كلية الدراسات العليا

Sudan University of Science and Technology

College of Graduate Studies

Assessment of Drinking Water Quality at Source and point of use

A Case Study of Al-Azhari Area

تقييم جودة مياه الشرب في المصدر ونقطة الإستخدام

(دراسة الحاله منطقة الأزهري)

A thesis submitted in partial fulfilment for the degree of Master of Science in Environmental Engineering

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الآية

قال الله تعالى:

(قُلْ لَوْ كَانَ الْبَحْرُ مِدَادًا لِكَلِمَاتِ رَبِّي
لَنَفِدَ الْبَحْرُ قَبْلَ أَنْ تَنْفَدَ كَلِمَاتُ رَبِّي
وَلَوْ جِئْنَا بِمِثْلِهِ مَدَداً)

سورة الكهف الآيه 109

Dedication

‘’ To my parents, brothers, sisters, friends, and all people that will be happy to our success’’

Acknowledgement

Firstly, Thanks for God for helping me to complete this project in perfect way. Secondly, I would like to express my gratitude to Dr. Masoud Gameel for this his valuable assistance and supervision through the project time.

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Abstract

The study examined the quality of drinking water in the Al-Azhari area South of Khartoum. To achieve this goal, samples were collected from twelve sites to represent the source of the water, the wells and the final use points in the houses (tap water).

Standard methods were used to collect, prepare and analyzing samples by using advanced measuring instruments and statistical methods for some important chemical, physical and Bacteriological factors , and compare results obtained by Sudanese standards and World Health Organisation WHO.

From the study, all the studied water properties were within the allowed Sudanese specifications except the total count of bacteria, which showed that the groundwater sources and networks are microbiologically contaminated except the Al-Salma block 3, Al-Azhari wells for blocks 2 and 9, and the Al-Bohaira well, which requires treating the source and improving the water supply network. The study showed a positive correlation between sodium levels and total dissolved solids.

المستخلص

تتناول الدراسة تحديد جودة مياه الشرب في منطقة الأزهري جنوب الخرطوم لتحقيق هذا الهدف تم جمع عينات من اثني عشر موقعاً لتمثيل مصدر المياه ةهي الآبار ونقاط الإستخدام النهائية في المنازل (مياه الصنبور).

إستُخدمت طرق معيارية لجمع العينات وتحضيرها وتحليلها بإستخدام أجهزة قياس متقدمة في الإختبارات وتحليلها بطرق إحصائية لبعض العوامل الكيميائية و الفيزيائية والإحيائية المهمة و مقارنة النتائج المُتحصل عليها بالمعايير السودانية ومنظمة الصحة العالمية.

من الدراسة جميع الخواص المدروسة للمياه كانت ضمن المواصفات السودانية المسموح بها ما عدا العد الكلي للبكتريا والتي أظهرت أن مصادر المياه الجوفية وشبكاتها ملوثة ميكروبيولوجياً ماعدا السلمة مربع 3 وبئر الأزهري مربعي 2 و 9 وبئر البحيرة ممايقتضي معالجة المصدر وتحسين شبكة إمدادات المياه.

أظهرت الدراسة وجود علاقة إيجابية بين مستويات الصوديوم و الأملاح الذائبة الكلية.

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Abbreviations

EC: Electric Conductivity

FAO: Food and Agriculture Organization of United States

GW: Ground Water

mg/l: milligram per litter

MPN: Most Probable Number

ppm: part per million

WHO: World Health Organization

SDWA: Safe Drinking Water Act

SSMO: Sudanese Standards and Meteorology Organization

TDS: Total Dissolved Solids

TH: Total Hardness

TA: Total Alkalinity

Cl: Chloride

Mg: Magnesium

Ca: Calcium

K: Potassium

Na: Sodium

Chapter One

Introduction

Chapter One

Introduction

1.1 Background:

Water is very important to sustain humanity and life. Good quality of drinking water is one of the most human necessities, and the lack of access to adequate safe water supplies leads to the spread of diseases.

It is unfortunate in many developing countries water-related diseases are a problem's result from contaminated drinking water, so that it will be a high risk to human health, if it contains pathogens (WHO, 2006). It has been reported that the death of most of the children in Africa who die before the age of 5 is caused by inadequate and safe water supplies (Loucks, 1996).

The major problem of drinking water in Sudan and other developing countries is not just a lack of water availability, but in fact, that the people are not concerned with the water quality and pathogenic bacteria which, causes health risk.

The first national standards for drinking water quality were established by the US Public Health Service in 1914. Over the years, it has been revised to include source protection and chemical standards. In 1974, congress passd the Safe Drinking Water Act (SDWA) which has designed to protect the ground water from contamination by organic and inorganic chemicals and microorganisms. In 1986, the act was amended. Support for such legislation has been high, since nearly half of the nation’s population relies on ground water as a primary source of drinking water (Edward,Charles and Harris, 1990).

In this research is to assess the drinking water quality in Al-Azhari City which is in Khartoum state, There is an obstacle in drinking water quality so the investigation of the reasons will help to know and trying to solve this problem, to avoid any health risk for human.

The main source of water under study is a ground water. As independent sources there are Six wells takes place in the research they are constructed in Khartoum South Nemairi well , Alsalama block3 well, Albagala well , Alazhari block 2 and block 9 wells, and Albohaira well.

1.2 Research problem:

The quality of drinking water has a powerful impact on public health and therefore effective monitoring and comprehensive assessment of drinking water supply systems are crucial.

Al-Azhari city have little or no data on their microbial safety. However there is no data on quality of water from these sources to certain their suitability for drinking. The inhabitants are vulnerable to water related dieses and complaining from the quality of drinking water which is taste salty and contains odour.

In view of this, there is need to assess drinking water quality of theses sources.

1.3 Research Objectives:

- The main objective of the research is to assess the quality of drinking water. Particularly at Khartoum South in Al-Azhari city as a case study. To achieve the goal of the study, the following objectives are performed:
  1. Determine the microbiological and physiochemical quality of water.
  2. Identify if there is any possible sources of contamination.
  3. Compare the results with WHO guidelines and Sudanese standards of drinking water quality.
  4. Establish correlation between total dissolved solids (TDS) and various water quality parameters.

1.4 Research Methodology:

Research methodology summarized in five steps:

1. Review of publications related with water quality assessment.
2. Collection of samples from different sites from wells and taps.
3. Chemical, Physical and biological variable were analyzed for water samples.
4. Results of the analysis were compared to World Health Organization (WHO) and Sudanese Standard and Meteorology Organization (SSMO).
5. Linear regression method used for samples analyze to figure out the most elements have an effect in the water quality. Total dissolved solid and electric conductivity are one of the important indicator of the water quality therefore they were the independent values and other elements were the dependent values for the regression analysis.

1.5 Research Outline:

Background information about the problem, objective and methodology are included in chapter 1. Chapter 2 presents literature review. Chapter 3 illustrates the methods adopted in this study where as the results and discussions are presented in chapter 4.

Chapter 5 describes the overall conclusions and recommendations from this research and future studies.

Chapter Two

Literature Review

Chapter Two

Literature Review

2.1 General:

Water is the single most important substance known in the world it is elixir of life without it life is not possible, it represents a fundamental requirement for all life activities, It is essential to man, animals and plants. That water intended for human consumption must be free from chemical substances and micro-organisms in amounts which would provide a hazard to health is universally accepted. Supplies of drinking-water should not only be safe and free from dangers to health, but should also be as aesthetically attractive as possible. Absence of turbidity, colour and disagreeable or detectable tastes and odours is important in water-supplies intended for domestic use. The location, construction, operation and supervision of a water-supply-its sources, reservoirs, treatment and distribution-must exclude all potential sources of pollution and contamination (Eshraga, 2005).

Some countries in the world have established standards of quality which are applicable to their respective areas and have developed a certain degree of uniformity in methods of analysis and in the expression of the results of such analyses. Other countries, however, lack official or recognized standards of water quality and have no accredited procedures for the examination of water to assess its quality and safety. During regional and international conferences sponsored by the World Health Organization, the problems of standards of quality for a safe and acceptable water-supply, and of accredited or approved methods for the examination of water, have been fully discussed by groups of expert hygienists and engineers concerned with matters of water sanitation. Great improvement in water quality can be achieved throughout the world if various treatment processes are made easily comparable by the adoption of uniform methods for the examination of water and for the expression of results of such examinations. Further, outbreaks of water-borne disease could be avoided through stricter control by the responsible water-supply and health authorities of the quality of water distributed for drinking purposes.

The World Health Organization has therefore conducted a study of these problems, in collaboration with Member States and with the assistance of a number of experts, in an effort to offer technical guidance to health and sanitation administrations wishing to revise their regulations on water quality control.

Water is utilised for many beneficial purposes such as domestic, industrial, agriculture and hydropower production. Although the domestic requirement is less, industrial and agricultural demand of water is large.

In developed countries, the major use for industrial production and in developing areas it occurs for agriculture.

2.2 Water pollution:

The definition of water pollution is given by FAO (1979): "The presence of any substance (organic, inorganic, biological, thermal or radiological) in water at intensity levels which tend to impair, degrade, or adversely affect its quality or usefulness for specific purposes". Here contamination is synonymous with the degradation of water quality. The early studies on water pollution were motivated primarily by public health considerations and were largely bacteriological investigations.

Although the terms contamination and pollution are often used synonymously, health authorities make the definition of water pollution as any undesirable quality of water other than contamination. Dirt, silt, organic matter, minerals, objectionable colours, odours or tastes, acidity and alkalinity are causes of pollution.

2.3 Water resources:

2.3.1 Surface water:

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge.

Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss.

Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing the stream flow.

2.3.2 Ground water:

Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water and deep groundwater in an aquifer.

Groundwater can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, groundwater storage is generally much larger (in volume) compared to inputs than it is for surface water. This difference makes it easy for humans to use groundwater unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a groundwater source is the upper bound for average consumption of water from that source.

Ground water is normally preferable to surface water because of it is purified by the filtering action of the soil through which it flows, and most of it free from pathogenic organisms and pathogenic bacteria.

Wells are classified for two types:

1. Shallow wells: Are dug for the depth of few meters (less than 35 m).
2. Deep wells: Are drilled to bring water from deeper layers (more than 35 m). Al-Azhari wells (area of study).

2.4 Water quality:

Water quality is the physical, chemical, and biological characteristics of water in association to the set of standards. These parameters directly related to the safety of the drinking water to human use. Water quality parameters provide important information about the health of a water body. These parameters are used to find out the quality of water for drinking purpose.
The quality of drinking water has great impact on human health, provision of a safe and adequate supply of drinking water is an essential component in the primary health care.

