UNIT 3: Characteristics of Water

❖ Physical Properties of Water

1. Water is a tasteless, odourless liquid at standard temperature and pressure.

2. Water has a high **specific heat**. Specific heat is the amount of energy required to change the temperature of a substance. Because water has a high specific heat, it can absorb large amounts of heat energy before it begins to get hot. It also means that water releases heat energy slowly when situations cause it to cool. Water's high specific heat allows for the moderation of the Earth's climate and helps organisms regulate their body temperature more effectively.

3. Water in a pure state has a neutral **pH**. As a result, pure water is neither **acidic** nor **basic**. Water changes its pH when substances are dissolved in it. Rain has a naturally acidic pH of about 5.6 because it contains natural derived carbon dioxide and sulfur dioxide.

4. Water **conducts** heat more easily than any liquid except mercury. This fact causes large bodies of liquid water like lakes and oceans to have essentially a uniform vertical temperature profile.

5. Water molecules exist in liquid form over an important range of temperature from 0 - 100° Celsius. This range allows water molecules to exist as a liquid in most places on our planet.

6. Water is a universal **solvent**. It is able to dissolve a large number of different chemical compounds. This feature also enables water to carry solvent nutrients in **runoff**, **infiltration**, **groundwater flow**, and living organisms.

7. Water has a high **surface tension** In other words, water is adhesive and elastic, and tends to aggregate in drops rather than spread out over a surface as a thin film. This phenomenon also causes water to stick to the sides of vertical structures despite gravity's downward pull. Water's high surface tension allows for the formation of water droplets and waves, allows plants to move water (and dissolved nutrients) from their roots to their leaves, and the movement of blood through tiny vessels in the bodies of some animals.

8. Water molecules are the only substance on Earth that exist in all three **physical states of matter**: **solid**, **liquid**, and **gas**. Incorporated in the changes of state are massive amounts of heat exchange. This feature plays an important role in the redistribution of heat energy in the Earth's atmosphere.

9. **Total dissolved solid (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 cations (calcium, magnesium, potassium and sodium) and anions (carbonates, nitrates, bicarbonates, chlorides and sulphates). As per WHO standard TDS acceptable for **drinking** purpose is less than 500 **ppm** . **Water** can be classified by the level of TDS in the **water**: Fresh **water**: less than 500 mg/L TDS=500 **ppm**. Brackish **water**: 500 to 30,000 mg/L TDS=500-30 000 **ppm**.

❖ Chemical Properties of Water

1. **Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD):** Dissolved oxygen analysis measures the amount of gaseous oxygen (O2) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. The amount of dissolved oxygen used by microorganisms in the biological process of metabolizing organic matter in water. The more organic matter there is (e.g., in sewage and polluted bodies of water), the greater the BOD; and the greater the BOD, the lower the amount of dissolved oxygen available for higher animals such as fishes.
2. **Chemical Oxygen Demand (COD):** COD is a measurement of the oxygen required to oxidize soluble and particulate organic matter in water**.** The chemical oxygen demand test procedure is based on the chemical decomposition of organic and inorganic contaminants, dissolved or suspended in water. The result of a chemical oxygen demand test indicates the amount of water-dissolved oxygen (expressed as parts per million or milligrams per liter of water) consumed by the contaminants, during two hours of decomposition from a solution of boiling potassium dichromate. The higher the chemical oxygen demand, the higher the amount of pollution in the test sample**.**
3. **Conductivity (EC):** Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. Compounds that dissolve into ions are also known as electrolytes. The more ions that are present, the higher the conductivity of water. Distilled or deionized water can act as an insulator due to its very low conductivity value. Sea water, on the other hand, has a very high conductivity.
4. **Sodium adsorption ratio** (**SAR**): **SAR** is an irrigation water quality parameter used in the management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water. It is a standard diagnostic parameter for the sodicity hazard of a soil, determined from analysis of pore water extracted from the soil**.**

$$SAR = \frac{\left[Na^{+}\right]}{\sqrt{\frac{\left[Ca^{2+}\right]+\left[Mg^{2+}\right]}{2}}}$$

(Where Na^{+}, Ca^{2+} and Mg^{2+} concentrations are expressed in milliequivalents/litre)

5. **Amphoteric nature**: Water can act as both acid or base that it is amphoteric in nature. Water in natural state is neither acidic nor basic.
Acidic Behavior : $H_2O(l)+NH_3(aq) \rightleftharpoons H_3O^+(aq)+NH_4^+(aq)$
Basic Behaviour: $H_2O(l)+H_2S(aq) \rightleftharpoons H_3O^+(aq)+HS^-(aq)$

6. **Redox reactions:** Electropositive elements reduce water to hydrogen molecule. Thus water is a great source of hydrogen. During the process of photosynthesis, water is oxidized to O_2. As water can be oxidized and reduced, it is very useful in redox reactions.

❖ Biological Properties of Water

Five types of parasitic organisms (i.e. bacteria, protozoa, viruses, worms and fungi) are generally known to be infective to main and are found in water.

1. Bacteria
These are the minute single cell organisms possessing no defined nucleus and having no green material to help them manufacture their own food. They are reproduced by binary fusion and may of various shapes and sizes are 1 to 4 microns, examined by microscope.

a) Non-disease causing bacteria – Non pathogenic bacteria.
b) Disease causing bacteria – Pathogenic bacteria.

2. Protozoa
These are single cell animals and are the lowest and the simplest form of animal life. They are bacteria eaters and thus destroy Pathogens. They are counted by microscope.

