WATER - A WONDER CHEMICAL IN THE WORLD

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ABSTRACT

Water is one of the most precious resources for domestic uses, agriculture, and industrial processes. It is an essential atmospheric component that maintains a reasonably uniform and moderate temperature on the planet's surface. There is a growing realization that if humankind is to thrive in the future, we must make improvements in existing systems and practices. A quantum leap in the right direction is required to move forward on the water management issues, connecting what science requires and what the people of the world demand. A watershed moment can be reached with the active participation of society and markets. This paper highlights the physical characteristics, chemical properties, the place of water in nature, and water for humanity to help the real-world perspective of water and how water affects our lives. *[African Journal of Chemical Education—AJCE 13(3), July 2023]*

INTRODUCTION

Water has always been an integral part of everyday life and the world around us. It is essential to almost every form of life, and all body fluids are dilute water solutions. It is of crucial importance for sustaining the specific biochemical reactions that keep us alive and hence the most significant solvent in the world for human survival. Molecular dynamics and structural fluctuations of many molecules in an aqueous medium have direct consequences on their fundamental functional roles. One of the most significant aspects of water is that it acts as an influencing factor in weather and climate. The discernible positive aspect is that it helps moderate the earth's temperature. In the hydrologic cycle, water is used and returned to the environment by evaporation and precipitation.

The industrial growth of a country strongly depends on the proper use of water resources. The statement "The next big ***wars will be fought*** over ***water"*** underlines the importance of water in the future. Life as we know it would not exist without the unique and unusual properties of water. The demand for water is escalating with increasing world population, increase in agricultural, industrial, and mining activities, deforestation, and changes in lifestyles, contributing to social pressure among users. The population of the planet is expected to exceed 9 billion by 2050, and severe depletion of crucial resources, including water, is predicted.

Domestic water uses include drinking, bathing, laundering, cooking, housecleaning, and watering the garden**.** ***Industrial*** uses include the generation of steam, building construction, manufacture of hydrogen, oxygen, and water gas, agricultural irrigation, making steel, hydroelectricity generation, as a food additive, flame retardant material, and as an industrial solvent. Water is essential in the industry for cooling products and equipment, boiler feed, process requirements, and sanitary purposes. It can act as a solvent, transport medium, participant, and catalyst. It is also useful in navigation, recreation, mining, and ecosystem support. It is used as a powerful polar protic solvent in organic synthesis and as a moderately strong monodentate ligand in inorganic complexes in the laboratory. It is used in commercial establishments like restaurants and educational institutions such as schools and colleges.

Water has an exceptional ability to dissolve a wide variety of substances, which is considered the universal solvent. This solvent property is vital in the transfer of substances in biological systems and the hydrological cycle. Water is a common ingredient in many food products; and is used as an agent for mixing or washing operations. Significant applications of ice include food processing, preservation and distribution, chemical industries, and special applications such as cold treatment of metals, medical items, and construction work. Ice is used to maintain the quality of fish, vegetables, and fruits during processing and transportation to distant places. Fisheries use water as a medium for growing fish, and transportation in the tropics is an essential use of water. Ships, steamers, and boats sailing on the surface of the sea save our time, money, and energy. Hydroelectric power stations extract energy from water. Steam is useful in cooking, energy production, and transport systems. It can be found in food processing factories, refineries, and chemical plants. Water is used as a cooling and heating medium over a wide range of temperatures, as a cleaning material, as a fire-fighting agent, and in aquaculture. Pure clay water bottles or containers with modern designs provide a facility to keep water cold, especially during the summer.

Moreover, water has a religious significance as a fundamental life element. Hydrotherapy that involves the use of water for treatment or to maintain health is a part of alternative medicine. It is essential in flushing toxic byproducts from our bodies. Thus, water is a basic necessity for life and health, and the economy in general. It is the life force that entertains us and makes our life colorful.

People contribute to water stress through excessive exploitation of surface and groundwater, pollution of water resources, and inefficient use of freshwater. Both natural and human-induced flooding can cause massive destruction of properties with social, economic, political consequences and broader consequences. Adequate water supply for all can be limited by drought, overuse, and pollution by oil spills, industrial effluents, and other waste materials. The products of human activities, when entering the environment, disturb aquatic ecosystems, and water quality is affected by pollution.

Water scarcity affects plants, animals, and the entire ecosystem as it plays a critical role in the forest environment. The composition and diversity of species change drastically in forests that suffer water stress, which can lead to disastrous consequences. The world’s water problems stem from a lack of sustainable water resource management. Sustainable water use involves the current and future rates of use and associated social policies for implementation to manage precious water resources. The water footprint of products, individual consumers, companies, and nations vary widely, and growing pressure on the available water supply and sanitation has a profound impact on our social, economic, and environmental health.

Electricity generation in hydroelectric power plants is considered to be a process having a low environmental impact. Water used for this purpose is not consumed, and there is no generation of harmful waste or emission of toxic gases. Further, this technology avoids the negative impacts of burning tons of coal in thermal power plants while preserving fossil fuel for future generations. Many of our recreational activities are based on water. Natural waterfalls in different parts of the globe attract tourists all over the world, and artificial musical water fountains installed in gardens in different parts of the world enhance happiness quotient. A fresh and exciting nature walk along the streams in the forest, enjoying the gentle breeze has caught the attention of youngsters and senior citizens alike. The panoramic view of waterfalls in the lap of nature, a safe pool of water that adorn the local landscape, a beautiful view of the coastline, or breezy beaches provide a refreshing break from the hectic life. Water can be considered as the world's most celebrated architect, as reflected in the glacial streams, gushing waterfalls, hills, valleys, shrubs, and landscape supporting plant and animal life. Water/ice is used for recreational purposes, such as swimming, rafting, surfing, and ice-skating. Some water sports and activities such as diving, water polo, water aerobics, surfing, and boat racing are becoming popular across the world.

World water day (WWD) is observed on March 22 every year, as recommended by the United Nations, to focus on international water issues. World environmental day (WED) is celebrated each year on June 5 to raise greater global public awareness and to promote actions to protect toxic-free nature for all. The primary usefulness of water in everyday life and its influence on modern society by creating several global job opportunities in water-related activities attract youngsters to have additional career options. Some subjects deal with the study of water-related topics. Hydrology deals with the occurrence, distribution, movement, monitoring, modeling, and properties of the water of the earth and related environmental interactions [1-5].

Limnology is a branch of ecology that deals with the study of inland waters, and oceanography is a branch of earth science that studies the ocean in great detail. The reader interested in understanding the subject matter by further reading can obtain specific information about water issues, quality, supply, and management in several dedicated websites and textbooks [6-11]. The recent developments in waterproofing technology for devices provide solutions to manufacturers regarding the actual use of electronics. The bottled water industry is rapidly growing, with a boost in sales across the globe. There are more than seventy journals publishing research studies on different aspects of water science and technology [12-13]. The top global water research institutes are working in different areas of specialization, such as membranes, desalination, drinking water and wastewater, nutrient recovery and infrastructure, and water reuse [14-15]. There is a growing body of research on different aspects of water, and it has a significant effect on how the sustainable use of water can change overall development.

