

2. LITERATURE REVIEW

The water quality of a given surface-water body is a direct reflection of the chemical inputs received from the air and surrounding landscape, and the biogeochemical processes that transform those inputs within the water body itself. Inputs such as atmospheric deposition to the water surface or point source pollutant discharge represent direct chemical injections into the aquatic system.⁽⁷⁾

2.1 Physico-chemical characteristics and heavy metal for water samples

2.1.1 Temperature

Water temperature is one of the most important characteristics of an aquatic system. The most important source of heat for fresh water is generally the sun. Human activities affecting water temperature can include the discharge of cooling water or heated industrial effluents, agriculture and forest harvesting (due to effects on shading), urban development that alters the characteristics and path of storm water runoff, and climate change.

Global increases in air temperature, and the associated increases in water temperature, can cause measurable changes in water quality that are independent of changes in moisture. Temperature alone can decrease the volume of surface waters through increases in ET. Warming of air and water temperatures and increased atmospheric CO₂ have been shown to increase biological productivity and decomposition by increasing rates of metabolism, the duration of the growing season. This increase in productivity will in turn increase nutrient cycling and accelerate eutrophication in aquatic systems with sufficient nutrient and oxygen supplies. Increase in water temperature cause increase in the rates of chemical transformations in surface waters and lengthened periods of biological activity could result in increased bioaccumulation of toxins in aquatic organisms. The toxicity of metals in aquatic ecosystems is enhanced by increased water temperature, through chemical interactions with dissolved organic carbon in low-pH waters.⁽⁷⁾

2.1.2 Turbidity

Turbidity is a principal physical characteristic of water and is an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample. It is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms. Simply stated, turbidity is the measure of relative clarity of a liquid. Clarity is important when producing drinking water for human consumption and in many manufacturing uses. Once considered as a mostly aesthetic characteristic of drinking water, significant evidence exists that controlling turbidity is a competent safeguard against pathogens in drinking water.⁽⁸⁾

Turbidity is a measure of the amount of suspended particles in the water. Algae, suspended sediment, and organic matter particles can cloud the water making it more turbid. Suspended particles diffuse sunlight and absorb heat. This can increase temperature

and reduce light available for algal photosynthesis. If the turbidity is caused by suspended sediment, it can be an indicator of erosion, either natural or man-made. Suspended sediments can clog the gills of fish. Once the sediment settles, it can foul gravel beds and smother fish eggs and benthic insects. The sediment can also carry pathogens, pollutants and nutrients.⁽⁹⁾

2.1.3 pH

pH is a measure of how acidic or basic (alkaline) the water. The term pH comes from the French: "puissance d'Hydrogène" which means strength of the hydrogen. It is defined as the negative log of the hydrogen ion concentration.⁽⁹⁾

The pH in most rivers unaffected by humans and it ranges from 6.5 to 8. The pH range of survivability of most freshwater organisms and it ranges from about 4.5 to 9.⁽¹⁾

Many chemical reactions inside aquatic organisms (cellular metabolism) that are necessary for survival and growth of organisms require a narrow pH range. At the extreme ends of the pH scale, (2 or 13) physical damage to gills, exoskeleton, fins, occurs. Changes in pH may alter the concentrations of other substances in water to a more toxic form. Examples: a decrease in pH (below 6) may increase the amount of mercury soluble in water. An increase in pH (above 8.5) enhances the conversion of nontoxic ammonia (ammonium ion) to a toxic form of ammonia (un-ionized ammonia).⁽⁹⁾

Osman and Kloas (2010)⁽¹⁰⁾ studied water quality in the Nile River-Egypt. pH was in the alkaline side where it was ranged from 7.8 to 8.4.

2.1.4 Electrical Conductivity

Substance to the passage of an electrical current as: $R = V/I$

Where: R is the electrical resistance (ohms), V is electrical potential (volts), and I is current (amperes).

The resistivity of a substance is defined by the resistance to electrical current passing between the faces of a unit cube of the substance.⁽¹¹⁾

Electrical Conductivity as an Indicator of Water Chemistry because EC depends on the overall ionic concentrations in water. It has often been used as an index of the total dissolved solids (TDS) carried by a stream. The ratio of TDS to electrical conductivity for solutions of pure salts ranges from 0.4 to 0.7 for EC up to about 500 $\mu\text{S}/\text{cm}$, depending on the salt. For natural stream waters, the ratio generally ranges from about 0.55 to 0.75, but may be near unity for high-sulfate water or less than 0.5 for strongly basic or acidic waters. One limitation to the use of EC as an indicator of TDS is that EC does not respond to the presence of uncharged dissolved substances, such as silica, a common weathering product from igneous rock.⁽¹¹⁾

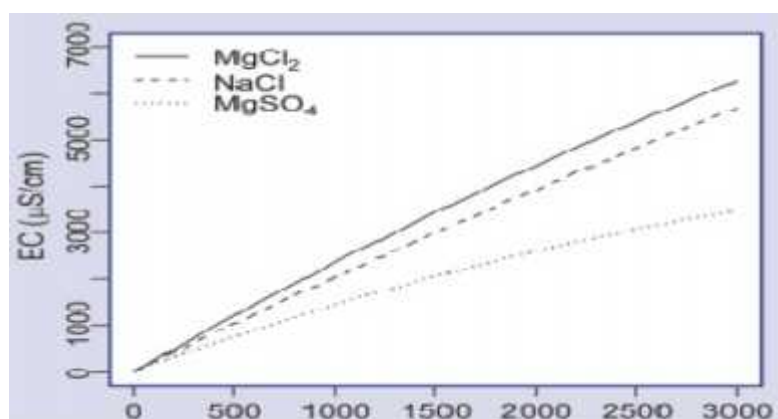


Figure: 2.1: Relations between electrical conductivity (EC) and concentration for different salts ⁽¹¹⁾

Osman and Kloas (2010) ⁽¹⁰⁾ studied water quality in the Nile River-Egypt. Conductivity results increase from Aswan to Domietta and then Rosetta branch due to the disposal of domestic and industrial effluent in the water of Damietta and Rosetta branches.

