CHAPTER ONE
Prosperities of water

1. Introduction

- **Water**, which is odorless, tasteless, transparent liquid that is colorless in small amounts but exhibits a bluish tinge in large quantities.
- It is the most familiar and abundant liquid on earth

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- In solid form(ice) and liquid form it covers about 70% of the earth's surface.
- with 1.6% of water below ground in aquifers and 0.001% in the air as vapor and clouds.
- **Water** is a common chemical substance that is essential to all known forms of life.
- Saltwater oceans hold 97.0% of surface water, glaciers and polar ice caps 2.4%,and other land surface water such as rivers and lakes 0.6%.

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- Water in these forms moves perpetually through the water cycle of **evaporation** and **transpiration**, **precipitation**, and **runoff** usually reaching the sea. Winds also carry water vapor over land at the same rate as runoff into the sea.
- about 36 Tt (teratones) per year Over land, evaporation and transpiration contribute another 71 Tt/year.

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1.1. What are physical properties?

- Physical properties of a substance are properties that have everything to do with the substance's appearance.

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a) The States of Water

- ✓ Water molecules are the only substance on Earth that exists in all three physical states of matter:**solid, liquid,** and **gas.**
- ✓ Water changing from solid to liquid is said to be ***melting.***
- ✓ When it changes from liquid to gas it is ***evaporating.***
- ✓ Water changing from gas to liquid is called ***condensation***
- ✓ ***Frost formation*** is when water changes from gas directly to solid form.
- ✓ When water changes directly from solid to gas the process is called ***sublimation.***

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b) Adhesion and Cohesion

- Water is attracted to other water. This is called ***cohesion.***
- Water can also be attracted to other materials. This is called ***adhesion.***
- The oxygen end of water has a negative charge and the hydrogen end has a positive charge. The hydrogens of one water molecule are attracted to the oxygen from other water molecules. This attractive force is what gives water its cohesive and adhesive properties.
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c) Surface Tension

- Surface tension is the name we give to the cohesion of water molecules at the surface of a body of water.
- Surface tension is related to the cohesive properties of water

d) Capillary Action

- Capillary action refers to the process of water moving up a narrow tube against the force of gravity.
- Capillary Action is related to the adhesive properties of water.

e.g. water intake by plant

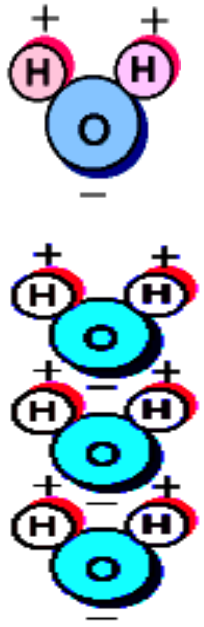

Figure1: The atomic structure of a water (or dihydrogen monoxide) molecule consists of two hydrogen (H) atoms joined to one oxygen (O) atom.

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e) Specific heat

- Specific heat is the amount of energy required to change the temperature of a substance.
- Water has a high specific heat due to this, 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.

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f) Miscibility and Condensation

- Water is miscible with many liquids, for example ethanol in all proportions, forming a single homogeneous liquid.
- On the other hand water and most oils are immiscible usually forming layers according to increasing density from the top.
- As a gas, water vapor is completely miscible with air. On the other hand the maximum water vapor pressure that is thermodynamically stable with the liquid (or solid) at a given temperature is relatively low compared with total atmospheric pressure.

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g) Solvent Nature

- Water is a very strong solvent, referred to as the universal solvent, dissolving many types of substances.
- Substances that will mix well and dissolve in water (e.g. salts) are known as "hydrophilic" (water-loving).
- substances, while those that do not mix well with water (e.g. fats and oils), are known as "hydrophobic (water-fearing) substances.

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- The ability of a substance to dissolve in water is determined by whether or not the substance can match or better the strong attractive forces that water molecules generate between other water molecules.
- If a substance has properties that do not allow it to overcome these strong intermolecular forces, the molecules are "pushed out" from amongst the water and do not dissolve.

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h) Viscosity

- This means the syrupiness of water and it determines the mobility of water. When the temperature rises,the viscosity degrades; this means that water will be more mobile at higher temperatures.

i) Density

- Density of water means the weight of a certain amount of water. It is usually expressed in kilograms per cubic meter.
- The density of pure water is constant at a particular temperature (1 kilograms per cubic meter).(Kg/m3)

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- The density of water does not depend on the size of the sample.
- The density of water varies with temperature and impurities. When water freezes it expands rapidly adding about 9 % by volume.
- Fresh water has a maximum density at around 4°c. Water is the only substance where the maximum density does not occur when solidified.
- As ice is lighter than water, that is why it floats.