In general ground water is purer, compared to surface water. It is dominant in gases and dissolved solids etc. Surface water on the other hand is rich in suspended sediments and sufficient dissolved oxygen.

Ground water quality has become an important water resources issue to rapid increase of population.

Potable water must have a level of constituents which doesn't cause any health hazard to the consumer. Water should conform to the following water quality characteristics; it should be:

1. Free from pathogenic.
2. Clear (i.e. no colour, odour, turbidity, taste).
3. Not saline.
4. Free from chemicals which may cause corrosion of water supply system.

Quality control is designed to ensure water services meet agreed national standards to be suitable for human consumption and for all usual domestic purposes.

2.5 Water quality monitoring and Integrated Water Resources Management (IWRM):

A specific definition of water quality monitoring is given by the U.S Environment Protection Agency in this terms "Monitoring of water quality might be defined as a scientifically designed program of continuing surveillance, including direct sampling and remote quality measurements, inventory of existing and potential causes of change, and analysis of the cause of past quality changes and prediction of the nature of future quality changes". Following this definition, the main purpose in monitoring water quality can be described as to obtain an early warning of water pollution and/or determine the progress of pollution or changes in water composition (FAO, 1979). One of the major types of monitoring is a research monitoring, which may be defined as: Measurements specifically related to research investigations (McNelis, 1973, and FAO, 1979). McNelis (1973) reported that monitoring is a necessary element of water quality considerations providing quantitative and qualitative data on existing circumstances and trends.

The concept of integrated water resources management (IWRM) has been developing over the past several decades. IWRM is the response to the growing pressure on our water resources systems caused by growing populations and socioeconomic developments. Water shortages and deteriorating water quality have forced many countries in the world to reconsider their development policies with respect to the management of their water resources. As a result water resources management (WRM) has been undergoing a change worldwide, moving from a mainly supply-oriented, engineering-biased approach toward a demand-oriented, multisectoral approach, often labeled integrated water resources management. (Daniel P. Loucks, 2016).

2.6 Physiochemical Standards of Water Quality:

The following criteria are important in assessing the potability of water:

Table 2.1: Sudanese Standards and WHO guidelines for Drinking water

Parameters	SSMO	WHO
pH	6.5 – 8.5	6.5-8.5
Electrical conductivity µS/cm	1000	500
Total dissolved solid mg/L	1000	1000
Total alkalinity mg/L	500 – 1000	500
Hardness as $CaCO_3$ mg/L	500	500
Chloride mg/L	250	250
Sodium mg/L	20	20

Potassium mg/L	NS	12
Magnesium mg/L	50	50
Calcium mg/L	75	75

NS= not Standard. WHO guidelines and SSMO 2008.

2.6.1 pH of water:

The pH of pure water is refers to the measure of hydrogen ions concentration in water. It ranges from 0 to 14. In general, water with a pH of 7 is considered neutral while lower of it referred acidic and a pH greater than 7 known as basic.

It is noticed that water with low pH is tend to be toxic and with high degree of pH it is turned into bitter taste. According to WHO standards pH of water should be 6.5 to 8.5.

2.6.2 Electrical Conductivity:

Pure water is not a good conductor of electric current rather a good insulator. Increase in ions concentration enhances the electrical conductivity of water. Generally, the amount of dissolved solids in water determines the electrical conductivity.

Electrical conductivity (EC) is actually measures the ionic process of a solution that enables it to transmit current.

According to WHO standards EC value should not exceeded 500 µS/cm.

2.6.3 Total Dissolved Solids (TDS):

TDS are the inorganic matters and small amounts of organic matter, which are present as solution in water. These minerals produced un-wanted taste and diluted colour in appearance of water. There is no agreement have been developed on negative or positive effects of water that exceeds the WHO standard limit of 1000 mg/l. Total dissolved solids (TDS) in drinking water is originates many ways from sewage to urban industrial wastewater etc.

Therefore, TDS test is considered a sign to determine the general quality of the water.

2.6.4 Alkalinity:

Alkalinity is the presence of one or more ions in water including hydroxides, carbonates and bicarbonates. It can be defined as the capacity to neutralize acid. Moderate concentration of alkalinity is desirable in most water supplies to stable the corrosive effects of acidity. However, excessive quantities may cause a number of problems.

The WHO standards tell the alkalinity only in terms of total dissolved solids (TDS) of 500 mg/l.

2.6.5 Total Hardness:

Hard water is characterized with high mineral contents that are usually not harmful for humans. It is often measured as calcium carbonate (CaCO3) because it consist mainly calcium and carbonates the most dissolved ions in hard water. According to World Health Organization (WHO) hardness of water should be 500 mg/l.

2.6.6 Calcium (Ca):

Calcium is 5th most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases. According to WHO (1996) standards its permissible range in drinking water is 75 mg/l, however, an adult requires 1,000 mg/ day to work properly.

2.6.7 Magnesium (Mg):

Magnesium is the 8th most abundant element on earth crust and natural constituent of water. It is an essential for proper functioning of living organisms and found in minerals like dolomite, magnesite etc. Human body contains about 25g of magnesium (60% in bones and 40% in muscles and tissues). According to WHO standards the permissible range of magnesium in water should be 150 mg/l.

2.6.8 Potassium (K):

Potassium is silver white alkali which is highly reactive with water. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total potassium amount in human body lies between 110 to 140 g. It is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Potassium is deficient in rare but may led to depression, muscle weakness, heart rhythm disorder etc. According to WHO standards the permissible limit of potassium is 12 mg/1.

2.6.9 Sodium (Na):

Sodium is a silver white metallic element and found in less quantity in water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc. In most of the countries, majority of water supply bears less than 20 mg/l while in some countries the sodium quantity in water exceeded from 250 mg/l (WHO, 1984). According to WHO standards, concentration of sodium in drinking water is 20 mg/1.

The most common sources of elevated Sodium levels in ground water are erosion of salt deposits and sodium bearing rock minerals. High percent may causes high blood pressure.

2.6.10 Chloride (Cl):

Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO2 and added through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration of chlorides as compare to ground water. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damage metallic pipes and structure as well as harms growing plants. According to WHO standards concentration of chloride should not exceed 250 mg/l.

2.7 Chemical and physical indicators of pollution:

Chemical constituents or properties of water other than those previously listed are important as indicators of pollution. They have no effect on health or on the acceptability or attractiveness of the water. Their inclusion in the general chemical analysis of water is important because of the significant data furnished as to the degree of pollution by wastes. Since concentrations of these substances vary widely in waters from different sources, no limiting amounts can be given. Increase above the normal concentration range for each of these characteristics provides an indication of pollution, and the magnitude of such increases should be a reasonable measure of the degree of pollution.

2.8 Bacteriological Water Quality Standards:

Effective chlorination yields water which is virtually free from coliform organisms, i.e. these organisms are absent in 100 ml portions. A standard demanding that coliform organisms be absent from each 100 ml sample of water entering the distribution system – whether the water be disinfected or naturally pure – and from at least 90% of the samples taken from distribution system can be applied in many parts of the world. For each individual sample, coliform density is estimated in terms of the "most probable number" in 100 ml of water or MPN index.

The following bacteriological standards are recommended for treated and untreated supplies for present use during the world:
In 90% of the samples examined during any year, coliform bacteria shall not be detected or the MPN index of coliform microorganisms shall be less than 1.0 per 100 ml. None of the samples shall have an MPN index of coliform bacteria in excess of 10 in 100 ml samples.

In untreated water which is naturally pure, the standards are the same as above but it is stated that none of the samples should show an MPN index greater than 20 per 100 ml samples. When samples are taken from the distribution system they should be free from coliform organisms. (International standard for drinking water,1958).

Table 2.2: Suggested Sudanese microbiology standards for water.

	Test	Limit per 100 ml			
		n	C	m	M
Drinking water	Thermotolerant coliforms or *E. coli*	Any number of samples	0	0	-
	Sulfite reducing bacteria (*Clostridium perfringens*)	Any number of samples	0	0	-
Treated water entering the distribution system	Thermotolerant coliforms or *E. coli*	Any number of samples	0	0	-
	Total coliforms	Any number of samples	0	0	-
	Sulfite reducing bacteria (*Clostridium perfringens*)	Any number of samples	0	0	-
Treated water in the distribution system	Thermotolerant coliforms or *E. coli*	Any number of samples	0	0	-
	Coliforms	Large number of samples	5% of n	1	10

n: No. of samples to be examined.

c: No. of samples exceeding but still water ok

m: maximum count allowed in any sample

M: count if exceeded by any one sample the whole water is rejected.

2.9 Bacteriological indicators of pollution:

The major danger associated with drinking-water is the possibility of its recent contamination by sewage or by human excrement, and even the danger of animal pollution must not be overlooked. If such contamination has recently occurred and if, among the contributors, there are cases or carriers of such infectious diseases as enteric fever or dysentery, the water may contain the living micro-organisms of these infections, and the drinking of such water may result in additional cases of the disease. Although modern bacteriological methods have made it possible to detect pathogenic bacteria in sewage and sewage effluents, it is not practicable to attempt to isolate them as a routine procedure from samples of drinking water. When pathogenic micro-organisms are present in faeces or sewage, they are almost always greatly outnumbered by the normal excremental organisms, and these normal intestinal organisms are easier to detect in water. If these organisms are not found in the water, it can be inferred that disease-producing micro-organisms are also absent. Thus, the use of normal excremental bacteria as indicators of faecal pollution introduces a margin of safety.

2.10 Water borne diseases:

Water borne illness remains a major source of worldwide human morbidity and mortality (Mc Festers and Singh, 1991) and that one-half of the world's population has suffered from diseases caused by polluted water (Barbaras, 1986) and that pathogenic bacteria when present in potable waters cause typhoid fever, bacillary dysentery and cholera (WHO, 1964). However, with improvements in epidemiological surveillance and in clinical diagnosis of bacterial and non-bacterial gastroenteritis there has been over the last two decades an emergence of new forms of water-related illness (West, 1991; Degner et al., 1983).

Several pathogenic strains of Escherichia coli in drinking water and food have been implicated in intestinal complaints of humans (Kurl, 1972, Madigan et al., 1997).

New York State Department of Health (2005) stated that coliform bacteria are found in the digestive tract of all birds and mammals. Most coliform bacteria are not harmful themselves, but point to an unsanitary condition and possible presence of disease-causing organisms.

The coliform bacteria may not form disease but can be used as an indicator of pathogenic disease (Sharon, 2004). Skipton *et al*. (2004) recommended that drinking water from private wells should be tested for the presence of bacteria at least once a year or when work has been done to the water supply system or when there is any time a change in the any of the water quality parameters (taste, colour, turbidity … etc).

