Structural Abiotic Constituents of Earth

Girdhari Lal Meena

Lecturer in Chemistry
Govt. PG College Rajgarh (Alwar)

The abiotic or non-living constituents of earth environment includes soil, air, water, temperature, moisture, radiations, etc. The soil, air and water are the structural abiotic constituents of environment and these constituents supports the life on earth's surface. These are discussed below in details:

Soil: The uppermost and natural grainy portion of earth's crust is basically known as soil. The word soil coined from the Latin word '***Solum***' that signifies earth granular material that help to grow plants. It is defined as "*A dynamic natural body on the surface of earth in which plant grow and composed of inorganic minerals, organic materials and living forms*"(Allison, 1973; Trivedi, 2018).

Soil is derived from parent rocks by the natural and climatic factors such as by the weathering processes, erosion, flow of water on earth surface, winds, heat, human activities, effect of microorganisms, etc. Soil is basically composed of mixture of inorganic minerals, trace elements, natural organic substances, microorganisms, gases, moisture, etc.

Air (Gases): Air is second abiotic structural component of environmental system and it produce a gaseous envelop across the earth's surface that is basically known as atmosphere. It is supporting the life on earth's surface, i.e., oxygen and carbon dioxide are the biological important gases and essential for the human beings and plants, respectively.

The pure atmospheric air is constituted by the mixture of numerous gases such as N_2 (78.09%), O_2 (20.95%), Ar (0.93%), CO_2(0.04%), and trace amount of hydrogen, helium, neon, krypton, and methane. Therefore, the atmospheric air is mainly composed of gaseous components and it is critically essential for biosphere because without air, the existing form of life on the earth would be impossible.

Water: Water is third abiotic structural component of environmental system which formulates the earth's hydrosphere. The hydrosphere includes oceans, seas, rivers, lakes, glaciers, reservoirs, groundwater, ponds, etc. Similar to air, water is another important component that supports the life on earth' surface, i.e., water is essential for human, plants and animals, and the living beings can only live few days without water. Therefore, water is most extensive substance on the earth's surface, and it is also critically essential substance for biosphere because without water, the existing form of life on the earth would also be impossible.

Water

Water is the most wide-spread, valuable and fundamental core component of natural environment which covers approximately 71% area of the earth's surface (Skinner and Porter, 1987; Barbara, 2005; Gleick, 1993 & 2011). It is nature's most precious, essential and life-sustaining element that has crucial importance for whole living beings including human, animals, plants and microorganisms to sustain their life on the earth's surface (Franks, 1972-1982; De, 2000; Ball, 2001; Valsami-Jones, 2004). It is earth's most common natural renewable resource that specifying and completes all the necessities of human beings and without it, life on earth and extensive human progress is not possible.

Water is a transparent, odourless and nearly colourless fluid which form the ***earth's hydrosphere*** (Skinner and Porter, 1987; Barbara, 2005; Gleick, 1993 & 2011). In the natural environment of earth, water exist in three natural physical states including water(Liquid state), iced water (Solid state) and water vapour (Gaseous state). The earth's hydrosphere comprises maximum liquid water resources of natural environment, since it covers ~71% area of earth's surface. It includes oceans, seas, rivers, lakes, ponds, glaciers, groundwater streams, reservoirs etc. (Rao, 1979). Around 97% water of the hydrosphere found in the oceans and seas, that is not readily useable for human beings. Since water is necessary for living beings, it is also found as major components of the fluids of whole living beings including human, animals, plants, microorganisms etc. It customizes ~60-78% of the human body and performs numerous critical functions therein.

Chemistry of Water: Water is a most popular universal liquid chemical substance and it is generally designated as '**Universal Solvent**' (Gleick, 1993). The chemical formula of water is '**H_2O**' and each water molecule are comprised of three atoms, i.e., one oxygen atom and two hydrogen atoms. The oxygen atom is covalently bonded with two hydrogen atoms in bent shape with the bond angle of ~104.45°. A water molecule is polar in nature and possesses extraordinary hydrogen bonding capacity. Due to hydrogen bonding, water molecule retains some unique properties such as high boiling point (100°C), high heat capacity, ice floats on water due to less density than water, high solubility of chemical substances in water, hydrophobic effect, etc.