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Note:

- 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.
- 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.

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Density;Water molecules are the only substance on Earth that exists in all three **physical states of matter: solid, liquid,** and **gas.**

- Water is the only on this planet where the maximum density of its mass does not occur when it becomes solidified.

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Temperature (degrees Celsius)	Density (grams per cubic centimeter)
0 (solid)	0.9150
0 (liquid)	0.9999
4	1.0000
20	0.9982
40	0.9922
60	0.9832
80	0.9718
100 (gas)	0.0006

Table 1.1: Density of water molecules at various temperatures

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j) Turbidity (total suspended solids, TSS)

- Used to measure the cloudiness of water
- High turbidity in water bodies may be caused by organic and inorganic substances,
- Turbidity expressed by NTU (Nephlometeric turbidity Unit)

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1.2. Chemical Properties of Water

- Water has been called the universal solvent, and chemical parameters are related to the solvent capabilities of water.

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Chemical Properties of Water…….

- The most important chemical characteristics of water are its **acidity, alkalinity, hardness, and corrosiveness.**
- Chemical impurities can be either natural, man-made or be deployed in raw water sources by enemy forces.
- Some chemical impurities cause water to behave as either an acid or a base. Since either condition has an important bearing on the water treatment process, the pH value must be determined.
- Generally the pH influences the corrosiveness.

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A). pH

- pH is an indicator of the acid or alkaline condition of water. The pH scale ranges from 0-14;
- 7 indicates the theoretical neutral point. Water with a pH value less than 7 indicates acidity and tends to be corrosive,
- while water with a value greater than 7 indicates alkalinity and tends to affect the taste of the water.

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- ***Potential Health Effects***

✓ The pH of drinking water is not a health concern; however, acidic water (low pH) can leach metals from plumbing systems, which can cause health problems.

- ***Indications of Low pH***

✓ Symptoms of **low pH** are bluish **green stains** on **fixtures** with **copper plumbing;**

✓ **reddish stains** with **galvanized iron plumbing**; and water system corrosion problems and plumbing leaks.

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B). Hardness

- Water hardness is a term Used to express the total concentration of cations; specifically calcium,magnesium, Iron and manganese and also other metals Zinc and Aluminum also contribute.
- It is a measure of the total mineral content expressed as mg/l equivalents of calcium carbonate.

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- Hardness however, refers primarily to the amount of calcium and magnesium ions present.
- Hardness is caused by the soluble salts of calcium, magnesium, iron, manganese, sodium, sulfates, chlorides, and nitrates.
- The **degree of hardness depends on** the **type** and **amount of impurities** present in the water.
- Hardness also depends on the amount of carbon dioxide in solution. Carbon dioxide influences the solubility of the impurities that cause hardness.

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- The hardness caused by carbonates and bicarbonates is called **carbonate hardness**.
- The hardness caused by all others (chlorides, sulfates, nitrates etc.) is called **noncarbonated hardness.**
- Hardness is undesirable in that it consumes soap, makes water less satisfactory for cooking, and **produces scale** in boilers and distillation units.

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- The following minerals cause hardness in ground and surface waters:

1. Calcium carbonate: Alkaline and only lightly soluble; causes carbonate hardness and alkalinity in water.

2. Calcium bicarbonate: Contributes to the alkalinity and carbonate hardness of water. Calcium bicarbonate when heated produces carbon dioxide and calcium carbonate. This calcium carbonate precipitates as scale in boilers and distillation units.

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3. Calcium sulfate or gypsum: Causes noncarbonated hardness in water. Being more soluble in cold water than in hot, it separates from the water in boilers and forms scale on the boiler tubes.

4. Calcium chloride: Causes noncarbonated hardness in water. In steam boilers and distillation units, the presence of calcium chloride causes chemical reactions that can pit metallic tubing.

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5. Magnesium carbonate (magnesite) and magnesium bicarbonate: Act the same in water as calcium carbonate and bicarbonate.

6. Magnesium sulfate (Epsom salts): Adds to the noncarbonated hardness of water and causes boiler scale. In amounts greater than 500 parts per million in drinking water, it acts as a laxative.

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7. Magnesium chloride: Has the same properties and effects as calcium chloride. However, the magnesium will contribute to the formation of magnesium hydroxide scale on boilers and evaporators. .

8. Iron: Iron is undesirable because it imparts a rusty color and objectionable taste to water. It also forms crusts in plumbing and piping.