Water is an essential substance in the literary ecosystem, and it is unique from multiple perspectives. It has been a source of inspiration for many centuries across the world, transforming life into literature. The people of early civilizations, such as the Indus Valley Civilization, Mesopotamian Civilization, and Egyptian Civilizations, settled near rivers as they needed water for drinking and their crops. In the historical context, water conflicts were frequent from ancient to contemporary times reflecting the immeasurable value of water. There are many idioms in the English language referring to water like a fish out of water, in deep water, test the waters, and keep one's head above water. They reflect the critical role of 'water' in history [8,16].

The images of water representing dreams, desires, love, and fears play a prominent role in many novels and other literary works. There are several quotes related to water such as "water is the driving force in nature," "life in us is like water in a river," "you can't cross the sea merely by standing and staring at the water," "pure water is the world's first, and foremost medicine," "in one drop of water are found all the secrets of the oceans." The proverbs "water is the only drink for a wise" and "water seeks its level" illustrate a practical precept. Water is of central importance in all world religions and is considered an ultimate natural fluid with multiple benefits. Water is considered one of the five fundamental elements of life as a symbol of life and cleansing in ancient philosophy and as one of the basic alchemical symbols. It has been an enormous source of inspiration for poets in different continents and countries as it touches different aspects of life and is essential for human existence on earth.

Water is a powerful metaphor in the expression of poets as it is a force of nature. Many thought-provoking and visually stimulating artworks depict different aspects related to water, conveying meaningful messages. One can enjoy some spectacular digital images on different websites on various themes related to water and wastewater processes [17]. There are several movies involving water in their title or those set in or around water [18-19]. Exposure to the literature would certainly help people develop a sharing and caring mindset regarding water usage and develop nature-friendly behavior and use of eco-friendly technologies. Water is characterized by distinct physical and chemical properties, theoretical and mathematical models, multiple applications in various fields of activity, and unique structure and bonding features.

PHYSICAL CHARACTERISTICS

Water is a chemical with the molecular formula H_2O, and it consists of one oxygen atom bonded by two hydrogen atoms. When hydrogen burns in the air, it combines with oxygen to form water. Its enthalpy of formation is -285.8 kJ/mol, and energy is required to break the stable bonds. It has a bent or V-shaped structure with an H-O-H bond angle of 104.5^o and an O-H bond length of 0.096 nm. There are two pairs of non-bonding electrons (lone pairs) on the oxygen atom and two bonding pairs in the water molecule's electronic structure. It belongs to the C_{2v} point group with two mirror planes and only one rotational axis C_2. According to the valence shell electron pair theory, the two lone pairs strongly repel each other, resulting in the decreased bond angle from that of a regular tetrahedron, 109.5°. The bonding in water can be considered as an sp^3 hybridization of orbitals on the oxygen atoms. Two hybrid orbitals overlap with the 1s orbital of the hydrogen atom to form two covalent bonds, while the other two contain lone pairs of electrons.

It is the most abundant compound in the Earth's biosphere, with a molar mass of 18 g/mol. There are three normal modes of vibrations, symmetric stretching and bending, and symmetric stretching. It is in a liquid form at room temperature without odor, taste, or color, and it can readily transform from liquid to solid and gaseous states. Its chemical name is dihydrogen monoxide. It is a polar molecule with a significant electric dipole moment (μ) of 1.84 D and a dielectric constant of 78.39. The oxygen atom has a partial negative charge, and the hydrogen atoms have a partial positive charge. The bond dipoles, though equal in magnitude, do not cancel each other, because of a bent structure and because the water molecules have an overall dipole moment.

It is an excellent solvent due to its strong solvation power, the solute-solvent (ion-dipole) attractions and because of the highest dielectric constant of all common liquids, which decreases the interionic attractions. The energy of separation between two dipoles or two ions is inversely proportional to the dielectric constant of the solvent. It can dissolve a wide range of ionic and polar covalent molecules. The table salt readily dissolves in water because of strong ion-dipole forces between the ions (cations and anions) and the polar water molecules that overcome the lattice energy of solid sodium chloride. It can form hydrogen bonds with other polar species that play a significant role in forming the solution. Compounds such as ethanol, acetone, tetrahydrofuran, and sugar dissolve in water and are completely miscible because of H-bonded interaction with the solvent. When a covalent molecule dissolves in water, the solution consists of discrete molecules dispersed throughout the medium. A few molecules such as hydrogen chloride gas, when it dissolves in a water medium contain H^+ and Cl^- ions.

Water dissolves a wide range of ionic and polar-covalent substances and is the most readily available liquid on Earth. It is interesting to note that water-soluble vitamins like vitamin C are polar, while fat-soluble vitamins like vitamin A are non-polar. Commercial products like sodium chloride, bromine, and magnesium are obtained from seawater. Water in a chemical compound could exist as coordinated water, interstitial water, hydrogen-bonded water, clathrate water, adsorbed water, occluded water, absorbed water, lattice water, and zeolitic water. They differ in the degree of association between water molecules and the other components of the crystal, and several compounds may have more than one type of bonding.

Water has a melting point of 0 ^oC and a standard boiling point of 100 ^oC at atmospheric pressure. An exciting feature in the phase diagram of water is that the melting point of water decreases as the external pressure increases. The triple point of water is at 0.01 ^oC and 0.006 atm, at which all three phases (ice, water, and vapor) are in equilibrium. The abnormally high boiling point is due to the more considerable energy required to break the hydrogen bonds that hold the water molecules together. The boiling point is essential for many processes that involve thermal energy input, including cooking. The high pressure inside pressure cookers causes water to boil at a higher temperature (~120 ^{o}C), and the time required to cook food is reduced to half the usual time. It takes longer to cook food at higher altitudes, as the water boils at a lower temperature (~ 71^{o}C on top of the Himalayas).

The density of water at 20 ^{o}C is 0.998 g/mL, and at 25 ^{o}C, it is 1.00 g/mL. It has a maximum density at 4 ^{o}C and expands upon freezing because of open framework formation, and these properties cause seasonal lake stratification. From 0 ^{o}C to 4 ^{o}C, the trapping of water molecules in the cavities of the three-dimensional ice structure continues to make water progressively denser. Beyond 4 ^{o}C, the density of water decreases with increasing temperature because of the higher contribution of the thermal expansion process. It has the second-highest specific heat capacity of 4.186 Joule/gram°C. This helps in moderating the temperature by preventing extremes in the geographical regions and stabilizing the temperatures of organisms by absorbing the heat formed in the cells and transporting it to the skin where it can be lost. Thus, water keeps the temperatures of the oceans constant and maintains our normal body temperature.

Similarly, the efficiency of water heating systems in the house depends on this high specific heat of the water. Water can absorb much heat to enhance the average kinetic energy by breaking many intermolecular hydrogen bonds, with only a slight increase in temperature. It can give off a substantial amount of heat while its temperature decreases only slightly. Large water bodies absorb heat in the summer season while they release heat in the winter season, to effectively moderate the local ecosystem's climate. Energy used in the evaporation of water over land and sea each year is estimated to be 1.25 x 10^{21} KJ and thereby tends to decrease the temperature of the atmosphere. When water vapor condenses to raindrops over the land each year, 0.31 x 10^{21} KJ energy is released, leading to an increase in the temperature of the atmosphere [20-22].

