hysicochemical characteristics of ground water in Azaza basin, Algadarif state, Sudan

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November /2016
Physicochemical characteristics of ground water in Azaza basin, Algadarif state, Sudan

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Date: November /2016
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Date of examination: 2/11/2016
CHAPTER ONE  DEDICATION

To my parents

To my brothers

To my sisters

To my all friends
Acknowledgement

First and foremost my thanks and praise are due to almighty Allah for giving me the capability and health to accomplish this work.

I am greatly indebted to my supervisor Dr. Fathelrahman Abbas for providing me with fruitful suggestions, valuable advice and genuine help.

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Physicochemical characteristics of ground water in Azaza basin, Algadarif state, Sudan

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Abstract

The study area, Azaza basin, lies about 7 Km North West Algadarif city. The people in this area suffer from dental fluorosis and complain of salty taste of water, this may be due to high concentration of fluoride in addition to other salts. This study was conducted to assess ground water quality of Azaza basin through determination of some physicochemical parameters (Taste and odor, turbidity, EC, pH, TDS, total hardness, alkalinity, calcium, magnesium, iron, chloride, sulphate, Fluoride, Nitrate and Nitrite). Ten samples were collected from Azaza basin and the studies carried out in the period from 25 June to 20 July. The results obtained were compared with WHO (1993) and SSMO (2015). There is no objectionable odor, samples AZ1, AZ5, AZ6, AZ9 are salty. The pH ranges between 6.73 and 7.62, and the turbidity range between 0.6 and 4.68 NTU, they are within the permissible values of WHO and SSMO (Turbidity 5NTU and pH 6.5-8.5). TDS values are between 659 and 1266 ppm, samples AZ1 (1266mg/L) and AZ9 (1150 mg/L) were above the permissible value of WHO and SSMO (1000 ppm). Hardness range (390.0-888.9 mg/L), all water samples are extremely hard and most of them contain temporary hardness. Alkalinity in all samples is due to bicarbonate (pH<8.3). Fluoride range between 0.23 and 2.88 ppm, samples AZ1, AZ5, AZ6, AZ10 contain high fluoride concentration above 1.5 mg/L the limit set by WHO and SSMO. This may be the main reason of dental fluorosis in the study area. The concentration of sulphate is between 33 and 66 ppm, and that of chloride is between 26 and 171.4 ppm, they are within the permissible limits of WHO and SSMO (250 ppm Cl\(^{-}\) and 250 ppm SO\(_4^{2-}\)). Calcium concentrations range between 31.1 and 121mg/L, while that of Magnesium ranges between 61.8and 158.6 mg/L. Iron concentration is between 0.07 and 0.49 ppm, sample AZ1 is above the permissible value of WHO and SSMO (0.3mg/L). Nitrate and Nitrite are within the permissible limit of WHO and SSMO, except AZ9 which contain high nitrate, this may be due to use of fertilizer in the farm. It is recommended that water should be treated to remove fluoride. Reverse osmosis can be employed for such treatment. Also water harvesting should be re-explored to improve the water quality. Additional studies are needed in this area.
الخصائص الفيزيائية والكيميائية للمياه الجوفية بحوض العزازة
ولاية القضارف، السودان
اخلاص محمد عبداللطيف محمد
ماجستير العلوم في الكيمياء (2016)
قسم هندسة وتكنولوجيا الكيمياء
كلية الهندسة والتكنولوجيا
جامعة الجزيرة
ملخص البحث
تقع منطقة الدراسة - حوض العزازة - على بعد 7 كيلومتر شمال غرب مدينة القضارف. سكان المنطقة يعانون من تلون الأسنان ويشكون من الطعم المالح للماء والتي عادة ما تعزي لتواءد تراكيز عالية من الفلورايد والأحماض الأخرى. أجريت هذه الدراسة لتقديم جودة المياه بحوض العزازة. وذلك بتبعين الخصائص الفيزيائية والكيميائية (الطعم والرائحة،العكارة،الوأكالاهم،الكالسيوم، الحديد،الماغنزيوم، الكلوريد، الفلورايد، النترات والنتريت). جمعت (10) عينات من حوض العزازة في الفترة من (25 يونيو-20 يوليو) واجريت عليها الدراسة. تمت مقارنة النتائج مع مواصفات منظمة الصحة العالمية والهيئة السودانية للمواصفات والمقاييس. الرائحة قابلة في جميع العينات، وجد أن العينات طعمها مالح. تراوحت قيمة pH بين 6.73 إلى 7.62 والعكارة بين 0.6 إلى 4.68. السد دولة كل هذه القيم تقع في الحد المسموح به من قبل منظمة الصحة العالمية والهيئة السودانية للمواصفات والمقاييس (pH 6.5-8.5 والعكارة 5NTU). كما تراوحت كمية الاملاح الكلية الذائبة بين 659 إلى 1266 ملجم/لتر العينات AZ1,AZ5,AZ6,AZ9 (1266ملجم/لتر) و9 (1150ملجم/لتر) أعلى من الحد المسموح به (1000ملجم/لتر). العصر في المدي من (9.85) إلى (360-390) ملجم/لتر. العينات تحتوي على عسل مؤقت كما صنفت جميعها على أنها شديدة العصر. أما الفلورايد فنها في جميع العينات تعزي للبيكربونات (<8.3). pH في المدي بين 0.23 إلى 2.88. الفلورايد يراوح في المدي بين 26 إلى 171 ملجم/لتر، الكبريتات بين 33 إلى 66 ملجم/لتر، الكلوريدات بالنسبة للكالسيوم وجد في المدي بين 31.1 إلى 121ملجم/لتر. الماغنزيوم في المدي بين AZ1 ملجم/لتر بينما الحديد في المدي بين 0.07 إلى 0.49 ملجم/لتر، العينة AZ2 تقع أعلى من الحد المسموح به (0.3 ملجم/لتر). اصطر تشترط النترات والنتريت والتي تقع في الحد المسموح فيما tuttiati تقع على تراكيز عالي من النترات وهذا قد يعني لإستخدام الأسمدة في الحد المسموح الب. اوصت الدراسة بضرورة عمل معالجة للفلورايد بحوض العزازة والتي يمكن ان تكون عن طريق الضغط الأزومي العكسي. كما أن حصاد المياه يمكن تجربة كعامل آخر في تحسين جودة المياه.
تحتاج المياه في هذه المنطقة إلى المزيد من الدراسة. 
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List of Abbreviation

APHA : American Public Health Association
EC : Electrical Conductivity
EDTA : Ethylene diamine tetra acetic acid
EEC : European Economic Community Guidelines
EPA : Environmental Protection Agency
NTU : Nephelometric Turbidity Unit
pH : Potential of Hydrogen
SSMO : Sudanese Standard and Metrology Organization
TDS : Total Dissolved Solids
TCU : True color unit
USEPA : United States Environmental Protection Agency
WHO : World Health Organization
INTRODUCTION

1.1 General:

Water is essential for life. It is a universal solvent and is the most abundant substance in plants and animals tissues, as well as, the world around us. Metabolic functions within living cells occur in aqueous medium. Water occurs in all spheres of the environment- in the oceans as a vast reservoir of salt water, on land as surface water in lakes and rivers, underground as ground water, in the atmosphere as water vapor and in polar ice caps as solid ice (Bhatia, 2002). About 97.2% of water on earth is salty and only 2.8% is present as fresh water from which about 20% constitutes ground water (Goel, 2000).