2.1.5 Total hardness

Water hardness is the traditional measure of the capacity of water to react with soap. Hard water requiring considerably more soap to produce lather. Hard water often produces a noticeable deposit of precipitate (e.g. insoluble metals, soaps or salts) in containers, including “bathtub ring”. It is not caused by a single substance but by variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, although other cations (e.g. aluminium, barium, iron, manganese, strontium and zinc) also contribute. Hardness is most commonly expressed as milligrams of calcium carbonate equivalent per liter. Water containing calcium carbonate at concentrations below 60 mg/l is generally considered as soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard. Although hardness is caused by cations, it may also be discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness. ⁽¹²⁾

Water is a good solvent and picks up impurities easily. As water moves through soil and rock, it dissolves very small amounts of minerals and holds them in solutions. Dissolved calcium and magnesium are the two most common minerals that make water hard. The degree of hardness becomes greater as the calcium and magnesium content increases. ⁽¹³⁾

Both calcium and magnesium are essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences. Recommended daily intakes of each element have been set at national and international levels. Individuals vary considerably in their needs for and consumption of these elements. ⁽¹²⁾

2.1.6 Chloride

Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium (CaCl₂). ⁽¹⁴⁾ Sodium chloride is widely used in the production of

industrial chemicals such as caustic soda, chlorine, sodium chlorite, and sodium hypochlorite. Sodium chloride, calcium chloride, and magnesium chloride are extensively used in snow and ice control. Potassium chloride is used in the production of fertilizers. ⁽¹⁵⁾

Chlorides are leached from various rocks into soil and water by weathering. The chloride ion is highly mobile and is transported to closed basins or oceans. ⁽¹⁴⁾

A normal adult human body contains approximately 81.7 g chloride. On the basis of a total obligatory loss of chloride of approximately 530 mg/day, a dietary intake for adults of 9 mg of chloride per kg of body weight has been recommended (equivalent to slightly more than 1 g of table salt per person per day). For children up to 18 years of age, a daily dietary intake of 45 mg of chloride should be sufficient. ⁽¹⁵⁾ A dose of 1 g of sodium chloride per kg of body weight was reported to have been lethal in a 9-week-old child. ⁽¹⁶⁾ Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure. ⁽¹⁷⁾ Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet. As in experimental animals, hypertension associated with sodium chloride intake appears to be related to the sodium rather than the chloride ion. ⁽¹⁵⁾

2.1.7 Color

Color is vital as most water users, be it domestic or industrial, They usually prefer colorless water. Determination of color can help in estimated costs related to discoloration of the water.

2.1.8 Alkalinity

Total alkalinity (TA) is one of the few measurable quantities that can be used together with other quantities to calculate concentrations of species of the carbonate system (CO_2 , HCO_3^- , CO_3^{2-} , H^+ , and OH^-). ⁽¹⁸⁾

It is composed primarily of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-), alkalinity acts as a stabilizer for pH. Alkalinity, pH and hardness affect the toxicity of many substances in the water. It is determined by simple diluted HCl titration in the presence of phenolphthalein and methyl orange indicators. Alkalinity in boiler water essentially results from the presence of hydroxyl and carbonate ions. Hydroxyl alkalinity (causticity) in boiler water is necessary to protect the boiler against corrosion. Too high a causticity causes other operating problems, such as foaming. Excessively high causticity levels can result in a type of caustic attack of the boiler called "embrittlement". Whenever the pH touches 8.3, the presence of carbonates is indicated. It is measured by titration with standardized hydrochloric acid using phenolphthalein as indicator. Below pH 8.3, the carbonates are converted into equivalent amount of bicarbonates. The titration can also be done pH metrically or potentiometrically. ⁽¹⁹⁾

Osman and Kloas (2010) ⁽¹⁰⁾ studied water quality in the Nile River-Egypt. Alkalinity results recorded highest values at Rosetta branch (124.3 ppm).

2.1.9 Total dissolved solids

The total dissolved solids (TDS) concentration is a measure of the quantity of various inorganic salts dissolved in water. The TDS concentration is directly proportional to the electrical conductivity (EC) of water. Since EC is much easier to measure than TDS, it is routinely used as an estimate of the TDS concentration.⁽²⁰⁾

The total dissolved solids (TDS) in water consist of inorganic salts and dissolved materials. In natural waters, salts are chemical compounds comprised of anions such as carbonates, chlorides, sulphates, and nitrates (primarily in ground water), and cations such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na). In ambient conditions, these compounds are present in proportions that create a balanced solution. If there are additional inputs of dissolved solids to the system, the balance is altered and detrimental effects may be seen. Inputs include both natural and anthropogenic source. Total Dissolved Solids measures the solids remaining in a water sample filtered through a 1.2 μm filter. According to the World Health Organization, the compounds and elements remaining after filtration are commonly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulfate, silica and nitrate-n. High TDS concentrations can produce laxative effects and can give an unpleasant mineral taste to water.⁽²⁰⁾

2.1.10 Sulphate

Sulfate in water sources is often leached from rock or soil containing gypsum and other sulfate containing minerals. Sulfate can also come from wastewater plant or industrial plant discharges or from agricultural runoff. Sulfate salts with low molecular weight metals such as sodium, potassium, and magnesium are very soluble in water.

Sulphate is the oxy-anion of sulphur in the VI oxidation state and forms salts with various cations such as potassium, sodium, calcium, magnesium, barium, lead and ammonium. Potassium, sodium, magnesium and ammonium sulphates are highly soluble whereas calcium sulphate is partially soluble and barium and lead sulphates are insoluble. Sulphur is essential for life, mainly as a component of amino acids, saliva, bile and the hormone insulin. Water with excessive amounts of sulphate is unpalatable and ingestion thereof typically results in diarrhea.⁽²⁰⁾

Sulfate is a commonly occurring anion in groundwater and surface water. Low concentrations (<0.5 mg/L) of sulfate can encourage algal growth, however, sulfate concentrations greater than 250 mg/L can cause water to have a salty taste and may cause pipe and fixture corrosion.

