

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

**EVALUATION OF DRINKING WATER QUALITY  
FROM SURFACE AND GROUND RESOURCES IN  
GEZIRA STATE**

By

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# DEDICATION

*To :-*

*Soul of my father,*

*My mother,*

*My sisters,*

*My brothers*

*and*

*My friends*

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Great thanks and gratitude to Allah for assistance to complete this work.

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# **Evaluation of Drinking Water Quality from Surface and Ground Resources in Gezira State**

M.Sc. Dissertation

By

Hagar Khidir Elbakri

**Abstract:** The objective of this study was to investigate the physical, chemical and bacteriological parameters of six water samples collected from two resources: ground water and surface water, both being used for human consumption. The ground water samples were collected from the center of Gezira State (Elamara and Tabat water station) and from northern Gezira State (Elhasahisa water station), while the surface water samples were collected from Raselphil water station, 24 Elgorshi and 21 Elmancy water station in western Gezira State.

The samples were subjected to physical, chemical and microbial examination. The main investigated parameters were, total dissolved solid and heavy metals, PH, turbidity, electrical conductivity, total hardness, alkalinity, and total viable count of microbial load. The results were compared with international drinking water specification guidelines to evaluate the quality of drinking water in the Gezira State. The turbidity level in ground water ranged from 0.3 to 0.95 NTU, while that in surface water ranged from 5.5to 197 NTU, thus being higher than the maximum acceptable level stated by WHO standard as 5NTU. The levels of alkalinity, and total dissolved solids and hardness in samples from ground water were lower than the maximum levels accepted for drinking water as recommended by WHO and SSMO (Sudanese Standard Metrology Organization) specifications. However, sodium in Elamara water station and water hardness in Tabat water station as magnesium carbonates levels were higher than the values accepted by WHO .On the other hand , alkalinity levels of surface water, total hardness and total dissolved solids

were lower than the values accepted by WHO. Ammonia content in all samples from the two sources of water ranged from 2.1 to 3.3 mg/L which were higher than the maximum values (1.5 mg/L) of WHO. For micro-elements, manganese was lower than the maximum levels accepted by SSMO standards 0.5 mg/L. Zinc ranged from 0.0014 to 0.02 mg/L in ground water, while surface water was free of zinc. Copper was higher in surface water than in ground water. The levels of cadmium and Lead were found in ground water, while surface water was free of lead. The study revealed that the drinking water samples were polluted by coliform bacteria "*Escherichia coli*" except ground water from Elhasahisa which was free of coliform bacteria. The Physical examination of drinking water gave low values of pH, electrical conductivity and turbidity in both ground and surface water compared with SSMO standards. But surface water were higher in turbidity. The chemical parameters were lower in surface water than ground water.

Generally the water collected from the different sources at the Gezira state need more treatment to improve the drinking water quality especially for their microbial load.

## تقييم جودة مياه الشرب من الموارد السطحية و الجوفية في ولاية الجزيرة

### أطروحة ماجستير

#### بواسطة: هاجر خضر البكرى

**المستخلص:** الهدف من هذه الدراسة التي اجريت على 6 عينات من مياه الشرب للتحقيق في العناصر الفيزيائية والكيميائية والميكروبيولوجية للتأكد من صلاحية المياه للإستهلاك الأدمي .

وقد جمعت عينات المياه من مصدرين مياه جوفية ومياه سطحية وهما يستخدمان للشرب ، المياه الجوفية جمعت من وسط الجزيرة من محطة العمارة وطابت الشيخ عبدالمحمود و أخرى من شمال الجزيرة من محطة الحصاصي ، بينما المياه السطحية جمعت من محطة رأس الفيل و 24 القرشي و 21 المنسي بمنطقة غرب الجزيرة .

العينات عرضت للإختبارات الفيزيائية والكيميائية والميكروبيولوجية والعناصر الأساسية التي تم تحليلها تشمل الأملاح وبعض العناصر الثقيلة والعكارة والتوصيل الكهربائي وعسر الماء والعد الكلي الحيوي للميكروبات .

تمت مقارنة النتائج المتحصل عليها للمقاييس العالمية والمحلية لتقييم صلاحية مياه الشرب في ولاية الجزيرة .

مستوى العكارة في المياه الجوفية يتراوح بين 0.3 – 0.95 NTU ، بينما في المياه السطحية يتراوح بين 5.5-197 NTU لذلك تعتبر أعلى من الحد المسموح به بواسطة هيئة الصحة العالمية كذلك مستوى القاعدية والأملاح الذائبة فهو في المياه الجوفية أقل من الحد الموصى به ولكن تركيز الصوديوم في محطة العمارة وعسر الماء في محطة طابت المتمثل في شكل كربونات الماغنيزيوم فقد وجد أعلى من الحد الموصى به .محتوى الأمونيافي كل العينات يتراوح بين 2.1 – 3.3 mg/L أما العناصر الصغرى مثل المنجنيز فهو أقل من أقصى حد موصى به من هيئة المواصفات والمقاييس السودانية ، أما الزنك فقد انعدم في المياه السطحية و النحاس فهو بنسب أعلى في المياه السطحية مقارنة بالمياه الجوفية . أما الكاديوم والرصاص فقد وجد بنسب أعلى في المياه الجوفية مقارنة بأقصى حد مسموح به بينما انعدم في المياه السطحية.

أظهرت الدراسة أيضا أن مياه الشرب ملوثة ببكتريا القولون "*Escherichia coli*" ما عدا محطة مياه الحصاصي فهي خالية من البكتيريا، الاختبارات الفيزيائية أعطت مستويات أدنى في كل من pH والتوصيل الكهربائي لكن المياه السطحية أعطت نسبة عكارة عالية . العناصر الكيميائية أقل في المياه السطحية عنها في المياه الجوفية .

عموما مياه الشرب في ولاية الجزيرة تحتاج إلى معالجة حتى يتم تحسين جودتها خصوصا من الناحية الميكروبيولوجية .

# **CHAPTER ONE**

## **INTRODUCTION**

Water is one of the world most important natural resources and essential in maintainings human plant and animal life .It has a great influence on a nation's economy and it is vital to life and to all human activities .For the past twenty years growing pressure on water resources due to population growth and industrial, agricultural and domestic demand has been a major concern for the international community.

The human searches for pure water supplies have begun in pre historic time. 20% of the worlds population does not have access to clean water half of this don't have adequate means of water purification. Pollution from water contamination and the lack of appropriate water processing facilities lead to loss of human life annually (Chad, 2000).

It has been estimated that over 90% of deaths from the developing world to day occur in children under 5years old is caused by inadequate supplies of safe water and inadequate sanitation facilities and lack of hygiene behavior by the mother (WHO, 2005).

The WHO reported that thousands of organic and inorganic chemicals have been identified in drinking water supplies around the world, many are in extremely low in concentration, the chemicals selected include those considered potentially hazard to human health (WHO, 1993).

The levels of these chemicals in drinking water however are seldom high enough to cause acute health effects but tend to cause chronic health effects that occur after exposure to small amount of chemical over along period .Examples of these effects include cancer, birth defects, disorders of the nervous system and damage to the immune system .The problem of

supplying adequate amount of safe water for distribution to the public doesn't end with the construction of water works.

Another important disease which effect human health is caused by the water –borne or water associated diseases including typhoid, cholera and amoebic dysenteries and many varieties of gastrointestinal diseases and these are responsible for the loss of productivity and deaths of people in the developing world (WHO, 1976).

For many years the Sudanese people did not pay much attention to water pollution problems but today the population is aware of the importance of good water quality and its relation to health.

Previous studies in Sudan have only dealt with certain aspects of water pollution problems .Detailed considerations have come to light as a result of the work done by Dirar (1986) and Abdel magid et al (1984) on the pollution of water from the Nile and from wells in Khartoum area.

In the Gezira scheme the water system provides the population with ground water of different qualities from different depths other source is surface water from Blue Nile used for irrigation scheme. In recent years man has become increasingly carefully and look critically to the environmental pollution by chemicals during application in the fields, therefore it is expected to be contaminated with chemicals and it may cause health problems such as toxicity and some diseases.

This study aims to investigate the quality of the drinking water of some parts of Gezira State at different locations to investigate the physical, chemical and bacteriological parameters of drinking water. And to determine the concentration of some trace elements in drinking water in different areas.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2-1 Importance of water:-**

Water is the most important liquid found on earth and is substance most familiar to man. It is vital for sustaining all life and for economic and social development, including energy production, agriculture, industry and domestic water supplies.

Water is considered an economically water should be used efficiently, equitably and soundly (UNESCO,1997).Perhaps the most unique characteristic of water is that it occurs on earth as solid, liquid and gas within the range of climatic condition commonly encountered .Fresh water the most precious of our planets natural resources is a basic ingredient for supporting all life, therefore its resources must be characterized as finite and irreplaceable although availability of fresh water varies widely with geographic location, earths water cycle is abundant proider (James & lamp,1985) .

WHO (1993) stated that water sources must be protected from contamination by human and animal waste. It's better to protect water from contamination than to treat it after has been contaminated to ensure that the quality of the water is satisfactory for human consumption.

