1. Water quality is a major concern in management of tickle irrigation systems. In fact, partial or complete clogging reduces uniformity of water distribution and as a consequence, decreases irrigation efficiency\(^1\)-\(^2\). Physical clogging is caused by suspended inorganic particles (such as sand silt, clay, plastics), organic materials (animal residues, snails, etc.) and microbiological debris (algae, etc.)\(^3\)-\(^4\) Chemical problems are due to dissolved solids when they interact with each other to form precipitates and the precipitation of calcium carbonate in waters rich in calcium and bicarbonates\(^5\). The surface water quality is a matter of serious concern today. Rivers, due to their role in carrying off the municipal and industrial wastewater and runoff from agricultural land in their vast drainage basins are among the most vulnerable water bodies to pollution. The surface water quality in a region is largely determined both by the natural process and the anthropogenic influence of water quality\(^6\)-\(^8\). Many different sources and processes are known to contribute to the deterioration in quality and contamination of surface water. Thus, a thorough understanding of the nature and extent of contamination in an area requires detailed hydrochemical data\(^9\)-\(^10\). Multivariate statistical analyses are used to incorporate larger numbers of variables measured in water systems\(^11\). The application of different multivariate statistical techniques, such as cluster analysis (CA), principal component analysis (PCA) and factor analysis (FA), help in the interpretation of complex data matrices to better understand the water quality and ecological status of the studies systems, allows the identification of possible factors that influence water streams and offers a
valuable tool for reliable management of water resources as well as rapid solution to pollution problems\textsuperscript{12-13}. The shortage of rain and capillarity rise from shallow ground water or from sea water intrusion in coastal areas makes necessary the use of water of low quality for irrigation\textsuperscript{14}. The use of saline water for irrigation purposes with the risk of salt accumulation in the root zone and consequent damage to crop production and soil fertility\textsuperscript{15}. Nearby half of the irrigated surface increasing problem\textsuperscript{16}. In coastal areas, seawater intrusion into the groundwater due to excessive withdrawals causes increasing salinity of both water resources and soils\textsuperscript{17}. It is difficult to cultivate or increase crops or pepper yield in areas with salt affected soils and or irrigate with saline waters. One approach to control salinity is leaching of soluble salts from root zone soil by giving additional amount of irrigation water known leaching fraction\textsuperscript{18}. Agricultural water use plays the most critical role in water resources management all around the world. Currently, 17\% of the total agricultural land is irrigated and 40\% of food and fiber demand are supplied from this irrigated land with the use of 70\% of available water resources\textsuperscript{19}. In addition, irrigated agriculture is dependent on an adequate water supply of usable quality. Water qualities concerns have often been neglected because of good quality supplies have been plentiful and readily available. This situation is now changing in the many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound
planning to ensure that the quality of water available is put to the best use\textsuperscript{20}. Heavy metals (Cu, Pb, and Zn) normally present at much lower concentrations in waters compared to major ions ($\text{SO}_4^{2-}$, $\text{Cl}^-$, $\text{Mg}^{2+}$, $\text{Ca}^{2+}$, etc.). They are continuously released in the aquatic environment via natural and anthropogenic influx. Nowadays, the contamination of soils, sediments, water resources and biota by heavy metals in a major concern especially in many industrialized areas due to their toxicity, persistence and bioaccumulative nature\textsuperscript{21-22}. Water is one of the most basic requirements of all forms of life and is the key to the socio-economic development of the country. It is estimated that at present 1.1 billion of world’s population do not have access to adequate drinking water facilities and projections for the year 2050 indicate that about $2/3$rd of the population of the world would be facing moderate to severe water scarcity. Preserving the quality of water and ensuring its availability on a sustainable basis have been the major challenges that India is facing today. Increased water pollution due to industrial activities, growth of population and increasing requirement of water for the agricultural sector have led a scenario where access to safe drinking water in some parts rural areas has become a major problem\textsuperscript{23-25}. Copper is rarely found in natural water and its higher amount is attributed to corrosive action of water. Persons exposed to cadmium are reported to have the adverse effects like bronchitis, emphysema, anemia and renal stones. Mercury in nature exists as mono and divalent salts or as organomercury compounds, of which the important and most is methylmercury. It is accumulated in food chain. The harmful effects in man are dye to hexavalent chromium. Its