Apart from these, water molecule exists in three different physical states in our surroundings, i.e., liquid (water), solid (iced water) and gas (water vapour) (Water's three physical states). From which, liquid water is the most common and well-known form of water and it is occurs in normal conditions of the environment. These forms of water are vigorously interchangeable simply by environmental conditions such as changing in temperature and pressure of water (Sharp, 2001).

Physicochemical Characteristics of Water: Since water is the most common and important major constituent of earth's environment and key component of most of the life forms on earth, it is necessary to analysis the physicochemical characteristics of water. The performance and permanence of life depends on the physicochemical characteristics of water. Some important and major physicochemical characteristics of water are discussed below and also tabulated in **Table 1**:

Physical Characteristics of Water: On earth's surface, water is the most abundant and priceless matter that have numerous physical characteristics such as water has three different physical states, and it is colourless, odourless and tasteless liquid at standard environments. Apart from these precise properties of water, the hydrogen bonding of water molecules is answerable for numerous properties such as high value of surface tension, viscosity, boiling point, and heat and entropy of vaporization

(Boyacioglu&Boyacioglu, 2008; Halliday et al., 1971).Some of the important physical characteristics of water are reviewed below in details:

Table 1: Important physicochemical characteristics of water.

Entry	Properties of Water	Value
1.	Chemical Formula	H_2O
2.	Molar Mass (M)	18.012 g.mol^{-1}
3.	Melting Temperature	0ºC
4.	Boiling Temperature	99.98ºC
5.	Density (□□ Liquid water)	999.839 kg.m^{-3} (0ºC) 997.05 kg.m^{-3} (25ºC)
6.	Density (□□ Solid water or ice)	916.80 kg.m^{-3} (0ºC)
7.	Dielectric Constant	80.4 (20ºC)
8.	Thermal Conductivity	0.6065 W/(m.K)
9.	Refractive Index (n_D)	1.3330 (20ºC)
10.	Dipole Moment	1.8546 D

A. Physical States of Water: In natural environment of earth's surface, water exist in three different natural physical states such as water (liquid state), ice (Solid state) and water vapour (Gaseous state) (**Fig. 3**). It is the only chemical material on earth's surface that naturally exists in all three-physical states. These forms of water are naturally interconvertible, and it is depending on the atmospheric pressure and temperature.

The states of water can change through various processes and changes in amount of heat (**Fig. 3**). The equivalent amount of heat that required to change the state of water are generally known as ***specific latent heat***. For water, the specific latent heat for melting or solidification and evaporation or boiling are ~333.3 kJ/kg and ~2257 kJ/kg, respectively (Datt, 2011; Mottaghy and Rath, 2006; Tölgyessy, 1993). That means, the addition or removal of little amount of heat can convert ice to liquid water or liquid water to ice through the process of melting and solidification, respectively. Similarly, the addition of large amount of heat can convert liquid water to water vapour (gaseous water).