#### **2-2 Water Resources:-**

The most accessible fresh water resources are lakes, rivers and streams. Water changing from a state to another includes sublimation of ice, evaporation of liquid, transportation of moisture by air, rain and oceans. Atlantic , Indian and pacific oceans cover 71% of the earth surface and contain 97% of all water, less than 1% is fresh water and 2-3% is ice and has 20 % of the world fresh water supply (Mark and Benjamin 2002) Addition to (Charles, 1969) classified water source to:

Rain water, surface water and ground water. Rain falls water percolate and infiltrate into the soil and finally reach a level at which all voids of the earth materials are filled with water this zone is known as zone of saturation in which water is referred to as ground water this includes springs and wells.

### **2- 3 Water Resources in Sudan: -**

Although Sudan is the largest country in Africa and lies mostly in the arid region where water is scarce commodity, it is considered to be rich in water resources (Ginawi, 1994). Most of population and the majority of live stock live around the Nile areas the recent drought with civil war have lead to migrations to urban centers resulting in over use of available and limited urban facilities including water and sanitation systems. The available water resources are Nile system, rain water and ground water. The main Nile and its tributaries provide perennial fresh water of good chemical composition.

Only 20 % of the total populations live along the Nile where they make use of its water either by collecting water directly from the Nile or pumped from irrigation canals e.g. New Halfa and Gezira especially the western side where water is treated with slow sand filters and distributed to the house holds. The remaining 80% live away from the Nile depending on the rain water and ground water.

### **2-4 The Study Area:-**

The Gezira Scheme is one of the largest irrigation project in the world. located on the flat plain south of Khartoum between the Blue Nile on the east and the White Nile on the west .Central of the Sudanese state. The Scheme was established in 1925 and the Managil Extension was established in 1957 /58.The area of whole Scheme is 2 -12 million feddans it constitutes 12 % of the total cultivated area and about 50% of the

irrigated area in the Sudan by gravity irrigation and distributes water from blue Nile through the canals and ditches to form the 4300 km canal. The irrigated area covers 8800 km<sup>2</sup>. The main crops grown are cotton, wheat and durra (World Bank, 2000).

In recent years man has become increasingly conscious and critical towards the environmental pollution by chemicals during application of pesticides in the field. The resources of water supply in the villages are variable. The center of Gezira depend on ground water from wells either shallow or deep wells.

WHO(1985) recommended that the depth of well should be at least 30m<sup>3</sup> from any potential sources of contamination and should be located higher than all such sources. The villages in western of the Scheme are depending mostly on surface water as main resources. They obtain water from the irrigation water by canals which distribute water by the net work and this water is unsafe and can spread diseases to human. Tameim et al, (1980) pointed out that the Bilharzias prevalence in the Gezira is about 40% of population where infected people between 10 and 24 years of age and most of them are male because they are most in contact with the infected canal water through their agricultural activities. BNHP (1989) reported that in the whole Gezira and Managil irrigated area there are only a thousand groundwater systems and the water supply sanitation services cover only 60%of the area.

### **2-5 Water Quality: -**

The objective of water quality is to minimize or eliminate contaminants within a watershed basin in the geographic area that drains to the source of water intake (Chauret *et al.*, 1995).

The quality of water defined by the (WHO,1984 ), water must be suitable for human consumption and for all usual domestic purposes including

personal hygiene, however water of higher quality may be required for some special purposes such as renal dialysis .When guideline value is exceeded the cause should be investigated and corrective action be taken. Drinking water therefore concerns both the quantity and quality of the water required to meet the needs of man in an efficient and economical manner (Mahgoub, 1984) .It is necessary to determine the physical, chemical and biological parameters that affect the quality of waters.

## **2 -6 Physical parameters of water:-**

### **2-6 -1 pH:**

pH value represent the concentration of hydrogen ions present in water Mahgoub,(1984) found that the pH value from the three Niles ranged from 7.5 to 8.5 .And pH values for the tap and canal water ranged from 7.9 to 8.8.

### **2- 6 -2 Electrical Conductivity (EC):**

Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions solutions of most inorganic acids, bases and salt are relatively good conductors .EC is measured in micro siemens per centimeter  $\mu\text{s}/\text{c}$  (Abdelmagid *et al.*, 1984) found EC for tap water to be  $0.17 \mu\text{s} / \text{cm}$ .

### **2- 6 -3 Turbidity:**

Suspended matter such as clay, silt finely divided organic and inorganic matter, soluble colored organic compounds and other organisms can cause turbidity in water. Turbidity is an expression of the optical property that causes light to be scattere and absorbed rather than transmitted in straight line. Abdelmagid et al (1984) found that the turbidity of Nile ranged from 0.05 to 0.07 O.D, for wells water it ranged from 0.01 to 0.56 O.D, and for tap water it was 0.01 O.D .Dirar (1986) determined the turbidity of the

water in the Blue Nile and found the optical density was in the range of 0.07 to 0.1 O.D.

## **2-7 Chemical Parameters of Water**

### **2 - 7 -1 Total dissolved solids (TDS):**

TDS have an important effect on the taste of drinking water .According to WHO (1993) the palatability of water with a TDS level of less than 600 mg/L would be considered as good, but drinking water would become increasingly unpalatable at TDS levels greater than 1200mg/L, however water with extremely low concentration of TDS might be unacceptable because of its flat taste.

Nurain (1998) found that the TDS varied widely for well and canal being 174and 495 mg/L respectively.

### **2-7 -2 Hardness:-**

Water hardness which is property of water that prevent lather formation when mixed with soap caused by calcium and magnesium carbonate McCarty *et al.*, (1985) reported that some hardness could also be precipitated by boiling and would form the scale usually inside kettle and utensils. The precipitate formed by heating could be due to temporary or carbonate hardness and would consist of the bicarbonates of calcium and magnesium. Permanent or non carbonate hardness would not be precipitated by heating and was found to be due to other salts than calcium and magnesium which present in the water usually in lesser quantities than the bicarbonates. The degree of hardness in drinking water has been classified in terms of equivalent calcium carbonate as soft hardness 0 – 50 mg/L, moderately soft 50 – 100 mg/L, slightly hard 100 – 150 mg/L, moderately hard 150 – 200 mg/L and hard over 200 mg/L. The WHO guide lines (1997) suggested a maximum desirable concentration for total hardness of 500 mg/L as CaCO<sub>3</sub>.

### **2-7 -3 Calcium:-**

Calcium is found in most waters and the level was found to depend on the type of rock through which the water has passed. Nurrain (1998) found that the calcium level of water from well, canal and tap water were 19.7, 18.1 and 24 mg/L respectively.

### **2-7-4 Magnesium:-**

Magnesium is an essential trace element with an estimated daily nutritional requirement of 30 - 50  $\mu\text{g/Kg}$  body weight .The concentration below 0.1 mg/L are usually acceptable to consumer as reported by WHO (1993 ) .

### **2 -7 -5 Alkalinity: -**

Alkalinity is referred to as amount of buffering material in water. If a body of water had an abundance of buffering material (high alkalinity) it would be more stable and resistant to changes in pH. If a body of water had very little buffering material (low alkalinity) it would be susceptible to changes in pH .As increasing amounts of acids were added to ponds and lakes their buffering capacity would be consumed. If surrounding soils and rocks supplied additional buffering material the alkalinity could be eventually restored (Edmunds *et al.*, 1992).

### **2 -7 -6 Sodium: -**

The concentration of sodium in potable water were stated to be typically less than 20 mg/ L, however they could greatly exceed that value in some countries .According to WHO (1993) no firm conclusion could be drawn concerning the possible association between sodium in drinking water and the occurrence of hypertension therefore no health based guide line value were proposed.

### **2 -7 -7 Potassium:**

Although potassium was known as abundant element the concentration found in most natural waters would rarely exceed 20 mg /L as reported by (McCarty *et al*; 1985).

#### **2 -7 -8 Chloride: -**

WHO (1986) reported that chloride content in water is an indicator of sewage pollution. The permissible level is 200 mg /L to 600 mg /L that are unlikely to be harmful to consumer health. Excessive chloride concentration increase rates of corrosion of metals in the distribution system depending on the alkalinity of the water this can lead to increased concentration of metals in the supply and give rise to detectable taste in water. Nurrain (1998) found that the amount of chloride in canal and well water is 9.8 and 120 mg/L respectively.

#### **2 -7-9 Fluoride: -**

It is known to prevent or reduce dental decay and strengthen bones thus preventing bone fracture in old people .Where the fluoride level is low studies have shown higher levels of both tooth decay and fractures as reported by (WHO& UNICEF, 2005 ). Fluoride is added to water during treatment in some areas with low levels but in the case of high levels of fluoride in water above 1.5 mg /L and for long term it was found to have negative effects like in Tanzania more than 95 mg/L where the rocks are rich in fluoride containing minerals and in the Karibi where excessive fluoride levels in ground water caused many people to be crippled for life and the victims suffered from severe anemia -stiff joints, painful and restricted movement, mottled teeth and kidney failure .

#### **2 -7 -10 Ammonia:-**

Ammonia includes the non-ionized  $\text{NH}_3$  and ionized  $\text{NH}_4$  .Natural levels in ground and surface waters were usually below 0.2mg /L. Intensive rearing of farm animals could give rise to much higher levels in surface

water ammonia. Also higher levels could be an indicator of possible bacterial sewage and animal waste pollution. Nurrain (1998) found that the amount of ammonia in canal water was 1.2 mg/L and well water was 0.5 mg/L in the Gezira area

#### **2 -7- 11 Nitrate: -**

It could be formed due to ammonia oxidation. Also the use of nitrogenous fertilizers on the land could give rise to increased nitrate concentration in both surface and ground water. The guide line value pointed out by WHO (1986) is 50 mg/L while Abel Magid and Elhassan (1986) stated that the acceptable level was 45 mg/L and at higher concentration a health hazard particularly on children might occur for e.g. Blue Babies disease.