There are no known chronic adverse health effects from exposure to sulfate.⁽²¹⁾ Elevated sulfate levels can cause health concerns when there is an abrupt change from drinking water with a low sulfate concentration to drinking water with a high sulfate concentration. Diarrhea is the main health effect caused by ingestion of drinking water with a high sulfate concentration.⁽²²⁾

2.1.11 Phosphate

Phosphorus occurs in natural waters and in wastewaters almost solely as phosphates. These are classified as orthophosphates (PO_4^{3-}), condensed phosphates (pyro-, meta-, and

other polyphosphates), and organically bound phosphates. They occur in solution, in particle or detritus, or in the bodies of aquatic organisms. Sources of phosphorus enrichment may include some detergents, fertilizers (in both rural and urban areas), animal faeces (e.g. from farms and feed lots), sewage and some industrial wastes. High levels of phosphorus and/or other key nutrients may lead to related problems such as nuisance or toxic algal blooms, although some waterways are naturally eutrophic (nutrient enriched).⁽²³⁾

Phosphorus is an essential element for all life. It is part of the backbone of DNA. ATP is the fuel, or energy currency of cellular metabolism. Phosphorus at different energy states is organically bound and essential to the operation of photosynthesis, metabolism, and catabolism (the building of molecules). Because of the central role of phosphorus, when crop yields are high, phosphorus is always in adequate supply.⁽²⁴⁾ There are several forms of phosphorous, called white, red and black phosphorous, although their colors are more likely to be slightly different. White phosphorous is the one manufactured industrial; it glows in the dark, is spontaneously flammable when exposed to air and is deadly poison. Red phosphorous can vary in color from orange to purple, due to slight variations in its chemical structure. The third form, black phosphorous, is made under high pressure, looks like graphite and, like graphite, and has the ability to conduct electricity.⁽²⁵⁾

Exposure to high levels of Phosphate can cause vomiting, abdominal cramps and pain, Kidney, liver, cardiovascular and CNS effects.⁽²⁶⁾

2.1.12 Nitrates and Nitrites

Nitrates and nitrites are nitrogen-oxygen chemical units which combine with various organic and inorganic compounds. Once taken into the body, nitrates are converted into nitrites. The greatest use of nitrates is as a fertilizer. It is also used as an oxidizing agent and in the production of explosives, and purified potassium nitrate is used for glass making. Sodium nitrite is used as a food preservative, especially in cured meats. Nitrate is sometimes also added to food to serve as reservoir for nitrite. Nitrates occur naturally in plants, for which it is a key nutrient. Nitrate and nitrite are also formed endogenously in mammals, including humans. Nitrate is secreted in saliva and then converted to nitrite by oral micro flora. Nitrate can reach both surface water and ground water as a consequence of agricultural activity (including excess application of nitrogenous mineral fertilizers and manures), from waste water treatment and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks.⁽²⁷⁾

Nitrites and nitrates are produced naturally as a part of the nitrogen cycle, when a bacteria 'production line' breaks down toxic ammonia wastes first into nitrite, and then into nitrate.⁽²⁸⁾ In soil, fertilizers containing inorganic nitrogen and wastes containing organic nitrogen are first decomposed to give ammonia, which is then oxidized to nitrite and nitrate. The nitrate is taken up by plants during their growth and used in the synthesis of organic nitrogenous compounds. Surplus nitrate readily moves with the ground water. Under aerobic conditions, nitrate can percolate in relatively large quantities into the aquifer when there is no growing plant material to take up the nitrate and when the net movement of soil water is downward to the aquifer. Degradation or denitrification occurs only to a small extent in the soil and in the rocks forming the aquifer. Under anaerobic conditions, nitrate may be denitrified or degraded almost completely to nitrogen. The presence of high

or low water tables, the amount of rain water, the presence of other organic material and other physicochemical properties are also important in determining the fate of nitrate in soil. In surface water, nitrification and denitrification may also occur, depending on the temperature and the pH. The uptake of nitrate by plants, however, is responsible for most of the nitrate reduction in surface water.⁽²⁹⁾

Nitrites are relatively short-lived because they're quickly converted to nitrates by bacteria. Nitrites produce a serious illness (brown blood disease) in fish, even though they don't exist for very long in the environment. Nitrites also react directly with hemoglobin in human blood to produce methemoglobin, which destroys the ability of blood cells to transport oxygen. This condition is especially serious in babies under three months of age as it causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1.0 mg/L should not be given to babies. Nitrite concentrations in drinking water seldom exceed 0.1 mg/L.⁽²⁸⁾

Nitrate-nitrogen levels below 90 mg/L and nitrite levels below 0.5 mg/L seem to have no effect on warm-water fish, but salmon and other cold-water fish are more sensitive. The recommended nitrite minimum for salmon is 0.06 mg/L.⁽³⁰⁾

Elewa (2012)⁽³¹⁾ studied water resources in Nile River Delta in Egypt. Nitrates results in Rosetta branch ranged from 0.017 to 0.9 mg/l with a general trend of increase towards north.