The drinking water quality standard for coliform bacteria is set at less than one coliform organism per 100 ml of water. Among the chemical toxin which can endanger human health, are those substances which can be present in water as decomposition products of organic compounds (Kurl, 1972).

Chapter Three

Materials and Methods

Chapter Three

Materials and Methods

3.1 Description of study area:

Khartoum city the capital of Sudan is located in the central part of the country the state lies between longitudes 31.5 to 34 °E and latitudes 15 to 16 °N. It is surrounded by River Nile State in the north-east, in the north-west by the Northern State, in the east and southeast by the states of Kassala, Qadarif, Gezira and White Nile State, and in the west by North Kurdufan. The northern region of the state is mostly desert because it receives barely any rainfall, whereas the other regions have semi-desert climates. The weather is rainy in the fall, and cold and dry in the winter. Average rainfall reaches 100–200 mm in the north-eastern areas and 200–300 mm in the north-western areas. The temperature in summer ranges from 25 to 40 °C from April to June, and from 20 to 35 °C in the months of July to October. In winter, the temperature declines gradually from 25 to 15 °C between March and November.

The area under study is located at the southern part of Greater Khartoum State, Sudan. Wells under investigation were drilled in Al-Azhari and Al-Salma suburban communities.

Figure 3.1: Location of the case study area, from Google map.

Water Samples were collected from different sites along the network line of drinking water system that supply Al-Azhari city.

Table 3.1: Shows the names of sources and points of sampling

Source	Well	Tap
Nemairi	GW1	Tap1
Al-Salama block3	GW2	Tap2
Al-Bagala	GW3	Tap3
Al-Azhari block2	GW4	Tap4
Al-Bohaira	GW5	Tap5
Al-Azhari block9	GW6	Tap6

3.2 Sampling Techniques:

Standard methods used for sampling:

Water samples were collected aseptically in sterile bottles. The opening of the tap was cleaned and sterilized by alcohol and flaming.

The tap was opened and first stream was discarded, after two minutes the target sample was collected in sterile bottle.

The bottle was tightly closed and immediately transported to laboratory for chemical, physical and for bacteriological analysis.

Physiochemical analysis (pH,TDS, EC,TH,TA,Cl,Mg.Ca,K,Na) for samples was at UNESCO chair in water resources, at AL-Assad steel factory in the water quality lab and Sudan University.

Bacteriological analysis was carried out in Sudan University of science and technology, Department of water and environmental engineering at Al-Kdro Laboratory.

3.3 Methods of Analysis:

3.3.1 Physiochemical Tests:

1) pH ,Total Dissolved Solids (TDS) and Electric conductivity (E.C):

Determination of the pH, TDS and EC carried out using Plaintest meter in Figure 3.2.

Regarding to three above tests the following steps has been used for measuring:

a. Rinse the electrode with distilled water before use to remove any impurities.
b. Press **ON** to switch on meter.
c. Press the **MODE** key to select pH or TDS or conductivity measurement mode.
d. Dip the probe into the sample.
e. Allow time for reading to stabilize.
f. Take stable reading.

2) Total alkalinity and Total Hardness:

Total alkalinity and total hardness was determined using Palintest photometer apparatus Fig 3.2 according to the following steps:

a. Fill the test tube with sample and retain for use as the BLANK tube.
b. Fill the test tube with 10 ml of sample.
c. Select the test name on the Photometer.
d. Take Photometer reading.

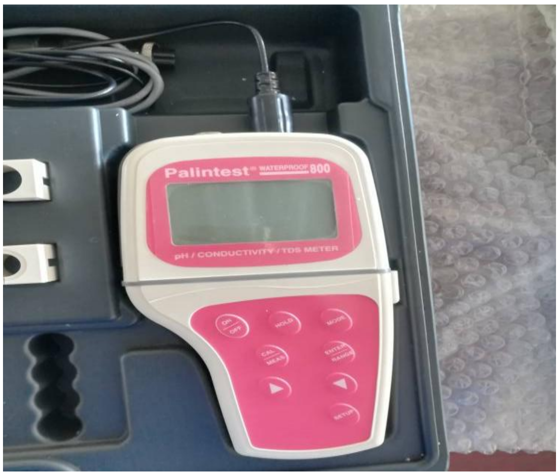

Figure 3.2: Palintest pH / EC/ TDS meter.

Figure 3.3: Palintest photometer apparatus.

3) Sodium and Potassium:

Determination of the Na and K was carried out using flame photometer by preparing different concentrations with specific rates of Na and K in liquid phase, and directly measure them with flame photometer in Fig 3.3.

Figure 3.4: Flame photometer.

4) Chloride:

Determination of the Cl was carried out using titration, by following the below steps:

a) 25 ml of sample has been taken.
b) Added 1 ml of Potassium dichromate $K_2Cr_2O_2$.
c) It's titrated with Silver Nitrate Ag NO_3 solution.
d) An equation 3.1 used to determine Cl^{-1}:

$$Cl^{-1} = \frac{V*M*1000}{Vsample} \quad \text{------ } 3.1$$

V = Volume Ag NO_3.

M = Molarities of Ag NO_3.

Vsample = Volume of Sample.

5) Calcium:

Determination of Calcium carried out by titration following below steps:

a) 25 ml of sample has been taken in flask.
b) Added 2 ml of Sodium Hydroxide NaOH.
c) Drops of indicator added to the solution.
d) Titrate with EDTA solution found in burette.
e) Calculation takes place.

6) <u>Magnesium:</u>

Magnesium determination carried out using below equation:

Mg = Total Hardness- Calcium Hardness ------- 3.2

3.3.2 Bacteriological Tests:

Most probable number (MPN) analysis is a method based on the random dispersion of microorganisms per volume in a water sample. MPN is most commonly applied for quality testing of water i.e. to ensure whether the water is safe or not in terms of bacteria presence.

In this method, measured volumes of water are added to series of tube containing a liquid indicator growth medium.

Multiple Tube Fermentation Methods: Specific dilution was made, inoculate multiple tubes (3 or 5) of media with water sample, Incubate 35 C, and Count positive growth tubes, Use Most-Probable-Number (MPN) table to estimate density.

<u>Methodology:</u>

a) Prepare and sterilize 3 MaCconkey broth (10ml) with Durham tubes, 6 Mac broth (5ml) with Durham tubes.
b) Inoculation: first 3 tubes with 10ml of the original sample, next 3 with 1ml of the original sample, next 3with 0.1ml of the original sample.
c) Incubation for 35-37 ˚C for 48 hours. Observe for gas production, turbidity, and change in colour to yellow.

3.3.3 Statistical correlation:

Correlation: is a statistical technique that can show whether and how strongly pairs of variables are related. Correlation coefficient (R) formulas are used to find how strong a relationship is between data. The formulas return a value between -1 and 1, where: 1 indicates a strong positive relationship, -1 indicates a strong negative relationship and result of zero indicates no relationship at all.

In statistics, the correlation coefficient r measures the strength and direction of a linear relationship between two variables on a scatter plot.

The regression equation was used as a mathematical calculates different dependent characteristics of water substituting the values for independent parameters equation.

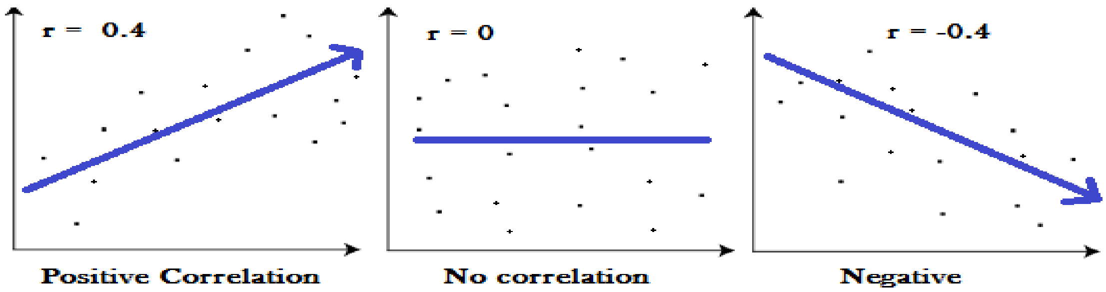

Figure 3.5: Graphs showing a correlation of -1, 0 and +1.

The graphic method indicates the existence of correlation, to find the relationship between two parameters x and y. R determined by:

$$r = \frac{SSxy}{(SSxx\ SSyy)^{\wedge}0.5} \quad \text{---------------} \ 3.3$$

$$r^2 = b\ SSxy\ /SSyy \quad \text{---------------} \ 3.4$$

- Sum of squares of xy, xx,yy:

$$SSxy = \sum XY - \frac{(\sum X - \sum Y)}{N} \quad \text{-------------} 3.5$$

$$SSxx = \sum X^2 - \frac{(\sum X)^{\wedge}2}{N} \quad \text{---------------} \ 3.6$$

$$SSyy = \sum Y^2 - \frac{(\sum Y)^{\wedge}2}{N} \quad \text{---------------} \ 3.7$$

$$b = SSxy\ /SSxx \quad \text{---------------} \ 3.8$$

$$a = y - bx \quad \text{---------------} \ 3.9$$

r^2 = Coefficient of determination.

r = Linear correlation coefficient.

X = Independent value.

Y= Dependent value.

a = Slope line,   b = intercept on Y-Axis.

Chapter Four

Results and Discussion

Chapter Four

Results and Discussion

4.1Physiochemical Results:

The respective values of all water quality parameters of the ground water samples are presented. All the results are compared with standard's permissible limit recommended by the World Health Organization (WHO) and Sudanese Standard and Metrology Organization.

The below tables illustrate the analysis results of water from wells and sampling points.