Water is essential to sustain life and satisfactory supply must be available to all. Safe drinking-water does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Those at greatest risk of waterborne disease are infants and young children (WHO, 2006).

Chemically pure water is not found in nature, because the almost universal solvent power of water. All sources of water have different chemical characteristics, because the sources have different types of soil moving from place to another and the water dissolve constituents of each type to different extent (Babitt et al, 1959).

The problem associated with chemical constituents of drinking water arise primary from their ability to cause adverse health effect after prolong period exposure, of particular concern are contaminant that have cumulative toxic properties such as heavy metals, and substances that are carcinogenic (WHO, 1993).

1.2. Water sources:

The sources of water supply are divided in two major classes:

1.2.1. Surface water:

There are many forms of surface water. This include rivers, streams, lakes and reservoirs (WHO1993). The common characteristics of
surface water are that it contain few minerals, not very hard, usually large in volume, and it is convenient for many people. It is easily contaminated, and total bacterial content are high. Therefore proper treatment (filtration and chlorination) is required before human consumption (Forrest, 1976).

1.2.2. **Ground water:**
Ground water is supplied mainly from river and lake. It comes into contact with various mineral which are soluble in water, the dissolved minerals determine the usefulness of water for various purpose, the presence of some minerals beyond certain limits may make water unsuitable for irrigation, drinking or industrial purpose (WHO, 1993). Ground water can be classified into three classes according to the layer in which it is stored (IDC, 1981).

(i) Ground water:
It is water that collects above the first stable impervious layer of rocks. It can move freely and its surface is known as ground water surface. It is supplied mainly by percolation of rain, rivers or lakes water.

(ii) Artesian water:
This type of ground water is stored in water containing layer sandwiched between and confined by two impervious layers.

(iii) Perched water
It exists above sectional impervious layer. It is not widely distributed and is seasonal.

1.3. **The Safe and Wholesome Drinking Water:**
Water intended for human consumption should be both safe and wholesome. This has been defined as water that is:

- Free from harmful chemical substances.
- Free from pathogenic agents.
- Pleasant to the taste, free from odor and color.
- Usable for domestic purposes.

Water is said to be polluted or contaminated when it does not fulfill the above criteria. (Park, 2002).
1.4. Location and Extent of the Study Area:

Algadarif state is located between longitudes 22.30 and 36.30 degrees east and latitudes 12.40 and 15.40 North. Consisting of towns: (Gadarif, Alfaw, Alhawata, Doka and Alshowak), the area under consideration (Azaza area) lies in North West Algadarif city about 7 KM

Figure(1): Gadarif State map
1.5. Objective:
1.5.1. General objective:
To assess the quality of ground water in Azaza basin through determination of some physicochemical characteristic.

1.5.2. Specific objective:
- To determine the concentration of some chemical parameters of ground water of Azaza (total dissolved solids, Total alkalinity, Calcium, magnesium, Chloride, Fluoride, Iron, Sulphate, Nitrate and Nitrite) and values of some physical parameters (pH, EC, Turbidity).
- To compare water quality indicators obtained with their corresponding value limits set by World Health Organization guidelines and Sudanese standards.
- To suggest recommendations for improving quality of Azaza ground water to provide safe drinking water for domestic and human uses.
CHAPTER TWO
LITERATURE REVIEW

2.1. Ground water quality:

Groundwater is actually a complex, generally dilute, chemical solution. The chemical composition is derived mainly from the dissolution of minerals in the soil and rocks with which it is or has been in contact. The type and extent of chemical contamination of the groundwater is largely dependent on the geochemistry of the soil through which the water flows prior to reaching the Aquifers (Zuane, 1990).

Groundwater in its natural state is generally of good quality. This is because rocks and their derivatives such as soils act as filters. However, not all soils are equally effective in this respect and therefore pathogens contained in human excreta such as bacteria and viruses are likely to be small enough to be transmitted through the soil and aquifer matrix to groundwater bodies (Lewis et al., 1982).

Rainfall is a dilute chemical solution and contributes significant proportions to some constituents in groundwater, especially in regions with little soil cover where hard compact rocks occur at or near the surface. As water flows through the ground the dissolution of minerals continues and the concentration of dissolved constituents tends to increase with the length of the flow path. At great depths, where the rate of flow is extremely slow, groundwater is saline, with concentrations ranging up to ten times the salinity of the sea.

Groundwater can become unpotable if it becomes polluted and is no longer safe to drink. In areas where the material above the aquifer is permeable, pollutants can seep into groundwater. This is particularly so in a fractured aquifer (Afua, 2008).

2.2. Physico-chemical indictor for water quality:

Each freshwater body has an individual pattern of physical and chemical characteristics which are determined largely by the climatic, geomorphological and geochemical conditions prevailing in the drainage basin and the underlying aquifer (Chapman, 1996).
The dissolved constituents in groundwater, including calcium, magnesium, sodium, potassium, bicarbonate, nitrite, sulphate and chloride occur in the form of electrically charged ions. Many other minor constituents such as iron, manganese and fluoride. Zinc and Lead are trace elements which may be found in groundwater (Afua, 2008).

2.2.1. Physical parameters:

The physical parameters of water quality include the following:

2.2.1.1. Color

The color in drinking water is usually due to presence of colored organic matter associated with the humans fraction of soil. Color is strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products, it may also result from contamination of water source with industrial effluents.

Color above 15 TCU (True color units) can be detected in glass of water by most people. Color below 15 TCU are usually acceptable to consumers, but acceptability may vary according to local circumstances (WHO, 1993)

2.2.1.2. Taste and odor:

In the assessment of drinking-water quality, the sensations of taste and odor are complementary. In general, the sense of taste is the most useful in detecting inorganic constituent of drinking water, while the sense of smell is more useful in detecting organic constituents (WHO, 1988).

Water should be free of tastes and odors that would be objectionable to the majority of consumers. In assessing the quality of drinking-water, consumers rely principally upon their senses. Microbial, chemical and physical constituents of water may affect the appearance, odor or taste of the water, and the consumer will evaluate the quality and acceptability of the water on the basis of these criteria. Although these constituents may have no direct health effects, water that is highly turbid, is highly colored or has an objectionable taste or odor may be regarded by consumers as unsafe and rejected (WHO, 2011).
2.2.1.3. Electrical conductivity (EC):

Electrical conductivity is measure of ability of water to conduct an electrical current that passes through it. EC is directly proportional to amount of dissolve solids in water, and it an excellent indicator of TDS in water, EC is expressed in micro mohs per centimeter (Twort et al 1985).

2.2.1.4. Turbidity:

The turbidity measures the degree to which the water losses its transparency due to the presence of suspended particles. Turbidity in water arises from the presence of very finely divided solids. The existence of turbidity in water affects its acceptability to consumers and it will also affect markedly its utility in certain industries (EPA, 2001).

2.2.1.5. pH

pH is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration. The pH scale runs from 0 to 14 (i.e. very acidic to very alkaline), with pH 7 representing a neutral condition (Chapman, 1996).

The pH of unpolluted water controlled by the balance between carbon dioxide, carbonate and bicarbonates ions. The pH of most natural water is between 6.0 – 8.5.