2.1.13 Dissolved Oxygen

A dissolved oxygen test measures the amount of oxygen dissolved in the water. DO is one of the most important parameter. Its correlation with water body gives direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, stratification etc. In the progress of summer, dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity. The high DO in summer is due to increase in temperature and duration of bright sunlight has influence on the percentage of soluble gases (O_2 & CO_2). During summer the long days and intense sunlight seem to accelerate photosynthesis by phytoplankton, utilizing CO_2 and giving off oxygen. This possibly accounts for the greater qualities of O_2 recorded during summer.⁽¹⁹⁾

2.1.14 Chemical Oxygen Demand

The chemical oxygen demand test, which is widely used as an indicator to identify the characteristics of wastewater, could be disturbed by the inorganic substances such as nitrite, chloride, hydrogen peroxide, etc.⁽³²⁾

COD is another measure of organic material contamination in water specified in mg/L. COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in water. Both BOD and COD are key indicators of the environmental health of a surface water supply. They are commonly used in waste water treatment but rarely in general water treatment.⁽¹⁹⁾

2.1.15 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is a measure of the dissolved oxygen demand consumed by microorganisms during the oxidation of reduced substances in waters and wastes. Typical sources of BOD are readily biodegradable organic carbon (Carbonaceous, CBOD) and ammonia (nitrogenous, NBOD). These compounds are common constituents or metabolic byproducts of plant and animal wastes and human activities (domestic and industrial waste water). The discharge of wastes with high levels of BOD can cause water quality problems such as severe dissolved oxygen depletion and fishkills in receiving water bodies. Standardized methods for the quantification of BOD in waste waters have remained virtually unchanged for decades despite numerous shortcomings. Alternative techniques and estimation methods have been proposed. The kinetics of dissolved oxygen consumption resulting from BOD discharges have been formulated into several mathematical models for simulating surface water quality. The long history of the BOD test and its incorporation into many major water quality models ensures that it will continue to be measured for decades in the future. ⁽³³⁾

El- Sayed E.A. (2013) ⁽³⁴⁾ studied the assessing and mapping water quality in Western Delta in Egypt. The water quality at the Western Delta Canals is impacted by high concentration of DO, COD and BOD due to the presence of different sources of pollution. This can be attributed to the official and non-official reuse of agricultural drainage water used in feeding the studying canals.

2.1.16 Total Suspended Solids

Total Suspended solids are an indication of the amount of erosion that took place nearby or upstream. This parameter would be the most significant measurement as it would depict the effective and compliance of control measures e.g. riparian reserve along the waterways.

Total suspended solids (TSS) are considered to be one of the major pollutants that contribute to the deterioration of water quality, contributing to higher costs for water treatment, decreases in fish resources, and the general aesthetics of the water. The activities associated with wastewater treatment include control of water quality, protection of the shoreline, and identification of economic life of protective structures. Predicting suspended sediments is important in controlling the quality of waste water. TSS is an important parameter, because excess TSS depletes the dissolved oxygen (DO) in the effluent water. Thus, it is imperative to know the values of influent TSS at future time horizons in order to maintain the desired characteristics of the effluent. ⁽³⁵⁾

2.1.17 Silica

Silica or silicon dioxide (SiO_2), also called quartz, is one of the most common minerals found on the earth's surface. Silica is major component of many different kinds of rocks (like granites and gneiss) and comes in many different varieties. Sand refers to a particle size. All sands are not the same. For example, construction sand and gravel is used to build and maintain roads and bridges. Construction sand and gravel consists of many different rock types and sizes. Some rocks are angular and other rocks are rounded. In contrast, silica sand is mined from sandstone formations that have undergone geologic

processes that produced well-rounded, well-sorted sand and gravel that consists of almost pure quartz (silicon dioxide).⁽³⁶⁾

Silica is the second most abundant element found on earth. Although silicon itself (Si) is a glassy insoluble solid, the various oxides (primarily "SiO₂") are somewhat soluble in water. Indeed, all natural water supplies contain some dissolved "silica". Many supplies also contain suspended or colloidal silica. Silica, like its sister element carbon, has four covalent bonding sites and can, therefore, form a very large number of potential molecules. Silica chemistry is quite complex, second only to the chemistry of carbon compounds. Because the silica nucleus is larger than the carbon nucleus, silica does not easily form double or triple bonds, and silica does not readily form chains more than 6 silica atoms long. In water treatment, we are concerned with silica because of its tendency to form deposits (scale) on surfaces it comes in contact with. In boiler and turbine systems, the deposition is often associated with temperature, pressure, and phase state changes that occur. In microelectronics, the concern is deposition and/or changes to the surface properties of the "silicon" wafers.⁽³⁷⁾

2.1.18 Fluoride

Fluoride is classified as one of the contaminants of water for human consumption by the World Health Organization (WHO), in addition to arsenic and nitrate, which cause large-scale health problems.⁽³⁸⁾

The industries which discharge wastewater containing high fluoride concentrations include glass and ceramic production, semiconductor manufacturing, electroplating, coal fired power stations and aluminium smelters. The effluents of these industries have higher fluoride concentrations than natural waters, ranging from 10 to 1000 of mg/L. It is estimated that more than 200 million people worldwide rely on drinking water with fluoride concentrations that exceed the WHO guideline of 1.5 mg/L.⁽³⁸⁾

Depending on the concentration and the duration of continuous uptake, the impact of fluoride in drinking water can be beneficial or detrimental to mankind. Fluoride in drinking water has a narrow beneficial concentration range in relation to human health. Small amounts in ingested water are usually considered to have a beneficial effect on the rate of occurrence of dental caries, particularly among children.⁽³⁸⁾

Inorganic fluorine compounds are used in industry for a wide range of purposes. They are used in aluminium production and as a flux in the steel and glass fibre industries. They can also be released to the environment during the production of phosphate fertilizers (which contain an average of 3.8% fluorine), bricks, tiles and ceramics. Fluorosilicic acid, sodium hexafluorosilicate and sodium fluoride are used in municipal water fluoridation schemes.⁽³⁹⁾

Traces of fluorides are present in many waters. Fluorides may enter a river as a result of industrial discharges.⁽³⁹⁾

Ismail and Ramadan (1995)⁽⁴⁰⁾ studied Nile-and drinking water samples from several locations between Aswan city and Cairo before and during the flood. Fluoride results ranged from 0.11 to 0.4 mg/l.