Table 4.1Parameters at different sampling wells:

Parameter	**Source**							
	GW1	GW2	GW3	GW4	GW5	GW6	WHO	SSMO
PH,	7.4	7.3	7.4	7.6	6.6	7.6	6.5-8.5	6.5-8.5
Total dissolved soids(mg/l)	377	306.8	275.6	345	275.6	291	1000	1000
Electric conductivity(µS/cm)	460	472	424	628	424	451	500	1000
Hardness(mg/l)	215	172	84	216	236	262	500	500
Alkalinity(mg/l)	190	358.87	336.1	196	576.2	176	500-1000	500-1000
Cl(mg/l)	85.97	99.93	39.98	36	69.98	9	250	250
Mg(mg/l)	3.42	28.25	14.18	28.8	45.67	16.32	150	150
Ca(mg/l)	60.92	41.62	26.65	38.4	48.1	18.4	75	75
K(mg/l)	7	2.05	12.81	4.1	0.25	3	NS	12
Na(mg/l)	75.45	2.84	2.7	38	3.27	41.5	200	200

Table 4.2 Parameters at different sampling points of use:

	Points of use							
Prameter	Tap1	Tap2	Tap3	Tap4	Tap5	Tap6	WHO	SSMO
PH,	7.1	7.2	7.6	7.4	7.1	8.3	6.5-8.5	6.5-8.5
Total dissolved soids(mg/l)	386	276.3	145.6	275.6	221.6	728	1000	1000
Electric conductivity(µS/cm)	776	425	224	424	341	1040	500	1000
Hardness(mg/l)	220	164	188	135	184	136	500	500
Alkalinity(mg/l)	185	54	278.9	20	164.9	439.2	500-1000	500-1000
Cl(mg/l)	97.9	63.98	29.99	81.9	55.98	63	250	250
Mg(mg/l)	0.004	28.17	25.65	25.12	34.94	9.72	50	10
Ca(mg/l)	68.93	48.1	25.65	32.06	40.24	38.4	75	75
K(mg/l)	7	0.28	10.67	0.32	0.1	9.728	NS	12
Na(mg/l)	75.45	1.98	3.24	1.1	63.17	190	200	200

1. <u>pH :</u>

The pH analysis was performed for wells and points of use and the results shows in the following table:

Table: (4.3) Results of pH analysis.

pH					
G.W1	**G.W2**	**G.W3**	**G.W4**	**G.W5**	**G.W6**
7.4	7.3	7.4	7.6	6.6	7.6
Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**
7.1	7.2	7.6	7.4	7.1	8.3

The pH values in the studied area varied between 6.6 to 8.3 at GW5 and Tap6 respectively with mean value of 7.38 as shown in figure 4.1below. All the sampling points showed pH values within the prescribed limit by WHO and SSMO for drinking water. The limit value of pH in drinking water is specified as 6.5 to 8.5. High pH (very alkaline water) can have unpleasant smell or taste. On the other side low pH water tend to corrosion of pipes and hence damaging them, it can also result in contamination of water with heavy metals such as lead and copper.

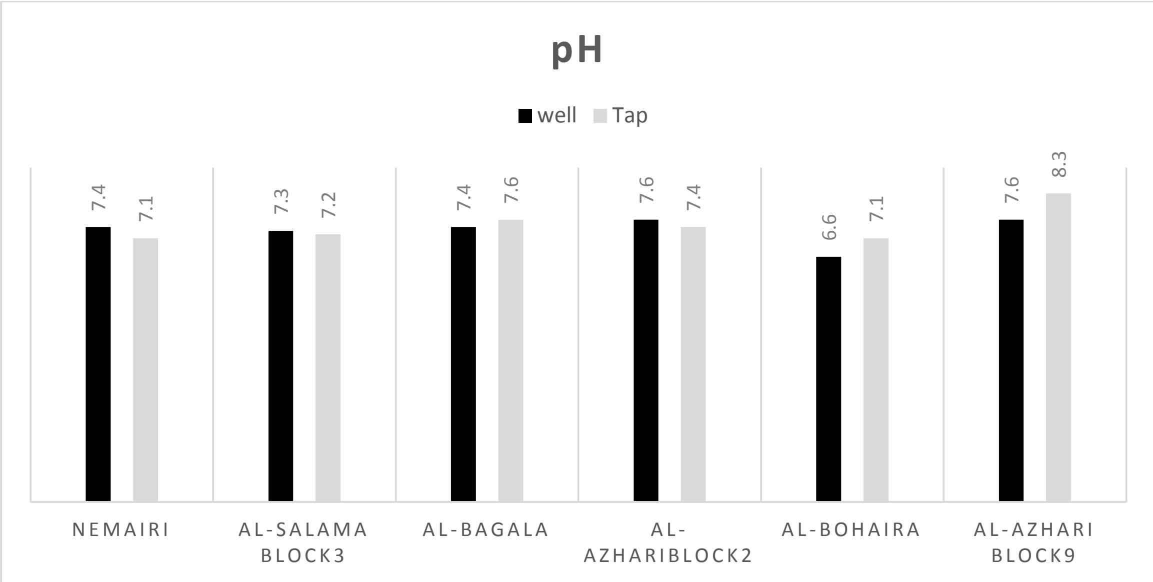

Figure 4.1: pH of ground and tap water.

2. TDS:

Table: (4.4) Results of TDS analysis.

TDS(mg/l)					
G.W1	**G.W2**	**G.W3**	**G.W4**	**G.W5**	**G.W6**
377	306.8	275.6	345	275.6	291
Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**
386	276.25	145.6	275.6	221.65	**728**

In the present study the TDS of analyzed water samples varied between 145.6 to 728 mg/l at tap3 and tap6 respectively as shown in table 4.2. The highest value of TDS was observed in Tap 6 with a value of 728 mg/l in figure 4.2 and this due to the accumulation of salts through time on pipes or the type of pipe reacted with water. Statistical correlation takes place to compare TDS with inorganic materials concentration.

According to World Health Organization, TDS concentration of 1000 mg/l is considered acceptable for water consumers.

All values of TDS within the standard limit of WHO and SSMO (1000 mg/l). High concentration of TDS has a bad taste and very low concentration of TDS unacceptable because of its flat taste of water.

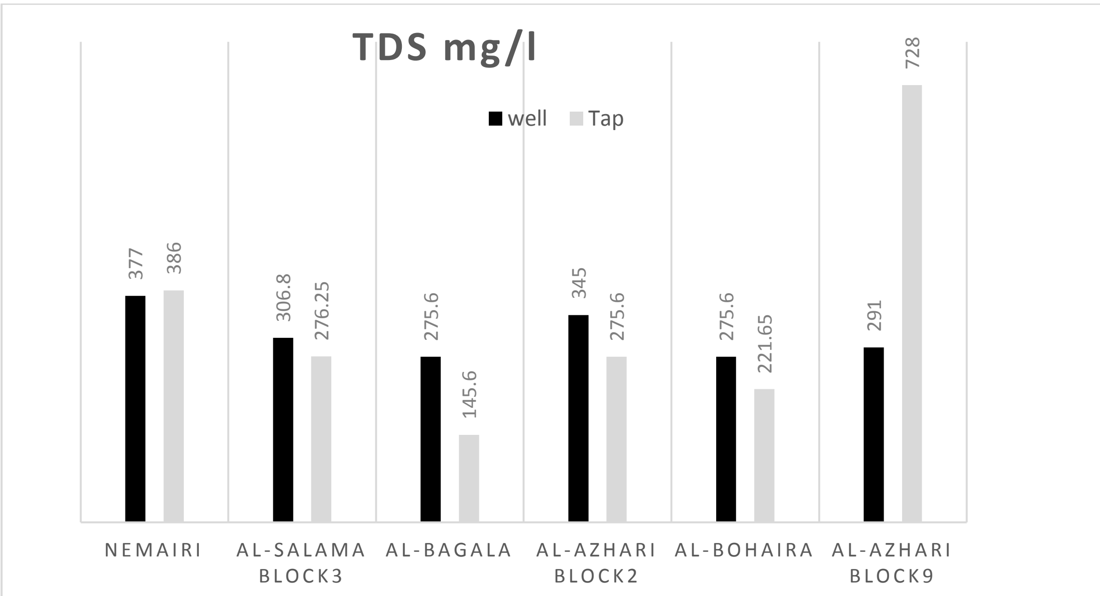

Figure 4.2: TDS of ground water and tap water.

4.2Correlation Results:

The below regression models have been obtained from the results of data analysis of water samples for Al-Azhari City from different sources and sampling point.

By considering a known values of Total dissolved solids comparing with the results of Chloride, Magnesium, Calcium, Potassium, and Sodium to discover which of these elements have a major effect of the quality of water.

4.2.1 Correlation between TDS and Cl:

Higher levels chloride tend to imply contamination by human activities, including road salt storage, use of road salt, discharges from water softeners, human or animal waste disposal. Therefore it may contribute to increase the values of total dissolved solids.

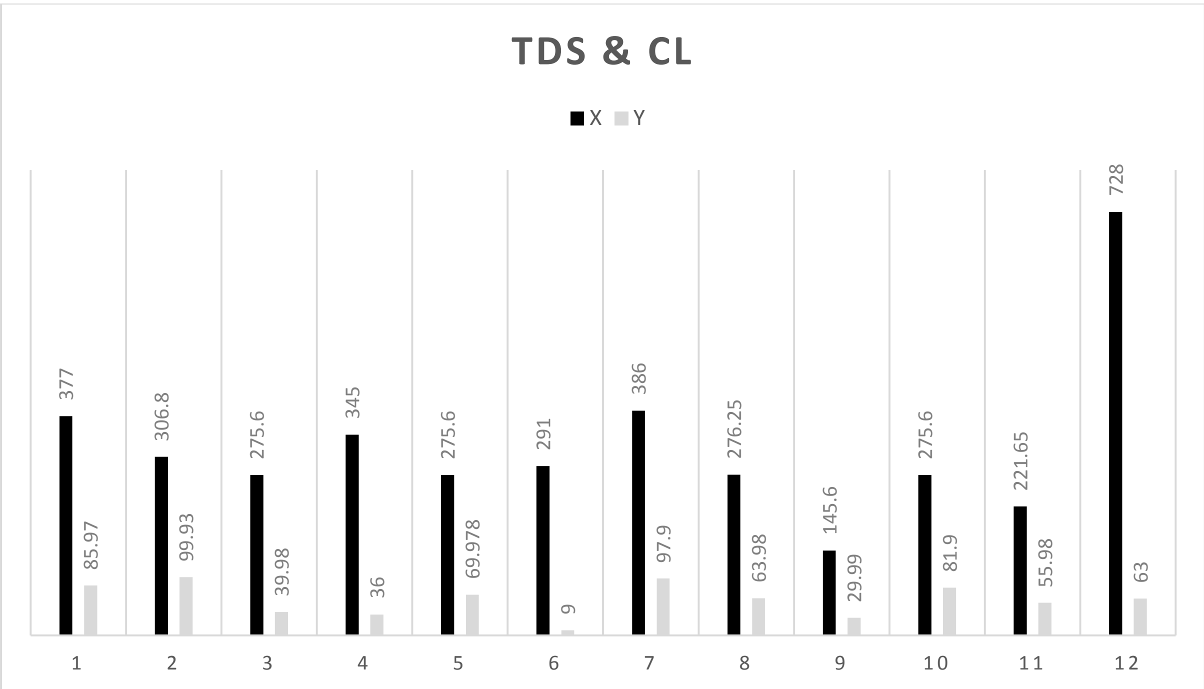

Figure 4.3: Data Analysis results of TDS and Cl.

Table: (4.5) Results of correlation between TDS and Chloride analysis.