2.2.2. Chemical parameters:
The chemical parameters of water quality include the following:
2.2.2.1 Total dissolved solids (TDS):

Total dissolved solid (TDS) comprise of inorganic salts (principally, calcium, magnesium, potassium, sodium for cations, and carbonates or bicarbonates, sulphates, chloride and nitrate for anions, and small amount of organic matters that dissolved in water. Concentration of TDS in water varies considerably in different geological regions owing to difference in the solubility of minerals. The total dissolved solids can be expressed in ppm and it is directly related to the conductivity (WHO, 1993).
According to Chapman (1996), TDS may be obtained by multiplying the conductivity by a factor between the ranges of 0.55 to 0.75. Total dissolved solids can have important effect on the taste of drinking water. The palatability of water with a TDS less than 600 mg/l is generally considered to be good; drinking water becomes increasingly unpalatable at TDS levels greater than 1200 mg/l. Water with extremely low concentration may be unacceptable (WHO, 1993).

Table 1: TDS health criteria (WHO, 1989).

<table>
<thead>
<tr>
<th>Range mg/l</th>
<th>TDS Quality</th>
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<tr>
<td>Less than 300</td>
<td>Excellent</td>
</tr>
<tr>
<td>300 — 600</td>
<td>Good</td>
</tr>
<tr>
<td>600 — 900</td>
<td>Acceptable</td>
</tr>
<tr>
<td>900 — 1200</td>
<td>Bad</td>
</tr>
<tr>
<td>Over 1200</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

Source: Guide lines for drinking-water quality volume 2 (1989)

2.2.2.2. Total Hardness

Hardness in water is defined as the presence of multivalent cations. Hardness in water can cause water to form scales and a resistance to soap, therefore, it can be defined as water that does not produce lather with soap solutions, but produces white precipitate (scum). Although water hardness usually only measures the total concentrations of calcium and magnesium (the two most prevalent, divalent metal ions), iron, aluminum and manganese may also be present at elevated levels in some geographical locations (USGS, 2009). Hardness may be classified into:

2.2.2.2.1. Temporary Hardness

Temporary hardness is caused by a combination of calcium ions and bicarbonate ions in water. It can be removed by boiling the water or by addition of lime (calcium hydroxide) (USGS, 2009).

\[
\text{Ca(HCO}_3\text{)}_2 \xrightarrow{\text{heat}} \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2
\]

\[
\text{Mg(HCO}_3\text{)}_2 \xrightarrow{\text{heat}} \text{MgCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2
\]
2.2.2.2. Permanent hardness

Permanent hardness or non-carbonate hardness is due to presence of chloride and sulfate. This hardness cannot be eliminated by boiling of water (Twort et al., 1985). permanent hardness can be removed using a water softener or ion exchange column, where the calcium and magnesium ions are exchanged with the sodium ions in the column (Abdelmonem, 2011).

Table (2): Water hardness classification according to Sudanese standardization.

<table>
<thead>
<tr>
<th>Hardness Quality</th>
<th>Range of Calcium Carbonate (mg/L)</th>
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<tbody>
<tr>
<td>Soft</td>
<td>0 — 65</td>
</tr>
<tr>
<td>Medium hard</td>
<td>65 — 120</td>
</tr>
<tr>
<td>Hard</td>
<td>120 — 180</td>
</tr>
<tr>
<td>Very hard</td>
<td>180 — 300</td>
</tr>
<tr>
<td>Extremely hard</td>
<td>300 and greater</td>
</tr>
</tbody>
</table>

When hardness is greater than alkalinity, the amount of hardness equivalent to total alkalinity is called carbonate hardness (temporary hardness) the mount of hardness in excess is called non-carbonate hardness. When hardness equal or less than alkalinity is called carbonate hardness.

2.2.2.3. Alkalinity:

The alkalinity of water is its capacity to neutralize acid. The amount of a strong acid needed to neutralize the alkalinity is called the total alkalinity, $T$, and is reported in mg L$^{-1}$ as CaCO$_3$. The alkalinity of some waters is due only to the bicarbonates of calcium and magnesium. The pH of such water does not exceed 8.3 and its total alkalinity is practically identical with its bicarbonate alkalinity. (UNEP/WHO, 1996).

Water having a pH above 8.3 contains carbonates and possibly hydroxides in addition to bicarbonates. The alkalinity fraction equivalent to the amount of acid needed to lower the pH value of the sample to 8.3 is called phenolphthalein alkalinity, $P$. This fraction is contributed by the
hydroxide, if present, and half of the carbonate (the pH range of 8.3 is approximately that of a dilute bicarbonate solution). (UNEP/WHO, 1996).

2.2.2.4. Nitrate and Nitrite:

Nitrate and nitrite are usually occurring ions that are part of the nitrogen cycle. Naturally occurring nitrate level in surface and ground water are generally a few milligrams per liter (Parks, 2000).

Nitrate may be biochemically reduced to nitrite (NO$_2^-$) by denitrification processes, usually under anaerobic conditions. The nitrite ion is rapidly oxidized to nitrate (Chapman, 1996). At the neutral pH of the infant stomach, nitrate can undergo bacterial reduction to nitrite (Rotnayka et al., 2009).

Elevated nitrate levels in drinking water are often caused by groundwater contamination from animal waste, excessive use of fertilizers, or seepage of human sewage from private septic systems. Nitrite is of particular health concern in the body because it causes the hemoglobin in the blood to change to methemoglobin. Methemoglobin reduces the amount of oxygen that can be carried in the blood. This results in cells throughout the body being deprived of sufficient oxygen to function properly. This condition is called methemoglobinemia (ATSDR, 2000). Nitrite can react with secondary amines in human stomach to form the highly carcinogenic N-nitroso compounds (Gray, 1994).

2.2.2.5. Fluoride:

Fluoride originates from the weathering of fluoride-containing minerals and enters surface waters with run-off and ground waters through direct contact (Chapman, 1996). Traces of fluorides are present in many waters, with higher concentrations often associated with ground waters. In some areas rich in fluoride-containing minerals, well water may contain up to about 10 mg of fluoride per liter, although much higher concentrations can be found (WHO, 2011).

A fluoride concentration of around 1mg/L can help to reduce incidence of tooth decay, but concentration above 1.5 mg/L may cause browning teeth; very high concentration may cause skeletal fluorosis. Addition of fluoride to drinking water supplies to reduce the incidence of dental
caries and should be closely monitored to ensure that safe levels are not exceeded (WHO, 1997).

**Table (3): Health Impact from Long Term Use of Fluoride Ridden Water:**

<table>
<thead>
<tr>
<th>Fluoride Level in Water (ppm)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.5</td>
<td>No effect and may prevent Dental caries.</td>
</tr>
<tr>
<td>1.5 – 3.0</td>
<td>Dental Fluorosis</td>
</tr>
<tr>
<td>3.0 – 6.0</td>
<td>Skeletal Fluorosis</td>
</tr>
<tr>
<td>&gt;10.0</td>
<td>Crippling Fluorosis (changes in bones)</td>
</tr>
</tbody>
</table>

Source: Misra (2007)

**2.2.2.6. Sulphate:**

The concentration of sulphate in natural waters can vary over a wide range from a few mg/L to several thousand mg/L in brackish waters. Sulphates come from several sources such as the dissolution of gypsum and other mineral deposits containing sulphates; the oxidation of sulphides, sulphites and thiosulphates in well aerated surface waters; and from industrial effluents where sulphates or sulphuric acid have been used in processes such as tanning and pulp paper manufacturing, results in acid rain water containing appreciable levels of sulphate (Rotnayka et al., 2009).

