clean methods

In the United States the TOD (Total Oxygen Demand) has been standardized and is used as a reference to the oxygen demand of organic substances in waste water. Another clean method to determine the chemical oxygen demand is the electrochemical oxidation using OH-radicals.

6. Total Suspended Solids in Water Samples Environmental waters may contain a variety of solid or dissolved impurities. suspended solids is the term used to describe particles in the water column. Practically, they are defined as particles large enough to not pass through the filter used to separate them from the water. Smaller particles, along with ionic species, are referred to as dissolved solids. The most common pollutant in the world is “dirt” in the form of TSS.

First, let’s consider some implications of total suspended solids (TSS). -High concentrations of suspended solids may settle out onto a streambed or lake bottom and cover aquatic organisms, eggs, or macro invertebrate larva. This coating can prevent sufficient oxygen transfer and result in the death of buried organisms.

High concentrations of suspended solids decrease the effectiveness of drinking water disinfection agents by allowing microorganisms to “hide” from disinfectants within solid aggregates. This is one of the reasons the TSS, or turbidity, is removed in drinking water treatment facilities.

Many organic and inorganic pollutants sorb to soils, so that the pollutant concentrations on the solids are high. Thus, pollutants (and solids) can be transported elsewhere in river and lake systems, resulting in the exposure of organisms to pollutants away from the point source.

TDS :

TDS stands for total dissolved solids, and represents the total concentration of dissolved substances in water. TDS is made up of inorganic salts, as well as a small amount of organic matter. Common inorganic salts that can be found in water include calcium, magnesium, potassium and sodium, which are all cations, and carbonates, nitrates, bicarbonates, chlorides and sulphate's, which are all anions. Cations are positively charged ions and anions are negatively charged ions.

Solids end up Dissolved in Water: . Mineral water with high levels of dissolved solids, because the water has flowed through a region where the have a high rocks salt content. The water in the Prairie Provinces tends to have high levels of dissolved solids, because of high amounts of calcium and magnesium in the ground. These minerals can also come from human activities.

Water TDS Levels

• a high concentration of dissolved solids is usually not a health hazard. In fact, many people buy mineral water, which has naturally elevated levels of dissolved solids. Most people think of TDS as being an aesthetic factor.

• a very low concentration of TDS has been found to give water a flat taste, which is undesirable to many people.

7. Hardness of water Hardness of water defined as which prevent the lathering of soap. This is due to presence of certain salts like Ca^{+2}, Mg^{+2} and other heavy metals dissolved in water.

Soft Water: The water which gives more lather with soap is called soft water.

$$C_{17}H_{35}COONa + H_2O \rightarrow C_{17}H_{35}COOH + NaOH$$

Hard Water: The water which does not give lather with soap is called hard water. This is due to presence of certain salts like Ca^{+2}, Mg^{+2} and other heavy metals dissolved in water

$$2C_{17}H_{35}COONa + CaCl_2/MgCl_2 \rightarrow (C_{17}H_{35}COO)\ 2\ Ca/Mg + 2NaCl$$

Causes of Hardness : Hardness of water is due to the presence of Bicarbonates, Chlorides, Sulphates and Nitrates of Calcium and Magnesium.

Types of hardness : Hardness of water is mainly two types:

1. Temporary Hardness 2. Permanent Hardness

1. Temporary Hardness: Temporary Hardness mainly caused by the presence of dissolved bicarbonates of Calcium, Magnesium ($Ca(HCO_3)_2$, $Mg(HCO_3)_2$). Temporary Hardness can be largely removed by boiling of water.

$(Ca(HCO_3)_2 \rightarrow CaCO_3\downarrow + H_2O + CO_2$ $Mg(HCO_3)_2 \rightarrow Mg(OH)_2\downarrow + 2CO_2$

2. Permanent Hardness: It is due to the presence of dissolved Chlorides, Nitrates and Sulphates of Calcium, Magnesium, Iron and other metals. Permanent hardness responsible salts are $CaCl_2$, $MgCl_2$, $CaSO_4$, $MgSO_4$, $FeSO_4$, $Al_2(SO_4)_3$. Permanent Hardness cannot be removed by boiling but it can be removed by the use of chemical agents.

8. Methods to convert temporary hard water into soft water :

Boiling method : temporary hardness can removed by Boling hard water. On boiling hard water, bi carbonates of calcium and magnesium decompose to form insoluble carbonates of the respective metal.