It has a large heat capacity of 75.3 J/mol K, caused by hydrogen bonding between water molecules, and this results in oceans cooling more slowly than the land. It has the highest thermal conductivity of all molecular liquids, i.e., 0.6 J/s m ^{o}C, and this helps in the transfer of thermal energy within living organisms. It has a very large enthalpy of vaporization (2250 J/g), which affects our ability to regulate our body temperature by evaporation of sweat. It is essential for heat transfer in the atmosphere and oceans. Condensation of water vapor in the atmosphere releases a large amount of heat, triggering storms. The higher heat of evaporation determines the transfer of heat and water molecules between the atmosphere and water bodies.

The critical temperature of the water is 374 ^{o}C, and the critical pressure at this temperature to bring about liquefaction is 217.7 atm. Supercritical water (SCW) is formed at a temperature and pressure above its critical point. At the critical point, the hydrogen bonds holding water molecules break entirely, and this phase can dissolve substances that were previously insoluble in ordinary water in the liquid phase. Supercritical water can behave both as a polar and a non-polar solvent, making it a powerful medium to dissolve a variety of substances and carry out chemical reactions. The practical value of this beautiful property lies in its application in the eco-friendly destruction of industrial wastes. Water is transparent to visible and longer-wavelength ultraviolet light, and this enables the light required for photosynthesis to reach considerable depths in water bodies and control atmospheric temperature. The high latent heat of fusion of water than any standard liquid helps in stabilizing temperature at the freezing point of water. The surface tension of water is 72 dynes/cm at 25 ^oC, and this high surface tension is essential in regulating drop formation in clouds and rain.

The property of wetting is due to its ability to adhere firmly to different materials. The freezing point of pure water at atmospheric pressure is 0 ^oC, and this value has been fixed at zero on the temperature scale as a convenient standard temperature point. Water has a relatively low viscosity of 0.890 centipoises at 25 ^oC and can make a significant impact on the rate at which blood is pumped around our bodies. The ionic product of water (Kw) = $[H_3O^+][OH^-]$ is 1.00×10^{-14} mol^2 dm^{-6} at 25 ^oC, and water is an inferior conductor of electricity. The ionic product of water has to be constant, and human plasma has to be electrically neutral. This mechanism protects plasma pH from severe deviations. The refractive index of water is 1.333 at 25 ^oC, and it has the least bending effect of light, among other liquids. Its dependence on temperature and wavelength has several applications in biomedical optics and optics of tissues, as it is the most crucial component of intercellular fluid and blood plasma.

The human baby at birth contains nearly 80 % water, while the healthy adult human body contains about 70 % water by weight. It carries nutrients to the cells and takes away waste products as a major component of blood. The three principal categories of water in the human body include intracellular fluid (ICF ~ 55 %), extracellular fluid (ECF ~ 37.5 %), and plasma (`7.5 %). Water deficiency will result in dehydration, and excess body water can cause water intoxication. Its distribution and availability vary widely over the surface of the earth, and over 70 % of the Earth's surface is covered by water. The total amount of freshwater on Earth is 2.5 % of the total water present, making it one of the most precious resources. The world's water consumption data provided by the United Nations in different categories involves agricultural 70 %, domestic 10 %, and industrial 20 %. The purification of water is necessary to get rid of contaminants that can affect our health, and it is now a significant industry with many plants operating at a water processing capacity of the megaton-per-day scale. The transformation of seawater to produce potable water through a large-scale desalination process is of enormous importance to meet the needs of the increasing world population.

Apart from making the easy availability of water, it is essential to introduce other changes to meet the growing consumer demands of a changing world, including an active policy approach to enhance and strengthen the green infrastructure. The most commonly used small-scale methods to obtain freshwater include ultrafiltration, distillation, ion-exchange techniques, ultraviolet sterilization, and multistage reverse osmosis processes. The selection of a particular treatment method or a combination of techniques depends on the source of the water, the end-use envisaged, and the quantity required. The infrastructure required for optimal utilization of available water must be constructed to meet future sustainable development challenges on the path. Globally, the response of people to practical green solutions will be a crucial indicator of the future.

There are three hydrogen isotopes (^{1}H, ^{2}D, ^{3}T) and three oxygen isotopes (^{16}O, ^{17}O, ^{18}O), and in principle, 18 different types of water are possible with slightly different properties. These are also known as isotopologues. The three common types of water are natural water (H_2O), heavy water (D_2O), and tritium water (T_2O). Heavy water (D_2O) is used as a coolant and a neutron moderator in nuclear research reactors. It reacts more slowly than ordinary hydrogen because of its extra mass. THO, HDO, and D_2O occur naturally in ordinary water in deficient concentrations.

he existence of tunneling behavior of water is unprecedented, and in this new state, the water molecules are delocalized around a ring, assuming an unusual double-top-like shape [23]. This discovery provides an opportunity for researchers to take a different approach to water-related phenomena. Hard water contains low percentages of $Fe^{2+,}$ Ca^{2+}, Mg^{2+} or Mn^{2+} ions in dissolved form, usually present as bicarbonates, chlorides, sulfates, and nitrates, due to contact of rainwater with soils and rocky substances on its way to the oceans. It does not give lather with soap, a qualitative indicator of the hardness of the water. The total hardness of water can be quantitatively estimated by complexometric titration using EDTA. Temporary hardness caused by carbonates and bicarbonates can be removed by boiling, while permanent hardness caused by sulfates and chlorides can be removed by treating zeolites.

Drinking water purification is the single most effective way required to prevent waterborne diseases such as cholera, typhoid, and dysentery. Water disinfection is an essential step in water treatment to make it fit for human consumption, in addition to other physical, chemical, or biological processes. Conventional surface water treatment includes coagulation, flocculation, sedimentation, filtration, and disinfection steps to obtain clean water. The buildup of boiler scales in hot water heating systems clogs the pipes and reduces the efficiency of heat transfer as well as the flow of water through the pipes. Hard water is responsible for the boiler scale, which may result in a boiler explosion, in extreme cases.

Wastewater corrosion can result in a loss of water carrying capacity of pipes, structural failures, and degradation in the quality of water transported. Water conditioning and wastewater treatment include removing particulate matter, organics and inorganics, hardness and other scale-forming substances, corrosive contaminants, pathogenic bacteria, viruses, and protozoans. Hard water can be softened on a large-scale by the lime-soda process and small-scale by ion-exchange methods. The lime-soda process involves treating water with lime, CaO, and soda ash, Na_2CO_3, precipitating Ca^{2+}, and Mg^{2+} into $CaCO_3$ and $Mg(OH)_2$. The ion exchange procedure involves passing the hard water through a bed of ion-exchange resin. The Na^+ ions available on the resin are exchanged with Ca^{2+} ions, and the resin is regenerated by flushing it with a concentrated solution of NaCl. Zeolite water softening process, using Zeolite bed, operates on alternate cycles of softening run and regeneration run, where calcium and magnesium ions are removed from the water, and the exhausted Zeolite bed is regenerated for reuse.