The presence of sulfate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste impairment varies with the nature of the associated cation; taste thresholds have been found to range from 250 mg/L for sodium sulfate to 1000 mg/L for calcium sulfate (WHO, 2011).

**2.2.2.7. Chloride:**

Chloride is one of the major anions in water. Chlorides are present as sodium chloride (NaCl, common salt) and to lesser extent as calcium and magnesium chlorides (Abdelgafar, 1999).
The salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. Some waters containing 250 mg Cl⁻/L may have a detectable salty taste if the cation is sodium. On the other hand, the typical salty taste may be absent in waters containing as much as 1000 mg/L when the predominant cations are calcium and magnesium (APHA, 1999). Chlorides in water are more of a taste than a health concern, although high concentrations may be harmful to people with heart or kidney problems (Weiner, 2000).

2.2.2.8. Calcium:

Calcium is present in all waters as Ca²⁺ and is readily dissolved from rocks rich in calcium minerals, particularly as carbonates and sulphates, especially limestone and gypsum. The cation is abundant in surface and ground waters. The salts of calcium, together with those of magnesium, are responsible for the hardness of water (Chapman, 1996). Calcium compounds are stable in water when carbon dioxide is present, but calcium concentrations can fall when calcium carbonate precipitates due to increased water temperature, photosynthetic activity or loss of carbon dioxide due to increases in pressure (Chapman, 1996). Calcium is necessary in plant and animal nutrition and is an essential component of bones, shells, and plant structures. Small concentrations of calcium carbonate combat corrosion of metal pipes by laying down a protective coating. Because precipitation of calcite in pipes and in heat-exchangers can cause damage, the amount of calcium in domestic and industrial waters is often controlled by water softening (e.g., ion exchange, reverse osmosis) (APHA, 1999).

2.2.2.9. Magnesium:

Magnesium is a relatively abundant element in the earth’s crust and hence a common constituent of natural water (UNEP/WHO, 1996). The predominant source of Mg²⁺ in groundwater is dolomite [CaMg(CO₃)₂]. The limits for Mg²⁺ should not be more than 30 mg/L if there are 250 mg/L of sulfate, if there is less sulfate, Mg²⁺ up to 150 mg/l may be allowed (Al-Redhaiman and Abdel-Magid, 2002).
By a similar action to that of calcium, magnesium imparts hardness to water. This may be reduced by chemical softening or by ion exchange. (UNEP/WHO, 1996).

2.2.2.10. Iron:

Iron is found in most natural water, in surface water it is usually found in ferric form (Fe$^{+3}$). Anaerobic groundwater may contain ferrous iron at concentrations up to several milligrams per liter without discoloration or turbidity in the water when directly pumped from a well. On exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish-brown color to the water (WHO, 2011).

Iron also promotes the growth of “iron bacteria”, which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping. At levels above 0.3 mg/l, iron stains laundry and plumbing fixtures. There is usually no noticeable taste at iron concentrations below 0.3 mg/l, although turbidity and color may develop (WHO, 2011).

2.3. Water quality standard:

International standards for drinking water were first published by WHO in 1985, then have been revised and reissued in a new form in 1993 and entitled as guidelines for drinking water quality (Abdelgafar, 1999).
Table (4); Sudanese drinking water standard in comparison with WHO, EEC, USEPA.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>5NTU</td>
<td>5NTU</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Taste and odor</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>pH</td>
<td>6.5 – 8.5</td>
<td>6.5 – 8.5</td>
<td>6.5 – 8.5</td>
<td>6.5 – 8.5</td>
</tr>
<tr>
<td>TDS</td>
<td>1000 mg/l</td>
<td>1000 mg/l</td>
<td>1500 mg/L</td>
<td>500 mg/l</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>Sulphate</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>Fluoride</td>
<td>1.5 mg/l</td>
<td>1.5 mg/l</td>
<td>1.5</td>
<td>4mg/L</td>
</tr>
<tr>
<td>Hardness as CaCO₃</td>
<td>NS</td>
<td>500</td>
<td>705</td>
<td>NS</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3 mg/l</td>
<td>0.3 mg/l</td>
<td>0.2 mg/l</td>
<td>0.3 mg/l</td>
</tr>
<tr>
<td>Nitrate as (NO₃)</td>
<td>33 mg/l</td>
<td>50 mg/l</td>
<td>250 mg/l</td>
<td>45 mg/l</td>
</tr>
<tr>
<td>Nitrite as (NO₂)</td>
<td>2 mg/l</td>
<td>3 mg/l</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Ns</td>
<td>Ns</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ns</td>
<td>Ns</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

CHAPTER 3
MATERIALS AND METHODS

3.1. Sample collection:

A total of ten water samples were collected in the period (25 June—20 July), samples location: (Seven samples from Azaza plant wells, one sample from a well of Abdelaziz Bala farm, one sample from Hashim Yousif farm and one sample from Koben factory) all these wells are in Azaza basin. The experiments were carried out at Central Laboratory of Al Gedarif State Water Corporation (GSWC) immediately after arrival of samples.

Table (5): Sampling Sites and their Designated Codes:

<table>
<thead>
<tr>
<th>Site codes</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ₁</td>
<td>Azaza well No.13</td>
</tr>
<tr>
<td>AZ₂</td>
<td>Azaza well No.14</td>
</tr>
<tr>
<td>AZ₃</td>
<td>Azaza well No.15</td>
</tr>
<tr>
<td>AZ₄</td>
<td>Azaza well No.16</td>
</tr>
<tr>
<td>AZ₅</td>
<td>Azaza well No.17</td>
</tr>
<tr>
<td>AZ₆</td>
<td>Azaza well No.18</td>
</tr>
<tr>
<td>AZ₇</td>
<td>Azaza well No.21</td>
</tr>
<tr>
<td>AZ₈</td>
<td>Hashim Yousif Farm</td>
</tr>
<tr>
<td>AZ₉</td>
<td>Abdelaziz Bala farm</td>
</tr>
<tr>
<td>AZ₁₀</td>
<td>Koben factory</td>
</tr>
</tbody>
</table>

3.2. Instruments:

3.2.1. pH/CONDUCTIVITY/TDS METER

Palintest WATERROOF 800

3.2.2. Turbidity meter:
HACH/ 2100 IS TURBIDIMETER(ISO METHOD 7027)

3.2.3. Spectrophotometer:

HACH/DR 5000

3.2.4. Digital titrators:

3.2.4.1. Digital titrator (TIT REX, 2000)

3.2.4.2. Digital titrator (665 Dosimat, Metrohm)

3.2.5. Analytical balance (HR-200)

3.2.6. Oven

3.3. Preparation of Reagents used in titrations:

3.3.1. Preparation of Erichrome black T:

0.5 g Erichrome black was mixed with 100 g Sodium chloride.

3.3.2. Preparation of Murexide:

Prepared by grinding 200 mg of the dye with 100 g of NaCl.

3.3.3. Preparation of Sodium hydroxide (1M):

4 g of anhydrous sodium hydroxide were dissolved in distilled water and diluted to 100 ml.

3.3.4. Ammonia buffer solution (pH 10):

16.6 g of ammonium chloride were dissolved in 143 ml conc ammonium hydroxide, to make solution (A).

1.179 g EDTA and 780 mg magnesium sulfate were dissolved in 50 ml distilled water, to make solution (B).