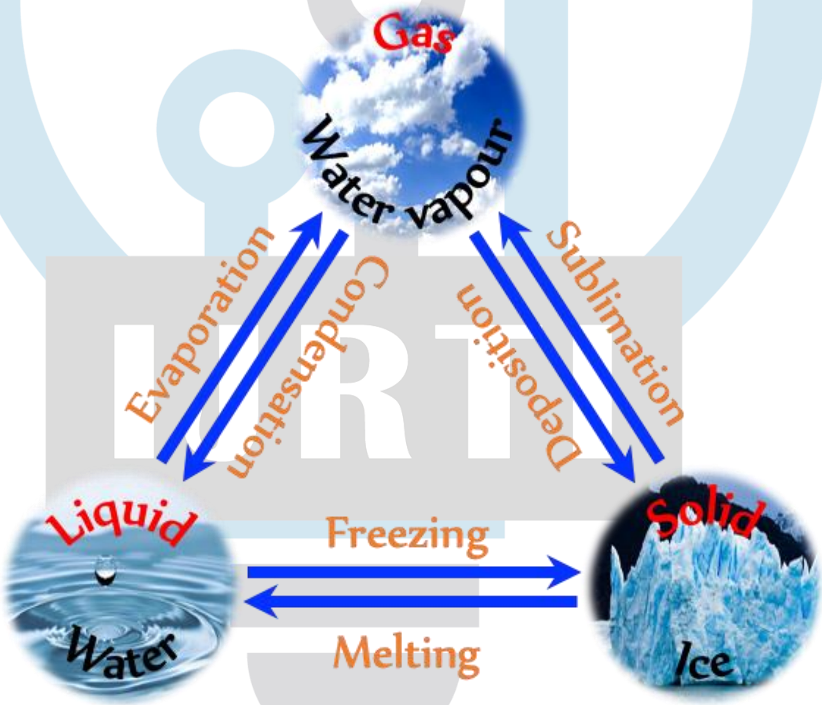

Figure 3: The physical states of water and processes through which water can changes their states.

B. Taste, Odour and Colour of Water: Naturally, pure water is tasteless, odourless and colourless at standard environment. Generally, the sensitivity of water, i.e., taste, odour and colour are fabricated by foreign substances or by pollution.

Water is tasteless but the taste of water is prominently manipulated by chemical substances and chemical salts that existing in water in soluble form. They can be essential or non-essential for human beings. The chemical substances or salts are calcium, magnesium, sodium, iron, zinc, silica, manganese, coper, chlorides, sulphates, carbonates, etc. The optimal concentration of these substances give water a considerably favorable taste, but the higher concentration of chemical substances and salts are responsible for the unfavorably hard and unpleasant taste of water.

Naturally, water is odourless when it is present in purest form on earth's surface. However, the odour of water is initiated by the natural or synthetic chemical substances or by the biological substances that introduced in water via natural activities or via man-made activities. For example, hydrogen sulphide is the natural fraction of water and produce rotten egg like odour in water, and chlorination of water produce chlorine-phenol odour in water.

The pure and comparatively small amount of water is seemed to be colourless substance at ambient conditions. The bulk amount of water or thick layer of pure water is seemed to be blue in colour and it is because of suspended particles, and selective absorption and scattering of visible light. The intensity of blue colour increases with the increasing depth of the water and decreasing insoluble suspended particles. The colour of water also depends on the soluble chemical substances, salts, impurities and pollution. For example, the greenish colour of natural water is produced both by microalgae that found in water or by calcium salts and the brown colour of water is produced by humus.

C. **Turbidity of Water:** The pure drinkable water is clear and transparent in nature. The turbidity of water mainly produced by inorganic or organic colloidal substances. The inorganic colloidal substances such as hydrated oxides of iron and magnesium, silicic oxide, clay minerals, etc., and organic colloidal substances such as bacteria, algae, plankton, organic colloids, etc., are responsible factor for highly turbid water on earth's surface. The turbid water appeared undesirable and not suitable for human drinking and other human uses.

D. **Density and Viscosity of Water:** The density and viscosity of pure water changes with temperature. The highest density (~999.972 kg/m^3) of pure water is instigated at ~4ºC temperature, and above and below this temperature, the density of pure water decreases (**Fig. 4**). Thus, the density of water increases from 0ºC (999.839 kg/m^3) to 4ºC (~999.972 kg/m^3) and then it is constantly decreased up to 100ºC (958.4 kg/m^3). Therefore, the icedwater (solid state) is less dense than the water (liquid state) and it is float on the surface of liquid water.