#### **2 -7 -12 Sulfates: -**

The presence of sulfate in drinking water could cause undesirable taste in water. The higher levels were usually occurring in ground water. It is generally considered that taste impairment is minimal at levels below 250 mg/L (WHO, 1993).

#### **2 -7 -13 Iron: -**

Iron is an essential element in human nutrition and the minimum daily requirement for human depend on age, sex and physiological status yet the range is 10-50mg/day. JECFA established provisional maximum tolerable daily intake (PMTDI) of 0.8 mg /kg of body weight. Iron would change the color of water to yellow or brown causing staining of plumbing fixtures and laundry. It could hence cause bacteria growth and the growth of microorganisms may clog the distribution system (WHO, 1971).

#### **2 - 7 -14 Trace elements:-**

Vanloon (1977) reported that some of the trace elements are essential for living organisms which need them in very small amounts. When they exceeded the need of the organism they would become toxic and hence

hazardous. The trace elements are essential for the growth of plants, so they could reach man directly through eating plants or indirectly from meat or milk and also through water or air. These trace elements might be increased due to disposal of waste water and contaminated drinking water e.g.

#### **2 -7 -14-1 Manganese:**

Occurs in many rocks and found in natural water. The major sources of man made environmental pollution by manganese are in the iron production and use of fertilizers. It is essential for animals and man for the formation of connective tissue and bone. The average manganese levels in drinking water were in the range of 5 to 25 µg /L (IPCS, 17) the deficiency of manganese is with association with vitamin K deficiency. Elhag (2004) found that the amount of manganese in Gezira well water range from 0.034 to 0.216 mg/L.

#### **2 -7 -14-2 Zinc:-**

Zinc ions are rarely present in natural water but might enter the water at consumer's taps as a result of corrosion of galvanized iron piping or tanks. The concentration usually found in drinking water would unlikely to be detrimental to health (McCarty *et al.*, 1985). Excess in zinc could give rise to undesirable taste. The UK standard recommendet maximum of 5000 µg/L at the consumer's tap water. Elhag (2004) found that the amount of zinc in well water was in the range 0.012 to 0.17 mg/L.

#### **2 -7 -14-3 Copper: -**

Harvey (1963) reported that copper might occur in most natural waters generally at concentration below 20.0 µg /L. Sea water copper level vary from 1.0 to 25.0 µg /L. Copper would contaminate drinking water as a corrosion by-product of copper pipes that remain in contact with water for

a prolonged period .High doses were shown to cause liver and kidney damage.

#### **2 -7 -14-4 Lead: -**

Lead could enter drinking water from the corrosion of pipes distribution systems. Accumulative poison and hazard of exposure to lead reported by (FWPCA, 1968).Alhag (2004) found that the amount of lead in tap water was in the range 0.004 to 0.016mg/L.

#### **2-7 -14-5 Cadmium:-**

Cadmium could be released to the environment in the waste water, also might cause pollution by contamination from fertilizers(Sharrett *et al.*,1982 ) reported that the levels of cadmium in drinking water should be less than 1.0µg /L and found that the medium level in tap water was 0.01µg /L .

#### **2- 8 Biological parameters of water quality: -**

The microbiological examination of water is necessary to disclose the presence of microorganisms that might constitute a health hazard. In report for WHO(1993) water was examined for specific types of bacteria which originate in large numbers from human and animals excreta and whose presence is an indicator of fecal contamination or fecal coli form .

#### **2 -8-1 Bacteria as an indicator of water sanitary quality: -**

Water supply could be subjected for contamination with sewage or pollution by the excreta of man or animals, thus it should be assumed that the water might also contain pathogenic bacteria and therefore be regarded as unsuitable for supply purpose (Brandt *et al*, 2000).Coli forms therefore could be taken as indicator organisms to indicate sanitary quality of water.

#### **2 - 8 - 2 Fecal coli form bacteria : - ( *E .Coli*).**

Coliforms of fecal origin including *Escherichia Coli* are capable of growth and of expressing their fermentation properties at higher

temperature of 44C°. The detection of *Escherichia coli* in water could be taken as indicator of fecal contamination, thus drinking water should be examined regularly to detect water pollution (Brandt *et al*, 2000).

### **2 -8-3 Water borne diseases: -**

Water borne diseases remain a major source of worldwide concern for illnesses caused by drinking water contaminated by pathogenic microorganisms. These diseases could spread by contamination of water system, especially where public and private drinking water system gets their water from surface water rain, rivers and lacks which could be contaminated by infected animals or people. It could be the cause of many diseases which include Cholera, malaria, anemia, lead poisoning, typhoid and diarrhea which could lead to severe dehydration and even death ([www.lenntech.com](http://www.lenntech.com)).

### **2-9 Contamination of drinking water:-**

The earliest interest in water pollution was stimulated by the discovery by microbiologists that water borne- diseases of human are to a large extent caused by pathogenic bacteria (Katz, 1971).

Elshazali and Erwa (1971) reported that recent studies in the Sudan have clearly demonstrated the close association of biological contamination of drinking water with the high prevalence of diarrhea diseases and certain enteric pathogens. Study in the Nile and wells water at Khartoum area by Elhassan *et al* (1984), indicated that there were 93 -460/100ml either coli forms or fecal coli form in Nile water 3 -2400/100ml also either coliforms or fecal coliform in wells. But tap water contained only 3 cells/100ml.

Hammed and Dirar (1982) found that zeers were contaminated with fecal coliforms in 69.88% of samples examined. Surface water supplies in rural area usually show various types of pollution as a result of animals and human contact, such waters must be treated before domestic use.

## **2 -10 Water pollution: -**

Water pollution can be defined as any chemical, physical or biological change in the quality of water that has a harmful effect on any living organism that drinks or uses or lives in it .Water pollution could be caused by human activities including sewage disposal, fertilizers for agricultural crops containing nutrients such as nitrates and phosphate, also growth of plants and algae might clog water pipes and increase growth of organisms. Another Pollution by agricultural activities might be commercial live stock and poultry farming as sources of many organic and inorganic pollutants in surface and ground water. In addition industrial pollution discharge through pipe lines or sewage into the surface water, organic chemicals such as pesticides, inorganic minerals and chemicals compounds could all be considered as major water pollutants (Krantz and kifferstein, 1996).

Furthermore pollution could come from many sources including untreated sewage, industrial discharges, leakage from oil storage tanks, mine draining and leaking from mine waste and drainage from the residues of agricultural fertilizers and pesticides.

In the Sudan Dirar (1986) reported that a particular point source of pollution of the White Nile at Khartoum was due to the continuously flowing stream of partially treated sewage coming from the city's sewage treatment plant and surroundings .The movement of animal wastes into the surface water is often cited as major factor contributing to the pollution of available water in many rural areas (Fernandez- Altered et al, 1991).

### **2-10 -1 Sources of water pollution:**

This can come from nature or man-made pollution.

### **2-10-2 Source of natural water pollution:**

FAO (1979) reported that most ground water and surface waters contain some natural dissolved salts. These salts most often originate from contact

of the liquid water moving in the hydrological cycle with various rock and soil minerals. Similarly water can pick up natural organic matter from leaves, grass and other vegetations in various stages of biodegradation, as well as dissolved gases native to the atmosphere. The result of these contacts is that water accumulates various amounts of physical, chemical and biological impurities.

### **2-10-3 Source of man made water pollution:**

There are wide numbers of activities that are associated with man's introduction of foreign chemical and biological material by direct or indirect route in surface or subsurface water environment. According to the FAO (1979) and Katz (1971) there are four main sources of water pollution:-

1. Agriculture (animal and crop waste, pesticides, fertilizers, etc ...)
2. Industry (serves as another originator of chemicals).
3. Waste generated domestically.
4. Radioactive materials.

All these constitute major sources of chemical or biological material (can be induced by man as artificial water contaminate) which threaten to degrade surface and under ground water supply. It is known that toxic substances may enter surface water from air drifting of chemicals and by direct application for the control of undesired aquatic life. The expanding food industry necessitates the application of chemicals for food preservation. As a result highly toxic substances find access to the aquatic environment (Dutt, 1982).

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3-1 Sampling**

Water samples were collected from different sites along the line of the drinking water system that supply the Gezira State. Samples were collected from six sites at the center and western of Gezira State. There were two types of water samples.

1- Surface water.

2- Ground water.

1- Surface water was collected from the head station from three sites:-

Site 1: Raw water of Raselphil water station.

Site 2: Raw water of 24 Elgorshi water station.

Site 3: Raw water of 21 Elmancy water station.

2- Ground water was collected from the head station from three sites:

Site 4: Raw water of Elamara water station.

Site 5: Raw water of Tabat Elshikh Abdelmahmmod water station.

Site 6: Raw water of Elhasahisa water station.