Solution A was added to solution (B) and diluted to 250 ml with distilled water (APHA, 1999).
3.3.5. **Preparation of potassium chromate:**

25g of potassium chromate were weighted and dissolved in 50ml distilled water. Then drops of silver nitrate were added, the solution was digested for 24 hours and then filtrate and transferred to 500 ml volumetric flask and the volume was completed to the mark with distilled water (Hadeel,2015).

3.4. **Preparation of standards:**

3.4.1. **Standard EDTA titrant (0.01M):**

3.723g of EDTA salt (Na$_2$H$_2$C$_{10}$H$_{14}$O$_8$N$_2$.2H$_2$O) were dissolved in distilled water and diluted to 1 liter and standardized against standard calcium carbonate solution (APHA,1999).

3.4.2. **Standard CaCO$_3$ (0.01M):**

1 g of anhydrous calcium carbonate is weighted and dissolved with small amount of distilled water then drops of HCl 1:1 (5.72 M) was added for complete dissolved then diluted to 200 ml and boiling on benzen burner after have been cold it was transferred to 1000 ml volumetric flask, finally the volume was completed with distilled water (Hadeel,2015).

3.4.3. **Standard silver nitrate solution( 0.0141 M):**

2.395 g was dissolved in distilled water and diluted to 1000 ml (APHA,1999).

3.4.4. **Standard sulfuric acid 0.01M:***

0.54 ml concentrated H$_2$SO$_4$ were diluted to 1000ml and standardized against Na$_2$CO$_3$(0.01 M).

3.4.5. **Standard Sodium carbonate 0.01M:**

3g of Na$_2$CO$_3$ was dried at 250 for 4 hours, cooled and 1.06 g was weighed, dissolved in distilled water and diluted to 1000 ml.
3.5. Standardization

3.5.1. Standardization of EDTA:

10ml of calcium carbonate (0.01M) were taken then; 1ml of buffer solution was added together with a small amount of EBT to the same flask. The mixture was stirred then titrated against EDTA. The titration was repeated two times and the results register bellow:

Table (6): Volumes of standardization of EDTA:

<table>
<thead>
<tr>
<th>No of experiment</th>
<th>Volume of CaCO₃</th>
<th>Volume EDTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.0 ml</td>
<td>10.2 ml</td>
</tr>
<tr>
<td>2</td>
<td>10.0 ml</td>
<td>10.2 ml</td>
</tr>
</tbody>
</table>

Calculation:

\[ H_3\text{In} \rightleftharpoons H\text{In}^{-2} + 2H^+ \]

\[ H_3\text{In}= \text{Eri Chromo Black T.} \]

\[ H\text{In}^{-2} + M^{+2} \rightleftharpoons M\text{In}^{-2}_{(\text{WINE RED})} + H^+ \]

\[ \text{In}(\text{Ca}^{+2}, \text{Mg}^{+2})^{-} + H_2Y^{-2} \rightleftharpoons (\text{Ca}, \text{Mg})Y^{-2} + H\text{In}^{-2}_{(\text{BLUE})} + H^+ \]

\[ H_2Y^{-2} = \text{EDTA} \]

\[ M_{\text{CaCO}_3} \times V_{\text{CaCO}_3} = M_{\text{EDTA}} \times V_{\text{EDTA}} \]

\[ 0.01 \times 10 = M_{\text{EDTA}} \times 10.2 \]

\[ M_{\text{EDTD}} = 0.0098 \text{ mole/L} \approx 0.01 \text{M} \]

3.5.2. Standardization of H₂SO₄:

10 ml of Na₂CO₃ were taken in a flask, methyl orange was added, then titrated against H₂SO₄. The results are listed below:
Table (7): Volumes of standardization of H$_2$SO$_4$:

<table>
<thead>
<tr>
<th>No of experiment</th>
<th>Volume of Na$_2$CO$_3$</th>
<th>Volume H$_2$SO$_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 ml</td>
<td>10.3</td>
</tr>
<tr>
<td>2</td>
<td>10 ml</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Calculation:

H$_2$SO$_4$ + Na$_2$CO$_3$ $\rightarrow$ Na$_2$SO$_4$ + H$_2$CO$_3$

$M_{\text{BASE}} \times V_{\text{BASE}} = M_{\text{ACID}} \times V_{\text{ACID}}$

$0.01 \times 10 = M_{\text{ACID}} \times 10.25$

$M_{\text{ACID}} = 0.0098 \text{ mole/L} \approx 0.01 \text{ M}$

3.6.Method of analysis:

3.6.1.Physical parameters:

The physical parameters were determined using the following methods:

3.6.1.1.Taste and odor :

The taste and odor of water samples was determined according to personal sense of taste and odor.

3.6.1.2.Determination of pH and Electrical conductivity:

The pH and EC were measured by Palintest pH/Conductivity/TDS meter. The pH was first adjusted using standard buffer solutions having pH of 4 and 10, the mode key was used to change from pH to EC and EC was adjusted using 0.01 M KCl (1413μs). The results of pH and EC were recorded directly.

3.6.1.3.Turbidity:

Turbidity was determined with a HACH /2100 Turbidity meter. The sample cell was filled to the line (approximately 30 ml). Then the cell was held by the cap and wiped to remove water spots and finger prints. The sample cell was placed in the instrument cell compartment and the lid was closed. The results were recorded in (NTU).
3.6.2. Chemical parameters:
The chemical parameters were determined using the following methods:

3.6.2.1. Determination of TDS:
Total dissolved solids (TDS) were measured at 25 °C using TDS meter (Liqua tec™/FULLertion, CA USA/PM 3000).

3.6.2.2. Determination of hardness: EDTA Titrimetric Method
50 ml of water sample were transferred to a conical flask and 2 ml buffer solution was added to produce a pH 10. A tiny amount of Eriochrome Black T indicator was also added to the solution which was then titrated against 0.01 M EDTA until the color changed from wine red to blue.

Calculation:
Hardness = \[ \frac{V \times 0.01 \times 100 \times 1000}{50} \]
Therefore hardness = 20 V ppm

V = Volume of EDTA required for titration.

3.6.2.3. Determination of Calcium: (EDTA titration method)
2 ml of NaOH were added to 50 ml sample. Then a small amount of murexide indicator was added, the solution titrated against EDTA solution of 0.01M until the color changed from pink to purple. The end point was checked by adding 2 drops of titrant in excess to make sure that no further color change occurred.

Calculation:
Ca (mg/l) = \[ \frac{A \times B \times 400.8}{\text{ml of sample}} \]

Where:
A = ml of EDTA used.

B = mg CaCO\text{3} equivalent to 1ml EDTA
3.6.2.4. **Determination of Magnesium** (Calculation method)

Magnesium was determined by calculation method as follows:

\[
\text{mg Mg/l} = (\text{total hardness as CaCO}_3 - \text{Ca hardness as CaCO}_3) \times 0.243
\]

3.6.2.5. **Determination of alkalinity:**

50 ml water sample were pipetted into conical flask, and then few drops of methyl orange were added, then the sample was titrated against H\textsubscript{2}SO\textsubscript{4} 0.01 M, at the end point the color changed from yellow to red.

\[
\text{H}_2\text{SO}_4 + \text{CaCO}_3 \rightarrow \text{CaSO}_4 + \text{CO}_2 + \text{H}_2\text{O}
\]

**Calculation:**

Alkalinity as mg CaCO\textsubscript{3}/L = 100000 x A x M/V mg/L

Where:

A = mL standard acid used
M = Molarity of standard acid.
V = Volume of sample.