higher concentration results in liver, intestinal and lung cancer narcosis, nephritis and even death\textsuperscript{26}. Copper is an important component of protein found in the enzymes that regulate the rate of many biochemical reactions in plants. The plants would not grow with the presence of these specific enzymes. Copper promotes seed production and formation and it plays an essential role in chlorophyll formation. It’s deficiency and toxicity; both are lethal to plants\textsuperscript{27}. Water is also known as ‘blue gold’ and it is life for all living beings, yet over one billion people across the world are deprived of safe drinking water. The underground drinking water contamination is sometimes of geogenic origin and mostly, it is due to different kinds of anthropogenic activities of human beings. Underground drinking water is gradually accumulating pollutants since industrial revolution started\textsuperscript{28-29}. Metals due to their natural abundance and by virtue of their natural usage in all sphere of life in their different chemical forms exist as ingredients of several compounds in the form of metals, inorganic, organic salts and complexes etc. Several adverse reports on metal exposure and toxicity have made human beings more conscious all over the world\textsuperscript{30-31}. Trace metals ingested by the human body tolerance limits can have severe consequences for health\textsuperscript{32}. Children and pregnant women are more prone to toxicity of trace metals. The zootechnic pollution proceeds from animal residues, erosion products of the soil, natural or synthetic fertilizers, inorganic salts, mineral substances resulted from irrigations, herbicides, bio-stimulations, antibiotics, etc\textsuperscript{33}. Pesticides contamination to water systems has received particular attention during these last few years. More than 700 pesticides
are approved for use around the world, many of which are suspected to endocrine disrupts. Other pesticides, though no longer used, persist in the environment where they bioaccumulation in the flora and fauna. If the compounds are present only in very low concentrations, they are hazardous because some species of aquatic life are known to concentrate 100-fold or more. There is no predictable safe level for pesticides in water where food chains can occur\textsuperscript{34}. These insecticides find their way into the water systems through leaching, channeling, direct spillage and wind drift\textsuperscript{35}. Many pesticides, particularly those with low solubility, show a tendency to bioaccumulation in organisms when present in water or sediment even in very low concentrations\textsuperscript{36}. Many pesticides have been shown to be potentially toxic, carcinogenic and mutagenic\textsuperscript{37}. For example, high concentrations of herbicides flushed with surface water during spring runoff may adversely affect the growth and survival of aquatic plants, which are essential food sources and breeding grounds for aquatic organisms\textsuperscript{38}. Molasses (one of the important bio-products of sugar industry) is the cheap source of production of alcohol in distilleries. They produce about 40 billion liters of wastewater known as raw spent wash (RSW), which is characterized by high biological oxygen demand (BOD: 5000-8000 mg/L) and chemical oxygen demand (COD: 25000-30000 mg/L)\textsuperscript{39}. Raw spent wash is normally discharge into open land or nearby water bodies resulting in a number of environmental problems including threat to plant and animal lives\textsuperscript{40}. Distillery spent wash contains highest content of organic nitrogen and nutrients\textsuperscript{41}. One of the measure objectives in the global clean-up action of WHO is to find out
strategies an analytical tool for the rapid monitoring of water pollution. This has accelerated the research activities of environmental scientists to find out analytical tools, model and method\textsuperscript{42}. The main threats to human health from heavy metals are associated with exposure to lead, cadmium, copper, nickel etc\textsuperscript{43}. The positive or negative effects of these metals on human health have been studied and reviewed by the researchers and environmental foundation like WHO\textsuperscript{43-46}. Heavy metal ions should be accurately evaluated in order to prevent the occurrence of harmful effects. The cycle of trace metals ions from the environment to human is also an important part of environmental studies\textsuperscript{47,48}. The most important portion of contamination due to pesticide is observed in agricultural areas and in surface waters that come from agricultural areas. An important quantity of pesticide is released from pesticide production plants. Pesticides usually have direct adverse effect on the living organisms. These compounds are toxic and carcinogenic in nature even at low concentration\textsuperscript{49}. Today world is more than ever subjected to increasing pressure on water resources caused by population growth, urbanization, irrigated agriculture expansion, industrial development and global climatic changes\textsuperscript{50}. Large-scale indices and severity of flourosis in different parts of India suggested that out of the various components of the environment, water is the major contributor to the flourosis problem\textsuperscript{51}. Water is the first need for human beings. About 25 million people in 8700 villages in India are using ground water having fluoride concentration more than 1.5 mg/L\textsuperscript{52,53}. In skeletal flourosis, high dose of fluoride replaces bone calcium fluoride, bones become soft, crumble and
chalky white. Maximum effects of fluoride are detected in the neck, knee, pelvic, shoulder joints, small joints of the hands and feet. In children dental fluorosis is observed but skeletal manifestations are not observed. In old age patients, disease like osteoporosis, rheumatoid arthritis etc. are chief causes of knee joint affection. In young patients, fluorosis is chiefly responsible for knee joint problem.