#### **3- 2 Sampling techniques:**

Water samples were collected after allowing the water pumps, from wells or stream basins, to run for short time to remove the first water flushes. Two liters of water samples were collected in clean and alcohol sterile bottles. The bottles were rinsed twice with water before collection. Then closed and immediately transported to laboratory for chemical and bacteriological analysis.

#### **3-3 Physical and chemical analysis:-**

The physical and chemical contamination analyses were carried according to the Standard methods (APHA, 1998).

**Appearance:**

The appearance of water was recorded in term of description change of color, turbidity, floating material and other matters that could be detected visually.

**3-3 -1 pH value:-**

The pH was measured by using digital pH meter with a glass electrode according to standard methods (APHA, 1998). Buffer solutions of pH 4.0 and 7.0 were prepared to adjust the pH –meter.

Procedure: -

For measuring the pH value, the electrode was first rinsed by the buffer solutions before adjusting for pH 4.0 and 7.0 each separately. Then rinsed with distilled water and with the water sample for measuring each sample. The electrode bulb was immersed well in the water sample and pH was measured at room temp.

**3 -3 - 2 Electrical Conductivity:-**

It is a measure of the ability of an aqueous solution to carry an electric current. The unit of conductivity is  $\mu\text{s}/\text{cm}$  or micro mhos/cm .It is a measure for salts concentrations in water.

Apparatus:

Conductivity meter Model 4510.

Reagents:

Deionized distilled water and standard Potassium chloride solution of electric conductivity  $1.41 \mu\text{s}/\text{cm}$  were used.

**Procedure:**

The conductivity cell was rinsed first with distilled water and then rinsed with standard KCL solution. The conductivity of the standard KCL was measured and adjusted to  $1.41 \mu\text{s}/\text{cm}$ . Then the conductivity of the 15 ml of water sample was measured and recorded.

### **3 -3 -3 Turbidity:**

Turbidity was a measure of water clarity from suspended solids often present in water like mud, clay, algae and minerals and these can be increased by the discharge of wastes like industrial and agricultural residues.

Apparatus: Turbidity meter type HACH (2000) was used according to standard methods (APHA, 1998).

#### **Procedure:-**

This method depend on comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by the standard reference suspension under the same conditions. The results were reported in nephelometric turbidity unites (NTU).

### **3 -4 Chemical analyses:**

#### **3 -4 -1 Total dissolved solids (TDS):**

Total dissolved solid was measured by using electrical conductivity meter to read TDS directly.

Apparatus: Electrical conductivity meter Model 4510 was used. Deionized distilled water was used to adjust conductivity meter at zero.

#### **Procedure:**

About 60 ml of water sample was taken in a 100 ml beaker. The conductivity cell electrode was rinsed in deionized water before each measurement, and then immersed in the samples and the measurement was repeated three times to take three readings to get the average result as TDS mg/L.

#### **3- 4-2 Total Hardness:**

Total hardness of water is defined as sum of the calcium and magnesium salts concentration, expressed as calcium carbonate, measured by EDTA titrimetric method (ethylene diamine tetra acetic acid disodium salts) as

described by standard methods (APHA, 1998). The end point of titration is marked by the addition of Eriochrome black T, which turned the color from wine red color to blue color at pH about 10.0.

Procedure:

Twenty five ml of water sample were diluted to 50 ml with distilled water then 2ml of buffer solution were added to adjust the pH of sample to 10.0. Addition of two drops of Eriochrome black T indicator was followed by the titration against standard EDTA solution with continuous stirring until the last reddish color disappeared from the solution which became blue in color.

Calculation:

$$\text{Total hardness as CaCO}_3 \text{ mg /L} = \frac{A \times B \times 1000}{C \text{ ml of sample}}$$

Where:

A=ml titration for sample.

B= mg CaCO<sub>3</sub> equivalent to ml of EDTA titration.

C=volume of sample was used.

Results were recorded as CaCO<sub>3</sub> mg / L.

### **3- 4-3 Calcium:**

Calcium content in water was determined by using EDTA Titrimetric method according to standard methods (APHA, 1998). After removing magnesium interference by using EDTA titration it reacts with calcium before magnesium .The indicator used was one that reacts with calcium only and gives a color change when all of the calcium has been complexes by EDTA at pH of 12 to 13 with addition of sodium hydroxide solution.

Procedure:

Sample was diluted to 50 ml then two ml of 4N NaOH solution were added As indicator two drops of Murexide indicator solution was added .Then

standard EDTA was titrated slowly with continuous stirring to the end point to change the color from pink to purple color.

Calculation:

$$\text{Ca mg/L} = \frac{A \times B \times 400.8}{C \text{ ml of sample}}$$

Where:

A= ml of EDTA titration for sample.

B= mg CaCO<sub>3</sub> of equivalent to ml EDTA titration.

C= volume of sample used.

Result was recorded as Ca mg / L.

3- 4-4 Magnesium:

Magnesium was determined by subtracting the calcium hardness from total hardness as mg /L.

### **3- 4-5 Alkalinity:**

Alkalinity of water was determined by titration of the sample against the standard solution of strong acid according to standards methods (APHA, 1998). Twenty five ml of sample, 2-3 drops of phenolphthalein indicator were added. If no color was produced the alkalinity of phenolphthalein was zero if the color was changed to red color then titrate to the colorless end point. To the same sample 2-3 drops methyl orange indicator were added and titrated with standard sulphuric acid to give orange color at the end point.

Calculation:

$$\text{Phenolphthalein alkalinity CaCO}_3 \text{ mg /L} = \frac{A \times B \times 100000}{C \text{ ml of sample}}$$

$$\text{Total alkalinity as CaCO}_3 \text{ mg /L} = \frac{A \times B \times 100000}{C \text{ ml of sample}}$$

Where:

C ml of sample

A = ml of acid titration for sample.

B= ml of acid used, phenolphthalein end point.

C=volume of sample used.

The result was recorded as CaCO<sub>3</sub> mg /L.

### **3- 4-6 Sodium:**

Sodium was determined according to standard methods (APHA, 1998). By using Flame photometric method (Flame photometer).

Reagents: Deionized water and standard solution of Sodium chloride 10ppm.

#### **Procedure:**

Sample preparation. If Na concentration is out of the standard curve range take appropriate volume from the sample and dilute it to bring sample emission to standard curve range. Adjusted the flame photometer to zero by deionized water and wait for 15 min before doing any measurement. The zero to 100 emissions was adjusted by using stock NaCl, then the sample was allowed to emit enough times to emission and reading the range to determine the concentration.

Calculation:

$$\text{Na mg /L} = \frac{\text{FR} \times \text{DF}}{\text{Ppm}}$$

Where:

FR= flame reading.

DF= dilution factor.

Ppm = concentration of stock solution NaCl.

### **3- 4-7 Potassium:**

Potassium was determined according to standard methods (APHA, 1998). By using Flame photometric method (Flame photometer).

Stock solution used was potassium chloride 10ppm concentration. Result was recorded as K mg /L.

### **3- 4-8 Chloride:**

It was determined in a neutral or slightly alkaline solution by titration with standard silver nitrate solution .Potassium chromate was the indicator used. Silver chloride was precipitated quantitatively before red silver chromate was formed.

Reagents: Potassium chromate as indicator and standard Silver nitrate.

Procedure:

Twenty five ml of water sample was taken in a beaker and the pH was adjusted to 8.0. One ml of potassium chromate indicator solution was added. The sample was titrated against Silver nitrate solution with constant stirring until a pinkish yellow color was appeared. Twenty five ml of distilled water was used for blank.

Calculation:

$$\text{Cl mg /L} = \frac{(A - B) \times M \times 35.5}{C \text{ ml of sample}}$$

Where:

A= ml titration for sample.

B= ml titration for blank.

M= molarity of AgNo<sub>3</sub>.

C= volume of sample used.

### **3- 4-9 Fluoride:**

To determine fluoride in water, the sample was analyzed using SPANDS method as described by standard methods APHA (1998). Using Spectrophotometer at wave length  $\lambda$  580 nm. Twenty five ml of water sample were put in dry cell. Twenty five ml of distilled water were put in second dry cell as blank. Five ml of SPANDS reagent was pipetted into each cell.

Place blank into the cell holder and directly read fluoride at wave length  $\lambda 580$  nm as F mg /L.

### **3 -4-10 Ammonia:**

To determine the ammonia in water sample was measured by using Distillation apparatus, according to Standard methods APHA (1998) .The analysis was based on shifting the equilibrium between the ammonia ion and free ammonia and the release of gaseous ammonia along with steam.

Apparatus: Distillation unit.

Reagents: Magnesium oxide solution.

Procedure:

Distilled water was boiled in distillation unit. Twenty ml of water sample were measured and placed in flask and the unit was closed. A buffer solution was added to increase the pH of the sample.

The condenser unit in the distillation system was attached to the flask and the mixture was distilled driving off steam and free ammonia. The steam containing ammonia was condensed and collected in Boric acid solution in a beaker .The reaction with boric acid forms ammonia. The amount of ammonia in the sample was determined by the quantity of boric acid consumption in the collecting beaker .The amount of ammonia was determined by titration with Hydrochloric acid.

Calculation:

$$\text{NH}_3 \text{ mg/L} = \frac{A \times B \times 14 \times 1000}{C \text{ ml of sample}}$$

Where:

A= volume of acid.

B= normality of acid.

C=volume of sample used.

