Introduction

Water is nature's most wonderful, abundant and useful compound and is the second most important need for life to exist after air. The distribution of water on the Earth's surface is extremely uneven. Only 3% Of freshwater (69% resides in glaciers, 30% underground, and less than 1% is located in lakes, rivers and swamps.) of water on the surface is fresh; the remaining 97% resides in the ocean. Looked at another way, only one percent of the water on the Earth's surface is usable by humans, and 99% of the usable quantity is situated underground. As a result, water quality has been described extensively in the scientific literature. The most popular definition of water quality is "it is the physical, chemical, and biological characteristics of water". Water quality is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose. Water gets degraded in quality when it contains an excess of unwanted chemicals and harmful microorganisms. Water gets polluted by various causes and sources. Water bodies have many uses such as municipal use, agricultural, industry, fisheries, recreation etc and the term quality must be considered relative to the intended use. There are many aspects of water pollution and there are many variables that determine water quality for a given use.

2.1. Classification of water

Based on its source, water can be divided into ground water and surface water. Both types of water can be exposed to contamination risks from agricultural, industrial, and domestic activities, which may include many types of pollutants such as heavy metals, pesticides, fertilizers, hazardous chemicals, and oils. Water quality can be classified into four types—potable water, palatable water, contaminated (polluted) water, and infected water.

1. Potable water: It is safe to drink, pleasant to taste, and usable for domestic purposes.

2. Palatable water: It is esthetically pleasing; it considers the presence of chemicals that do not cause a threat to human health.

3. Contaminated (polluted) water: It is that water containing unwanted physical, chemical, biological, or radiological substances, and it is unfit for drinking or domestic use.

4. Infected water: It is contaminated with pathogenic organisms.

2.2. Parameters of water quality

There are three types of water quality parameters physical, chemical, and biological. They are summarized in Table 1.

Physical	Chemical	Biological
It includes the dissolved and suspended soilds in water body. Plants, leaves and degraded organic material becomes the part of suspended matter. Ions like nitrates, hydroxides, chlorides etc are completely soluble in water and are called as dissolved solids.	It includes the chemical changes where solubility, chemical reactivity, temperature etc. play an important rule in Chemical quality of water. High level of alkalinity or acidity toxics and carcinogens etc degrade the water to a large extent	It includes microorganisms cellular and microscopic bacteria. These contaminate both surface as well as ground water and thus are responsible for various water borne diseases like diarrhea, cholera, typhoid etc.

2.2.1 Physical parameters of water quality

(a) Turbidity: Turbidity is the cloudiness of water. It is a measure of the ability of light to pass through water. It is caused by suspended material such as clay, silt, organic material, plankton, and other particulate materials in water. Turbidity in drinking water is esthetically unacceptable, which makes the water look unappetizing. The impact of turbidity can be summarized in the following points: 1. It can increase the cost of water treatment for various uses.

2. The particulates can provide hiding places for harmful microorganisms and thereby shield them from the disinfection process.

3. Suspended materials can clog or damage fish gills, decreasing its resistance to diseases, reducing its growth rates, affecting egg and larval maturing, and affecting the efficiency of fish catching method. 4. Suspended particles provide adsorption media for heavy metals such as mercury, chromium, lead, cadmium, and many hazardous organic pollutants such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and many pesticides

. 5. The amount of available food is reduced because higher turbidity raises water temperatures in light of the fact that suspended particles absorb more sun heat. Consequently, the concentration of the dissolved oxygen (DO) can be decreased since warm water carries less dissolved oxygen than cold water. Turbidity is measured by an instrument called nephelometric turbidimeter, which expresses turbidity in terms of NTU or TU. A TU is equivalent to 1 mg/L of silica in suspension Turbidity more than 5 NTU can be visible to the average person while turbidity in muddy water, it exceeds 100 NTU. Groundwater normally has very low turbidity because of the natural filtration that occurs as the water penetrates through the soil.

(b) Temperature: Palatability, viscosity, solubility, odors, and chemical reactions are influenced by temperature. Thereby, the sedimentation and chlorination processes and biological oxygen demand (BOD) are temperature dependent. It also affects the biosorption process of the dissolved heavy metals in water. Most people find water at temperatures of 10– 15°C most palatable.