TDS = X mg/l
Chloride =Y mg/l

	X	Y	XY	X^2	Y^2		
	377	85.97	32410.69	142129	7390.8409		
	306.8	99.93	30658.524	94126.24	9986.0049		
	275.6	39.98	11018.488	75955.36	1598.4004		
	345	36	12420	119025	1296	mean x	325.3417
	275.6	69.978	19285.937	75955.36	4896.9205	mean y	61.134
	291	9	2619	84681	81	SS xy	10413.42
	386	97.9	37789.4	148996	9584.41	SS xx	223283.1
	276.25	63.98	17674.475	76314.063	4093.4404	SS yy	8788.396
	145.6	29.99	4366.544	21199.36	899.4001	b	0.046638
	275.6	81.9	22571.64	75955.36	6707.61	a	45.9608
	221.65	55.98	12407.967	49128.723	3133.7604	r^2	0.055261
	728	63	45864	529984	3969	r	0.235077
SUM	3904.1	733.608	249086.66	1493449.5	53636.788		

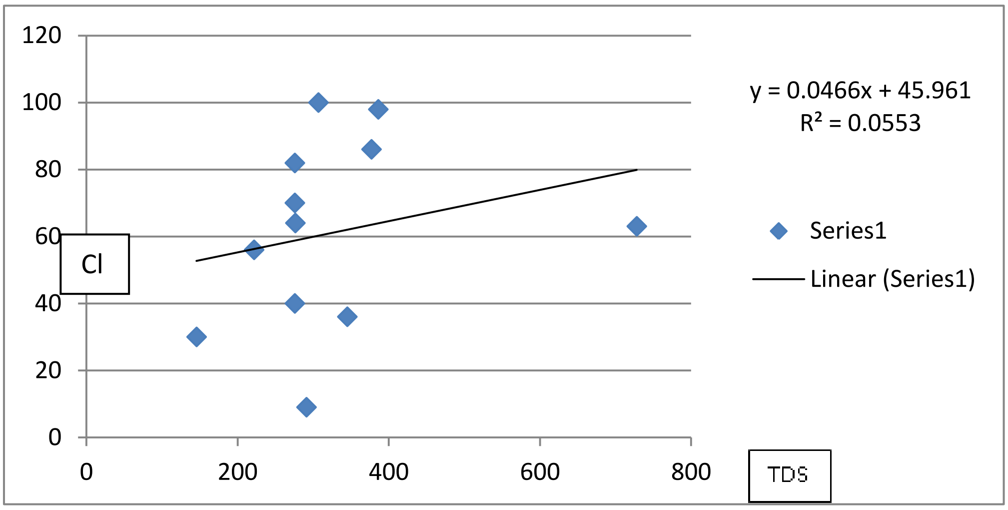

Figure 4.4: Correlation between TDS and Cl.

4.2.2 Correlation between TDS and Mg:

Magnesium is an essential mineral. However, having too much magnesium in the blood can be dangerous.

Referring to the results all the sampling values did not exceed the permissible limit of WHO standards.

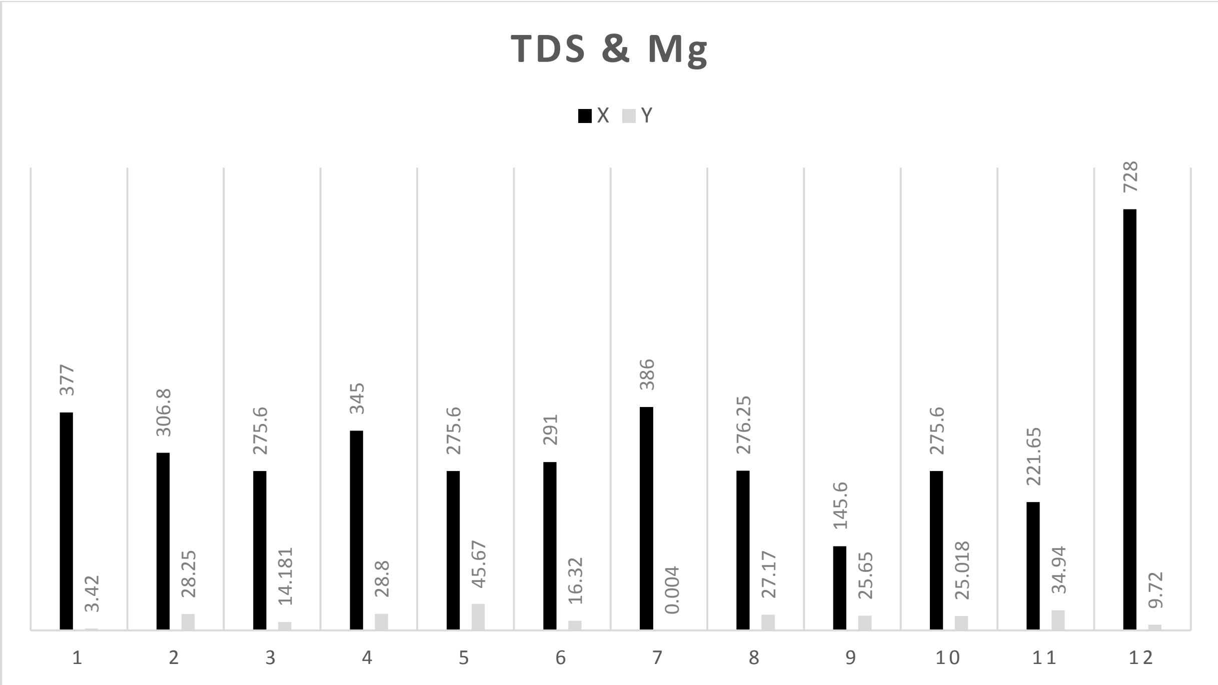

Figure 4.5: Data Analysis results of TDS and Mg.

Table: (4.6) Results of correlation between TDS and Magnesium analysis.

TDS = X mg/l
Magnesium =Y mg/l

	X	Y	XY	X^2	Y^2		
	377	3.42	1289.34	142129	11.6964		
	306.8	28.25	8667.1	94126.24	798.0625		
	275.6	14.181	3908.2836	75955.36	201.10076		
	345	28.8	9936	119025	829.44	mean x	325.3417
	275.6	45.67	12586.652	75955.36	2085.7489	mean y	21.59525
	291	16.32	4749.12	84681	266.3424	SS xy	-10216.1
	386	0.004	1.544	148996	0.000016	SS xx	223283.1
	276.25	27.17	7505.7125	76314.063	738.2089	SS yy	1933.447
	145.6	25.65	3734.64	21199.36	657.9225	b	-0.04575
	275.6	25.018	6894.9608	75955.36	625.90032	a	36.48087
	221.65	34.94	7744.451	49128.723	1220.8036	r^2	0.241756
	728	9.72	7076.16	529984	94.4784	r	-0.49169
SUM	3904.1	259.143	74093.964	1493449.5	7529.7047		

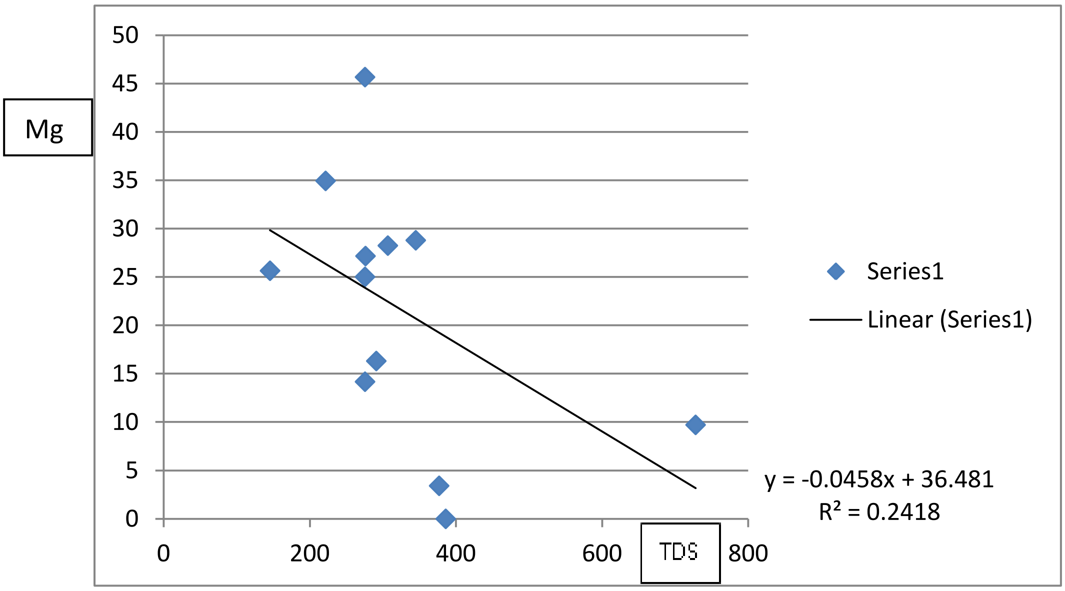

Figure 4.6: TDS and Mg correlation.

4.2.3 Correlation between TDS and Ca:

Calcium concentration varied in the range of 18.4 mg/l to 68.39 mg/l. Calcium is a major element responsible for water hardness. Natural water sources typically contained concentrations of up to 10 mg/l of Calcium.

The obtained results from Calcium test show that all samples within the recommended range according to WHO standards.

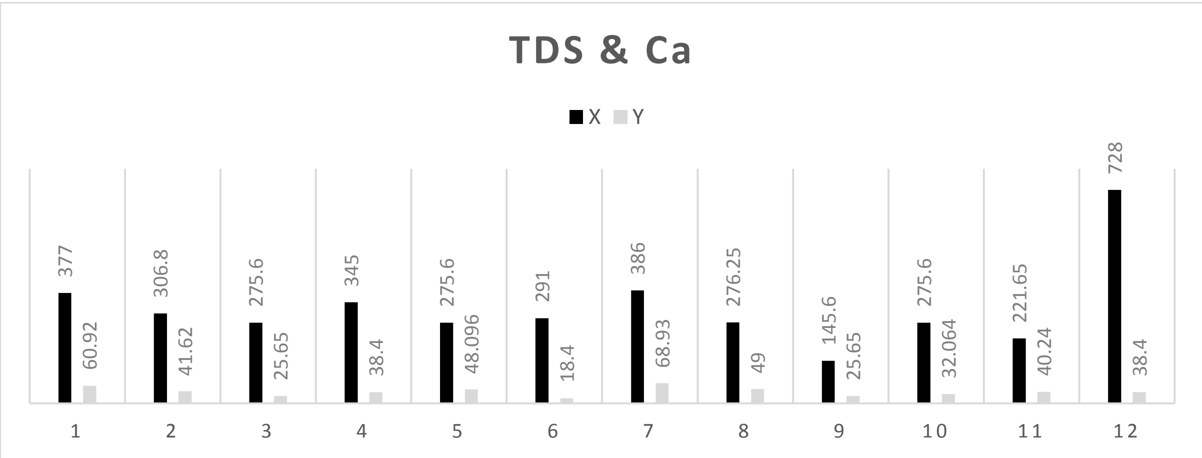

Figure 4.7: Data Analysis results of TDS and Ca.