Result was reported as  $\text{NH}_3$  mg /L.

### **3- 4-11 Nitrate:**

Nitrate was determined using Cadmium reduction method according to Standards methods (APHA, 1998).

This method use powder pillows to determine the nitrate concentration in water sample by direct reading using Spectrophotometer DR HACH (2000) programmed adjusted to the wave length  $\lambda$  400nm the result was reported as  $\text{NO}_3$  mg /L.

### **3- 4-12 Sulfate:**

The standard methods of (APHA, 1998) were used to determine the sulfate concentration in water sample. Using the method of Barium Sulfate this method determine sulfate by precipitated Barium sulfate by Hydrochloric acid solution in Barium chloride and the Barium sulfate is filtered ignited and weighed .

Apparatus:

1- Water path.

2- Muffle furnace.

Reagents: Hydrochloric acid (HCL), barium chloride solution and methyl orange as indicator.

Procedure:

100ml of water sample were measured in a beaker. A few drops of methyl orange and one ml of concentrated hydrochloric acid were added to adjust the pH from 4.5 to 5.0 and change the color to pink color. The sample was heated to boiling and barium chloride was added drop wise with constant stirring. The sample was allowed to stand on water bath until the volume was reduced to about 50 ml .After cooling the sample, the precipitate of barium sulfate was filtered through an ashless filter paper and washed with water until free of chloride.

The filter paper was carefully folded and placed in silica crucible ignited in muffle furnace and the residue was weighed.

Calculation:

$$\text{SO}_4 \text{ mg /L} = \frac{\text{mg BaSO}_4 \times 411.6}{\text{C ml of sample}}$$

Where : BaSO<sub>4</sub> = residue of BaSO<sub>4</sub>.

C = volume of sample.

### **3- 4-13 Minerals:**

The following minerals and heavy metals were determined Iron, Manganese, Zinc, Copper and some toxic elements namely Lead and Cadmium.

These metals were determined according to the Standard methods, APHA (1998). By using Atomic Absorption Spectro photometry. The AAS was calibrated by using standard solution for each element. The standard solution was prepared from a known weight of the element and then standard curve was drawn. The calibration curve was plotted for each element concentration measured in all samples. The AAS has specific lamp for measuring each ion concentration. The atomization tube was rinsed with distilled water after each sample measuring. The results were recorded and data was then analyzed statistically.

### **3-5 Microbiological Examination:**

#### **3- 5-1 Total Plate count:**

Total viable count was done for all samples using the pour plate technique as described by Harrigan and MacCance (1976).

One ml of sample was transferred aseptically into sterile Petri -dishes 10 ml of melted plate count agar (45- 46 C°) were poured into the dishes. The dishes were then thoroughly mixed to facilitate distribution of the sample

throughout the media. The media was allowed to solidify and the plates were incubated at 37C° for 48 hours.

The total bacterial count was determined by using the Colony counter (Quebec colony counter).

### **3- 5-2 Enumeration of Coliform Bacteria:**

The Most Probable Number (MPN) technique was used for enumeration of total coli forms and fecal coliforms according to standard methods (APHA, 1989).The multiple tubes fermentation method comprises three steps:

A-presumptive test

B- Confirmed test

C- Completed test

#### **A- Presumptive test:**

The multiple tube fermentation technique was performed as presumptive test. Determination of the most probable number (MPN ) coliform bacteria was carried out using tubes containing MacConkey broth and inverted Durham tubes as indicated in figure 1 .The inoculation was done in replicates of three. To each of 3 double -strength MacConkey broth tubes 10ml of the original sample were added. Also to each 3 – single - strength MacConkey broth tubes 1 ml of the original sample and then 0.1 ml of original sample were added to 3 - single -strength MacConkey broth tubes. All tubes were incubated at 35c for 48 hours for the observation of gas production .First reading was taken after 24 hours to record positive tubes and the negative ones were incubated for another 24 hours .

#### **B- Confirmed test:**

Each gas positive presumptive tube was inoculated into a tube containing brilliant green lactose bile broth (BGB) media at 37c for 48 hours for the observation of gas production.

#### **C- Completed test (fecal coliform test):**

At least 3 loopfuls of each confirmed positive tubes were subcultured into Escherichia coli (E.coli) broth media and then incubated at 44.5 c for 24 hours. Tubes showing any amount of gas production were considered as positive and the most probable number (MPN) was recorded.

**3 -6 Statistical Analyses:**

The analysis of variance (ANOVA) was performed to examine the significant level in all parameters measured. Least significant differences (LSD) test was used to separate between the means. All analyses were performed in triplicate (Gomez and Gomez, 1984).



Figure 1: Presumptive test in surface water from 24 Elgorashi surface water.

## **CHAPTER FOUR**

### **RESULTS AND DISCUSSION**

#### **4-1 Physical parameters:**

##### **4 -1-1 pH**

Table 1 shows the pH values for the water samples collected from the six different sites. The highest mean value (7.67) was found in surface water from 24 Elgorshi water station, while the lowest one (7.15) was found in surface water from Raselphil water station. The values obtained were slightly lower than those reported by Nurain (1998) who found that the pH of the tap and canal water were 7.9 and 8.8 respectively. All the pH readings fall within the acceptable level of WHO (1993) and SSMO (2002) standards (6.5 -8.5).

##### **4- 1-2 Electrical conductivity (EC):**

Table 1 shows the EC values for the water collected from the six sites. The data was showed significant differences in the values. The highest mean value (1151.67 $\mu$ s/cm) was found in ground water from Elamara water station, while the lowest mean values (227.67 $\mu$ s/cm) was found in surface water from 24 Elgorshi water station, thus not agreeing with findings of Abdelmagid et al (1984) who found EC for tap water as 0.17 $\mu$ s/cm .All these readings fall below the maximum level of WHO (1993) and SSMO (2002) standards (1500 $\mu$ s/cm).

##### **4- 1-3 Turbidity:**

The turbidity values of the water samples under study are shown in table 1. The highest mean value (197.33 NTU) was found in surface water from 24 Elgorshi water station, while the lowest value (0.3 NTU) was found in ground water from Elhasahisa water station .The high value of turbidity in the canal water can be due to the that fact canal becomes very shallow in summer and this caused difficulty in water pumping and contaminates the

**Table 1:- pH values, Electrical conductivity (EC) and Turbidity levels of Gezira drinking water at six different sources and sites.**

Water sites						
Parameter	1	2	3	4	5	6
pH	7.15 <sup>f</sup> (±0.01)	7.67 <sup>a</sup> (±0.015)	7.24 <sup>e</sup> (±0.01)	7.61 <sup>b</sup> (±0.006)	7.35 <sup>d</sup> (±0.03)	7.54 <sup>c</sup> (±0.023)
EC	257 <sup>d</sup> (±1.0)	227.67 <sup>e</sup> (±3.21)	257.67 <sup>d</sup> (±3.06)	1151.67 <sup>a</sup> (±1.539)	825.67 <sup>b</sup> (±1.53)	273.67 <sup>c</sup> (±2.52)
Turbidity	5.53 <sup>b</sup> (±0.21)	197.33 <sup>a</sup> ±(1.53)	6.47 <sup>b</sup> ±(0.25)	0.73 <sup>c</sup> (±0.0)	0.95 <sup>c</sup> (±1.002)	0.3 <sup>c</sup> (±0.0)

Means not sharing a common superscript in a row are significantly different ( $p \leq 0.05$ ).

Sites:

- 1- Surface water from Raselphil water station.
- 2- Surface water from 24 Elgorshi water station.
- 3- Surface water from 21Elmancy water station.
- 4- Ground water from Elamara water station.
- 5- Ground water from Tabat water station.
- 6- Ground water from Elhasahisa water station.

water with solids and soil particles thus turbidity values of surface water from Raselphil, 24 Elgorshi and 21 Elamancy water stations has highly exceed the acceptable level of WHO (1993) and SSMO (2002) standards (5NTU ).

#### **4-2 Chemical parameters:**

4- 2-1 Total dissolved solids (TDS): Table 2 shows the TDS levels of the water collected from the six different sites .The highest mean value (757mg /L) was found in ground water from Elamara water station ,while the lowest one (152.33 mg/L)was found in surface water from 24 Elgorshi water station . Nurrain (1998) found that the TDS level for well and canal waters were 174 and 495 mg/L respectively. There are significant differences among the samples .All the readings fall below the highest level of WHO (1993) standards (1000 mg/L).

#### **4-2-2 Total Hardness:**

Table 2 shows the total hardness levels of the water from six different sites. The highest mean value (517.33mg/L) as  $\text{mgCo}_3$  was found in ground water from Tabat water station, while the lowest value (216mg/L) was found in surface water from Raselphil water station. There are significant differences among the samples. Tabat water station has gave higher value compared to WHO(1993)standards for maximum level (500mg /L),and could be considered as very hard water according to McCarty et al,(1985).

#### **4- 2-3 Alkalinity:**

Table 2 shows the alkalinity concentration of the water collected from the six different sites. The data was showed significant differences among the samples .The highest concentration mean value (328.33mg/L) was found in Ground water from Elamara water station, while the lowest value

(123.33mg/L) was found in surface water from 24 Elgorshi water station.  
All the reading fall below the value of the WHO (1993) (500mg/L).