Groundwater is one of the earth’s renewable resources, which occurs as a part of hydrological cycle. The quality of groundwater is the resultant of all the processes and reactions that act on the water from the moment it condenses in the atmosphere to the time it is discharged by a well. The problems of ground water quality are more acute in the areas that are densely populated and with highly agriculture practice\textsuperscript{54,55}. The intrusion of salty sea water into wells is a ground water pollution problem in many coastal cities and towns. The quality of ground water is more important as the case of quantity. Since ground water contains a number of undesired constituents such as dissolved solids, suspended impurities, biological matters, etc., it has to be treated to remove their constituents before consumption. About 90 % of the population in the coastal area utilized a shallow ground water for drinking and other needs. Regular monitoring of the quality of ground water should be undertaken, temporarily and spatially to identify the sources of toxic contaminants and other inhibitory compounds that affect the potability of water\textsuperscript{56}. When establishing and observing the environmental regulations and legislation, the bioavailability, bioaccumulation and persistence to biological activities of the heavy metals are to be significantly considered\textsuperscript{57-59}.
Heavy metals can enter river systems through natural sources (erosion, forest fires and volcanic eruptions) and anthropogenic activities such as discharge through of wastewaters with heavy metals content, which can be generated through industrial and agricultural activities and domestic use. Sediments have high affinity to store heavy metals as well as many other pollutants and may contain heavy metals at higher concentrations compared to those of water bodies. As a fact, heavy metals stabilized within the contents and structure of the sediments is no longer a significant threat to water organisms. On the other hand, sediments can act as a carrier for heavy metals when these sediments are resuspended in water bodies through changes in the hydrological conditions of the rivers, anthropogenic activities on river beds and biological activities such as bioturbation & bioirrigation. Salinity is the total concentration of water-soluble salts in water and soil. It is measured in the form of electrical conductivity. Irrigation with water of higher salinity than a crop can tolerate will result in loss in yield and decrease in quality of crop. Plant varies greatly in their tolerance to irrigation with saline water. Generally a reduction in plant growth is evident by a reduction in height of plant or in the number of leaves or shoots is the first plant response to salinity. As the plant becomes more affected, it may appear wilted, despite a moist soil, and the leaves may show leaf burn. Under these circumstances, the plant may die; shoots are generally more inhibited in growth than roots and at low salinity levels, root growth may not decrease at all. The heavy metals are important components of pollutants, which not only causes phytotoxicity but also enters into
the food chain causing hazardous impacts on human health and animals. The phytotoxic impact of heavy metal pollution is very commonly observed on crops. Chemicals in drinking water, which are toxic, may cause either acute or chronic effects. An acute effect usually follows a large dose of a chemical and occurs almost immediately. It is important to understand that primary standards for drinking water contaminants do not guarantee that water with a contaminant level below the standard is risk-free\textsuperscript{70}. Organic acid of leaf leachate absorbed on soil surface increases its cation exchange capacity and catalyze the whole process. A two stage pathway is most likely followed. At the two-phase interface the metals are immobilized through their adsorption or mineralization. Later organic acids-humic and fulvic acid, from aqueous complexes through water sequestering of metals thereby facilitating their mobility and replenish lower levels of minerals from soil to aqueous phase. Since more micro metals are especially susceptible to ion exchange and facilitated by pH based humic acid and fulvic acid catalysis\textsuperscript{71}.