Table: (4.7) Results of correlation between TDS and Calcium analysis.

TDS = X mg/l
Calcium =Y mg/l

	X	Y	XY	X^2	Y^2		
	377	60.92	22966.84	142129	3711.2464		
	306.8	41.62	12769.016	94126.24	1732.2244		
	275.6	25.65	7069.14	75955.36	657.9225		
	345	38.4	13248	119025	1474.56	mean x	325.3417
	275.6	48.096	13255.258	75955.36	2313.2252	mean y	40.61417
	291	18.4	5354.4	84681	338.56	SS xy	5689.99
	386	68.93	26606.98	148996	4751.3449	SS xx	223283.1
	276.25	49	13536.25	76314.063	2401	SS yy	2365.797
	145.6	25.65	3734.64	21199.36	657.9225	b	0.025483
	275.6	32.064	8836.8384	75955.36	1028.1001	a	32.32339
	221.65	40.24	8919.196	49128.723	1619.2576	r^2	0.06129
	728	38.4	27955.2	529984	1474.56	r	0.247568
SUM	3904.1	487.37	164251.76	1493449.5	22159.924		

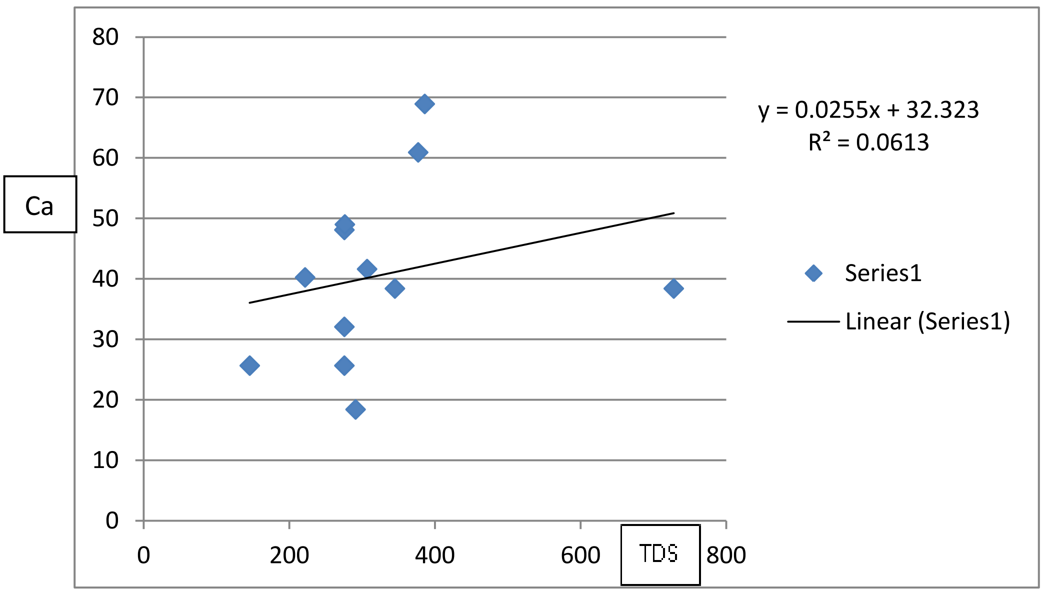

Figure 4.8: TDS and Ca correlation.

4.2.4 Correlation between TDS and K:

The highest level of Potassium found at GW3 with 12.81 mg/l, whereas the lowest value found to be 0.1 mg/l at Tap5.

The mean value of potassium concentration is 4.776 mg/l. With the exception of station GW3 which is exceed the limit of WHO, But all the remaining values of potassium concentrations are within the standard limit of WHO and SSMO (12 mg/l).

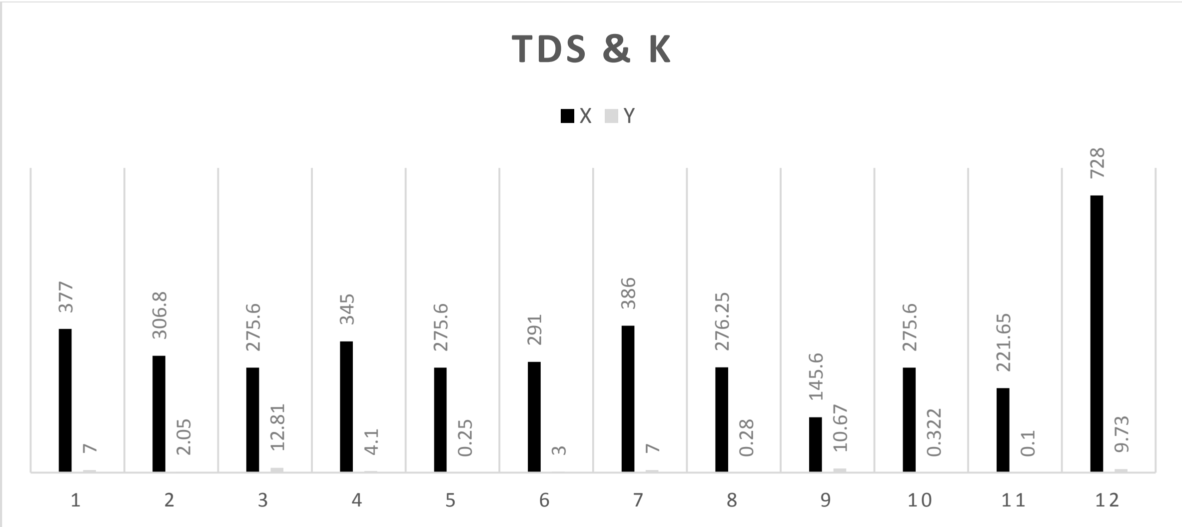

Figure 4.9: Data Analysis results of TDS and K.

Table: (4.8) Results of correlation between TDS and Potassium analysis.

TDS = X mg/l
Potassium =Y mg/l

	X	Y	XY	X^2	Y^2		
	377	7	2639	142129	49		
	306.8	2.05	628.94	94126.24	4.2025		
	275.6	12.81	3530.436	75955.36	164.0961		
	345	4.1	1414.5	119025	16.81	mean x	325.3417
	275.6	0.25	68.9	75955.36	0.0625	mean y	4.776
	291	3	873	84681	9	SS xy	2036.045
	386	7	2702	148996	49	SS xx	223283.1
	276.25	0.28	77.35	76314.063	0.0784	SS yy	227.1629
	145.6	10.67	1553.552	21199.36	113.8489	b	0.009119
	275.6	0.322	88.7432	75955.36	0.103684	a	1.809317
	221.65	0.1	22.165	49128.723	0.01	r^2	0.08173
	728	9.73	7083.44	529984	94.6729	r	0.285885
SUM	3904.1	57.312	20682.026	1493449.5	500.88498		

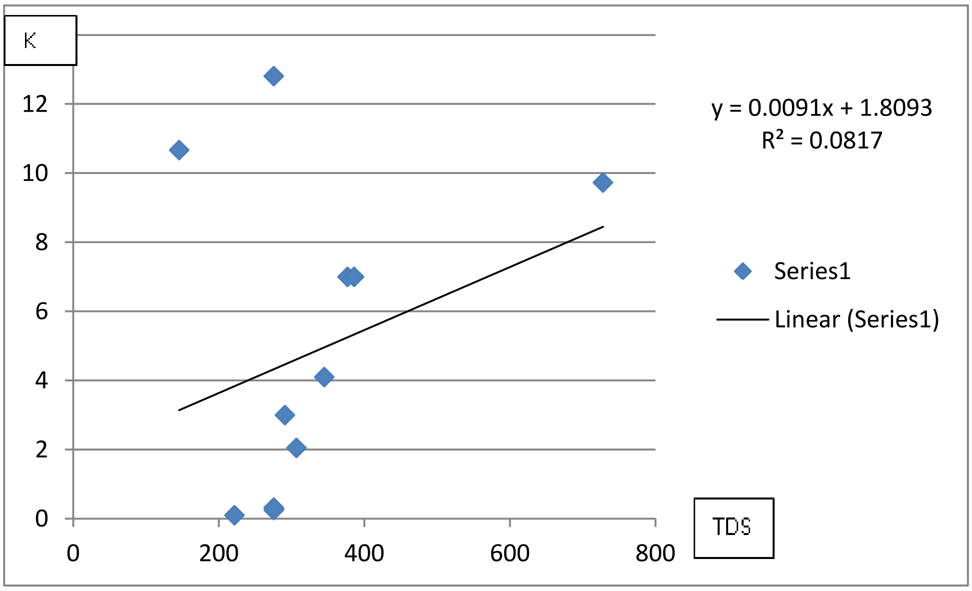

Figure 4.10: TDS and K correlation.

4.2.5 Correlation between TDS and Na:

Regarding to the WHO standards Sodium concentration should not exceed 20 mg/l.

It is found that a significant positive correlation holds for TDS with Na (r =0.883), this tend to a high correlation between Sodium and TDS.

The amount of sodium recorded in ranges between 1.1 to 190 mg/l.

Six sampling points showed higher Sodium values than the prescribed limit by WHO recorded at GW1, GW3, GW6, Tap1, Tap5 and Tap6 with values 75.45, 38, 41.5, 75.45 and 63.17 mg/l respectively, While the remaining values within the standard limits.