(c) Color: Materials decayed from organic matter, namely, vegetation and inorganic matter such as soil, stones, and rocks impart color to water, which is objectionable for esthetic reasons, not for health reasons. Color is measured by comparing the water sample with standard color solutions or colored glass disks. One color unit is equivalent to the color produced by a 1 mg/L solution of platinum (potassium chloroplatinate (K_2PtCl_6). The color of a water sample can be reported as follows:

- Apparent color is the entire water sample color and consists of both dissolved and• suspended components color.

- True color is measured after filtering the water sample to remove all suspended• material.

Color is graded on scale of 0 (clear) to 70 color units. Pure water is colorless, which is equivalent to 0 color units.

(d) Taste and odor : Taste and odor in water can be caused by foreign matter such as organic materials, inorganic compounds, or dissolved gasses. These materials may come from natural, domestic, or agricultural sources. The numerical value of odor or taste is determined quantitatively by measuring a volume of sample A and diluting it with a volume of sample B of an odor-free distilled water so that the odor of the resulting mixture is just detectable at a total mixture volume of 200 ml.

(e) Solids: Solids occur in water either in solution or in suspension. These two types of solids can be identified by using a glass fiber filter that the water sample passes through. By definition, the suspended solids are retained on the top of the filter and the dissolved solids pass through the filter with the water.

If the filtered portion of the water sample is placed in a small dish and then evaporated, the solids as a residue. This material is usually called total dissolved solids or TDS.

Total solid(TS)=Total dissolved solid(TDS)+Total suspended solid(TSS) Water can be classified by the amount of TDS per liter as follows:

- Freshwater:• 5000 mg/L TDS. The residue of TSS and TDS after heating to dryness for a defined period of time and at a specific temperature is defined as fixed solids. Volatile solids are those solids lost on ignition (heating to 550°C). Figure 1 describes the interrelationship of solids found in water. They are calculated as follows:

Sample Evaporation TS Filter (Glass Fiber Evaporation of Filter Evaporation of Filterate TSS TDS Muffle Oven Muffle Oven VSS FSS VDS FDS TVS TFS TS TS = Total Solids TDS = Total Dissolved Solids TSS = Total Suspended Solids FSS = Fixed Suspended Solids VSS = Volatile Suspended Soilds FDS = Fixed Volatile Solids TVS = Total Volatile Solids VDS = Volatile Dissolved Solids Figure 1. Interrelationship of solids found in water. Total Solids:• Total solids(mg/L)=[(TSA−TSB)]×1000/sample(mL) where TSA = weight of dried residue + dish in milligrams and TSB = weight of dish in milligrams. Total dissolved solids:• Total dissolved solids(mg/L)=[(TDSA−TDSB)]×1000/sample(mL) where TDSA = weight of dried residue + dish in milligrams and TDSB = weight of dish in milligrams. Total suspended solids:• Total suspended solids(mg/L)=[(TSSA−TSSB)]×1000/sample(mL) where TSSA = weight of dish and filter paper + dried residue and TSSB = weight of dish and filter paper in milligram. Fixed and volatile suspended solids:• Volatile suspended solids(mg/L)=[(VSSA−VSSB)]×1000/sample(mL) where VSSA = weight of residue + dish and filter before ignition, mg and VSSB = weight of residue + dish and filter after ignition, mg.

(f) Electrical conductivity (EC)

The electrical conductivity (EC) of water is a measure of the ability of a solution to carry or conduct an electrical current. Since the electrical current is carried by ions in solution, the conductivity increases as the concentration of ions increases. Therefore, it is one of the main parameters used to determine the suitability of water for irrigation and firefighting.

Units of its measurement are as follows:

U.S. units = micromhos/cm

S.I. units = milliSiemens/m; (mS/m) or dS/m (deciSiemens/m) S/cm = 1dS/m)μ

Where, (mS/m = 10umho/cm; (1000 S/cm = 1dS/m)μ

Pure water is not a good conductor of electricity.

Typical conductivity of water is as follows:

Ultra-pure water: 5.5 × 10−6 S/m;

Drinking water: 0.005–0.05 S/m;

Seawater: 5 S/m.

2.2.2. Chemical parameters of water quality

(a) pH : pH is one of the most important parameters of water quality. It is defined as the negative logarithm of the hydrogen ion concentration. It is a dimensionless number indicating the strength of an acidic or a basic solution. Actually, pH of water is a measure of how acidic/basic water is. Acidic water contains extra hydrogen ions (H^+) and basic water contains extra hydroxyl (OH^-) ions.