1.1 Hydrochemistry: The main source of water on this earth is rainfall, a portion of it is penetrated beneath the surface, a portion is evaporated into the atmosphere and some of it runs off. A portion which is penetrated into the earth is called the ground water. So groundwater is the portion of water beneath the surface of earth that can be collected with wells, tunnels or drainage galleries or that which flows naturally to the earth’s surface.

Below a certain level, all porous and fissured rocks are saturated with water. The upper surface of this groundwater is called the water table. The water table is
arched up under hills, roughly following the relief of the ground, but with a more subdued surface. In general three successive zones are recognized.

A) The zone of non-saturation; which is never completely filled, but the water percolates on its way to the under-lying zones. A certain amount of water is retained by the soil, which yields upto plant roots.

B) The zone of intermittent saturation; which extends down the highest level reached by groundwater after a period of prolonged wet weather, down to the lowest level to which water table recedes after droughts.

C) The zone of permanent saturation, which extends down to the limit beneath which groundwater is not encountered. Wherever the zone of permanent saturation rises above ground level, seepage swamps, lakes or rivers occur. When the zone of intermittent saturation temporarily reaches the surface, floods develop and intermittent springs appear. The amount of rainfall and rate of percolation differ from place to place, the water table is high in some places and lower in the others. The water table is higher in regions of heavy rainfall or in places situated near lakes and rivers. On the other hand water table is low in mountainous regions and on steep slopes. The water table also fluctuates from time to time. It is higher in the rainy season and lower in dry and hot weather. The water table that fluctuates from time to time is called the temporary water table. But there is a limit below which it never falls and this is known as permanent water table.
1.2 Origin of Groundwater: Atmospheric precipitation is the main source of fresh ground water. The water may be infiltrated directly into the groundwater where it landed or it may first have collected in streams and lakes via surface runoff and then seeped into the ground. Groundwater of atmospheric origin that has been recent part of hydrologic cycle is called meteoric water.

Much older ground water that is still of atmospheric origin which may have been isolated from the hydrologic cycle for millions of years is called a connate water. This water typically is groundwater that was already present in the geologic formation when it was formed, such as the water is often found in the lower part of deep groundwater basins. It is normally of poor quality, especially if it has been in contact with salt deposit or other evaporates. Because of its long underground residence, connate water can have moved long distances, even though its velocity is very small.

Juvenile water, also called primary water, ground water that has never been part of hydrologic cycle. It is formed within the earth itself and is of volcanic or magmatic origin. Juvenile water can move up in the earth’s crust with volcanic activity. It is high in mineral content and insignificant as a water resource. Magmatic waters include volcanic water and plutonic water derived from deep magma. Metamorphic water is water that was in rocks during the period of metamorphism. Marine water is water that has moved into aquifers form oceans.

The presence of heavy metals in the sea and groundwater in the ship breaking area of Sitakund Upazilla, Chittagong has remained largely unexplored. Ship
scraping activities polluted the soil and seawater environment in the coastal area of Fauzdarhat to Kumara of Chittagong, Bangladesh. While dis-mantling the ships, the industry generated all kinds of miscible and immiscible wastes in the form of solids, liquids and gases which accumulated over the soil first and then migrated incrementally to the tidal zone, sub-tidal zone, and subsequently to the deep seawater and into the respective sediments. The main pollutants constituted of heavy metals, petroleum hydrocarbons and other contaminants. Amongst these, petroleum hydrocarbons and heavy metals were the most serious pollutants because of their toxicity and persistence. The heavy metal concentrations in the aquatic environment were also of critical concern, due to toxicity of metals and their accumulation in aquatic habitats. Water is the valuable natural resource and its quality is of much concerned for the welfare of human being. Recently, frequent and indiscriminate exploitation and destruction of natural resources of water have largely disturbed the ecosystem of water\textsuperscript{72}. The socioeconomic growth of a region is severely constrained by non-availability of sage drinking water: keeping this in view Govt. of India had constituted a Water technology Mission\textsuperscript{73} for drinking water in 1987. Trace metal contamination in sediment is one of the major threats to environment and human health. Trace metals when discharged into the coastal waters, are rapidly removed to the sediment through particle surface adsorption or oxidation or by incorporating into phytoplankton. These sediments become an important reservoir for metals to the ecosystem. However, some of the sediment-bound metals may remobilize and be released to the waters
due to the changes in the redox condition of the ambient water and might adversely affect the growth of organisms. Monitoring the trace metal enrichment in sediment might therefore an important component of understanding environmental pollution. Metals that are of concern for their toxicity to the aquatic organisms are Pb, Cd, Hg, Cu, etc. Sources of the heavy metals included weathering of rocks, dissolution of these metals from natural deposits, discharges of effluent from mining, metallurgical, plastic and paint industries, fertilizers and by many other pathways. Water is a key resource in all-economic activities ranging from agriculture to industry. During last two decades, the quality of drinking water has undergone radical changes. The surface water sources are not acceptable for drinking purpose as these are often loaded by various organic, inorganic and biological constituents, which are potentially hazardous to consumers. The over exploitation of ground water to improper land use and management has led to contamination of ground water in urban areas. Ground water is one of the aquatic biotope that harbors varied microflora. The existence of the bacterial microflora depends upon several factors, such as solid particles mobility, the hydrodynamics and the hydrogeochemistry of the ground water. Most of the surveys on pollution indicator bacteria are on the nature of sanitary quality of surface or groundwater except for a few which describe seasonal variations and environmental influences on bacterial abundance. The quality of water used by man for various purposes varies widely and what is satisfactory for one purpose may not be so for another. Water for human consumption must be
free from pathogenic microorganisms and other substances which are hazardous to health. A water sample is normally rejected for drinking purposes if it is highly turbid, highly colored or has an objectionable taste, but the absence of these adverse sensory effects does not guarantee the safety of water for drinking. The enormous pressure exerted by rapidly increasing population, massive industrial activities, modern agricultural practices have resulted in discharge of very large amount of pollutants to the water bodies. The problem is particularly manifested as the fresh water suitable for drinking purposes is in very short supply.