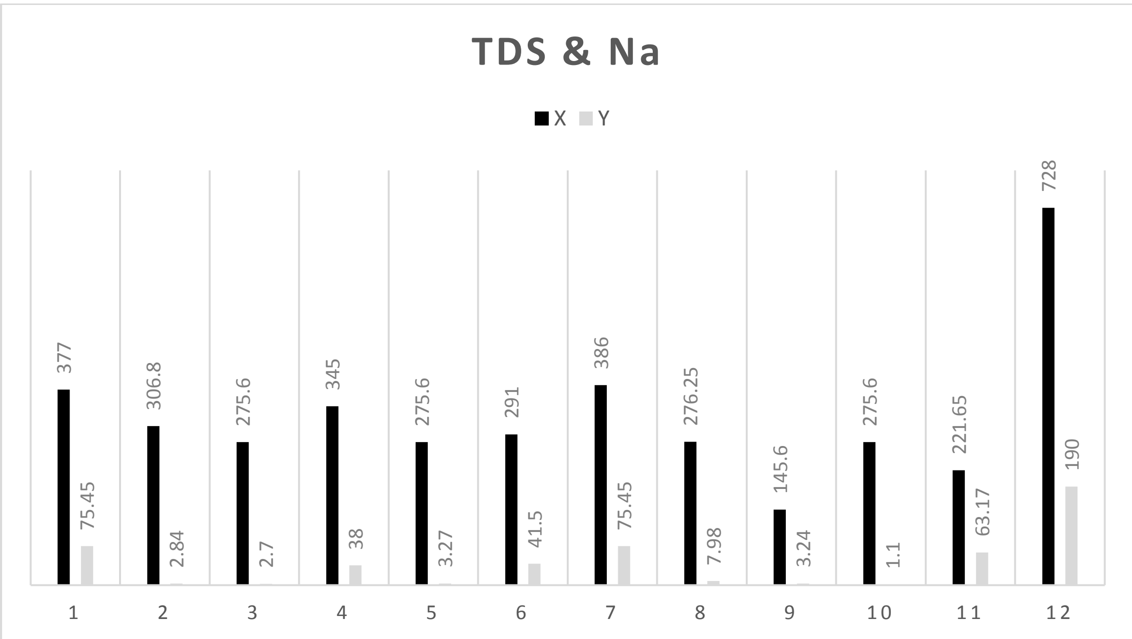

Figure 4.11: Data Analysis results of TDS and Na.

Table: (4.9) Results of correlation between TDS and Sodium analysis.

TDS = X mg/l
Sodium =Y mg/l

	X	Y	XY	X^2	Y^2		
	377	75.45	28444.65	142129	5692.7025		
	306.8	2.84	871.312	94126.24	8.0656		
	275.6	2.7	744.12	75955.36	7.29		
	345	38	13110	119025	1444	mean x	325.3417
	275.6	3.27	901.212	75955.36	10.6929	mean y	42.05833
	291	41.5	12076.5	84681	1722.25	SS xy	76372.56
	386	75.45	29123.7	148996	5692.7025	SS xx	223283.1
	276.25	7.98	2204.475	76314.063	63.6804	SS yy	33516.7
	145.6	3.24	471.744	21199.36	10.4976	b	0.342044
	275.6	1.1	303.16	75955.36	1.21	a	-69.2227
	221.65	63.17	14001.631	49128.723	3990.4489	r^2	0.779395
	728	190	138320	529984	36100	r	0.882834
SUM	3904.1	504.7	240572.5	1493449.5	54743.54		

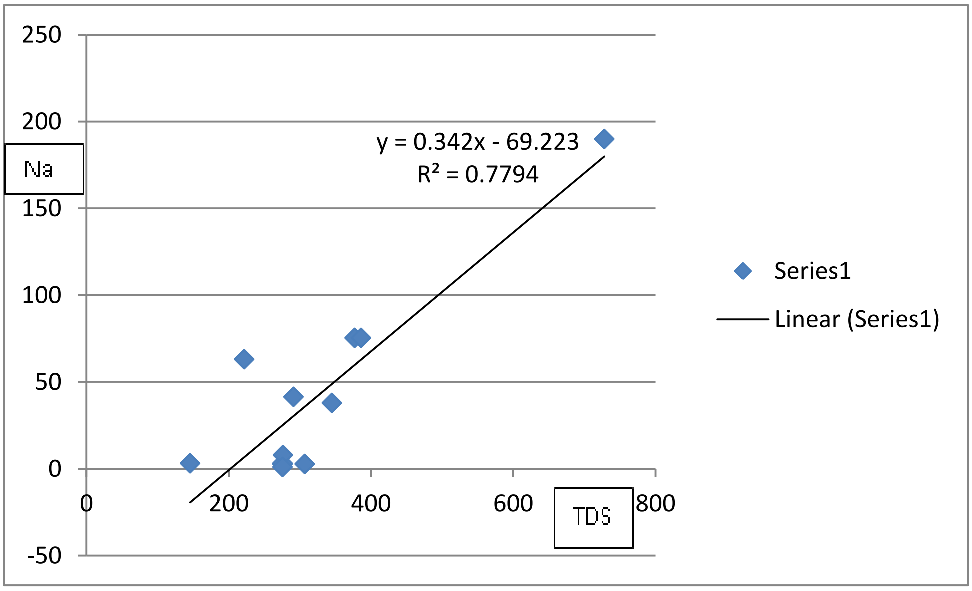

Figure 4.12: TDS and Na correlation.

3. Electric Conductivity:

Table: (4.10) Results of E.C analysis.

E.C (*µS/cm*)					
G.W1	**G.W2**	**G.W3**	**G.W4**	**G.W5**	**G.W6**
760	472	424	**628**	424	451
Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**
776	425	224	424	341	**1040**

Electrical conductivity (EC) of water is a direct function of its total dissolved salts. A relationship between electrical conductivity and total dissolved solids made by using linear regression, and the correlation R^2 = 0.89. Ions from TDS in water to conduct an electrical current, so electrical conductivity can be used to estimate TDS. Conductivity value in the studied area varied between 224-1040 at Tap 3 and Tap 6 respectively. Four obtained result with values 760, 628, 776, 1040 µS/cm at GW1, GW4, Tap 1, and Tap 6 showed higher conductivity than the prescribed limit by WHO, this indicates the presence of high amount of inorganic substances in ionized form, Whereas the remaining value within the range by WHO.

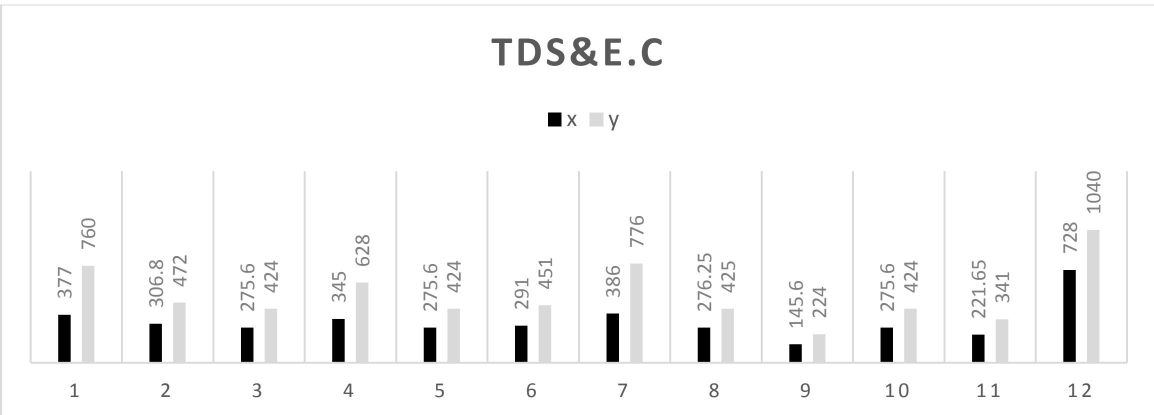

Figure 4.13: Data Analysis results of TDS and EC.

Table: (4.11) Results of correlation between TDS and EC analysis.

TDS = X mg/l
EC =Y µS/cm

	X	Y	XY	X^2	Y^2
	377	760	286520	142129	577600
	306.8	472	144809.6	94126.24	222784
	275.6	424	116854.4	75955.36	179776
	345	628	216660	119025	394384
	275.6	424	116854.4	75955.36	179776
	291	451	131241	84681	203401
	386	776	299536	148996	602176
	276.25	425	117406.25	76314.063	180625
	145.6	224	32614.4	21199.36	50176
	275.6	424	116854.4	75955.36	179776
	221.65	341	75582.65	49128.723	116281
	728	1040	757120	529984	1081600
SUM	3904.1	6389	2412053.1	1493449.5	3968355

mean x	325.3417
mean y	532.4167
SS xy	333445.2
SS xx	223283.1
SS yy	566744.9
b	1.493374
a	46.55978
r^2	0.878629
r	0.937352

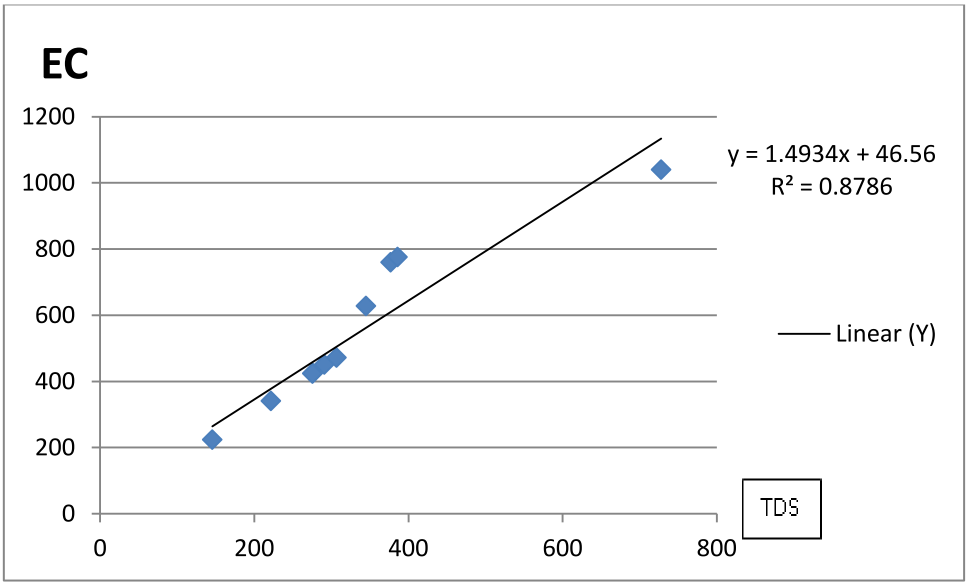

Figure 4.14: TDS and EC correlation.

4. Total Hardness:

Table: (4.12) Results of T.H analysis.

T.H (mg/l)					
G.W1	**G.W2**	**G.W3**	**G.W4**	**G.W5**	**G.W6**
215	172	84	216	236	262
Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**
200	164	188	135	184	136

The mean value of total hardness for studied samples was 182.7 mg/l and varies from 84-262 mg/l at GW3 and GW6 respectively. The hardness of water is mainly due to inorganic compounds such as carbonate, bicarbonate and sulphate of calcium and magnesium.

All results of hardness revealed the results within acceptable limit according to the WHO standards.

On the basis level of hardness, samples were classified into four categories: Soft from 0-60 ppm, Moderate from 61-120 ppm, Hard from 121-180 ppm and Very hard >180 ppm. Among the studied samples 8.34% moderate, 33.33% hard, 58.33 % very hard.