CHEMICAL PROPERTIES

It is of interest to note that water participates in making and breaking bonds in different types of reactions including, simple dissolution, acid-base reactions, redox reactions, hydration and dehydration reactions, ionic dissociation, solvolysis, and ligand chemistry [24-28]. Water is amphoteric and it has the unique ability to act as either an acid or a base and can participate in acid-base reactions [Proton donor: $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$; Proton acceptor: $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$]. The autoionization reaction of water can be written as $H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$. At room temperature, this ionization process is extremely rapid in both directions, and at any given instant, a tiny fraction of molecules undergo ionization. Moreover, the H^+ ion in water interacts strongly with the non-bonding electron pairs of liquid water molecules to form hydronium ions [$H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$]. The electrolysis of water by electrical energy input decomposes it into hydrogen and oxygen as per the overall electrochemical reaction $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$. In this electrolytic production, hydrogen is produced at the cathode and oxygen at the anode, and this is the basis of the fuel cells used in hydrogen-powered vehicles [Anodic oxidation: $2H_2O(l) \rightarrow O_2(g) + 4H+(aq) + 4e^-$ Cathodic reduction: $4H^+(aq) + 4\ e^- \rightarrow 2H_2(g)$].

Limestone caves are formed by the dissolving action of underground water containing CO_2 that is slightly acidic on $CaCO_3$ in the limestone [$CaCO_3(s) + H_2O(l) + CO_2(aq) \rightarrow Ca(HCO_3)_2(aq)$]. Calcium oxide (lime) reacts with water to produce calcium hydroxide (slaked lime) [$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$]. Chlorine reacts with water to form aqueous solutions of hypochlorous acid, an active oxidizing agent and hydrochloric acid [$H_2O(l) + Cl_2(g) \rightarrow HOCl(aq) + HCl(aq)$]. The usefulness of chlorine water lies in its antibacterial action due to hypochlorous acid and its use as a bleach. Most metal oxides that dissolve in water react to form metal hydroxides, i.e., Metal oxide + water → Metal hydroxide [$BaO(s) + H_2O(l) \rightarrow Ba(OH)_2(aq)$]. The basicity of metal oxides is due to the reaction of the oxide ion with water [$O^{2-}(aq) + H_2O(l) \rightarrow 2OH^-(aq)$]. The alkali metals react vigorously with water, forming hydrogen gas and alkali metal hydroxides [$2M(s) + 2H_2O(l) \rightarrow 2MOH\ (aq) + H_2(g)$]. Among the alkaline earth metals, Magnesium reacts with steam to form magnesium oxide and hydrogen [$Mg(s) + H_2O(l) \rightarrow MgO(s) + H_2(g)$]. Calcium and other elements down the group react with water at room temperature to form respective hydroxides [$Ca(s) + 2H_2O \rightarrow Ca(OH)_2(aq) + H_2(g)$]. The transition metal, iron reacts with steam to give iron oxide and hydrogen gas [$3Fe(s) + 4H_2O(l) \rightarrow Fe_3O_4(s) + 4H_2(g)$].

Steam reacts with red-hot coke to produce the product water gas [$H_2O(g) + C(s) \rightarrow H_2(g) + CO(g)$]. Non-metal oxides react with water to form acids containing oxygen [$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$]. Another non-metal compound, ammonia dissolves in water to form ammonium and hydroxide ions [$NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$]. This ammonia solution acts as a weak base. Non-metal chlorides react with water forming acidic solutions [$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$]. The electrochemical corrosion reaction involves the reaction of water and oxygen to give hydroxide ions at the cathode: [$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$]. Water reacts with certain metal salts to form hydrates [$CuSO_4 + 5H_2O \rightarrow CuSO_4{\cdot}5H_2O$]. Plaster of Paris forms a paste on mixing with water and then hardens into a solid mass, used in making casts and sculptures. [$(CaSO_4)_2 \cdot H_2O + 3H_2O \rightarrow 2CaSO_4 \cdot 2H_2O$]. Some hydrates lose their water of crystallization spontaneously at room temperature on exposure to air in a process called 'efflorescence' [$Na_2CO_3 \cdot 10H_2O(s) \rightarrow 10H_2O(g) + Na_2CO_3(s)$]. Deliquescence is the process in which a substance absorbs water from the air to form a solution [$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$]. Deliquescent substances are used as drying agents; for instance, anhydrous calcium chloride is used in desiccators for storing materials that pick-up moisture.

Water decomposes into hydrogen and oxygen in the ratio of 2:1 by volume when electrolyzed by direct current [$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$]. Some practical applications of this chemistry include the use of ***cold or hot packs*** as an immediate ***first aid*** product as they will help to reduce inflammation, and they function by dissolving salt into the water. Commercial instant cold packs often use either ammonium nitrate or urea as their salt component, while hot packs use either magnesium sulfate or calcium chloride. When these chemical ingredients dissolve in water, heat is either released in an exothermic reaction or absorbed in an endothermic reaction [An endothermic process: $NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$; An exothermic process: $MgSO_4(s) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq)$]. The double replacement reaction of water with calcium dicarbide produces acetylene gas and calcium hydroxide solid, i.e. $CaC_2(s) + 2H_2O(l) \rightarrow C_2H_2(g) + Ca(OH)_2(s)$. Iron(III) salts react with water to form hexaaqua iron(III) complex, i.e., $FeCl_3(s) + 6H_2O(l) \rightarrow [Fe(H_2O)_6]^{3+} + 3Cl^-(aq)$]. Hydrolytic cleavage takes place when phosphorous oxide, P_4O_{10} reacts with water [$P_4O_{10}(s) + xH_2O$

→ $4H_3PO_4(aq)$]. Similarly, aluminum chloride undergoes hydrolysis when it reacts with water [$AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$]. The solution of aluminum chloride is very acidic. This property is because of a small but highly charged Al^{3+} ion that draws electrons in the O-H bonds of water towards itself to enable them to become proton donors. The following equilibrium is established. [$[Al(H_2O)_6]^{3+}(aq) + H_2O \rightarrow [Al(H_2O)_5(OH)]^{2+} + H_3O^+$].

Water reacts with some organic compounds to form different products. Water reacts with butyl chloride, producing butyl alcohol and hydrochloric acid [$C_4H_9Cl(aq) + H_2O \rightarrow C_4H_9OH(aq) + HCl(aq)$]. The direct hydration of alkenes produces alcohol, and ethanol is manufactured by reacting ethene with steam [$CH_2{=}CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(g)$]. The reaction involves breaking the π bond in the alkene and an O-H bond in water, as well as the formation of a C-H bond and a C-OH bond. Carbon dioxide dissolves in water to an extent, forming carbonic acid that lowers the pH of the water, and this is responsible for the popping sensation of carbonated soft drinks [$H_2O(l) + CO_2(g) \rightarrow H_2CO_3(aq)$]. Industrial manufacture of sulfuric acid by the contact process involves the reaction of water with oleum to form concentrated sulfuric acid in the final step [$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$]. The production of sulfuric acid is an indicator of the industrial strength of a nation. Concentrated sulfuric acid removes water of crystallization from copper(II) sulfate pentahydrate [$CuSO_4.5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$]. Common dehydrating agents used in organic syntheses include concentrated sulfuric acid, concentrated phosphoric acid, and hot aluminum oxide. Acid anhydrides react with water to give the carboxylic acid [$(CH_3CO)_2O(l) + H_2O(l) \rightarrow$

$2CH_3COOH(aq)$]. Acyl halides undergo nucleophilic substitution readily with nucleophiles such as water [$CH_3COOCl(l) + H_2O(l) \rightarrow CH_3COOH(aq) + HCl(g)$].