3. Viruses A sub-microscopic infectious agent that replicates only inside the living cells of an organism.

4. Worms: These are the larva of flies.

5. Fungi: These are those plants which grow without sunlight and live on other plants or animals, dead or alive.

6. Pathogenic bacteria
These can be tested and counted in the laboratories but with great difficulty. These tests are therefore, generally not performed in routine to check up of the water quality. The usual routine tests are generally conducted to detect and count the presence of coliforms which in themselves harmless organisms, but their presence or absence indicates the presence or absence of pathogenic bacteria

❖ Methods to measure the presence of coliform bacteria:

1. Membrane filter technique (modern technique)
2. Mixing different dilution of a sample of water with lactose froth and incubating them in test-tubes for 48 hours at 37^0C. the presence of acid or carbon dioxide gas in tubes will indicate the presence of coliform bacteria.

Most probable number (MPN) represent the bacterial density.

❖ **Coliform index**

It may be defined as the reciprocal of the smallest quantity of a sample which would give a positive portion. Coliform sometimes called bacteria coli (B-coli) or Escherichia (E-coli) are harmless aerobic micro-organisms.If not more than 1 coliform is present per 100ml of water, then water is said to be safe for drinking.

$$\text{MPN/100 ml} = \frac{100\ x\ Number\ of\ positive\ portion}{\sqrt{(ml\ in\ all\ positive\ portion)x\ (ml\ in\ all\ negative\ portion)}}$$

7. BIO-INDICATOR AND BIO-MONITOR

A Bioindicator is any species **(an "indicator species")** or group of species whose function, population, or status can reveal the qualitative status of the environment. For example, ***copepods and other small water crustaceans*** that are present in many water bodies can be monitored for changes (***biochemical, physiological, or behavioural)*** that may indicate a problem within their ecosystem. Bioindicators can tell us about the cumulative effects of different pollutants in the ecosystem and about how long a problem may have been present, which physical and chemical testing cannot

A **Biomonitor**, can be defined as an organism that provides quantitative information on the quality of the environment around it. Therefore, a good biomonitor will indicate the presence of the pollutant and also attempt to provide additional information about the amount and intensity of the exposure. There are several types of plant and fungibiomonitors, including ***mosses, lichens, tree bark, bark pockets, tree rings, leaves*** *and fungi.*

Lichens are important **bio-monitor for air pollution**.. They are found on rocks and tree trunks, and they respond to environmental changes in forests, including changes in forest structure – conservation biology, air quality, and climate

MACRO-INVERTEBRATES AS BIO-INDICATOR

Macro-invertebrates are organisms without backbones, which are visible to the eye without the aid of a microscope. Aquatic macroinvertebrates live on, under, and around rocks and sediment on the bottoms of lakes, rivers, and streams. As a result of their habitat choice, macroinvertebrates are often regarded as "benthos" which refers collectively to organisms which live on, in or near the bottom. Examples of freshwater benthic macro-invertebrates include the immature and adult stages of many different types of invertebrates. A freshwater benthic community may consist of the immature stages of many flies, beetles (adults and immatures), mayflies, caddisflies, stoneflies, dragonflies, aquatic worms, snails, leeches and numerous other organisms that inhabit the benthos.

❖ HOW ARE THESE ORGANISMS USED IN ENVIRONMENTAL ASSESSMENT?

Benthic macro-invertebrates, especially aquatic insects, represent a choice group of organisms used in biological monitoring programs. Macro-invertebrates within the same system may be residents for several months to multiple years, depending on the lifespan of the particular organism. Macro-invertebrate communities therefore reside in an aquatic system long enough to reflect the chronic effects of pollutants, and yet short enough to respond to relatively acute changes in water quality. Unlike fish, these populations tend to be relatively immobile, and as a result are continuously exposed to the constituents of the surface water they inhabit. Thus, because of the limited mobility of macro-invertebrates and their relative inability to move away from adverse conditions, the location of chronic sources of pollution often can be pinpointed by comparing communities of these organisms.Macro-invertebrates exhibit varying responses to changes in water chemistry, water quality and physical habitat. Each macro-invertebrate's response to environmental perturbations produces measurable, and often predictable, shifts in abundance and composition at the community level.

Individually, macro-invertebrates can also be used to indicate sublethal effects, such as mouthpart deformities in chironomid midges (aquatic fly larvae). Benthic macroinvertebrates and chironomids in particular, are used as bioindicators for environmental stress in aquatic ecosystems at different levels, including morphological deformities. Deformities of invertebrates are used frequently as ecotoxicological endpoints in cases of legacy environmental issues.

❖ BENTHIC MACRO-INVERTEBRATE SAMPLING

Many watershed monitoring programs include biological indicators in addition to chemical and physical tests for routine monitoring:

- Because of their sensitivity to different degrees of pollution, shifts in macroinvertebrate communities can **identify the impacts of pollution as well as the effectiveness of pollution control activities**.
- According to the Clean Water Act, individual states are required to report those waters which do not support their designated uses. Biological surveys directly

examine the aquatic communities in streams and any stressors which may affect them, and are therefore ideal tools to determine whether a stream's **designated aquatic life uses** are supported.

- Over time, studies of stream macroinvertebrates can be used to identify **water quality trends**, whether increasing or decreasing, at a site over several years or decades.
- Surveys of aquatic insect communities can be used to **identify areas of concern within streams and rivers**, as they can reflect the presence of non-optimal conditions that other measurements (such as chemical monitoring) might miss. Individual stream sites can then be ranked from best to worst, in comparison to reference conditions, and priorities can be set for their improvement.
- **Habitat assessments** used in conjunction with aquatic surveys can help determine whether shifts in benthic community structure are caused, at least in part, by habitat limitations such as bank erosion, siltation or substrate embeddedness.
- To evaluate a **catastrophic environmental event**, such as a spill or explosion from an environmental standpoint, and to track the acute and chronic effects of a system's recovery over time.