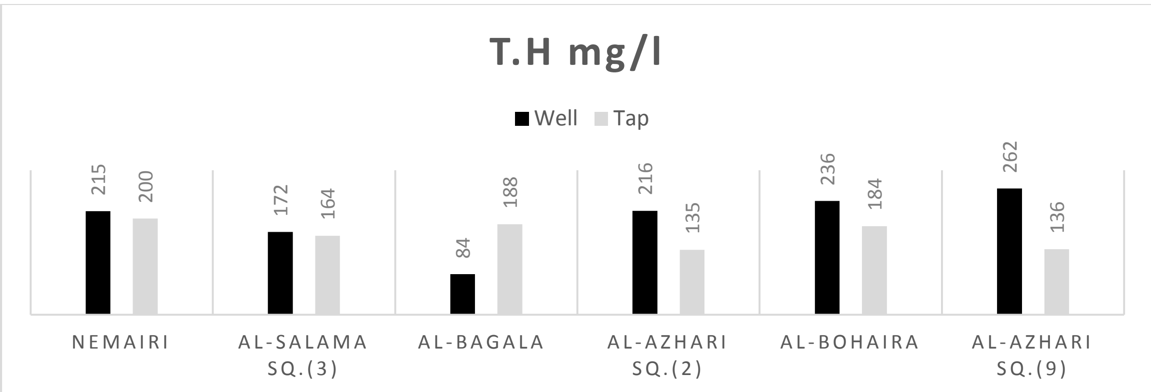

Figure 4.15: T.H of ground water and tap water.

5. **Total Alkalinity:**

Table: (4.13) Results of Alkalinity analysis.

T.A (mg/l)					
G.W1	**G.W2**	**G.W3**	**G.W4**	**G.W5**	**G.W6**
190	358.87	336.12	196	**576.2**	176
Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**
185	54	278.88	20	164.88	439.2

Alkalinity values in the studied area varied between 20-576.2 mg/l.

Total alkalinity found within the range assigned by SSMO. But for the WHO standards just one sample showed higher total alkalinity value which is 576.2 mg/l at G.W5.Drinking water with a high amount of alkalinity results unpleasant taste to water.

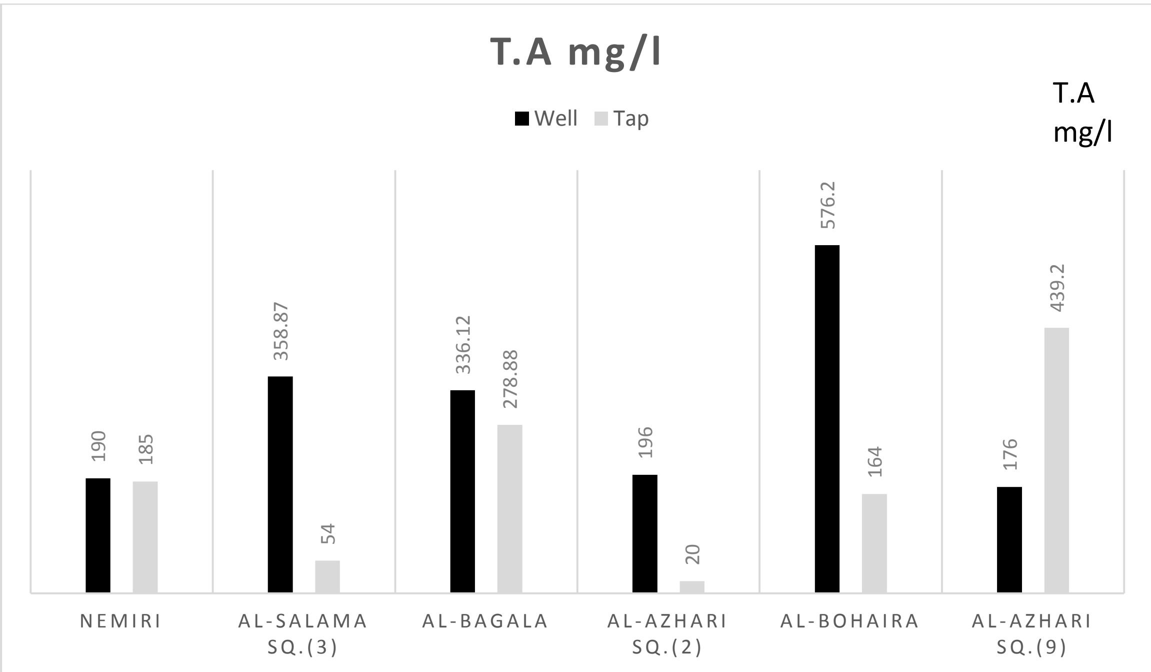

Figure 4.16: T.A of ground water and tap water.

4.3 Bacteriological Results:

Table 4.14: Results of Bacteriological analysis:

Sample Number	Sample Name	E.coli MPN/100 ml
1	Well 1	3
2	Tap 1	3
3	Well 2	0
4	Tap 2	0
5	Well 3	1100
6	Tap 3	1100
7	Well 4	0
8	Tap 4	4
9	Well 5	0
10	Tap 5	460
11	Well 6	0
12	Tap 6	43

It is apparent from table (4.14) that the samples collected from well1, Tap1, well3, Tap3, Tap4, Tap5 and Tap6 are polluted by E.coli. The number detected varied between 3 and 1100 at well and Tap1 and well and Tap 3 respectively. Results obtained for samples collected from well2, Tap2, well4, well5, and well6 indicate the absence of E.coli.

The highest level of E.coli was found at well3 and Tap3 (1100/100 ml) and Tap5 (460/100 ml) presence of high bacterial counts indicate inadequate treatment, post treatment.

The microbiological examination of water in this study showed that the water network distribution system is the source of contamination and contaminated water source. Therefore, everything possible should be done to prevent pollution of the drinking water, although well1, tap1, tap4 and tap6 showed less number of bacteria (3-43 /100 ml) but same attention should be taken to prevent bacteriological pollution.

Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

5.1 Conclusions:

This study based on experimental work to assess water quality of Al-Azhari city, the important findings of the study are summarised below:

All samples collected from households were found faecal contaminated, about 33% of the samples collected from the source were found were contaminated.

Physical and chemical parameters concentrations were mostly found within permissible limits according to SSMO.

A significant positive correlation was found between total dissolved solids with Sodium (R=0.88) and electric conductivity versus total dissolved solids (R=0.93).

5.2 Recommendations:

1. Detailed studies should be undertaken along the distribution lines strains from the source to the households to find out the actual points of contamination and their sources in the distribution networks.
2. Before a new source of drinking water supply is selected, it is important to ensure that the quality of the water satisfactory for drinking.
3. The old pipelines of the network must be replaced by a new one.
4. Adequate treatment by chloride to prevent contamination by microorganisms along the distribution system.
5. Sources of ground water wells should be sited a constructed so as to be protected and to prevent public access and animals.
6. The statistical tools developed, for further studies required to be extended to larger areas covering several water resources and proposing water

quality models. in addition to study remaining parameters that have an effect in water quality.

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Appendices

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WATER IS LIFE people are sharers of water

كرسي اليونسكو للمياه الماء هو الحياه الناس شركاء في الماء

Water Quality Lab

Date: 16/5/2018
Sampler: نادية بدرالدين عثمان
Location:(شبكة (منطقة الأزهرى

Parameter	Results	Units
T. Hardness	172	ppm
Calcium	68.93	ppm
Magnesium	0.004	ppm
T. Alkalinity	256.2	ppm
Ph.ph- Alkalinity	0	ppm
Chloride	97.9	ppm
Sodium	75.45	ppm
Potassium	7	ppm

Comments: All parameters are within the permissible limits of the Sudanese drinking water specification.

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WATER IS LIFE people are sharers of water

كرسي اليونسكو للمياه الماء هو الحياه الناس شركاء في الماء

Water Quality Lab

Date: 16/5/2018

Sampler: نادية بدرالدين عثمان

Location:(بئر (النيميرى

Parameter	Results	Units
T. Hardness	166	ppm
Calcium	60.92	ppm
Magnesium	3.42	ppm
T. Alkalinity	173.24	ppm
Ph.ph- Alkalinity	0	ppm
Chloride	85.97	ppm
Sodium	75.45	ppm
Potassium	7	ppm

Comments: All parameters are within the permissible limits of the Sudanese drinking water specification.

كرسي اليونسكو للمياه UCWR UNESCO Chair In Water Resources

مقدمــــة

الهيئة السودانية للمواصفات والمقاييس، هيئة علمية رقابية من مهامها إعداد المواصفات الوطنية بواسطة لجان فنية سودانية متخصصة بالتعاون مع الجهات ذات الصلة.

تم إعداد هذه المواصفة من قبل الهيئة السودانية للمواصفات والمقاييس ضمن برنامج عمل اللجنة الفنية للمياه والمشروبات.

الإدارة العامة للمواصفات القياسية

4. محتوى الأحياء المجهرية والحيوية

Organisms	Guideline Value
1. All water intended for drinking A/ E. coli or thermotolerant coliform bacteria B/ Pathogenic intestinal protozoa	Must not be detectable in any 100-ml sample
2. Treated water entering the distribution system. A/ E. coli or thermotolerant coliform bacteria B/ Total coliform bacteria C/ Pathogenic intestinal protozoa	Must not be detectable in any 100-ml sample
3. Treated water in the distribution system A/ E. coli or thermotolerant coliform bacteria	Must not be detectable in any 100-ml sample
B/ Total coliform	Must not be detectable in any 100-ml sample. In the case of large supplies where sufficient samples are examined, must not by detectable in 95% of samples examined throughout any consecutive 12 months period.
C/ Pathogenic intestinal protozoa	Must not be detectable in any 100-ml sample.

وزارة مجلس الوزراء
الهيئة السودانية للمواصفات والمقاييس
ادارة المواصفات القياسية

9. الحد الأقصى المسموح به للمواد المختلفة التي قد تؤثر على قبول المستهلك للماء.

Parameter	Levels Likely to Give Rise to Consumer Complaints
Physical Parameters:	
Colour	15 TCU
Taste & Odour	Acceptable
Temperature	Acceptable
Turbidity	5 NTU
pH	6.5 – 8.5
Inorganic Constituents:	
Aluminium	0.13 mg/l
Ammonia	1.5 mg/l
Chloride	250 mg/l
Hydrogen sulphide	0.05 mg/l
Iron (total)	0.3 mg/l
Manganese	0.27 mg/l
Sodium	250 mg/l
Sulfate	250 mg/l
Total Dissolved Solids (TDS)	1000 mg/l
Zinc	3 mg/l
Organic Constituents.	
2-Chlorophenol	5 μg/l
2,4- Dichlorophenol	2 μg/l