The carbon dioxide in the atmosphere reacts with water in the raindrops to produce H^+ ions [$H_2O(l) + CO_2(g) \rightarrow H^+(aq) + HCO_3^-(aq)$]. Nitrogen dioxide reacts with water to give a mixture of nitrous acid and nitric acid [$H_2O(l) + NO_2(g) \rightarrow HNO_2(aq) + HNO_3(aq)$]. Water reacts with sulfur trioxide, formed by oxidation of sulfur dioxide, to form sulfuric acid [$H_2O(l) + SO_3(g) \rightarrow H_2SO_4(aq)$]. This acid rain produced by polluted air present in the atmosphere damages marble structures, architectural monuments, and statues all over the world. It can leach minerals as the rain percolates through soil and rocks [29-31]. In agriculture-intensive areas of the world, water contains significant quantities of sulfate and nitrate ions, partly due to the widespread use of nitrogenous fertilizers containing these ions. Water vapor is the most important greenhouse gas in Earth's atmosphere that trap heat, which makes the Earth warmer and vibrates in response to the absorption of infrared radiation (3756, 3657, & 1595 cm^{-1}). Water plays an important role in the rusting of iron, and it is an electrochemical process that requires the presence of oxygen, water, and an electrolyte. Water-line corrosion is a special type of corrosion when water is stagnant in a steel tank for a long time. This corrosion results from differential aeration leading to the formation of oxygen concentration cells and corrosion take place just below the water level.

Hydration, hydrolysis, dehydration, redox, and acid-base reactions occur during the breakdown and the reassimilation process to transform foodstuffs into specific metabolites in living systems. All the body's critical functions, including the reactions of metabolism and the transfer of chemical energy, depend on the presence of a proper amount of water. Proper intake of water per day varies depending on the climate, dietary habits, body structure, and physical activities, and we need to drink about three liters of water every day. Water containing traces of dissolved salts of Ca, Na, Mg, and Fe are essential for good health, and water is the medium for the transport of nutrients. The surface-active properties of soaps and detergents are attributed to their structure, having both hydrophilic and hydrophobic parts. The water-soluble polymers such as cellulose, polyoxyethylene, polyvinyl alcohol, polyvinyl pyrrolidone, polymethacrylic acid, polyphosphoric acid, and polysilicic acid have a significant commercial impact, and they are used as food sources, blood plasma substitutes, cosmetics, and as diluents in certain medicines.

The role of water in human life, its contributions to humankind, and the research opportunities available for discoveries have a profound positive impact on consumers of different categories, and water shortage can have severe economic consequences. The world of water chemistry would require more rigorous experimental investigations and precise calculations based on different models to discover new phenomena that occur in water mediums and to have a better understanding of the impact of climate change or global warming on natural water resources. Acidification of water supplies due to the dissolution of toxic metals such as Cd, Al, Pb, and Hg from the soil, sediments, metal pipes, and soldering materials is a potential public health hazard. The functions crucial to producing pure water include hazardous waste reduction, breakdown of pollutants, developing adequate sewage water treatment systems, the cycling of nutrients, recharging catchment systems, and re-establishing natural ecosystem services. Further, understanding water variability, conducting laboratory and field studies of water, establishing aqueous reaction mechanisms, performing real-time estimates of ice pack thickness in the Arctic, and implementing long-term water supply measures to help prevent drought-induced migration of people or drought-caused failure of agriculture.

THE PLACE OF WATER IN NATURE

Water is present as solid ice in polar icecaps and glaciers in the Arctic and Antarctic zones and as liquid water in other places on the earth, in rivers and lakes [32-34]. Water vapor is always present in the atmosphere to different extents. About 71 % of the Earth's surface is covered with water, and the oceans contain about 96.5 % of the total water content of the Earth. The conversion of carbon dioxide and water into carbohydrates takes place by the process of photosynthesis.

$$6CO_2\,(g) + 6\,H_2O(l) \xrightarrow{h\nu} C_6H_{12}O_6(aq) + 6O_2(g)$$

It is the most important reaction in the world, and the energy released in the reverse reaction called respiration is essential to keep us alive. We depend on plant photosynthesis to supply the bulk of our energy needs, as we do not have the capacity for using solar energy directly. Glucose dissolves as a molecule due to its ability to form hydrogen bonds with water molecules. Water is a liquid at room temperature because of hydrogen bonding, and it plays a prominent role in our daily lives. The properties and functions of biological molecules materialize in a water medium. Oceans, rivers, lakes, and ponds would exist, and it would rain as an integral part of the water cycle in nature. Water is the most abundant and widespread solvent on Earth and an aqueous solution that occurs in nature, such as biological fluids and seawater, contains many solutes in different concentrations [35-42].

Water would rise through the capillary tubes in the roots and stems of plants because of high surface tension, and they can obtain salts required for their growth as water can dissolve ionic substances. Ponds and lakes freeze from the surface downwards as solid ice is less dense than liquid water, making a layer of ice on the top in the winter. This phenomenon helps the aquatic plants, fish, and other water-living organisms to survive in the warmer water below the ice in winter. In the solid state, hydrogen bonds have directional nature with specific orientations in the rigid ice crystal lattice, whereas, in the liquid state, they are continuously formed and broken. Water expands as it freezes into ice, and in the ice, the strong hydrogen bonds hold the molecules in a relatively open tetrahedral network structure. Water, with weak bonds between its particles, clings to the walls of the container and curves upwards.

Essential ionic compounds are absorbed into the bloodstream from the aqueous solution in the intestines of animals. Cells in the human body require water to regulate their volume and osmotic pressure to enable biological structures to perform bodily tasks such as transporting nutrients and waste and serving as physical barriers. Small fluctuations in different body systems can build up and cause profound changes over time. Fish and other lake-dwelling organisms obtain nutrients and oxygen dissolved in water. The amount of dissolved oxygen in water is about 9 ppm when it is completely saturated with air at 1 atm and 20 ^{o}C.

Water vapor consists of discrete water molecules, and intermolecular H-bonding chances are small due to the mobility of molecules at high temperatures. It is continuously generated by evaporation in the atmosphere and moves upwards, leading to cloud formation by condensation. The amount of water vapor in the air is known as humidity, and it is measured by hygrometers. The local climate is influenced by evaporative cooling and enhanced relative humidity due to the transpiration process. Unfavorable micro-climatic conditions, unseasonal rains, hot weather, or high humidity can affect certain crops and shake people’s confidence. Water vapor is effective at absorbing the thermal radiation from the Earth's surface, and it is known to be present outside the solar system in small quantities. Extraterrestrial liquid water is a topic of wide interest as it is one of the prerequisites for extraterrestrial life. In the solar system, the asteroid Ceres has large amounts of ice on its surface and also an atmosphere. Thus, water is a precious, life-sustaining resource for the community required for drinking, livestock, irrigation, and industries. As water is crucial for our survival, and to fulfill the needs of the plant and animal kingdoms, pollution of local water sources, development of water-intensive industries, climate change, and lack of legislation can lead to threatening consequences. While adapting modern water treatment techniques, judicious use of water and proper water policies can lead to water as a path to growth. The procedures for obtaining necessary approvals and the regulatory framework need to be streamlined to have an enabling policy framework.