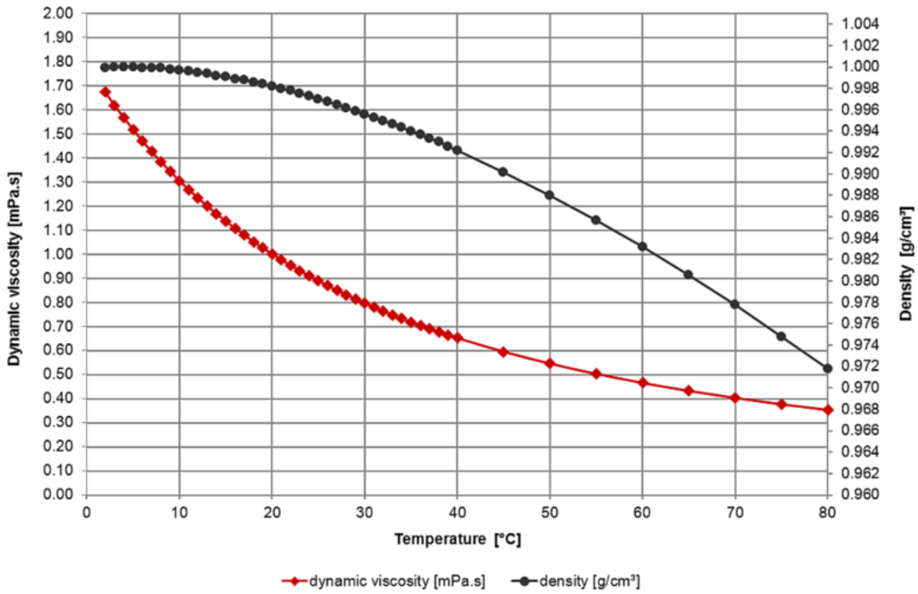

Figure 4: Density (black line) and dynamic viscosity (red line) of pure water over broad temperature range (Anton-Paar: Viscosity of Water).

The viscosity of water always decreases with increasing temperature range, i.e., water is highly viscous at room temperature or below room temperature and less viscous at high temperature range. The highest dynamic viscosity of pure water is noted about 1.6735 mPa.s at 2ºC temperature and at 25ºC and 80ºC temperature, the dynamic viscosity of water is about 0.89 mPa.s and 0.354 mPa.s, respectively (**Fig. 4**).

E. **Solubility of Liquid, Solid and Gases in Water:** Water is generally introduced as 'Universal solvent' and has ability to dissolve most of the chemical substances. The dissolution of chemical substance in water is the most important physical property of water and it is because of dipolar character, high hydrogen bonding capacity and high dielectric constant of water (Kudesia, 1985; Kudesia and Kudesia, 1998).

Most of the solids, liquids and gaseous substances are readily dissolved in water. Water is good solvent for solid ionic substance, inorganic salts, organic compounds, polar liquids, and gases. The solubility of chemical substances in water is generally affected by temperature, i.e., the solubility of solid and liquid substances increases with increasing temperature while the solubility of gases decreases. In particular cases, the solubility of solid substances decreases with increasing temperature such as sulphate, carbonate and hydroxide of Ca andMg (Messel, 1966).

Most of the inorganic ionic compounds such as sodium chloride, potassium hydroxide, potassium bromide, magnesium chloride, etc., are readily soluble in water. The organic substances also willingly soluble in water but the solubility of organic substances sometimes affected by the addition of ionic compounds and it happened because of the salting out effect (Xie et al., 1997). Polar liquids such as organic and inorganic acids, lower alcohols, etc., are willingly soluble in water whereas the non-polar liquids (Hydrocarbons) and higher alcohol (Cetylalcohol) are water insoluble substances.

Most of the environmental gases such as biological important gases (O_2 and CO_2), N_2, H_2, NH_3, and SO_2 are also willingly soluble in water. The solubility of gases affected by the increasing amount of dissolved inorganic salts in water, that means the solubility of oxygen and other gases in water decreases with increasing amount of dissolved salts in water (MacArthur, 1916).