3.6.2.6. **Determination of Chloride:**

50 ml of water sample were transferred to a conical flask. 1ml of K\textsubscript{2}CrO\textsubscript{4} indicator was added to the flask, then the mixture was titrated with AgNO\textsubscript{3}(0.0141M) to pinkish yellow end point.

The distilled water used as blank was treated in the same manner.

**Calculation:**

\[
\text{Cl}^- (\text{mg/l}) = \frac{(A-B) \times M \times 35.450 \times 1000}{\text{ml of sample}}
\]

Where:

A = ml titration of sample
B = ml titration of blank
M = Molarity of AgNO\textsubscript{3}
3.6.2.7. **Determination of Fluoride**: (SPADNS method)

The program number was entered in the spectrophotometer (Hach DR 5000). 10 ml sample were taken by pipette into sample cell. 10 ml Distilled water was taken in another cell, 2 ml of SPDNS were added to each cell swirled to mix, after one minute the spectrophotometer was reset to zero with the blank (0.00 mg/L F⁻), and the reading of water sample was taken as mg F⁻/L.

The SPADNS Method for fluoride determination involves the reaction of fluoride with a red zirconium-dye solution. The fluoride combines with part of the zirconium to form a colorless complex, thus bleaching the red color in an amount proportional to the fluoride concentration. Test results were measured at 580 nm (Hach, 2005).

3.6.2.8. **Determination of Sulphate**: (SulfaVer 4 Method)

The program number was entered in spectrophotometer. The contents of one Sulfa Ver4 reagent powder pillow was added to 25 ml sample in the sample cell, swirled vigorously to dissolve the powder. Another sample cell was filled by 25 ml sample (the blank). After 5 minutes the spectrophotometer was reset to zero with the blank (0 mg SO₄²⁻/L), and the reading of water sample was taken as mg/L SO₄²⁻.

Sulfate ions in the sample react with barium in the SulfaVer 4 and form a precipitate of barium sulfate. The amount of turbidity formed is proportional to the sulfate concentration. Test results were measured at 450 nm (Hach, 2005).

3.6.2.9. **Determination of Iron**: (FerroVer method):

The program number was entered in the spectrophotometer. A sample cell was filled with 10 ml sample, then the contents of one FerroVer Iron reagent powder pillow was added and swirled. Another sample cell was filled by 10 ml sample (blank). After 3 minutes, the spectrophotometer was reset to zero with the blank (0.00 mg Fe /L), and the reading of water sample was taken as mg/L Fe.

FerroVer Iron Reagent converts all soluble iron and most insoluble forms of iron in the sample to soluble ferrous iron. The ferrous iron reacts with the 1,10 phenanthroline indicator in the reagent to form an orange color.
in proportion to the iron concentration. Test results were measured at 510 nm (Hach, 2005).

3.6.2.10. Determination of Nitrate: (Cadmium reduction method):

The program number was entered in the spectrophotometer. The sample cell was filled with 10 ml sample. The content of one NitraVer5 powder pillow was added, stoppered immediately and shaken for one minute. The sample was allowed to stand for 5 minutes. Another sample cell was filled with 10 ml sample (blank). The spectrophotometer was reset to zero with the blank (0.0 mg NO$_3^-$/L) and then the reading of the sample was taken as mg/L NO$_3^-$ at 500 nm. Nitra Ver5 contains Cadmium, Sulfanamic acid and gentisic acid. Cadmium metal reduces nitrates in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt couples with gentisic acid to form an amber colored solution (Hach, 2005).

$$\text{NO}_3^- + \text{Cd} + 2\text{H}^+ \rightarrow \text{NO}_2^- + \text{Cd}^{+2} + \text{H}_2\text{O}$$

\[ \text{NO}_2^- + \begin{array}{c} \text{sulfanilic acid} \\ \text{Diazoneium Salt} \end{array} + 2\text{H}^+ \rightarrow \begin{array}{c} \text{HO}_3\text{S-} \text{N=N} \\ \text{Diazoneium Salt} \end{array} + \begin{array}{c} \text{HO}_3\text{S-} \text{N=N} \\ \text{Diazoneium Salt} \end{array} + 2\text{H}_2\text{O} \]

\[ \text{HO}_3\text{S-} \text{N=N} + \begin{array}{c} \text{Gentisic acid} \\ \text{Amber colored species} \end{array} \rightarrow \begin{array}{c} \text{HO}_3\text{S-} \text{N=N} \\ \text{Diazoneium Salt} \end{array} + \begin{array}{c} \text{HO}_3\text{S-} \text{N=N} \\ \text{Diazoneium Salt} \end{array} + \begin{array}{c} \text{HO}_3\text{S-} \text{N=N} \\ \text{Diazoneium Salt} \end{array} + \text{H}^+ \]
3.6.2.11. Determination of Nitrite:
The program number was entered in the spectrophotometer. A sample cell was filled with 10 ml sample. The contents of one NitriVer3 Nitrite reagent powder pillow was added and swirled. Another sample cell was filled by 10 ml sample (blank). After 20 minutes, the spectrophotometer was reset to zero with the blank (0.000 mg/L NO$_2$), and the reading of water sample was taken as mg/L NO$_2$.

Nitri Ver3 contains sulfanilic acid and chromotropic acid. Nitrite in the sample reacts with sulfanilic acid to form an intermediate diazonium salt. This couples with chromotropic acid to produce a pink colored complex directly proportional to the amount of nitrite present. Test results were measured at 507 nm (Hach, 2005).

\[
\begin{align*}
1- \text{NO}_2^- + \text{H}_2\text{N}^- \text{SO}_3^- &\rightarrow \text{HO}_2\text{S}-\text{N=N} + 2\text{H}_2\text{O} \\
\text{N=N} + \text{HO}_2\text{SO}_3^- \text{SO}_3^- &\rightarrow \text{HO}_2\text{S}-\text{N=N} + \text{H}^+
\end{align*}
\]
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1. Results

4.1.1. Result of physical parameters

The results for physical parameters are shown in table (8). They also represented by figure (2)→figure (4).

Table (8): results of physical parameters for samples (AZ1- AZ10)