2.1.19 Ammonia

Ammonia-nitrogen, including non-ionized (NH_3) and ionized (NH_4^+), is the predominant pollutant in the main drinking water sources. It originates from human activities in the urban areas, metabolic, agricultural and industrial processes, and from disinfection with chloramine. Ammonia-nitrogen concentration in surface water is affected by hydrogeology and climate change. Ammonia toxicity in water has been widely investigated: its incomplete nitrification elevates toxic nitrite contents; due to its property to combine chlorine easily, the chlorine necessity during disinfection processes increases, and consequently the content of mutagenic disinfection by-products (DBP) is changing in an ascending mode. It also causes the failure of filters for the removal of manganese, and causes taste and odor problems.⁽⁴¹⁾

Ammonia is a toxic compound that can adversely affect fish health. The nature and degree of toxicity depends on many factors, including the chemical form of ammonia, the pH and temperature of the water, the length of exposure, and the life stage of the exposed fish. Issues associated with toxicity testing and the consequences of ammonia exposure are also discussed.⁽⁴²⁾

Ammonia and its ionized form, ammonium is naturally occurring organic compounds that are formed during decomposition of proteins, manure wastes and urine wastes, and from other nitrogen-containing compounds. Ammonia gas is most commonly encountered where animals, chickens or birds are confined in large numbers, and it is responsible for the sharp odor associated with soiled diapers and diaper pails. Ammonia gas is also used commonly in industry. Ammonia and ammonium compounds are excellent sources of plant nitrogen, and are present in most fertilizers, whether natural or synthetic fertilizer formulations. Ammonia solutions are also very effective for cleaning hard surfaces. Household cleaners such as glass, floor and counter cleaners are often ammonia-based. Ammonia gas is used as a refrigerant gas. It is also used extensively in chemical and pharmaceutical manufacturing. Some drinking water treatment processes add small amounts, generally less than 0.4 mg/l (ppm) of ammonia to water to increase and extend the disinfecting ability of chlorine.⁽⁴³⁾

Fu *et al.*, (2012)⁽⁴¹⁾ studied ammonia levels in some drinking water sources in china and found that ammonia concentration increase during winter and results ranged between (0.15-0.44 mg/l).

Elewa (2012)⁽³¹⁾ studied water resources in Nile River Delta in Egypt. Ammonia results in Rosetta branch ranged from 2.7 to 3.8 mg/l with a general trend of increase towards north.

Heavy Metals

The toxicity of heavy metals to aquatic organisms has been a subject of interest to biologist for many years. Among different types of pollution the industrial wastes constitute the major sources of metal pollution. Toxic metals such as Cd, Zn, Cr, Pb, and Cu find their ways to the industries as metal plating industries, nickel batteries, pigments, and as stabilizers of alloys.⁽⁴⁴⁾

2.1.20 Aluminium

In water treatment processes surface waters are most commonly treated with chemical coagulation. Aluminium salts are widely used as a coagulant to reduce the organic matter, color and turbidity of raw water. Using aluminium salts in a water treatment process may lead to an increased concentration of aluminium in drinking water if aluminium is overdosed or the water treatment process is dysfunctional. The residual aluminum increases the water turbidity, may have some health effects on consumers and aluminium hydroxide may deposit on the walls of the pipes decreasing flow capacity. ⁽⁴⁵⁾

The total intake level of aluminum from drinking water varies according to the aluminium level in raw water and whether aluminium coagulants are used in a water treatment process. The concentration of aluminium in natural waters can vary significantly depending on various physicochemical and mineralogical factors. The aluminium intake from food and water is unavoidable but only 5% of the total intake is from drinking water. The major part (5 mg day^{-1}) of the total intake comes from food and its additives. ⁽⁴⁵⁾

Aluminium residual in drinking water enter the human body through the gastrointestinal tract. Dissolved aluminium in drinking water is classified as highly reactive (due to inorganic complex) to non-reactive (bound to inorganic complexes). Aluminium is more dissolved in the stomach when the pH is extremely low. The absorption in the stomach may be a risk. Chronic exposure to aluminum (toxic form: Al^{3+} , $\text{Al}(\text{OH})^{2+}$, $\text{Al}(\text{OH})^{2+}$) is associated with various health problems. ⁽⁴⁶⁾

Aluminium accumulation in the brain is proposed to be associated with neurodegenerative diseases, including Alzheimer's dementia, Parkinson's disease, amyotrophic lateral sclerosis, and dialysis encephalopathy. ⁽⁴⁶⁾

2.1.21 Cadmium

Cadmium is generally classified as toxic trace element. It is found in very low concentration in most rocks, as well as in coal and petroleum and often in combination with zinc. Geologic deposits of cadmium can serve as sources to groundwater and surface water, especially when in contact with soft, acidic waters. There is no evidence indicating its essentiality to humans. Cd appears to accumulate with age, especially in the kidney and it is considered also as a cancer and cardiovascular diseases. ⁽⁴⁷⁾

Salem *et al.* reported that geochemical implications of Cd in human health related to: Bone and renal disease in populations exposed to industrially contaminated drinking water, Lung and renal dysfunction in industrial workers exposed to air-borne Cd and Implication in human hypertension. Galvanized steel is plated with zinc, which is normally contains about 1% Cd. ⁽⁴⁷⁾

Cd also has specific uses in paint, photography, and nickel-cadmium batteries. Some cases of cadmium poisoning are linked to cadmium-plated food utensils. It is introduced into the environment from paint and pigments, and plastic stabilizers mining and smelting operations and industrial operations, including electroplating, reprocessing cadmium scrap, and incineration of cadmium containing plastics. The remaining cadmium emissions are from fossil fuel use, fertilizer application, and sewage sludge disposal. Cadmium may enter drinking water as a result of corrosion of galvanized pipe. Landfill leachates are also an

important source of cadmium in the environment. In low doses, cadmium can produce coughing, headaches, and vomiting. In larger doses, cadmium can accumulate in the liver and kidneys, and can replace calcium in bones, leading to painful bone disorders and to a renal failure. The kidney is considered to be the critical target organ in humans chronically exposed to cadmium by ingestion. Cadmium that is taken into the body usually remains there. Inhaled cadmium is more hazardous than ingested cadmium. A major source of inhaled cadmium is tobacco smoke. Ingestion of metals such as lead and cadmium may pose great risks to human health.⁽⁴⁷⁾