**Table 2:-Total dissolved solid value, hardness and alkalinity levels (mg/L) of Gezira drinking water at six different sources and sites.**

Water sites						
Parameter	1	2	3	4	5	6
Total dissolved solid	168.63 <sup>e</sup> (±0.65)	152.03 <sup>f</sup> (±0.25)	177 <sup>d</sup> (±0.0)	757 <sup>a</sup> (±0.0)	508.33 <sup>b</sup> (±0.58)	178 <sup>c</sup> (±0.35)
Hardness	216 <sup>b</sup> (±8.0)	222.67 <sup>b</sup> (±6.11)	238.67 <sup>b</sup> (±2.31)	253.33 <sup>b</sup> (±86.9)	517.33 <sup>a</sup> (±4.62)	224 <sup>b</sup> (±4)
Alkalinity	153.33 <sup>c</sup> (±5.8)	123.33 <sup>e</sup> (±2.9)	146.67 <sup>c</sup> (±5.77)	328.33 <sup>a</sup> (±2.89)	236.6 <sup>b</sup> (±2.89)	140 <sup>d</sup> (±0.0)

**Means not sharing a common superscript in a row are significantly different ( $p \leq 0.05$ ).**

**Sites:**

- 1 – Surface water from Raselphil water station.
- 2- Surface water from 24 Elgorshi water station.
- 3- Surface water from 21 Elmancy water station.
- 4- Ground water from Elamara water station.
- 5- Ground water from Tabat water station.
- 6- Ground water from Elhasahisa water station.

#### **4- 2-4 Calcium:**

Table 3 shows the calcium level in the water collected from the six different sites. The highest mean value (56.53 mg/L) was detected in surface water from 21Elmancy water station, while the lowest mean value (26.133mg/L) was detected in ground water from Tabat water station. There are significant differences among samples .These values were higher than the values reported by Nurain (1998) who found that the calcium level of water from well and canal were 19.7 and 18.1 mg/L respectively. The great variation could be due to soil type.

#### **4- 2-5 Magnesium:**

Table 3 shows the Magnesium level of the water collected from six different sites. The highest mean value (108.48mg/L) was found in ground water from Tabat water station, while the lowest mean value (21.12 mg/L) was found in surface water from Raselphil water station. There are significant differences among samples. All the readings fall below the maximum level allowed by WHO (1993) standards (150mg/L).

#### **4- 2-6 Sodium:**

Table 3 shows the Sodium concentration of the six water samples. The highest mean value (225.83 mg/L) was found in ground water from Elamara water station, while the lowest mean value (8.233mg/L) was found in surface water from 24Elgorshi water station. The data showed significant differences among the samples .The highest mean value (225.83mg/L) in samples Elamara water station which caused the water to be salt because it contains higher total dissolved sodium compared with other samples .All the samples readings fall below the permissible level of WHO (1993) standards (20mg/L) and SSMO (2002) standards (20 mg/L) except the ground water from Elamara water station.

**Table 3:-The Calcium values, Magnesium, Sodium and Potassium content (mg/L) of Gezera drinking water at six different sources and sites.**

Water sites						
Parameter	1	2	3	4	5	6
Calcium	51.2 <sup>ab</sup> (±0.01)	51.2 <sup>ab</sup> (±3.2)	56.53 <sup>a</sup> (±0.92)	46.93 <sup>b</sup> (±10.7)	26.133 <sup>c</sup> (±2.44)	50.133 <sup>ab</sup> (±0.92)
Magnesium	21.12 <sup>c</sup> (±1.92)	22.7 <sup>bc</sup> (±3.4)	23.36 <sup>bc</sup> (±0.55)	32.65 <sup>b</sup> (±15.8)	108.48 <sup>a</sup> (±0.96)	23.68 <sup>bc</sup> (±0.55)
Sodium	12.67 <sup>d</sup> (±0.58)	8.23 <sup>e</sup> (±0.29)	12.17 <sup>d</sup> (±0.29)	225.8 <sup>a</sup> (±1.45)	71 <sup>b</sup> (±0.0)	19.67 <sup>c</sup> (±0.58)
Potassium	2.73 <sup>c</sup> (±0.12)	3.67 <sup>a</sup> (±0.06)	3.17 <sup>b</sup> (±0.06)	3.6 <sup>a</sup> (±0.00)	3.1 <sup>b</sup> (±0.0)	1.8 <sup>d</sup> (±0.0)

Mean not sharing a common superscript in a row are significant differences ( $P \leq 0.05$ ).

Sites:

- 1- Surface water from Raselphil water station.
- 2 -Surface water from 24Elgorshi water station.
- 3- Surface water from 21Elmancy water station.
- 4- Ground water from Elamara water station.
- 5- Ground water from Tabat water station.
- 6- Ground water from Elhasahisa water station.

#### **4-2-7 Potassium:**

Table 3 shows the Potassium levels of the water collected from six different samples. The highest mean value (3.67mg/L) was detected in surface water from 24 Elgorshi water station, while the lowest one (1.8mg/L) was detected in ground water from Elhasahisa water station. There are significant differences among sample.

#### **4- 2-8 Chloride:**

Table 4 shows the concentration of chloride in the six water samples. The highest mean value (86.87 mg/L) was detected in ground water from Tabat water station, while the lowest mean value (3.23mg/L) was detected in surface water from 24 Elgorshi water station. There are significant differences among samples. These levels can be related to those reported by Nurain (1998) who found that the amount of chloride in canal and well water was 9.8 and 120mg/L respectively. All these readings fall below the maximum acceptable level of WHO (1993) and SSMO (2002) standards (250mg/L).

#### **4- 2-9 Fluoride:**

Table 4 shows the level of Fluoride in the six water samples. The highest mean value (0.353mg/L) was detected in ground water from Elamara water station, while the lowest one (0.167mg/L) was detected in ground water from Elhasahisa water station. There are significant differences among samples. All the readings fall below the maximum level of the WHO (1993) standards (1.5mg/L).

#### **4.2.10 Nitrate:**

Table 4 shows the level of Nitrate in the six different water samples. The highest mean value (11.82 mg/L) was found in ground water from Elhasahisa water station, while the lowest mean value (3.23mg/L) was

found in surface water from 24 Elgorshi water station. The data showed significant differences among samples .All these levels were below these

**Table 4:-The Chloride values, Fluoride and Nitrate contents (mg/L) of Gezira drinking water at six different sources and sites.**

water sites						
Parameter	1	2	3	4	5	6
Chloride	5.98 <sup>c</sup> (±0.02)	3.23 <sup>d</sup> (±0.064)	6.03 <sup>c</sup> (±0.06)	65.9 <sup>b</sup> (±0.1)	86.87 <sup>a</sup> (±0.15)	4.99 <sup>cd</sup> (±0.06)
Fluoride	0.323 <sup>a</sup> (±0.02)	0.18 <sup>b</sup> (±0.01)	0.3 <sup>a</sup> (±0.1)	0.353 <sup>a</sup> (±0.015)	0.307 <sup>a</sup> (±0.015)	0.167 <sup>b</sup> (±0.09)
Nitrate	5.27 <sup>b</sup> (±0.39)	3.23 <sup>b</sup> (±5.12)	7.42 <sup>ab</sup> (±0.051)	5.7 <sup>b</sup> (±0.02)	4.2 <sup>b</sup> (±0.2)	11.82 <sup>a</sup> (±0.05)

Mean not sharing a common superscript in a row are significant differences ( $P \leq 0.05$ ).

Sites:

- 1- Surface water from Raselphil water station.
- 2- Surface water from 24Elgorashi water station.
- 3-Surface water from 21Elmancy water station.
- 4-Ground water from Elamara water station.
- 5- Ground water from Tabat water station.
- 6- Ground water from Elhasahisa water station.

found by Abdelmagid and Elhassan (1986) who stated that the level was (45mg/L). All the readings fall below the maximum level of WHO (1993) standard (45- 50 mg/L).

#### **4.2.11 Ammonia:**

Table 5 shows the levels of Ammonia in the water collected from six sites. The highest mean value (3.27mg/L) was found in ground water from Elamara water station, while the lowest mean value (2.1mg/L) was found in surface water from Raselphil water station. The data showed no significant differences among samples. The values were higher than those reported by Nurain (1998) who found that the amount of ammonia in canal water was (1.2mg/L) and in well water was (0.5mg/L). All these readings registered higher value than acceptable level of WHO (1993) and the SSMO (2002), standards (1.5mg/L). The higher value of ammonia may be caused by the location and sources of samples being contaminated by animal remains.

#### **4- 2-12 Sulfate:**

Table 5 shows the levels of sulfate in the six water samples. The highest mean value (0.413mg/L) was found in ground water collected from Elamara water station, while the lowest value (0.224mg/L) was found in surface water from Raselphil water station. There are significant differences among the samples. All the readings fall below the acceptable level of SSMO (2002), standards (250mg/L).

#### **4-2-13 Iron:**

Table 5 shows the levels of Iron in the water collected from six water samples. Only surface water from 24Elgorashi water station was found to contain iron as 0.83mg/L which was higher than the level allowed by SSMO (2002) of 0.3mg/L. The other water samples were found to contain

no detectable iron concentration .The higher value of iron due to the source of water sample.