<table>
<thead>
<tr>
<th>Location</th>
<th>Parameters</th>
<th>Odor</th>
<th>Taste</th>
<th>Turbidity(NTU)</th>
<th>pH</th>
<th>Conductivity(µS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ1</td>
<td></td>
<td>Acc</td>
<td>Salty</td>
<td>4.68</td>
<td>6.73</td>
<td>1952</td>
</tr>
<tr>
<td>AZ2</td>
<td></td>
<td>Acc</td>
<td>Acc</td>
<td>0.6</td>
<td>7.48</td>
<td>1238</td>
</tr>
<tr>
<td>AZ3</td>
<td></td>
<td>Acc</td>
<td>Acc</td>
<td>1.2</td>
<td>7.62</td>
<td>1055</td>
</tr>
<tr>
<td>AZ4</td>
<td></td>
<td>Acc</td>
<td>Acc</td>
<td>3.11</td>
<td>7.60</td>
<td>1088</td>
</tr>
<tr>
<td>AZ5</td>
<td></td>
<td>Acc</td>
<td>Salty</td>
<td>2.5</td>
<td>6.87</td>
<td>1492</td>
</tr>
<tr>
<td>AZ6</td>
<td></td>
<td>Acc</td>
<td>Salty</td>
<td>2.94</td>
<td>6.99</td>
<td>1432</td>
</tr>
<tr>
<td>AZ7</td>
<td></td>
<td>Acc</td>
<td>Acc</td>
<td>2.74</td>
<td>7.56</td>
<td>1086</td>
</tr>
<tr>
<td>AZ8</td>
<td></td>
<td>Acc</td>
<td>Acc</td>
<td>1.69</td>
<td>7.42</td>
<td>1053</td>
</tr>
<tr>
<td>AZ9</td>
<td></td>
<td>Acc</td>
<td>Salty</td>
<td>1.97</td>
<td>7.61</td>
<td>1696</td>
</tr>
<tr>
<td>AZ10</td>
<td></td>
<td>Acc</td>
<td>Acc</td>
<td>2.68</td>
<td>7.13</td>
<td>1315</td>
</tr>
</tbody>
</table>

Acc: Acceptable
Figure (2): Diagram of Electric conductivity

Figure (3): Diagram of Turbidity
4.2. Discussion

4.2.1. Taste:

The taste of samples (AZ₂, AZ₃, AZ₄, AZ₇, AZ₈, AZ₁₀) was acceptable, while samples (AZ₁, AZ₅, AZ₆, AZ₉) showed salty taste; that may be due to high content of TDS in the samples.

4.2.2. Odor:

No odor detected in water samples taken from different wells in Azaza basin.

4.2.3. Electric Conductivity:

Electric conductivity values of samples are recorded in table (8), also represented by figure(2).

Conductivity of water sample ranged from 1053 to 1952 µs/cm. Conductivity is related to the concentration of total dissolved salts and
ionic compounds."The WHO guidelines do not specify the limit for EC however any value above 1380 μS/cm of EC indicate high TDS above 1000mg/l using an average correlation factor f 0.725" (Hoko, 2005). Sample AZ1, AZ5, AZ6 and AZ9 have an EC above 1380 μS/cm.

4.2.4. Turbidity:

Turbidity values of samples are recorded in table (8), also represented by figure (3).

The turbidity values in NTU of water samples showed values ranging from 0.6 to 4.68, the highest turbidity value was recorded for AZ1. This may be caused by the presence of iron in higher concentration. The turbidity of all samples are lower than (5 NTU) the maximum permissible limits of SSMO and WHO.

4.2.5. pH:

pH values of samples are recorded in table (8), also represented by figure (4).

The pH of water samples ranged from 6.73 to 7.62 which are within the WHO and SSMO standards. The SSMO(2015) and WHO (1993) range for pH level in drinking water is (6.5-8.5). Therefore all samples are acceptable for drinking in terms of pH, since they are not excessively acidic or alkaline.

4.1.2. Result of chemicals parameters:

The results for chemical parameters are shown in table (9). They also represented by figure (5)→figure (15)
Table 9: Result of Chemical parameters (mg/L) for samples (AZ1 - AZ10):

<table>
<thead>
<tr>
<th>Location</th>
<th>TDS</th>
<th>Total Hardness</th>
<th>Total Alkalinity</th>
<th>Calcium</th>
<th>Magnesium</th>
<th>Iron</th>
<th>Chloride</th>
<th>Fluoride</th>
<th>Sulphate</th>
<th>Nitrate</th>
<th>Nitrite</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ1</td>
<td>1266</td>
<td>639.0</td>
<td>910</td>
<td>121.6</td>
<td>81.6</td>
<td>0.49</td>
<td>39.8</td>
<td>2.72</td>
<td>62</td>
<td>2.5</td>
<td>0.010</td>
</tr>
<tr>
<td>AZ2</td>
<td>788</td>
<td>402.8</td>
<td>550</td>
<td>32.6</td>
<td>78.1</td>
<td>0.07</td>
<td>44.0</td>
<td>0.82</td>
<td>37</td>
<td>13.2</td>
<td>0.009</td>
</tr>
<tr>
<td>AZ3</td>
<td>660</td>
<td>367.6</td>
<td>480</td>
<td>45.3</td>
<td>61.8</td>
<td>0.17</td>
<td>28.7</td>
<td>0.60</td>
<td>27</td>
<td>14.6</td>
<td>0.010</td>
</tr>
<tr>
<td>AZ4</td>
<td>707</td>
<td>390.0</td>
<td>468</td>
<td>39.4</td>
<td>71.1</td>
<td>0.07</td>
<td>26.0</td>
<td>0.23</td>
<td>35</td>
<td>6.4</td>
<td>0.012</td>
</tr>
<tr>
<td>AZ5</td>
<td>984</td>
<td>443.6</td>
<td>584</td>
<td>35.8</td>
<td>86.1</td>
<td>0.19</td>
<td>89.3</td>
<td>2.26</td>
<td>54</td>
<td>2.9</td>
<td>0.032</td>
</tr>
<tr>
<td>AZ6</td>
<td>942</td>
<td>428.0</td>
<td>524</td>
<td>40.0</td>
<td>79.8</td>
<td>0.07</td>
<td>109.2</td>
<td>2.88</td>
<td>60</td>
<td>1.2</td>
<td>0.012</td>
</tr>
<tr>
<td>AZ7</td>
<td>706</td>
<td>398.8</td>
<td>446</td>
<td>43.9</td>
<td>70.3</td>
<td>0.15</td>
<td>35.7</td>
<td>0.47</td>
<td>23</td>
<td>24.7</td>
<td>0.017</td>
</tr>
<tr>
<td>AZ8</td>
<td>659</td>
<td>438.8</td>
<td>440</td>
<td>34.6</td>
<td>85.6</td>
<td>0.01</td>
<td>38.9</td>
<td>0.43</td>
<td>48</td>
<td>8.6</td>
<td>0.015</td>
</tr>
<tr>
<td>AZ9</td>
<td>1150</td>
<td>688.4</td>
<td>280</td>
<td>14.3</td>
<td>158.6</td>
<td>0.06</td>
<td>171.4</td>
<td>0.03</td>
<td>55</td>
<td>73</td>
<td>0.047</td>
</tr>
<tr>
<td>AZ10</td>
<td>852</td>
<td>401.6</td>
<td>620</td>
<td>31.1</td>
<td>78.7</td>
<td>0.11</td>
<td>88.8</td>
<td>2.04</td>
<td>66</td>
<td>1.8</td>
<td>0.022</td>
</tr>
</tbody>
</table>
Figure (5): Diagram of TDS

Figure (6): Diagram of Total hardness
Figure (7): Diagram of Calcium

Figure (8): Diagram of Magnesium
Figure (9): Diagram of Alkalinity

Figure (10): Diagram of Chloride
Figure(11): Diagram of Fluoride

Figure(12): Diagram of Sulphate
Figure (13): Diagram of Iron

Figure (14): Diagram of Nitrate
4.2.6. Total dissolved solids:

TDS values of water samples are recorded in table (9), also represented by figure (5). Values of total dissolved solids in mg/L for water samples ranged from (659-1266) mg/L. The WHO and SSMO recommended a value of 1000 mg/L as safe water for drinking. Sample (AZ\textsubscript{1}) and (AZ\textsubscript{9}) were above the maximum levels of SSMO and WHO, so they are unfit for drinking in terms of TDS values, other samples were within the permissible level. According to the WHO classification of TDS shown in table (1), samples (AZ\textsubscript{2},AZ\textsubscript{3},AZ\textsubscript{4},AZ\textsubscript{8},AZ\textsubscript{10}) are acceptable ,samples (AZ\textsubscript{5},AZ\textsubscript{6},AZ\textsubscript{9}) are bad, and sample (AZ\textsubscript{1}) is unacceptable.