F. **Electrical Conductivity (EC) of Water:** The ultra-pure water (H_2O) is not anupright conductor of electricity while the ordinary fresh water is an electrical conducting matter on the earth's surface. The ordinary fresh water and sea water showed a specific electrical conductance of ~10-20 μS/cm and ~50,000 μS/cm at 25°C, respectively (Golnabi et al., 2009; McCleskey et al., 2011; Artemov, 2019).

The large number of ECs of water is because of total dissolved solids in water. Thus, the EC of H_2O is the function of concentration of dissolved solids, i.e., the EC of water rises with increase concentration of dissolved solids in water (McCleskey et al., 2011). The ordinary surface water and groundwater containing little amount of dissolved inorganic and organic substances, minerals, salts, ions, electrolytes, etc., and due to these chemical substances, surface water and groundwater showed measurable number of ECs. The contaminated and polluted water also behaved like a good conductor because it contains large concentration of dissolved solids.

The ultra-pure is behaved like an insulator because it is free from dissolved solids. The deionized water is not completely free from dissolved solids and the concentration of dissolved matter is very small. Thus, the deionized water behaved like a poor conductor and the EC of deionized water is detected ~0.05501 μS/cm at 25°C (Light et al., 2005).

I.3.2.1. Chemical Characteristics of Water: Chemically, water is a simplest and most abundant chemical substance on earth's surface. It is most precious molecule of nature that has one oxygen atom which covalently bonded with two hydrogen atoms in bent shape. Water molecule behaves like a weak oxidizing agent with metal atoms and sometime behaves like a reducing agent. It is amphoteric in nature that means it behaves like both acidic substance (a proton donor) and basic substance (a proton acceptor). Some other important chemical properties of water are deliberated below in details:

A. Acid-Base Reaction in Water and pH: Water is an amphoteric substance that behaves like both acid (a proton donor) and base (a proton acceptor). Thus, water undergoes acid-base reaction and this behavior of water is absolutely seen in auto-ionization of water (Self-ionization of water).

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + OH^-{}_{(aq)}$$

At equilibrium, the concentration of both hydronium ion (H_3O^+; hydrogen ion, H^+) and hydroxide ion (OH^-) in water is equal because both hydronium ion and hydroxide ion formed in equal amount. The concentration of both ions in water is about 1.0 x 10^{-7} M at 25°C. In this reaction, one water molecule behaves like an acid (Donate proton in the solution) and second water molecule behaves like a base (Accept proton from solution) and the reaction is reversible in nature.

When the concentration of both H^+ and OH^- ion is equal ($H^+ = OH^-$) then the aqueous solution is said to be neutral (pH = 7.0) in nature. When an organic or inorganic acid is dissolved in water then H^+ ion concentration in aqueous solution increases ($H^+ > OH^-$) and the resulting aqueous solution is said to be acidic (pH < 7.0). When a basic chemical substance is added to the water then OH^- ion concentration in aqueous solution increases ($H^+ < OH^-$) and the resulting aqueous solution is said to be basic (pH > 7.0).

B. Redox Reactions in Water: Redox reaction is an important chemical process which occurs between two molecules. In which one molecule is oxidized by losing electrons and another molecule is reduced by gaining those electrons. Therefore, the redox reaction can also be named as 'Oxidation-Reduction Reaction'.For example, sodium (Na) is an active alkali metal and it gives redox reaction with water. In the redox reaction of sodium and water, the electrons are transferred from sodium to water molecule. Thus, the sodium metal is oxidized to Na^+ ion by losing or donating electrons and water molecules is reduced to hydrogen gas and hydroxide ion by gaining or accepting electrons.

$$2H_2O_{(l)} + 2Na_{(s)} \longrightarrow 2Na^+{}_{(aq)} + H_{2(g)} + 2OH^-{}_{(aq)}$$

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