Trace metals such as lead and cadmium will interfere with essential nutrients of similar appearance, such as calcium and zinc. Because of size and charge similarities, lead can substitute for calcium and included in bone. Children are especially susceptible to lead because developing skeletal systems require high calcium levels. Lead that is stored in bone is not harmful, but if high levels of calcium are ingested later, the lead in the bone may be replaced by calcium and mobilized. Once free in the system, lead may cause nephrotoxicity, neurotoxicity, and hypertension. The pollution of drinking water with lead and cadmium arise from industrial sources at the studied areas and renal failures were related to them.⁽⁴⁷⁾

2.1.22 Cobalt

The occurrence of cobalt in the earth's surface varies greatly. This element does not exist in its native form and is encountered only in meteorites. Cobalt is most often found in the form of arsenides and sulphides. The most important cobalt minerals are cobaltite CoAsS , linnaet Co_3S_4 , smaltyn CoAs_2 and karrolit CuCo_2S_4 . The source of cobalt pollution (apart from industrial waste) is the burning of cobalt. Cobalt may occur at oxidation levels of from -1 to +4, but in nature it occurs usually as a double-valenced cation Co^{2+} (cobalt compounds). In erosive environments it easily undergoes oxidation from Co^{2+} to Co^{3+} and creates the complex anion $\text{Co}(\text{OH})_3^{-3}$. It relatively easily becomes mobile in acidic oxidizing environments, but does not undergo extensive aqueous migration, since it combines with the hydroxides of iron and manganese as well as silty minerals.⁽⁴⁸⁾

Cobalt is an essential micronutrient for man, animals and plants and it is a component of cyanocobalamin or vitamin B12. In environmental and biological samples, cobalt is present at a trace level. Surface water and groundwater concentrations of cobalt are low, $1 \mu\text{g L}^{-1}$ in pristine areas and $1 - 10 \mu\text{g L}^{-1}$ in populated areas. Dissolved cobalt occurs in seawater at concentrations ranging from 0.01 to 0.2 n mol L^{-1} and the levels in drinking water are generally $0.1-5.0 \mu\text{g L}^{-1}$.⁽⁴⁹⁾

2.1.23 Copper

Copper is a naturally occurring element that is commonly found in natural water from both natural and anthropogenic sources. Natural sources include the weathering of rocks and soils. Anthropogenic sources include mining and smelting industry and municipal incineration (USEPA, 2002b).⁽⁵⁰⁾

Water pipes are often made of copper and bath fixtures may be made from brass and bronze alloys that contain copper. The principal source of copper in drinking water results from the leaching of copper from pipes and bath fixtures due to acidic water. Blue-green stains left in bath fixtures are a sign of the presence of copper in water. Other releases of

copper to the environment include agricultural use against plant diseases and treatments applied to water bodies to eliminate algae.⁽⁵¹⁾

Copper is found in surface water, groundwater, seawater and drinking-water, but it is primarily present in complexes or as particulate matter. Copper concentrations in surface waters ranged from 0.0005 to 1 mg/litre in several. Copper concentrations in drinking-water vary widely as a result of variations in water characteristics, such as pH, hardness and copper availability in the distribution system.⁽⁵²⁾

Effects of copper deficiency can include anemia, low numbers of white blood cells, osteoporosis in infants and children, and defects in connective tissue leading to skeletal problems. Acute poisoning from ingestion of excessive copper can cause temporary gastrointestinal distress with symptoms such as nausea, vomiting, and abdominal pain. Liver toxicity was seen in doses high enough that resulted in death. High levels of exposure to copper can cause destruction of red blood cells, possibly resulting in anemia. Copper is currently categorized by the EPA as a Group D carcinogen (inadequate evidence to classify) and has not yet been reviewed for placement into one of the new cancer classification categories.⁽⁵¹⁾

Elewa (2012)⁽³¹⁾ studied water resources in Nile River Delta in Egypt. The Cu results in raw water ranged from 0.001 to 0.002 mg/l in Rosetta branch.

2.1.24 Iron

Iron is the second most abundant metal in the earth's crust, of which it accounts for about 5%. Elemental iron is rarely found in nature, as the iron ions Fe^{2+} and Fe^{3+} readily combine with oxygen- and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides. Iron is most commonly found in nature in the form of its oxides.⁽⁵⁶⁾ Iron may be dissolved from rock and soil. It may also come from iron pipes, pumps and other equipment if low pH water is present.⁽⁵³⁾

Iron is used as constructional material, inter alia for drinking-water pipes. Iron oxides are used as pigments in paints and plastics. Other compounds are used as food colors and for the treatment of iron deficiency in humans. Various iron salts are used as coagulants in water treatment.⁽⁵⁴⁾

Cast iron pipes have been used to transport potable water for over 500 years; corrosion of iron pipes negatively influences the quality of distributed water in many aspects. Color, turbidity, conductivity and iron concentration increase. Corrosion can also cause a failure of pipes and secondary contamination of drinking water.⁽⁵⁵⁾

Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day. The average lethal dose of iron is 200–250 mg/kg of body weight, but death has occurred following the ingestion of doses as low as 40 mg/kg of body weight. Autopsies have shown haemorrhagic necrosis and sloughing of areas of mucosa in the stomach with extension into the submucosa. Chronic iron overload results primarily from a genetic disorder (haemochromatosis) characterized by increased iron absorption and from diseases that require frequent transfusions. Adults have often taken

iron supplements for extended periods without deleterious effects, and an intake of 0.4–1 mg/kg of body weight per day is unlikely to cause adverse effects in healthy persons.⁽⁵⁴⁾

Mora *et al.*, (2009)⁽⁵⁶⁾ determined iron concentration in Venezuela drinking water. They reported that the mean value of the results was 0.2 mg/l. Imran (2003)⁽⁵⁷⁾ found that iron releases its corrosion or rust in the form of turbidity.