WATER FOR HUMANITY AND OBSERVATIONS

There is a need to recognize the biological, environmental, and industrial importance of water in the real world around us and to make reasoned choices on water consumption [43-48]. The amount of freshwater available to meet our industrial, domestic, and agricultural purposes is relatively limited. Of the 2.5 % freshwater, less than 1 % is available as surface water or groundwater, and the remaining portion of this freshwater is locked in glaciers and polar ice caps. The remaining part of the total volume of water on earth (96.5 %) is found in the oceans. Further, water must be treated to obtain the quality of water suitable for drinking purposes. The total hardness should be less than 400 mg/L, and chloride ion concentration should be less than 250 mg/L. As part of the water purification system, chlorination produces a group of by-products called trihalomethanes (THMs) that are suspected carcinogens.

The WHO has prescribed a concentration limit of 100-200 μg/L on the total quantity in potable water. A study on the health effects of arsenic in drinking water in some parts of the world indicates a lung and bladder cancer risk. The environmental protection agency (EPA) of the USA issued the standard for arsenic in public water supplies to less than 10 μg/L. Today, the water of several rivers is polluted by industrial and domestic wastes and even dead bodies. The types of water pollution could include physical (suspended matter, thermal, solid waste) chemical (nutrients, toxic inorganic materials, persistent organic pollutants), microbiological (oxygen demanding, pathogens).

Water pollution is a major global problem and one of the main problems of ecology [49-64]. This issue must be tackled by local bodies and the government by implementing preventive measures, corrective steps, and promoting local recycling of water at all levels. Ten people out of a hundred lack access to clean and safe drinking water and accessing it through local social enterprises via a network of subscribers for a nominal charge in a locality would make a difference in people's lives. Physical water scarcity arises as a result of inadequate natural water resources to meet the requirement of a geographical location. In contrast, economic water scarcity is a result of poor management of water resources. It is the latter type to be addressed in several countries facing a clean water crisis, and the limited availability of water impacts business. The joint effects of such a water crisis include reduced agricultural production, cost escalation of commodities, and economic pressures or political stresses.

Climate change and water scarcity could adversely impact forest biodiversity and multiple forest products, which in turn would severely impact local communities dependent on forests for their livelihoods and as a source of raw material for a wide range of domestic and commercial applications. The change in a forest ecosystem can serve as a kind of early warning system for environmental problems and could have unpredictable consequences. Water acts as a vital social lubricant in the economic chain through its use in the industrial sector, agriculture, and tourism industry. It is essential to recognize the economic value of water in addition to its ecosystem service, and all human beings should have access to clean water at an affordable price. Importantly, the goal of water for humanity will be achieved within the broad framework of science, technology, and product, and how we apply science practices more broadly.

The human population explosion on a global scale and increased human activities and development have resulted in multiple applications of the three typical phases of water [65-74]. Water is becoming an increasingly scarce resource, and the overexploitation of groundwater resources in the recent past has resulted in the drying of water tables, leading to several emerging water-related science, technology, and management issues. Increased depletion of groundwater, declining surface water sources, decreased replenishment, and excess evaporation due to global warming have caused many water-related issues and concerns [75-76]. The shortage of water harms ordinary citizens' lives, and the potential of distributing fresh water of good quality to all will positively impact societies. Snow measurements from Cryostat show that the Antarctic ice layer is losing 159 billion tons of ice each year, and more than a billion people depend on mountain snowflakes for their water needs. As the climate changes, snowfall may decrease in the future. Water conservation, harvesting, recycling, and the clean water act are essential parts of positive activities to restore the required amount of water for different domestic, industrial, and agricultural purposes.

There is a need to create awareness among the general public on rainwater harvesting, green belt development, and water conservation techniques. Conducting training, awareness, and sensitization programs for people will help maintain the sustainability of water resources. The right combination of recharging water bodies and reliable, responsible, and socially useful water delivery models are expected to make the desired positive impact on the ground. It is essential to improve water quality by regulating domestic sewage, runoff from agricultural lands and livestock areas, and industrial wastewaters from food-processing plants and paper mills. The service-specific regulations governing water use must specify the requirements relating to storage, packaging, transport, delivery, recycling, optimized utilization, distribution network, and regulated water tariff structure. Regulatory requirements are essential to have control over the introduction of toxic wastes from domestic, agricultural, and industrial sectors. Integrated wastewater management, large-scale public water transport systems, waste management legislation, and proper implementation aspects will inspire the next generation for a shared future.

Adaptation of global water quality standards involves significant technological development challenges as well as several management changes. Conflict resolution regarding water disputes involves negotiations seeking a fair and reasonable settlement, which is acceptable to all and causes minimum damage to the environment. In the broader context, it is more important to strike a balance between water conservation and social development goals and arrive at river water-sharing agreements with neighboring countries. Water supplies must be affordable to all as it is the basic need of every human being.

Further, progress in equipment, technology, and purification methods will stand the next generation in good stead. Funding for not-for-profit water-related research activities and application-oriented research programs should be encouraged by the government. The research outcome will help us better understand the benefits of water and social issues associated with its supply to enable us to make intelligent decisions in the future. An association of the government with non-profit organizations for constructing and maintaining water purification plants and managing water supply projects in different areas can make a substantial socio-economic impact. Building a state-of-the-art water treatment plant based on reverse osmosis technology in different locations can save millions of people from waterborne diseases in the world. Progressive and eco-friendly policies and practices in implementing effective water management to achieve tangible results will allow the government to fulfill its commitment to a greener tomorrow gradually.

Advanced wastewater treatment, disposal and analysis, water processing and distribution systems, and recycling and reuse of wastewater from various industries are necessary due to the contamination of water by hazardous wastes. The industries that require large quantities of water include tanneries, breweries, distilleries, refineries, aluminum, copper and zinc smelting, thermal power plants, and units engaged in the production of fertilizers, textiles, paper, sugar, cement, iron and steel, pesticides, petrochemicals, pulp and paper, dyes and dye intermediates, aerated drinks and packaged drinking water. Engineering systems for water purification include physical and chemical processes such as volatilization, dissolution, precipitation, hydrolysis, complexation, redox reaction, and photochemical reactions.

Evaluation of water for public distribution involves a battery of determinations such as dissolved oxygen content, biological oxygen demand, determination of dissolved constituents, and testing for the presence of various forms of harmful microorganisms. A few general principles may be observed in water conditioning and industrial wastewater treatment: increasing industrial reuse, pollution control, recovery of by-products, and the use of green chemistry and engineering principles in the manufacture of pulp and paper, petroleum, and chemical and allied products. The discovery, development, and commercialization of low-polluting processes, green manufacturing methods, and additional research efforts in environmental protection should be encouraged by funds and grant programs by the governments. The green movement has lit the spark for water struggle in several places, and water harvesting, and environmental conservation efforts directed towards meeting the challenge of water shortage have improved the situation dramatically.

The millennium development goal of safe drinking water has reached the international target. Setting up a drought and flood monitoring and management cell (DFMMC) to recommend dynamic short-term and long-term plans, and concrete steps to encourage massive afforestation, protecting natural forests, lakes and other catchments, preventing the destruction of existing forests, preventing soil erosion, recharging the tanks, rivers, and groundwater, and environmental norms to conserve, manage and reuse of water for the benefit of all is essential.