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- When iron is present in water, organisms whose life processes depend on iron compounds may also be present. These organisms may cause tastes and odors and create what is called red water.

9. Manganese: While not encountered as often as iron, it is found in both surface and ground water. Its presence in water normally causes a grey or black color.

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- ✓ The total concentrations of iron and manganese in potable water should not exceed 0.3 ppm.
- ✓ Carbonate hardness →***temporary hardness*** → it can be removed by boiling water.
- ✓ **Non-carbonate hardness** → ***permanent hardness*** → **cannot be broken down by boiling the water**.
- ✓ Oxidation by aeration, followed by sedimentation and filtration, is the most common method of removing iron and manganese
- ✓ The same methods may generally be used to remove both iron and manganese.

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Carbonate hardness	Non-carbonate hardness
Calcium carbonate ($CaCO_3$)	Calcium sulfate ($CaSO_4$)
Magnesium carbonate ($MgCO_3$)	Magnesium sulfate ($MgSO_4$)
Calcium bicarbonate ($Ca(HCO_3)_2$)	Calcium chloride ($CaCl_2$)
Magnesium bicarbonate ($Mg(HCO_3)_2$)	Magnesium chloride ($MgCl_2$)
Calcium hydroxide ($Ca(OH)_2$)	
Magnesium hydroxide ($Mg(OH)_2$)	

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- ✓ The addition of lime, Ca(OH)2, followed by sedimentation and filtration, is another method for removal of these substances.
- ✓ The concentration of chemical substances present in water for community water supply should not exceed the values shown below. If local conditions or short-term requirements make the use of water containing higher chemical concentrations necessary authorization must be obtained from the **Environmental Health Officer.**

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Sr.No	Chemical Substances	Maximum Values
1	Copper (Cu2+)	1.0 ppm
2	Iron (Fe2+)	0.3 ppm
3	Manganese (Mn2+)	0.05 ppm
4	Zinc (Zn2+)	5.0 ppm
5	Magnesium (Mn2+)	125.0 ppm
6	Chlorides (Cl-)	250.0 ppm
7	Sulfates (SO4+)	250.0 ppm

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8	Lead (Pb2+)	0.05 ppm
9	Hexavalent Chromium (Cr6+)	0.05 ppm
10	Fluoride (F-)	1.5 ppm

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11	Phenolic compounds	0.001 ppm
12	Turbidity (silica scale)	5.0 units
13	Color (platinum-cobalt scale)	15.0 units
14	Nitrate-Nitrogen	10.0 ppm
15	Total Solids	500.0 ppm

Table 1.2: concentration of chemical substances in drinking water

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C). Alkalinity

- Alkalinity is the water's capacity to resist changes in pH that would make the water more acidic, a capacity commonly termed as *'' buffering capacity''*.
- A buffer essentially absorbs the excess H+ ions and protects the water body from fluctuations in pH.
- Alkalinity is usually equivalent to the carbonate hardness. Sodium, however, also causes alkalinity.

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D). *Oxygen in drinking Water Supply*

- As rainwater falls through the atmosphere, it collects oxygen gas. This dissolved oxygen is not the same as the oxygen in the water molecule. Dissolved oxygen is present in all rainwater and surface supplies due to contact with the atmosphere.

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- Just how much dissolved oxygen a water supply will contain depends on:

I. Pressure: Under high pressure relatively large quantities of oxygen dissolve in water. When the pressure is reduced, a proportionate weight of the gas escapes (Henry's Law).

Henry's Law: The English chemist, William Henry, formulated a law regarding the effect of pressure on a gas.

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- The law states: “The weight of a gas that dissolves in any given liquid is directly proportional to the pressure, providing the temperature remains constant. If one gram of oxygen, for example, dissolves in 100 cubic centimeters of water at atmospheric pressure, two grams of oxygen will dissolve under twice the normal atmospheric pressure, providing there has been no change in temperature.”

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II. Mineral content: The amount of minerals in water affects its ability to dissolve oxygen.

- ✓ Distilled water can absorb more oxygen than well waters with higher mineral content.
- ✓ Obviously sea water, for this same reason, holds less dissolved oxygen than fresh water.
- ✓ Oxygen adds to the taste of water. For this reason a small amount of it is desirable in drinking water.

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- ✓ in a household water supply. The fact is that oxygen causes corrosion. In cold water, oxygen normally has little corrosive effect. In contrast, when the water is heated, the oxygen can cause serious corrosion problems.
- ✓ A number of chemicals are used in industry to remove oxygen from a water supply. Sodium sulfite (Na_2S0_3) is probably most widely used for this purpose.