As shown in Figure 2, pH ranges from 0 to 14, with 7 being neutral. pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base solution. Pure water is neutral, with a pH close to 7.0 at 25°C. Normal rainfall has a pH of approximately 5.6 (slightly acidic) owing to atmospheric carbon dioxide gas. Safe ranges of pH for drinking water are from 6.5 to 8.5 for domestic use and living organisms need. A change of 1 unit on a pH scale represents a 10-fold change in the pH, so that water with pH of 7 is 10 times more acidic than water with a pH of 8, and water with a pH of 5 is 100 times more acidic than water with a pH of 7. Excessively high and low pH can be detrimental for the use of water. A high pH makes the taste bitter and decreases the effectiveness of the chlorine disinfection, thereby causing the need for additional chlorine. The amount of oxygen in water increases as pH rises. Low-pH water will corrode or dissolve metals and other substances. Pollution can modify the pH of water, which can damage animals and plants that live in the water.

The effects of pH on animals and plants can be summarized as follows:

- Most aquatic animals and plants have adapted to life in water with a specific pH and• may suffer from even a slight change.
- Even moderately acidic water (low pH) can decrease the number of hatched fish eggs,• irritate fish and aquatic insect gills, and damage membranes.
- Water with very low or high pH is fatal. A pH below 4 or above 10 will kill most fish,• and very few animals can endure water with a pH below 3 or above 11.
- Amphibians are extremely endangered by low pH because their skin is very sensitive• to contaminants. Some scientists believe that the current decrease in amphibian population throughout the globe may be due to low pH levels induced by acid rain.

The effects of pH on other chemicals in water can be summarized as follows:

- Heavy metals such as cadmium, lead, and chromium dissolve more easily in highly acidic water (lower pH). This is important because many heavy metals become much more toxic when dissolved in water.
- A change in the pH can change the forms of some chemicals in the water. Therefore, it may affect aquatic plants and animals. For instance, ammonia is relatively harmless to fish in neutral or acidic water. However, as the water becomes more alkaline (the pH increases), ammonia becomes progressively more poisonous to these same organisms.

(b) Acidity: Acidity is the measure of acids in a solution. The acidity of water is its quantitative capacity to neutralize a strong base to a selected pH level. Acidity in water is usually due to carbon dioxide, mineral acids, and hydrolyzed salts such as ferric and aluminum sulfates. Acids can influence many processes such as corrosion, chemical reactions and biological activities. Carbon dioxide from the atmosphere or from the respiration of aquatic organisms causes acidity when dissolved in water by forming carbonic acid (H_2CO_3). The level of acidity is determined by titration with standard sodium hydroxide (0.02 N) using phenolphthalein as an indicator.

3.2.3 Alkalinity:The alkalinity of water is its acid-neutralizing capacity comprised of the total of all titratable bases. The measurement of alkalinity of water is necessary to determine the amount of lime and soda needed for water softening (e.g., for corrosion control in conditioning the boiler feed water). Alkalinity of water is mainly caused by the presence of hydroxide ions (OH^-), bicarbonate ions (HCO_3^-), and carbonate ions (CO_3^{2-}), or a mixture of two of these ions in water. As stated in the following equation, the possibility of OH^- and HCO_3^- ions together are not possible because they react together to produce CO_3^{2-} ions