In United Kingdom, Abessrer *et al.*, (2006)⁽⁵⁸⁾ studied iron levels in three catchments water sources in Scotland. Fe concentration ranged from (0.03-0.55 mg/l).

Geriesh *et al.*, (2008)⁽⁵⁹⁾ studied the problems of drinking water treatment along Ismailia Canal Province in Egypt. Fe results in raw water ranged from 0.008 to 0.11 mg/l and from 0.032 to 0.26 mg/l in winter and summer, respectively.

Elewa (2012)⁽³¹⁾ studied water resources in Nile River Delta in Egypt. Fe results in raw water ranged from 0.128 to 0.561 mg/l.

2.1.25 Manganese

Manganese is a naturally-occurring element that can be found ubiquitously in the air, soil, and water. Manganese is also an essential nutrient for humans and animals. Adverse health effects can be caused by inadequate intake or over exposure. The main exposure of humans to manganese is from ingestion of food. Manganese deficiency in humans appears to be rare because manganese is present in many common foods. Manganese is essential to the proper functioning of both humans and other animals as it is required by many cellular enzymes (e.g., manganese superoxide dismutase, pyruvate carboxylase) and can serve to activate many others (e.g., kinases, decarboxylases, transferases, hydrolases, etc.⁽⁶⁰⁾

Although manganese is an essential nutrient at low doses, chronic exposure to high doses may be harmful. There are substantial data supporting the neurological effects of inhaled manganese in both humans and animals, however, there are little data for the association between oral exposure to manganese and toxic effects. There is a need for EPA to issue a health advisory to provide guidance to communities on the concentrations for avoiding health and organoleptic problems. This Drinking Water Health Advisory does not mandate a standard for action; rather it provides practical guidelines for addressing Mn contamination problems. The advisory provides an analysis of the current health hazard and organoleptic (i.e., taste and odor) information associated with Mn-contaminated water, because organoleptic problems will affect consumer acceptance of water resources.⁽⁶⁰⁾

Occupational exposure, for example in manganese miners and smelters, to high levels of inhaled manganese has been associated with manganism, a neurotoxic condition similar to Parkinson's disease. Drinking water contaminated with manganese has also been associated with neurological and behavioural effects. There is an association between manganese accumulation and liver disease but this may be due to impaired biliary excretion caused by the liver disease rather than manganese toxicity. Effects on the immune system have been reported.⁽⁶¹⁾

Elewa (2012)⁽³¹⁾ studied water resources in Nile River Delta in Egypt. Mn results in Rosetta branch raw water ranged from 0.047 to 0.133 mg/l.

2.1.26 Nickel

Nickel is the 28th element in the periodic table. It is a silver-white metal found in several oxidation states (ranging from -1 to +4), however, the +2 oxidation state [Ni(II)] is the most common in biological systems. Nickel easily forms nickel-containing alloys, which have found an ever increasing use in modern technologies for over a hundred years now. Global input of nickel to the human environment is approximately 150 000 and 180 000 metric tonnes per year from natural and anthropogenic sources, respectively, including emissions from fossil fuel consumption, and the industrial production, use, and disposal of nickel compounds and alloys. ⁽⁶²⁾

Nickel is widely distributed in the environment, and can be found in air, water, and soil. Natural sources of atmospheric nickel include dusts from volcanic emissions and the weathering of rocks and soils. ⁽⁶²⁾

Nickel is a ubiquitous metal frequently responsible for allergic skin reactions and has been reported to be one of the most common causes of allergic contact dermatitis, as reflected by positive dermal patch tests. Gawik Rodger *et al.*, (2000) ⁽⁶³⁾ suggested that the higher number of antigens, or perhaps the larger nickel load, in the extended metal series resulted in a larger proportion of patients reacting. In clinical cases, allergic contact hypersensitivity to nickel develops much more readily in inflamed skin than normal skin. Sensitization might occur from any of the numerous metal products in common use, such as coins, jewellery (earrings, chains, wristwatches, bracelets) and even mobile phones. ⁽⁶⁴⁾

Of the general population, approximately 8-10% of women and 1-2% of men demonstrate sensitivity to nickel. In Poland, using “flake” test with nickel sulphate, it was shown that 12.5% of the female population is allergic to nickel. ⁽⁶⁴⁾

The adverse health effects of nickel depend on the route of exposure (inhalation, oral, or dermal) and can be classified according to systemic, immunologic, neurologic, reproductive, developmental, or carcinogenic effects following acute (01day), subchronic (10-100 days), and chronic (100 days or more) exposure periods. The most common harmful health effect of nickel in humans is an allergic skin reaction in those who are sensitive to nickel. Nickel is the most observed cause of immediate and delayed hypersensitivity noticed in occupationally exposed as well in the general population. The metal is not only an allergen but also a potential immunomodulatory and immunotoxic agent in humans. Based on studies of nickel workers and laboratory animals, all nickel compounds, except for metallic nickel, have been classified as human carcinogens by the International Agency for Research on Cancer (IARC) and the U.S. Department of Health and Human Services. ⁽⁶⁵⁾

2.1.27 lead

Lead (Pb) is a heavy metal, which has a bluish-white colour when freshly cut, turns into a dull grayish color upon exposure to air and has a shiny chrome silver luster when melted into a liquid. It is readily available, cheap, soft and malleable. For this reason, lead and lead compounds are being used in wide range of products such as building constructions, paints, ceramics, pipes, solders, gasoline, batteries and cosmetics. ⁽⁶⁶⁾

Lead is a poisonous metal. Lead ions are being released into the environment due to industrial activity and technological development. This poses a significant threat to the environment and public health because of toxicity, incremental accumulation in the food chain and persistence in the ecosystem.⁽⁶⁶⁾