**Table 5:-Ammonia values, Sulfate and Iron levels (mg/L) Of Gezera drinking water at six different sources and sites.**

Water Sites						
Parameter	1	2	3	4	5	6
Ammonia	2.1 <sup>a</sup> (±0.0)	2.57 <sup>a</sup> (±1.46)	2.33 <sup>a</sup> (±0.4)	3.27 <sup>a</sup> (±0.404)	2.33 <sup>a</sup> (±0.404)	2.8 <sup>a</sup> (±0.7)
Sulfate	0.224 <sup>f</sup> (±0.002)	0.373 <sup>b</sup> (±0.0002)	0.273 <sup>d</sup> (±0.0)	0.413 <sup>a</sup> (±0.0001)	0.37 <sup>c</sup> (±0.002)	0.2513 <sup>e</sup> (±0.0002)
Iron	ND	0.83	ND	ND	ND	ND

Mean not sharing a common superscript in a row are significant differences ( $P \leq 0.05$ ).

Sites:

- 1-Surface water from Raselphil water station.
- 2- Surface water from 24Elgorashi water station.
- 3- Surface water from 21Elmancy water station.
- 4- Ground water from Elamara water station.
- 5-Ground water from Tabat water station.
- 6-Groun water from Elhasahisa water station.

ND = not detected.

#### **4-2-14 Manganese:**

Table 6 shows the level of manganese in water collected from the six sites. The highest level (0.127mg/L) was detected in ground water from Tabat water station, while the surface water from 24Elgorshi water station was free of manganese. There are significant differences among sites. The results agree with finding of Elhag (2004) who found that amount of manganese in well water was in the range from 0.034 to 0.216 mg/L. All detected values fall below the maximum level of WHO (1993) and SSMO ((2002) standards (0.5 mg/L).

#### **4- 2-15 Zinc:**

Table 6 shows the level of zinc in the water collected from the six different sites. The highest mean value (0.015 mg/L) was detected in ground water from Elamara water station, while zinc was not detectable in surface water from Raselphil, 24 Elgorshi and 21 Elmancy water stations and ground water from Elhasahisa water station. The data showed significant differences among the samples. Elhag (2004) found that the amount of zinc in well water was 0.012 to 0.17mg/L. The amount fall below the maximum acceptable level of SSMO (2002) standards (3 mg/L).

#### **4- 2-16 Copper:**

Table 6 shows the level of copper in water collected from the six different sites. The highest mean value (0.028mg/L) was detected in surface water from Raselphil water station, while no copper was detected in ground water collected from Elamara, Tabat and Elhasahisa water stations. All these readings fall below the maximum acceptable level of SSMO (2002) standards (1.5mg/L).

#### **4-2-17 Lead:**

Table 6 shows the level of lead in water collected from the six different sites. The highest mean value (0.258 mg/L) was detected in ground water from Elhasahisa water station, while no lead was detected in surface water

**Table 6:- The Levels of Manganese, Zinc, Copper, Lead and Cadmium as (mg/L) in Gezira drinking water at six different sources and sites.**

Water Sites						
Element concentration. mg/L	1	2	3	4	5	6
Manganese	0.065 <sup>b</sup> (±0.0002)	ND	0.028 <sup>c</sup> (±0.00015)	0.033 <sup>c</sup> (±0.0002)	0.127 <sup>a</sup> (±0.00015)	0.103 <sup>a</sup> (±0.0002)
Zinc	ND	ND	ND	0.02 a (±0.001)	0.0014 <sup>b</sup> (±0.00015)	ND
Copper	0.028 <sup>a</sup> (± 0.003)	0.006 <sup>b</sup> (±0.001)	0.007 <sup>b</sup> (±0.0015)	ND	ND	ND
Lead	ND	ND	ND	ND	0.02803 <sup>b</sup> (±0.0002)	0.258 <sup>a</sup> (±0.0003)
Cadmium	ND	ND	0.0502 <sup>c</sup> (±0.004)	0.062 a (±0.0003)	0.0601 <sup>b</sup> (±0.004)	0.0224 <sup>b</sup> (±0.0003)

Mean not sharing a common superscript in a row are significant differences (P≤0.05).

Sites:

- 1= Surface water from Raselphil water station.
- 2= Surface water from 24Elgorashi water station.
- 3= Surface water from 21Elmancywater station.
- 4= Ground water from Elamara water station.
- 5= Ground water from Tabat water station.

6= Ground water from Elhasahisa water station.

ND= not detected.

from Raselphil, 24Elgorshi and 21 Elmancy water stations and ground water from Elamara water station. That value was higher than the finding of Elhag (2004) who found that the lead concentration in well water was in the range 0.004 to 0.016 mg/L. All these amounts were higher than the maximum acceptable level of SSMO (2002) standards (0.007mg/L).

#### **4-2-18 Cadmium:**

Table 6 also shows the cadmium level of the water from the six different sites. The highest mean value (0.062 mg/L) was detected in ground water collected from Elamara water station, while no cadmium was detected in surface water collected from Raselphil and 24 Elgorshi water station. There are significant differences among the samples. All detected values were higher than the SSMO (2002) standards (0.003 mg/L).

#### **4-3 Microbiological Parameters:**

##### **4- 3-1 Total Count:**

Table 7 shows the total viable count values in drinking water collected from six different sites. The highest value ( $6.8 \times 10^5$ ) was found in surface water collected from 24 Elgorshi water stations, while the lowest value ( $3.5 \times 10^2$ ) was found in the ground water collected from Elhasahisa water station. There are significant differences among the samples.

##### **4- 3-2 Total coli form bacteria:**

Table 7 shows the total coliform values found in the drinking water collected from six different sites. The highest value (150/ 100ml) was found in surface water collected from 24 Elgorshi station water, while no coliform was detected in ground water collected from Elhasahisa water station. The data show significant differences among the samples. The

presence of these microorganisms indicates fecal contamination. The SSMO (2002) recommended that the permissible coliform count around 0.0.

**Table 7: The Total microbial contamination in drinking water at six different sites.**

Water sites						
Microbial contamination	1	2	3	4	5	6
Total count	$4.8 \times 10^3$	$6.8 \times 10^5$	$3.5 \times 10^4$	$3.2 \times 10^3$	$4.0 \times 10^3$	$3.5 \times 10^2$
Total coli form	11	150	28	93	21	0
E.coli	0	20	7.3	7	4	0

Sites:

- 1- Surface water collected from Raselphil water station.
- 2- Surface water collected from 24Elgorshi water station.
- 3 -Surface water collected from 21Emancywater station.
- 4- Ground water collected from Elamara water station.
- 5- Ground water collected from Tabat water station.
- 6- Ground water collected from Elhasahisa water station.

### **4-3 -3 Escherichia coli (E. coli):**

Table 7 shows the E.coli count in the different water samples collected from the six sites. The data showed significant differences among the samples. The highest value (20/100ml) was detected in surface water collected from 24 Elgorshi, while no E.coli was found in ground water collected from Elhasahisa water station and surface water from Raselphil water station.

The microbiological examination of water in this study showed that the water distribution systems is generally polluted by bacteria including coliform and E.coli. These bacteria conform to the criteria for a coliform organism is regarded as an essential indicator of fecal pollution of human or animal origin (Coley *et al.*, 1996).

## **CHAPTER FIVE**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **5-1 Conclusions:**

- 1- The surface water in the area of study were higher in level of turbidity and low in minerals concentration.
- 2- The ground water was low in turbidity and in pH value but high in salts.
- 3- All the sample results were lower in chloride than the maximum Permissible level.
- 4-The ground water samples were high in cadmium and lead.
- 5- Microbial load was result of surface water samples were revealed that the microbial load was higher compared to those of ground water.
- 6-Results of the samples for fluoride, chloride, sulphate, nitrate, calcium, magnesium, potassium and total dissolved solids in ground water were higher than the surface water.

#### **5-2 Recommendations:**

- 1- Surface water in the area of study shall be subjected to treatment before used for human consumption.
- 2- Ground water from Elamara water station was not suitable for human consumption as it contains high levels of salts.
- 3- Chlorine need to be added in all water stations in the area of study.
- 4- Regular inspection for the water station for chemical, physical and microbial test shall be regularly conducted to determine suitability of water for drinking purpose.