Contamination of drinking water, either directly or indirectly by sewage and other wastes or by human or animal excrement is the most common and widespread danger associated with water quality problem particularly in the underdeveloped world. Faecal pollution leads to introduction of variety of intestinal pathogens—bacteria, virus and parasites—causing diseases starting from mild gastroenteritis to severe and fatal dysentery, cholera or typhoid. When drinking water is contaminated with sewage, gastroenteritis and infectious hepatitis may occur in epidemic proportion. Other diseases, like rashes, fever myocarditis, meningitis, respiratory diseases etc. are also likely. The chemical contaminations do not cause immediate acute health problems unless they are present in massive quantities through some accident. However, these are important in the respect that after prolonged period of exposure them, they can do considerable harm by being cumulative poison and carcinogens\(^7\). Investigation on the hydrographical as well as sedimentological parameters are of great concern in characterizing the general
features of an estuary generally depend upon the intrusions of seawater associated with tides and the influx of fresh water from rivers. The structure of the physical and chemical environment of an ecosystem is commonly expressed in terms of water quality parameters and they are equally significant for pollution control, harbor design, marine traffic routing, etc\textsuperscript{77}. Trace metal contamination in sediment is one of the major threats to environment and human health. Trace metals when discharged into the coastal waters, are rapidly removed to the sediment through particle surface adsorption or oxidation or by incorporating into phytoplankton. These sediments become an important reservoir for metals to the ecosystem. However, some of the sediment-bound metals may remobilize and be released to the waters due to the changes in the redox condition of the ambient water and might adversely affect the growth of organisms. Monitoring the trace metal enrichment in sediment might therefore an important component of understanding environmental pollution. Metals that are of concern for their toxicity to the aquatic organisms are Pb, Cd, Hg, Cu, etc. Sources of the heavy metals included weathering of rocks, dissolution of these metals from natural deposits, discharges of effluent form mining, metallurgical, plastic and paint industries, fertilizers and by many other pathways\textsuperscript{78}.

\subsection*{1.3 Hydrogeochemistry:}

Various water quality characteristics which can give us complete information regarding physical, chemical and biological quality of water as well as waste water are being discussed here.
1.3.1 **Turbidity:** The main reason behind turbidity is presence of suspended particles, slit, clay, sand, microscopic biota, organic matter etc. In wastewater from metallurgical plants like steel plants, copper and zinc smelter, usually heavy metals as released. Refinery wastes contain oil, greases, hydrocarbons etc. Wastewater from fertilizer industry contains ammonical nitrogen, fluorides, phosphate, hexavalent chromium etc.

Soil contamination takes place when solid wastes are dumped in the soil or when wastewater, containing pollutants, is let out into soil. Solid wastes generated in various industries often contain leachable materials, which are harmful e.g. oil sludge from refinery, phosphogypsum from fertilizers, spent catalyst from chemical industry, material waste from metallurgical industries etc.