$Mg(HCo_3)_2 \rightarrow MgCo_3 + H_2o + Co_2$

$Ca(HCo_3)_2 \rightarrow CaCo_3 + H_2o + Co_2$

Clark's method:

Clark's method of hardness removal is a temporary hardness removal method. In this method some amount of calcium hydroxide is added to the hard water, because of that some insoluble carbonates are found, which are separated through the method of filtration.

The slaked lime and the calcium hydroxide is added with the hard water (Temporary). And then the insoluble calcium carbonate can be precipitated out by filtration and there is no longer hardness can be produced

$Ca(HCo_3)_2 + CaCo_3 \rightarrow 2\ CaCo_3 + 2\ H_2o$

9. Methods to convert permanent hard water into soft water :

Permutt (Zeolite process) method : Zeolite is micro-porous mineral which is used as catalyst in many industrial purposes such as water purification and air purification. Permutt is the synthetic zeolite that is most used in water softening Zeolites are light in density, insoluble in water but can act as base exchangers in contact with water containing cations.

Zeolite process for water softening become a commercial success for the reason that zeolite can be easily regenerated. When Ca2+ and Mg2+ ions containing hard water is passes through a bed of sodium zeolite, the sodium ions are replace by the calcium and magnesium ions.

$$Na_2Ze + Ca(HCO_3)_2 \rightarrow 2NaHCO_3 + CaZe$$

$$Na_2Ze + Mg(HCO_3)_2 \rightarrow 2NaHCO_3 + MgZe$$

$$Na_2Ze + CaSO_4 \rightarrow Na_2SO_4 + CaZe$$

$$Na_2Ze + MgSO_4 \rightarrow Na_2SO_4 + MgZe$$

When all sodium ions are replaced by calcium and magnesium ions, the zeolite becomes inactive. Then the zeolite needs to be regenerated. Brine solutions are passing through the bed of inactivated zeolite. The following reactions are taken place and form Na_2Ze.

$$CaZe + 2NaCl \rightarrow Na_2Ze + CaCl_2$$

$$MgZe + 2NaCl \rightarrow Na_2Ze + MgCl_2$$

Ion-exchange resin method : Conventional water-softening appliances intended for household use depend on an ion-exchange resin in which "hardness ions"—mainly Ca^{2+} and $Mg^{2+}$are exchanged for sodium ions. Ion-exchange devices reduce the hardness by replacing magnesium and calcium (Mg^{2+} and Ca^{2+}) with sodium or potassium ions (Na^+ and K^+)."

Ion exchange resins, are organic polymers containing anionic functional groups to which the divalent cations (Ca2+) bind more strongly than monovalent cations (Na+).

The resin must be recharged by eluting the Mg^{2+} and Ca^{2+} ions using a solution of sodium chloride or sodium hydroxide, depending on the type of resin used. The waste waters eluted from the ion-exchange column containing the unwanted calcium and magnesium salts are typically discharged to the sewage system.

Reverse osmosis: Reverse osmosis uses an applied pressure gradient across a semi permeable membrane to overcome osmotic pressure and remove water molecules from the solution with hardness ions. The membrane has pores large enough to admit water molecules for passage; hardness ions such as Mg^{2+} and Ca^{2+} will not fit through the pores. The resulting soft water supply is free of hardness ions without any other ions being added. Membranes are a type of water filter requiring regular cleaning or replacement maintenance.

10. Eutrophication: Eutrophication the gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in an aging aquatic ecosystem such as a lake. The productivity or fertility of such an ecosystem naturally increases as the amount of organic material that can be broken down into nutrients increases. This material enters the ecosystem primarily by runoff from land that carries debris and products of the reproduction and death of terrestrial organisms. Water blooms, or great concentrations of algae and microscopic organisms, often develop on the surface, preventing the light penetration and oxygen absorption necessary for underwater life

The main effects caused by eutrophication

1. Species diversity decreases and the dominant biota changes
2. Plant and animal biomass increase
3. Turbidity increases
4. Rate of sedimentation increases, shortening the lifespan of the lake
5. Anoxic conditions may develop

The changes in nutrient levels and biology can directly affect human activities.

The main occurring problems can be summarized as follows:

1. The water can be injurious to health
2. The amenity value of the water may decline
3. Increased vegetation may impede water flow and navigation
4. Commercially important species of fish may disappear

UNIT-IV
Chemical Toxicology