$$OH^- + HCO_3^- \rightarrow CO_3^{2-} + H_2O$$

Alkalinity is determined by titration with a standard acid solution (H_2SO_4 of 0.02 N) using selective indicators (methyl orange or phenolphthalein). The high levels of either acidity or alkalinity in water may be an indication of industrial or chemical pollution. Alkalinity or acidity can also occur from natural sources such as volcanoes. The acidity and alkalinity in natural waters provide a buffering action that protects fish and other aquatic organisms from sudden changes in pH. For instance, if an acidic chemical has somehow contaminated a lake that had natural alkalinity, a neutralization reaction occurs between the acid and alkaline substances; the pH of the lake water remains unchanged. For the protection of aquatic life, the buffering capacity should be at least 20 mg/L as calcium carbonate. **(c) Chloride:** Chloride occurs naturally in groundwater, streams, and lakes, but the presence of relatively high chloride concentration in freshwater (about 250 mg/L or more) may indicate wastewater pollution. Chlorides may enter surface water from several sources including chloride-containing rock, agricultural runoff, and wastewater. Chloride ions Cl^- in drinking water do not cause any harmful effects on public health, but high concentrations can cause an unpleasant salty taste for most people. Chlorides are not usually harmful to people; however, the sodium part of table salt has been connected to kidney and heart diseases. Small amounts of chlorides are essential for ordinary cell functions in animal and plant life. Sodium chloride may impart a salty taste at 250 mg/L; however, magnesium or calcium chloride are generally not detected by taste until reaching levels of 1000 mg/L. Standards for public drinking water require chloride levels that do not exceed 250 mg/L. There are many methods to measure the chloride concentration in water, but the normal one is the titration method by silver nitrate.

(d) Sulfate: Sulfate ions (SO_4^{2-}) occur in natural water and in wastewater. The high concentration of sulfate in natural water is usually caused by leaching of natural deposits of sodium sulfate (Glauber's salt) or magnesium sulfate (Epson salt). If high concentrations are consumed in drinking water, there may be objectionable tastes or unwanted laxative effects, but there is no significant danger to public health.

(e) Nitrogen: There are four forms of nitrogen in water and wastewater: organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. If water is contaminated with sewage, most of the nitrogen is in the forms of organic and ammonia, which are transformed by microbes to form nitrites and nitrates. Nitrogen in the nitrate form is a basic nutrient to the growth of plants and can be a growth-limiting nutrient factor. A high concentration of nitrate in surface water can stimulate the rapid growth of the algae which degrades the water quality. Nitrates can enter the groundwater from chemical fertilizers used in the agricultural areas. Excessive nitrate concentration (more than 10 mg/L) in drinking water causes an immediate and severe health threat to infants. The nitrate ions react with blood hemoglobin, thereby reducing the blood's ability to hold oxygen which leads to a disease called blue baby or methemoglobinemia.

(f) Fluoride: A moderate amount of fluoride ions (F^-) in drinking water contributes to good dental health. About 1.0 mg/L is effective in preventing tooth decay, particularly in children. Excessive amounts of fluoride cause discolored teeth, a condition known as dental fluorosis. The maximum allowable levels of fluoride in public water supplies depend on local climate. In the warmer regions of the country, the maximum allowable concentration of fluoride for potable water is 1.4 mg/L; in colder climates, up to 2.4 mg/L is allowed.

(f) Iron and manganese: Although iron (Fe) and manganese (Mn) do not cause health problems, they impart a noticeable bitter taste to drinking water even at very low concentration. These metals usually occur in groundwater in solution as ferrous (Fe^{2+}) and manganous (Mn^{2+}) ions. When these ions are exposed to air, they form the insoluble ferric (Fe^{3+}) and manganic (Mn^{3+}) forms making the water turbid and unacceptable to most people. These ions can also cause black or brown stains on laundry and plumbing fixtures.

(g) Copper and zinc: Copper (Cu) and zinc (Zn) are nontoxic if found in small concentrations. Actually, they are both essential and beneficial for human health and growth of plants and animals. They can cause undesirable tastes in drinking water. At high concentrations, zinc imparts a milky appearance to the water. They are measured by the same methods used for iron and manganese measurements.

2.3. Hard Water

Hardness is a term used to express the properties of highly mineralized waters. Thus the water which contains high contents of dissolved salts in it is called as hard water. Hard water is formed when water percolates through deposits of limestone, chalk or gypsum, which are largely made up of calcium and magnesium carbonates, bicarbonates and sulfates. The dissolved minerals in water cause problems such as scale deposits in hot water pipes and difficulty in producing lather with soap. Thus, in simple terms hard water is also defined as the water which doesn't form leather with soap easily. Calcium ($Ca2+$) and magnesium ($Mg2+$) ions cause the greatest portion of hardness in naturally occurring waters. They enter water mainly from contact with soil and rock, particularly limestone deposits. These ions are present as bicarbonates, sulfates, and sometimes as chlorides and nitrates. Generally, groundwater is harder than surface water. There are two types of hardness:

Temporary hardness: That type of hardness which can be removed simply by boiling• is termed as temporary hardness. Temporary hardness (Carbonate hardness) is caused by the presence of dissolved bicarbonates of Calcium, Magnesium, Iron and other heavy elements. It can be eliminated by mere boiling. $Ca(HCO3)2 \rightarrow CaCO3\downarrow + H2O + CO2\uparrow$ $Mg(HCO3)2 \rightarrow MgCO3 + H2O + CO2\uparrow$ $MgCO3 \rightarrow Mg(OH)2\downarrow + CO2\uparrow$

Permanent hardness: The type of hardness which cannot be removed by simple• boiling or which still remains in water after boiling is termed as permanent hardness. Permanent Hardness (non-carbonate hardness) is due to the presence of dissolved chlorides and sulphates of Calcium, Magnesium, Iroother heavy elements.

Measurement or Degree of Hardness: Degree of hardness is extent of hardness. It is expressed as weight in milligrams of CaCO3 equivalent to all hardness causing substance in one million milligram of water. That is parts per million (ppm). Or it can be expressed as weight in milligrams of CaCO3 equivalent to all hardness causing substance in one litre of water.

Unit of hardness = ppm or mg/L

Different units used to express degree of hardness ppm (parts per million) = This is weight in milligrams of CaCO3 equivalent to all hardness causing substance in one million (106) milligram of water. mg/L (milligram per litre) = weight in milligrams of CaCO3 equivalents in one litre of water. ^{0}Cl (degree Clark) = weight in grams of CaCO3 equivalents in 70,000 gram of water. ^{0}Fr (degree French) = weight in grams of CaCO3 equivalents in 105 gram of water. 1 ppm = 1 mg/L = 0.1^{0}Fr = 0.07 ^{0}C

Degrees of Water Hardness

Soft water	0-17.1 mg/L of minerals

Slightly hard water	16.1-60 mg/L of minerals
Moderately hard water	61-120 mg/L of minerals Hard water 121- . . . 180 mg/L of minerals
Very hard water	more than 180 mg/L of minerals

$CaCO_3$ as reference for Hardness

a. $CaCO_3$ is stable, non-hygroscopic and is obtained in pure form. Therefore a standard hard water solution can be prepared by dissolving accurately weighed $CaCO_3$ in dilute HCl and make up to a known volume.

b. $CaCO_3$ is insoluble in water. Therefore it can be easily precipitated in water treatments.

c. Molecular weight of $CaCO_3$ is 100, so mathematical calculations are easy.

Hardness is normally determined by titration with ethylene diamine tetra acidic acid or (EDTA) and Eriochrome Black and Blue indicators. It is usually expressed in terms of mg/L of $CaCO_3$.

Total hardness mg/L as $CaCO_3$ = Calcium hardness mg/L as $CaCO_3$ + Magnesium hardness mg/L as $CaCO_3$

Soft Water

The water which gives lather with soap water is called soft water. It contains lower concentrations of minerals such as calcium and magnesium. It contains sodium ions. According to WHO, water containing calcium carbonate at concentrations below 60mg/l is soft water.

Difference between Hard and Soft Water

Soft water	Hard water
1. It readily lather with soap.	It does not readily lather with soap.
2. It will not form insoluble scum with soap.	It forms insoluble scum with soap.
3. It does not affect the cleaning action of soap.	It affects the cleaning action of soap

4. It does not contain dissolved Ca and Mg. .	It does contain dissolved salts of . salts of Ca and Mg.

2.4. Dissolved oxygen

Dissolved oxygen (DO) is considered to be one of the most important parameters of water quality in streams, rivers, and lakes. It is a key test of water pollution. The higher the concentration of dissolved oxygen, the better the water quality. Oxygen is slightly soluble in water and very sensitive to temperature. For example, the saturation concentration at 20°C is about 9 mg/L and at 0°C is 14.6 mg/L. The actual amount of dissolved oxygen varies depending on pressure, temperature, and salinity of the water. Dissolved oxygen has no direct effect on public health, but drinking water with very little or no oxygen tastes unpalatable to some people. There are three main methods used for measuring dissolved oxygen concentrations: the colorimetric method—quick and inexpensive, the Winkler titration method—traditional method, and the electrometric method.

2.5. Biochemical oxygen demand (BOD)

CO_3 is 100, so mathematical calculations are easy