4.2.7. Total hardness as CaCO\textsubscript{3}:

Total hardness values of water samples are recorded in table (9), also represented by figure (6).

The values of total hardness are less than total alkalinity in samples (AZ\textsubscript{1},AZ\textsubscript{2},AZ\textsubscript{3},AZ\textsubscript{4},AZ\textsubscript{5},AZ\textsubscript{6},AZ\textsubscript{7},AZ\textsubscript{8},AZ\textsubscript{10}), so the hardness of these
samples is carbonate hardness (temporary hardness), while hardness is greater than total alkalinity in (AZ9), so this sample contains non-carbonate hardness (permanent hardness), which indicate the presence of another calcium salt (SO$_4^{2-},$Cl$^-$), in addition to carbonate hardness. Hardness of all samples except (AZ1,AZ9) fall under the maximum value reported by WHO (500 mg/L as CaCO$_3$). According to Sudanese standards table (2) samples are classified as extremely hard when CaCO$_3$ is greater than 300 mg/L. Thus all sample are extremely hard.

4.2.8. Calcium:

Calcium values of water samples are recorded in table (9), also represented by figure (7). Calcium in mg/L for water sample range from (31.1-121) mg/L. No standard and guideline value was set for calcium level in drinking water by SSMO (2015) and WHO (1993). All water samples fall below the maximum permissible level of 200 mg/l set by USEPA(1976) and the EEC (1992) standards.

4.2.9. Magnesium:

Magnesium values of water samples are recorded in table (9), also represented by figure (8). Magnesium in mg/L for water sample range from (61.8 - 158.6) mg/L. No standard and guideline value was set for magnesium level in drinking water by SSMO (2015) and WHO (1993). All water samples except (AZ9) fall below the maximum permissible level of 150 mg/L set by USEPA (1976) standards.

The limits for Mg$^{+2}$ should not be more than 30 mg/L if there is 250 mg/L of sulfate, if there is less sulfate, Mg$^{+2}$ up to 150 mg/L may be allowed (Al-Redhaiman and Abdel-Magid, 2002).

4.2.10. Alkalinity as CaCO$_3$:

Alkalinity values of water samples are recorded in table (9), also represented by figure (9).
Alkalinity for water samples ranged from (280 to 910) mg/L. No standard and guideline value was set for alkalinity level in drinking water by SSMO (2015) and WHO (1993).

Alkalinity is due to bicarbonate when pH is less than 8.3, and is due to carbonate, bicarbonate and possibly hydroxide when pH is above 8.3. Alkalinity of all water samples is due to bicarbonate (pH less than 8.3).

4.2.11. Chloride:

Chloride values of water samples are recorded in table (9), also represented by figure (10). Chloride concentration in mg/L ranged from (26 -171.4) mg/L. The high value recorded in sample AZ9, may be the main reason to the presence of permanent hardness in this sample. none of the water samples studied being above the limit of 250 mg/L set by the SSMO and WHO standards and guidelines. Therefore all water samples are fit for drinking in terms of Chloride concentration.

4.2.12. Fluoride:

Fluoride values of water samples are recorded in table (9), also represented by figure (11). Fluoride levels in water samples ranged from (0.23 to 2.88) mg/L. The results showed that four of samples investigated (AZ1,AZ5,AZ6,AZ10) were found to have Fluoride concentration above the permissible level of SSMO and W.H.O standard, leading to the prevalence of dental flourosis in the study area due to the long term use of Fluoride ridden water.
Figure(16): Example of dental flourosis in the study area
4.2.13. **Sulphate:**

Sulphate values of water samples are recorded in table (9), also represented by figure (12). Sulphate concentration ranged from (33 – 66) mg/L. All of the water samples tested fall below the permissible limit of 250 mg/L set by SSMO and WHO standards and guidelines.

4.2.14. **Iron:**

Iron values of water samples are recorded in table (9), also represented by figure (13). Iron concentration in mg/L ranged from (0.07- 0.49) mg/L, sample AZ₁ was above the permissible limits of 0.3 recommended by SSMO and WHO.

4.2.15. **Nitrate (NO₃):**

Nitrate values of water samples are recorded in table (9), also represented by figure (14). Nitrate concentration ranged from 1.2 to 73 mg/L, all water samples, except sample (AZ₉) fall below the maximum permissible limit of 33 mg/L set by SSMO and the maximum limit of 50 mg/L set by WHO standards, so there is no health hazard with respect to their nitrate content. The higher value in sample AZ₉ may be due to excessive use of fertilizer in the farm.

4.2.16. **Nitrite (NO₂):**

Nitrite values of water samples are recorded in table (9), also represented by figure (15). Nitrite in mg/L ranged from 0.009 to 0.043 mg/L, all water samples have Nitrite concentration below the permissible limits of 2 mg/L and 3mg/L set by SSMO and WHO respectively. There is no health hazard with respect to nitrite content in all samples.
CHAPTER FIVE

CONCLUSION & RECOMMENDATION

5.1. Conclusion

Some physicochemical characteristic of (10) wells in Azaza basin were examined to assess the quality of water in this area.

The physical parameters examined include: pH, Turbidity, Electric conductivity. The chemical parameters include: Total dissolves solid (TDS), Total hardness, Alkalinity, Calcium, Magnesium, Chloride, Fluoride, Sulphate, Iron, Nitrate and Nitrite. The physicochemical parameters were compared with SSMO(2015) and WHO standards (1993).

pH and Turbidity of all water sample fall below threshold limits of WHO(1993) and SSMO(2015) standard. Alkalinity in water samples is due to bicarbonate, because they have (pH < 8.3). All sample are extremely hard and contain temporary hardness except AZ9 which contain permanent hardness in addition to temporary (hardness > alkalinity).

Four samples have fluoride concentration above the permissible limit and dental Fluorosis was observed among children in the study area.

Five samples of the 10 samples are unfit for drinking as indicated by some parameters. Sample AZ1 unfit for drinking because of high TDS, Fluoride and Iron, while Samples AZ5, AZ6 and AZ10 unfit for drinking because they contain high Fluoride concentration. AZ9 is unfit for drinking because it contains high Iron and Nitrate content. The other five samples are fit for drinking according to the measured parameters.
5.2. Recommendations:

The study recommends the following:

1- Ground water in this area should be treated with reverse osmosis or mixing with another water that contains low level of TDS and Fluoride.

Reverse osmosis should be designed correctly and tailored to suit the raw water characteristics i.e: suitable pre-treatment for iron removal and anti scale chemical should be applied to avoid quick blocking of R.O membranes due to the effects of Iron and Hardness.

2- The study area may need detailed studies based on seasonal variation and complete analysis for physicochemical parameters.

3- Consumption of water with high fluoride concentration should be avoided.

4- Water harvesting is needed to replenish groundwater.

5- Extensive water quality monitoring.

6- Further studies are needed in order to find a more economical and suitable method for excess fluoride removal.
REFERENCES


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