The most common sources of lead are lead-based paint, contaminated soil, household dust, drinking water, lead-glazed pottery and the effluents of industrial wastewaters. Soils rich in heavy metals such as lead create a possible risk to human health if directly ingested or if metal(loids) are transported through food. Furthermore elevated levels of heavy metals in soil are also known to have adverse effects on microfauna and flora and higher order plant life at contaminated sites. Hence, it is vital to efficiently remove before it reach to environment and food, especially from wastewater. This not only assures lead free environment but also helps to protect natural resources. Lead has been removed from gasoline, household paint, solder and other consumer products which resulted in a significant decrease in environmental lead concentrations. However humans are still exposed to low levels of lead through contaminated food, water, dust, soil and occupational activities. In adults the common cause of lead poisoning is occupational exposure whereas in children the main cause is lead paint, found in many homes particularly old ones. Other routes of lead exposure are contaminated air, water, soil, food and consumer products.⁽⁶⁶⁾

Lead is a pervasive environmental contaminant. The adverse health effects of lead exposure in children and adults are well documented, and no safe blood lead threshold in children has been identified. Lead can be ingested from various sources, including lead paint and house dust contaminated by lead paint, as well as soil, drinking water, and food. The concentration of lead, total amount of lead consumed, and duration of lead exposure influence the severity of health effects. Because lead accumulates in the body, all sources of lead should be controlled or eliminated to prevent childhood lead poisoning.⁽⁶⁷⁾

Exposure to lead is cumulative over time. High concentrations of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys. This damage commonly results in behavior and learning problems (such as hyperactivity), memory and concentration problems, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, muscle and joint pain. Studies on lead are numerous because of its hazardous effects. Lead is considered the number one health threat to children, and the effects of lead poisoning can last a lifetime. Not only does lead poisoning stunt a child's growth, damage the nervous system, and cause learning disabilities, but also it is now linked to crime and anti-social behavior in children.⁽⁷⁴⁾

Gerish et al., (2008)⁽⁵⁹⁾ studied the problems of drinking water treatment along Ismailia Canal Province in Egypt. Pb results in raw water ranged from 0.65 to 3.76 µg/l and from 1.37 to 5.88 µg/l in winter and summer.

Elewa (2012)⁽³¹⁾ studied water resources in Nile River Delta in Egypt. Pb results in different sites in Rosetta branch ranged from 5 to 8 µg/l.

2.1.28 Zinc

Zinc occurs in small amounts in almost all igneous rocks. The principal zinc ores are sulfides, such as sphalerite and wurzite. The natural zinc content of soils is estimated to be

1–300 mg/kg. Zinc is used in the production of corrosion-resistant alloys and brass, and for galvanizing steel and iron products. Zinc oxide, used in rubber as a white pigment, for example, is the most widely used zinc compound. Peroral zinc is occasionally used to treat zinc deficiency in humans. Zinc carbamates are used as pesticides.⁽⁶⁸⁾

In rural areas, atmospheric zinc concentrations are typically between 10 and 100 ng/m³, whereas levels in urban areas commonly fall within the range 100–500 ng/m³. Mean concentrations of zinc associated with particulate matter in ambient air in Canada were 85 ng/m³ and in Finland, 170 ng/m³. In natural surface waters, the concentration of zinc is usually below 10 µg/litre, and in groundwaters, 10–40 µg/litre. In tapwater, the zinc concentration can be much higher as a result of the leaching of zinc from piping and fittings. The most corrosive waters are those of low pH, high carbon dioxide content, and low mineral salts content. In a Finnish survey of 67% of public water supplies, the median zinc content in water samples taken upstream and downstream of the waterworks was below 20 µg/litre; much higher concentrations were found in tapwater, the highest being 1.1 mg/litre. Even higher zinc concentrations (up to 24 mg/litre) were reported in a Finnish survey of water from almost 6000 wells. Protein-rich foods, such as meat and marine organisms, contain high concentrations of zinc (10–50 mg/kg wet weight), whereas grains, vegetables, and fruit are low in zinc (usually <5 mg/kg).⁽⁶⁸⁾

Geriesh *et al.*, (2008)⁽⁵⁹⁾ determined Zn along Ismailia Canal Province in Egypt. Zn results in raw water ranged from 0.009 to 0.09 mg/l and from 0.001 to 0.012 mg/l in winter and summer.

Elewa (2012)⁽³¹⁾ studied water resources in Nile River Delta in Egypt. Zn results in raw water in different sites in Rosetta branch ranged from 0.006 to 0.04 mg/l.

2.2 Bacteriological parameters

2.2.1 Total and Fecal Coliform

Coliform bacteria are organisms that are present in the environment and in the feces of all warm-blooded animals and humans. Coliform bacteria will not likely cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. Testing drinking water for all possible pathogens is complex, time-consuming, and expensive. It is relatively easy and inexpensive to test for coliform bacteria. If coliform bacteria are found in a water sample, water system operators work to find the source of contamination and restore safe drinking water. There are three different groups of coliform bacteria; each has a different level of risk.⁽⁶⁹⁾

Total coliform bacteria are commonly found in the environment (e.g., soil or vegetation) and are generally harmless. If only total coliform bacteria are detected in drinking water, the source is probably from a non-pathogenic environmental origin (not likely sewage). Fecal contamination is not likely. However, if environmental contamination can enter the system, there may also be a way for pathogens to enter the system. Therefore, it is important to find the source and resolve the problem.⁽⁷⁰⁾

Fecal coliform bacteria are a sub-group of total coliform bacteria. They appear in great quantities in the intestines and feces of people and animals. The presence of fecal coliform in a drinking water sample often indicates recent fecal contamination, meaning that there is a greater risk that pathogens are present than if only total coliform bacteria is detected. ⁽³³⁾

Contamination of surface waters through the discharge of fecal material in surface run-off, combined sewer overflows and point source discharges is an important water quality problem in many urban environments. ⁽⁷¹⁾