1.3.2 **pH:** The pH is an important hydrographical factor indicating the level of dissolved carbon dioxide in the water, which may in turn reflect the activity of phytoplankton and the level of dissolved oxygen. Many of the estuarine processes are directly related to the pH of the aquatic environment. pH is one of the most important and frequently used tests in water chemistry. Particularly every phase of water supply and water treatment, for example acid-base neutralization, water softening, precipitation, coagulation, disinfection and corrosion control, is pH dependant. The pH is used in alkalinity and carbon dioxide measurement and many other acid-base equilibria. At a given temperature the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen ion activity.
1.3.3 **Electrical Conductivity:** Electrical conductivity is a good measure of salinity hazard to crops as it reacts the TDS in groundwater. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil. Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valance, and relative concentrations, and on the temperature of measurement. Solution of most inorganic acids, bases and salts are relative good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly. Electric conductivity is a measurement of water’s capacity for conveying electric current and is directly related to the concentration of ionized substance in the water. It is the measure of the mineralization and indicative of the salinity of groundwater. The electric conductivity with 400 micro-mohs/cm at 25°C is considered suitable for human consumption. EC of water is directly proportional to its dissolved mineral matter content.  

1.3.4 **Total Dissolved Solids:** To ascertain the suitability of groundwater for any purposes, it is essential to classify the groundwater depending upon their hydrochemical properties based on their TDS values. The total dissolve solid consist of inorganic substances. The principle constituents of TDS are Calcium, Magnesium, Sodium, Bicarbonate, Chlorides and Sulphates. An important aspect of TDS with respect to drinking water quality is the effect on test. The palability of water with a TDS level less than 600 mg/L is generally considered to be good
whereas at TDS levels greater than 1200 mg/L drinking water becomes increasingly unpalatable. The inorganic cations and anions such as Na\(^+\), Ca\(^{2+}\), Mg\(^{2+}\), Cl\(^-\), SO\(_4\)^{2-}, PO\(^{-3}\), etc. are mostly responsible for groundwater is directly related to the TDS in water. Apart from this there are pieces of sand, salt, leaves, fine organic matter etc. Very high value of suspended solid indicates high particulate matter due to pollution or eutrophication and hence is not a sign of healthy ecosystem. The TDS imparts undesirable taste. It also causes gastro-intestinal irritation\(^\text{80}\).

1.3.5 Turbidity & Odour: Release of the waste water containing decaying organic materials may impart bad odour to water and there may be a colour change to green or light yellow. The waste products are good sources of nutrients for microorganism and small insects. The yellowish colour is due to organic matter. The green colour may be due to the presence of green Alga or Fungi. The colour of waste water from distilleries is brownish yellow due to the molasses used as a raw material & other organic substance which are in the dissolved form. Rapid depletion of oxygen due to biological oxidation followed by anaerobic stabilization of the sugar mill waste causes the discharge to blacken\(^\text{81}\).

1.3.6 Total Hardness: Hard water contains Calcium and Magnesium ions. It is generally defined as the Calcium carbonate equivalent of Calcium and Magnesium ions present in water as expressed in ppm. There is evidence that death rates from cardiovascular diseases are inversely correlated with the hardness of water, the guideline value for hardness at 500 ppm (CaCO\(_3\)) is based on taste and household
use consideration. Hardness is defined as the concentration of multivalent metal ions in solution. At supersaturated conditions, the hardness causing ions will react with anions in the water to form a solid precipitates. Hardness is classified as carbonate hardness and non carbonate hardness, depending upon the anion with which it associates. The hardness, which is equivalent to alkalinity, is termed carbonate hardness, with remaining hardness being called as non carbonate hardness.

1.3.7 Calcium Hardness: Water with high concentration of calcium is not used for domestic use. Small concentration is useful in reducing corrosion in pipe. It antagonizes the toxicity of various substances such as, Pb, Zn, Al and toxic solution of Na, Mg, K, and Cl₂. Calcium is one of the principle cation in groundwater. The calcium is most abundant element in human body, which required 0.7 to 2.0 mg per day. However higher doses may required by pregnant women, those who are breast feeding or growing children. It helps in the formation of bones and teeth.