Local water management committees (WMC) can promote water conservation by documenting local water resources, developing guidelines for the extraction of water, conducting discussions and awareness sessions, and removing invasive species from waterbodies. It is crucial to have intricate water purification systems that remove harmful viruses, bacteria, hardness, turbidity, pesticides, harmful metal ions, organic compounds, lead, and other impurities for domestic purposes. The adherence to waste disposal rules, efficient effluent handling, and decreasing pollution levels in lakes and groundwater sources is a collective responsibility of both government and industry. Establishing an efficient effluent treatment plant in specific industries to ensure that either less amount or no residual harmful water is released helps them to achieve minimum liquid discharge (MLD) or zero liquid discharge (ZLD) status.

There is a threefold increase in fresh water withdrawals in the past fifty years. Development at the cost of forests, rivers, and other water bodies will result in desertification and agricultural land shrinkage. Heatwave conditions can lead to exhaustion, cramps, and sunstroke, killing many people across the world every year, and they harm the ecology. With extreme heatwave conditions and acute water shortage in several parts of the planet due to global warming, the heat-related mortality rate has increased substantially. Action plans include public awareness programs, early warning systems, drinking more water, and immediate medical attention. Ecological restoration measures have to be taken on a massive scale to reduce the impacts of heatwaves sustainably. Climate change will increase the evapotranspiration rate, leading to more demand for water. This shortage will result in water conflicts between industry and communities.

It is essential to implement a comprehensive water policy, making all industries, particularly water-intensive ones, recycle and reuse their wastewater back into integrated operations and install necessary pollution control equipment. Recycled wastewater in many industries can be used for maintaining gardens, washing, landscaping, and cooling towers. Saline water for the industry can be used after sedimentation, filtration, reverse osmosis, chlorination, chemical oxidation, carbon adsorption, electro-dialysis, solar desalination, multi-stage flash distillation, or other treatments. The quality and quantity of water available and the effect of impurities such as arsenic, pesticides, and fluorides on the process have to be considered while selecting a suitable location for constructing a factory. Breakthrough research outputs in energy conversion technologies or desalination technologies would make water available in large quantities at the location of industries and open prospects for further industrial development.

Conservation of water through the recycling of wastewaters and their use in the agricultural sector may help prevent severe ecological degradation and prevent environmental contamination. The protection of the environment requires strict laws related to water pollution control, reasonable water quality standards, standards for hazardous water pollutants, implementation aspects, and evaluation methods for both private and public water treatment plants globally. The laws, rules, and regulations will have a direct bearing on the water usage by the contemporary aspirational society. It is better to adapt the required international regulatory standards and have an institutional mechanism to implement the law's intent. The legislative framework should also include the option of enforcing penal action against defaulters as an essential component. We have to establish water testing laboratories to check the quality of water and set up pure drinking water units to ensure the supply of potable water to millions of residents across developing countries in the world by 2025. Water quality parameters to be checked include dissolved oxygen, specific conductivity, pH, alkalinity, major ions, temperature, suspended solids, and turbidity. The principal impurities in Municipal Corporation water include suspended matter and organic substances (sediment, microorganisms), dissolved mineral matter (bicarbonates, sulfate, chlorides of Ca, Mg & Na), and dissolved gases (O_2, N_2 & CO_2). Primary water treating operations include sedimentation, coagulation, filtration, chlorination, taste, and odor removal. The optional treating operations involve the hardness removal, zeolite process, lime-soda process, fluoridation/fluoride removal, demineralization, and removal of dissolved gases.

Water is a finite resource, and water usage needs to be carefully managed to prevent its rapid depletion. A combination of physical, psychological, environmental, and social factors leads to water pressures. Several concrete steps need to be taken to prevent the future water crisis and developing a sound long-term water supply strategy would certainly have some effect on reducing water pressures. The first step is to collect high-quality data about water resources. We have to learn lessons from hard-core environmental facts and figures of major development projects and carry out in-depth research that helps us to make a well-informed choice to avoid drought. The second step is to prevent water pollution as it means less need for purification. The third step is to ensure a clean potable water supply and better sanitation through better management practices.

A global surveillance network is required to monitor the quality of water used in different parts of the world. It is important to share best practices in reliable tools and technologies to replicate the model across the world. Fourth, a public campaign to promote awareness about the dangers of waterborne diseases and the need to have public interest safeguards to promote socioeconomic development. This awareness can bring about a big change. There is a need to increase awareness about the importance of water as a marketable commodity. Creating responsible water consumption patterns by the citizens could help in avoiding water-based conflicts between states or nations. Fifth, encouraging the use of existing water and wastewater technologies as well as developing new environment-friendly technologies. We need a multipronged approach that involves collaboration among neighboring nations and states and improves system efficiency, including distribution and delivery planning, adequate infrastructure, and specific training requirements.

Funding for research and development, innovative water treatment process marketing, and encouragement for creating brand equity would go a long way in establishing water conservation, management, and optimal use. Adopting water-efficient practices, technological innovations, and mandatory reuse in water-intensive industries have a major impact on the socio-economic life of local areas. Attracting private sector investments and participation in eco-friendly water purification plants, research and development efforts on water-related issues are necessary to help contribute towards sustainable development. Sixth, frame future policies on the continuous water supply and distribution systems for domestic, industrial, and irrigation purposes. It is becoming increasingly clear that manufacturing industries should follow environmentally sustainable business practices in their production activities with a focus on energy, water, and nature conservation. Geographic Information Systems (GIS) can be applied in developing water distribution system hydraulic models. Environmental impact assessment (EIA) of large water resources projects, drought assessment, and forecasting, estimating the area and intensity of rainfall, water quality management, corrective, preventive, and scheduled maintenance of water systems, reuse of water, rainwater harvesting, forest regrowth, artificial recharging of groundwater and analyses of other technical aspects play an important role in sustainable water management. Construction of modern rainwater harvesting systems such as dams, injection wells, percolation ponds/tanks, stepwells, open wells, and subsurface barriers serve as effective alternatives to rejuvenate depleted groundwater aquifers.

The key to managing water issues is to initiate local water conservation and management practices, and water sharing through dams and canals and the interlinking of rivers to enable water transfer from surplus to deficit regions. Periodical data collection on water pollution levels in different nations will equip the world to initiate and accelerate global level actions required to keep the pollution level minimum and increase the availability of pure water, under the concept of water for all. A transparent reporting mechanism will enable us to understand the actions implemented to promote a robust and meaningful water distribution system with optimum water efficiency and reuse of water, the impact of these actions on the degree of pollution, and the long-term prospects of sustainable water resources management. The beginning of change lies in each individual's mind, and we need to cultivate the habit of not wasting precious resources like water and causing pollution. Political will and delivery of services and synthetic engineering systems for drinking water are two of the numerous steps to deliver optimal results. Pricing of water should be determined based on working expenses, including the cost of operation and maintenance. Print and electronic media should present a positive and realistic image to the general public, and governments should encourage interdisciplinary research to meet the emerging challenges of the global water crisis.

Global climate change has attracted considerable attention from interdisciplinary researchers around the world in the last decade. The research on essential aspects of water-related topics is expected to reveal new insights on the scale of the impact and its environmental effects. The surface temperature of the earth is increased by 0.74 ^{o}C in the last hundred years. Global warming may lead to extreme hydrological events such as flash floods and severe droughts, driving many creatures to extinction. This warming will further affect the regional ecology and the life of local people, and in extreme cases, it may lead to ecological catastrophes and large-scale social disruptions. The problems of water quality, quantity, reuse, and pollution are complex. They may vary significantly from one location to another and depend on the prospective use, whether for power generation, heating/cooling, agriculture, domestic applications, or as a solvent.