1.3.8 Magnesium Hardness: After Calcium, Magnesium is the most important alkaline earth metal present in the groundwater. It is one of the most important contributors the hardness of water. The lower concentration of magnesium is not harmful but higher concentrations are laxative. Maximum acceptable and allowable limit of Magnesium in drinking water according to WHO is 30 ppm and 150 ppm, respectively.
1.3.9 Sodium: Sodium is one of the important cations occurring in natural water. The concentration in natural freshwater is lower than Ca & Mg. Major a source of Sodium in natural water is weathering of various rocks. Most of the industrial wastes and domestic sewage are rich in Sodium and increase its concentration in natural waters after disposal. Higher concentration of sodium ion the irrigation water and soil solution is of considerable interest as it affects soil permeability and texture, and leads to puddling and reduced rate of water intake. The high concentration of Sodium is considered harmful to persons suffering from cardiac and renal diseases.

1.3.10 Potassium: Potassium is less common cation in the ground water. Potassium being the most mobile cation apart from an involvement in metabolic processes. These ions participate in nerve impulse conductive via the brain. The concentration of potassium in natural wastes is very less when compared to Calcium, Magnesium and sodium. Its concentration in most drinking water seldom reaches 20 mg/l. It is a component of fertilizers and used as macronutrient for plant.

1.3.11 Iron: Iron is the second most abundant metallic element in the earth’s crust. It exists in water either as ferrous or ferric state, suspended or dissolved. Under reducing conditions, Iron is oxidized to ferric state. Iron gives a metallic taste to water and can affect food and beverages. Iron in water causes yellowish red or brown stains on laundry, dishes and plumbing fixtures. It can clog pumps, sprinkles and other devices. As per BIS (1991) the desirable and permissible limits
of iron in drinking water are 0.3 mg/L and 1 mg/L, respectively. Beyond 1 mg/L
taste and appearance of water are affected & it promoted growth of iron bacteria.
These bacteria also cause unpleasant odour and taste.\textsuperscript{83}

1.3.12 **Total Alkalinity:** Alkalinity is due to the presence of bicarbonates,
carbonates or hydroxides. Most of the alkalinity of water is because of the
bicarbonates produced by interaction of ground water with limestone. Alkalinity is
useful since it provides buffering to resist changes in pH. The amount of alkalinity
present is expressed in terms of calcium carbonate. Alkalinity itself is not harmful
to human beings: still water supplies with less than 100 mg/L are desirable for
domestic use. Alkalinity is defined as the quantity of ions in water that will react
to neutralize hydrogen ions. Alkalinity is thus a measure of the ability of water to
neutralize acids. Constituents that cause alkalinity in natural systems include CO$_3^{2-}$,
HCO$_3^-$, OH$^-$, HPO$_4^{2-}$, H$_2$PO$_4^-$, HS$^-$, NH$_4$OH. These compounds result from the
dissolution of mineral substances in the soil and atmosphere. The dissolved CO$_2$
gas combined with sodium carbonate & bi-carbonate, leads to alkalinity. Some of
the basic salts may get dissolved during the percolation of water up to the water
table. A.K. Das\textsuperscript{84}, revealed that the predominate form of alkalinity in the upper
complex of Ganga was due to bicarbonate, as the pH values never exceeded 8.25.

1.3.13 **Chloride:** Chlorides occur in all types of water but the concentration is
very low in natural water. The most important source of chlorides in the water is
the discharges of domestic sewage, and industrial waste. Threshold value for
Chloride is 250-500 mg/L, although Chloride concentration up to 500 mg/L is
harmless. Chlorides are responsible for brackish taste of water and are an indicator of sewage pollution because of the chloride content of urine. Chloride is present in all potable water supplies. High concentration of chloride in water gives an undesirable taste to water. Young children may suffer if they consume water high in chloride as their delicate kidney tissues may be damaged by the higher osmotic pressure brought about by the presence of high concentration of salts. It is therefore, important that the chloride content of water supplies should be kept as low as possible. Chlorides are present in water usually as NaCl, MgCl$_2$ & CaCl$_2$. It occurs naturally in all types of water. Chloride in drinking water is relatively harmless, if present in amounts below 250 ppm. The chloride content in groundwater originates from natural and anthropogenic sources$^{85}$.