A broad-based approach involving sustainable agriculture, water efficiency in agriculture, sustainable tropical forestry, sustainable development, technical and commercial efficiency of water supply systems, and a sustainable business model will facilitate the sharing of water. Creating ecological awareness, change in the mindset regarding development, better water use policies, responsible consumption of natural water resources, and the use of new techniques to sustainably use water is expected to have positive impacts on the sustainable use of H_2O for humanity. It is essential to take the application and usefulness of water harvesting and conservation ideas, and nature-friendly practices to the common man through the commercialization of products. Managing water harvesting on a large-scale is crucial for consideration in terms of the added load because of high demand due to increased human activities, which will lead to a substantial increase in water level.

The web of issues and concerns associated with effective water management affecting the stakeholders must be addressed through a pragmatic approach, social activism, and empowerment of people to achieve a long-term solution. We must cultivate a greater sense of universal responsibility and put it into practice for the good of humanity. Each should have the right to equal access to natural water resources and the responsibility of protecting the environment for future generations by performing all activities within existing resource constraints. There is an urgent need for intense goal-oriented action by the governmental system and all the stakeholders to foster community water management practices through a societal transformation as water is one of the most abundant, yet depleting, a chemical in nature and essential for life on Earth. Besides, preventing water loss due to leakage and illegal drawing of both surface and groundwater in some areas should become an integral part of sustainability services to preserve this precious commodity. The bottom line is that we have to increase groundwater levels, conserve water, reduce and reuse, plant trees, and fine-tune farming practices through participative ecosystem management and have integrated and sustainable water resources management for more equitable distribution as water is the fundamental substance of life.

The first observation is the rapid loss of forest cover in the recent past in various parts of the world. It is essential to carry out forest area evaluation and detect green cover changes based on satellite data. This survey helps us better understand the relationships between human activities and the change in natural ecosystems. Afforestation on a massive scale plays an essential part in preventing an accelerated reduction of forest cover and enhancing water holding capacity. New forest areas should be added each year to sensitive landscapes to decrease soil erosion and enhance transpiration. We have to protect them from forest fires, grazing, encroachment, and illegal cutting of trees. The second observation is that coal-based power plants are responsible for much of the world's greenhouse gas emissions. It is essential to develop novel technologies and use alternative power generation technologies such as solar, nuclear, and hydropower. The third observation is that the policymakers are focusing their attention on consumption rather than savings. The government should move the focus toward spreading awareness about the judicious use of this multi-use substance and popularizing water harvesting techniques to reduce the global water footprint. The structure and operational details of water treatment and distribution systems should be comprehensive, including supplying water, infrastructure development, exceptions, and administrative matters. The fourth observation is that the determination of the water prices is ad hoc and needs some structured approach and reforms. The fifth observation is that water conflicts arise because of vested interests, and we need to emphasize the importance of developing collective responsibility, primary national interests, and long-term sustainability goals.

There is a need for creating more online educational platforms to spread the message about water conservation and to disseminate articles, news, images, and videos about water. It is essential to provide mental, graphical, computational, or physical models to enhance understanding of key water chemistry concepts, acquire domain-specific knowledge, and use models to explain a specific observation or analyze new experimental outcomes. It is crucial to research issues connected with water consumption and development, to lead the people in the right direction. The social commitment of agriculture departments, civil society organizations, and corporate companies, coupled with positive initiatives can change the entire landscape and help holistic and balanced development of humanity's well-being.

The integrated organ and printing system uses water-based ink to hold cells and micro-channels to form tissues that can safely integrate into our bodies [77]. Developments in 3D bioprinters could make organs and human tissue good enough for transplant. The future of water purification could involve its treatment with ultraviolet light-emitting diode devices (UV-LED) at the point of use rather than conventional mercury lamps [78]. The recent advances in the water-based printing process involve the use of liquid, waterborne printing inks with negligible volatile organic compound content [79-83]. A significant advance in water-based batteries includes water-in-salt lithium-ion battery technology that could change the use of battery-powered electric vehicles in the future [84]. Smart underwater micro-drones could be used to monitor or map large areas of the oceans [85]. Further advancements in air-to-water generators or advanced versions of wastewater treatment plants, and the adoption of new technologies, help expand access to clean drinking water to new consumers.

CONCLUSIONS

In this paper, we have described the essential uses and different properties of water and emphasized the need to confirm, correct, apply, extend and improve water science and engineering concepts, principles and applications while solving problems related to water. Water is the critical substance for the survival of all civilizations and cultures. It has an essential role in continuing plant and animal life. It would serve to fortify people on the journey of their lives and their businesses.

The businesses can be grouped into verticals like municipal water supply and wastewater treatment, industrial water, and wastewater treatment, seawater desalination, pollution control, and green power generation. The water demand grows as populations increase, placing more significant stress on finding adequate supplies to meet the demand. A focused approach by governments on implementing strategies on the ground will have a significant impact on achieving the national population stabilization target within a short period. Liquid water, a collection of water molecules, is a powerful symbol of hope and literary imagination. It is supporting the whole ecosystem and is crucial for our existence in the laboratory of life. It is a common substance and a unique solvent, essential for living systems. We have to learn to respect nature because of the life-giving care of the water bodies like rivers and streams. We have to invest heavily in quality education and public health, such as clean water, sanitation, and disease control. The growth of an innovative healthcare delivery model depends on the incorporation of waterborne disease prevention through better sanitation and water purification processes in its ecosystem. Funds for developing comprehensive solar power infrastructures such as solar parks and solar farms will help achieve global energy generation targets, enhancing the solar energy capacity manifold.

Water can act either as an acid or as a base. All the chemistry that makes life possible takes place in water media, and different tests involve chemical reactions in water, including the analysis of blood and other body fluids. There are some chemical reactions in water with metals, non-metals, and compounds. Water plays a pivotal role in the metabolism of foodstuffs in the stomach or oxygen transport within the body system.

When raindrops come in contact with carbon dioxide in the atmosphere, water becomes acidic due to the formation of carbonic acid. Water pollution control methods and water treatment techniques used to soften hard water play an essential part in the supply of water required for domestic purposes and industrial processes. The challenges include mindset change, building better systems, achieving water security, maintaining high purity standards, reduction in water pollution levels, improvement in the quality of services, changes in technology, and fair price and transparency. The focus on innovative ideas, a proper plan, established processes, a business model, organizational structure, a strong network of mentors, better water management, access to risk capital, and a forward-looking workforce would pave the way toward sustainable global growth.

Further research and development efforts to improve the water purification and distribution system are warranted. Another direction for future research in this area is the exploration of the technical improvements in monitoring systems and the effective delivery of water fulfilling the regulations. It will be fascinating to see if the development of advanced and hybrid water technologies would significantly reduce the incidence of waterborne diseases. It is an enduring water link in the entire ecosystem that becomes important to the process of climate change. An analysis of specific geospatial data could help in overcoming the water crisis in the future by reconstructing concepts critical to the future of our society. ‘Save water-save the earth’ is a powerful message that would transform the world for the better. It is essential to realize that 'just do it' is not enough, but 'do it right' is the way to go, as many small expeditious steps in the right direction can make a great leap forward. It remains to be seen if the prospect depends on how water management plans reflect our close observation of images from contemporary situations, history, and life.

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