1.3.14 Fluoride: Fluoride in groundwater was one of the specific problems considered by this mission. Increasing incidences of high fluoride concentration in groundwater and fluorosis has promoted groundwater quality monitoring and investigation of fluoride contamination in different parts of India. High fluoride in concentration in groundwater was found in many parts of developing countries and fluorosis is endemic in at least 25 countries across the globe. The worst affected areas and parts of northern China, India, Sri Lanka, African countries, northern Mexico and central Argentina. Smut reported that around 250 million people worldwide are consuming water having fluoride concentration $> 1.0$ mg/L. In India, people of 196 districts of 19 states are drinking fluoride contaminated water above WHO maximum allowed concentration (MAC) of fluoride in
drinking water of 1.5 mg/L. Fluoride occurs widespread in lithosphere as component of rocks and minerals. Earth crust contains abundant fluoride as in high calcium granite (520 mg/L), low calcium granite (850 mg/L), alkaline rocks (1200-8500 mg/L), deep sea clay (1300 mg/L), sandstone (270 mg/L) and in deep sea carbonate (540 mg/L). India is considered as one of the richest country in the world for occurrence of fluoride bearing minerals. Fluoride is sparingly soluble in water and occurs in natural water in trace amount. Due to its highly electronegative characteristics it form only fluorides and no other oxidation states are found in natural water. In acidic medium, species found are in the form of hydrogen fluoride (HF). Fluoride forms strong complexes with aluminum, barilium and iron (III). The fluoride ion has same charge nearly similar ionic radius as of OH (F=1.36 Å and OH= 1.40 Å) hence, they can replace each other and can form series of F-OH complexes with metals. In acidic medium, F-could be associated with silica in four or six co-ordinate structure, though seldom. Aluminum Fluoride complex are likely to be found in water, whose pH is below neutral. The main sources of fluoride in natural water are minerals present in rock. flourosis is a well-defined clinical disorder generally caused by ingestion of excessive amounts of fluoride through potable water. It is a serious health problem in India. Excessive intake of fluoride during pre-eruptive stage of teeth leads to dental flourosis and continued ingestion over years and decades causes skeletal flourosis. In its advance stages, flourosis causes crippling deformities and neurological complications. Dental flourosis mainly involves enamel and motting
is one of the most easily recognizable features. Permanent teeth are affected which become rough, opaque and chalky white. Pitting and chipping are other marks of dental fluorosis. Brown or black pigment is deposited on the defective enamel and once established tends to remain there permanently. Dental fluorosis does not obviously occur. When there has been no exposure to fluoride in first decade of life. Skeletal fluorosis is generally characterized by severe pain and stiffness in the back. Stiffness increases steadily and leads to restriction of back movements. Soon stiffness spreads to various joints of the limbs. With the increasing immobilization of the joints due to contractures, flexion deformities may develop at hips, knee and other joints, which make patient bedridden. Neurological stage is a late stage of skeletal fluorosis where in spinal nerves and spinal cord is compressed by deforming bones. This leads to paralysis and sensory defects affecting touch, vibration, position and joint sense.  

1.3.15 Nitrate: Nitrogen is originally fixed from the atmosphere and then mineralized by soil bacteria into ammonium. Under aerobic conditions nitrogen is finally converted into nitrate by nitrifying bacteria. The high concentration of nitrate in drinking water is toxic and causes blue baby disease/methaemoglobinemia in children and gastric carcinomas. Excessive and indiscriminate use of chemical fertilizers and synthetic feed for live stocks often leads to accumulation of nitrates in water. When such waters are consumed by human beings or cattle, nitrates are taken into the body and are converted to toxic nitrates by intestinal bacteria. This in turn combines with the hemoglobin to form
methaemoglobin which interferes with the oxygen carrying capacity of the blood. Nitrates can also be converted to carcinogen, namely nitrosamines in cattle\textsuperscript{87}. 

It has also been suggested that a high level of nitrate can reduce the assimilation of iodine in the body thus causing Goitre. It has also been suggested that an increased nitrate intake through drinking water carries an increased risk of bearing a malformed child in pregnant woman\textsuperscript{88}.

1.3.16 Sulphate: Sulphur is an essential element for ruminants. A diet deficient in sulphur results in decreased microbial protein synthesis, microbial number, and lactate utilization. High concentrations of sulphates in drinking water decreased feed and water consumption.

Water, during periods of high ambient temperatures, can provide substantial quantities of sulphur to finishing steers. Excessive sulphur consumption has deleterious effects on performance of feedlot steers. Adverse effects of high concentration of sulphate in water were more extreme for younger cattle and with high ambient temperatur. Sulphate is contributed to ground water from fertilizers\textsuperscript{89}. 
References:


80. Howard E Johnson and Robert C Ball; Fate of organic pesticides in the Aquatic Environment doi 10.1021/ba-1972-0111.ch001.