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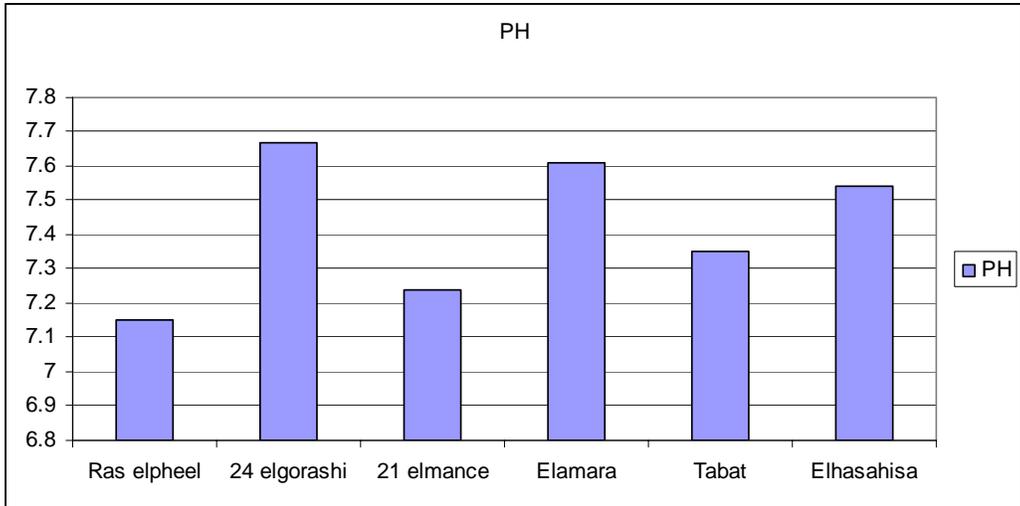
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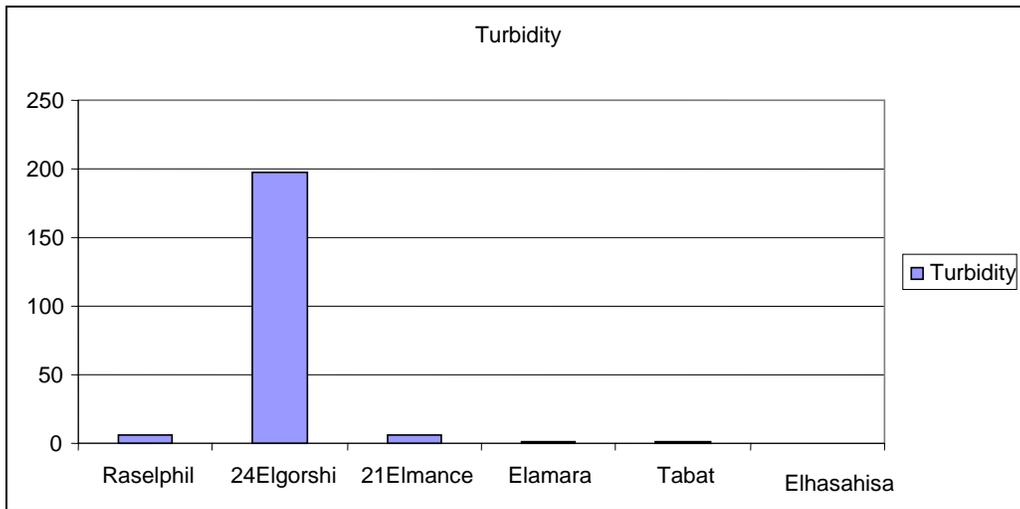
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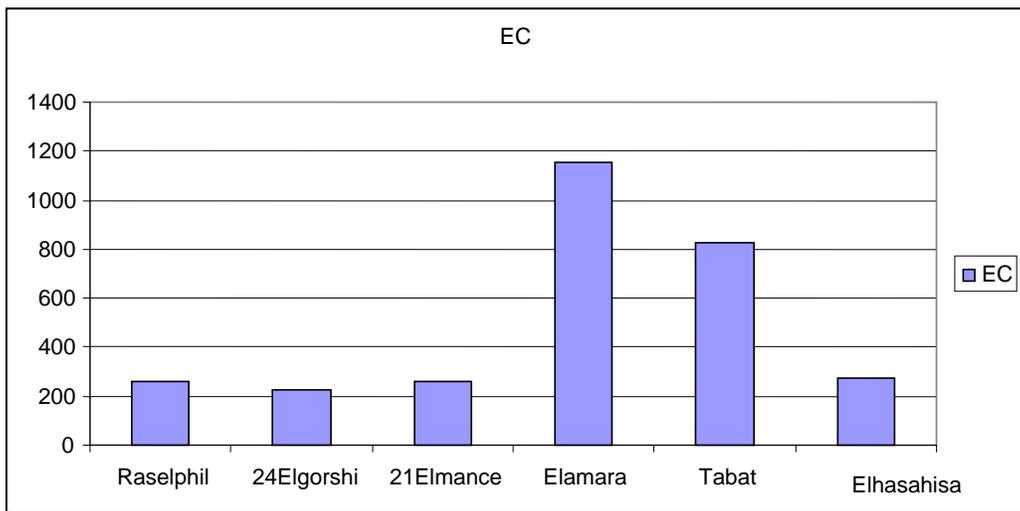
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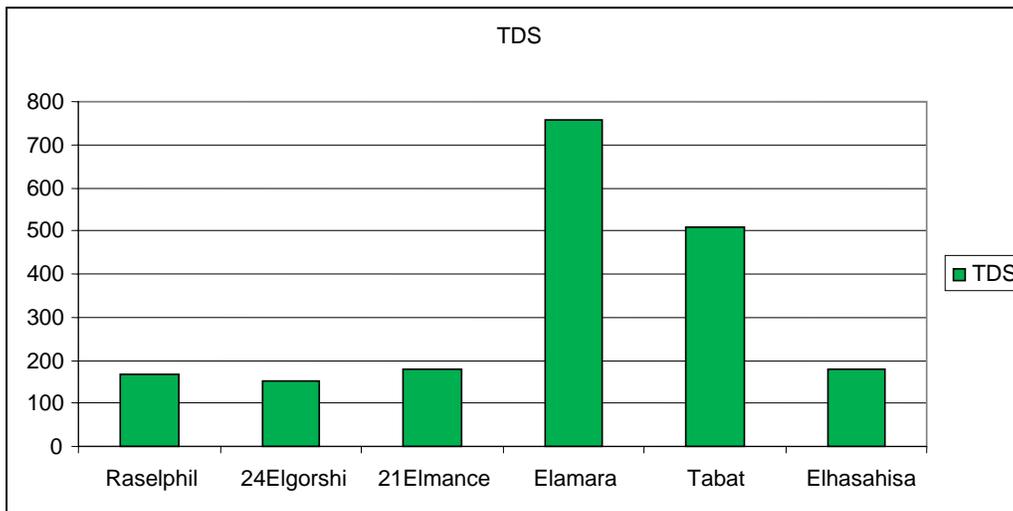
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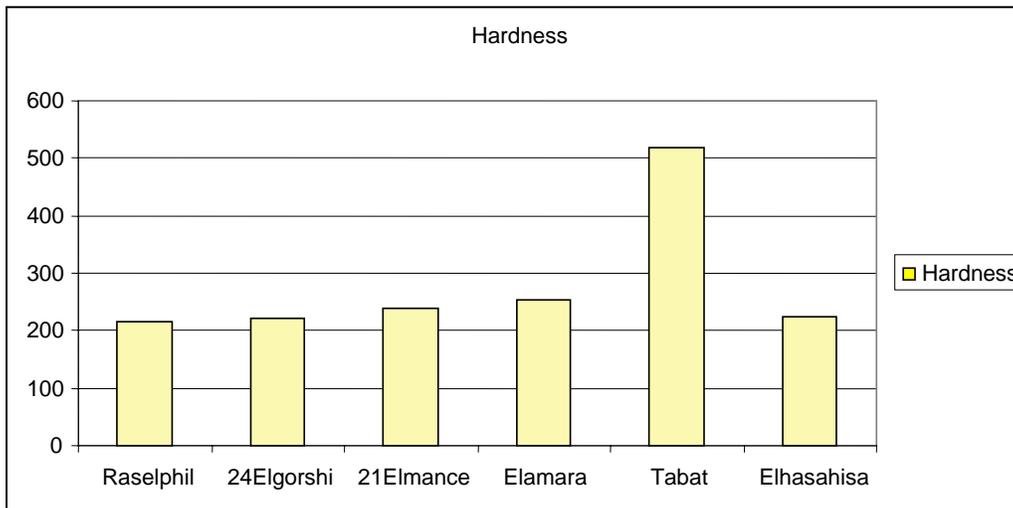
**Turbidity levels in study area.**



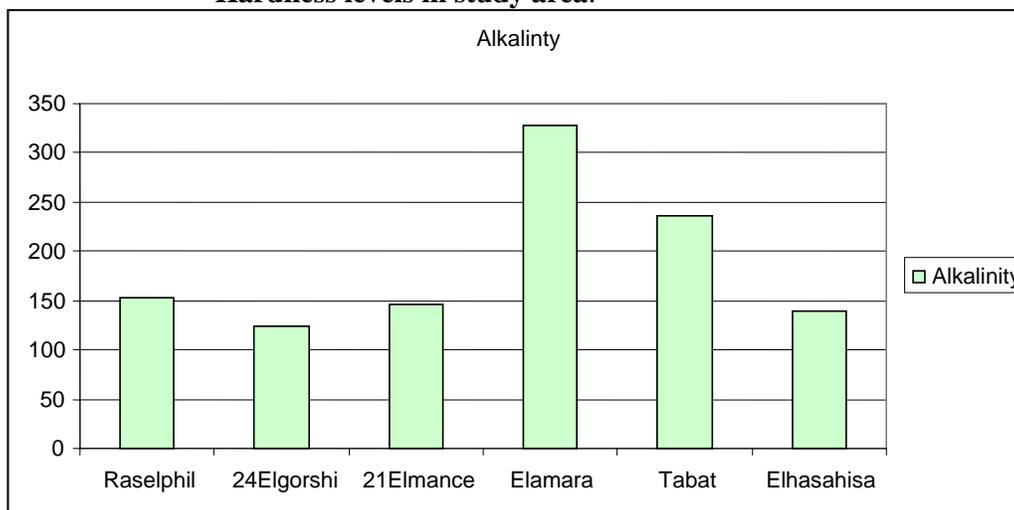
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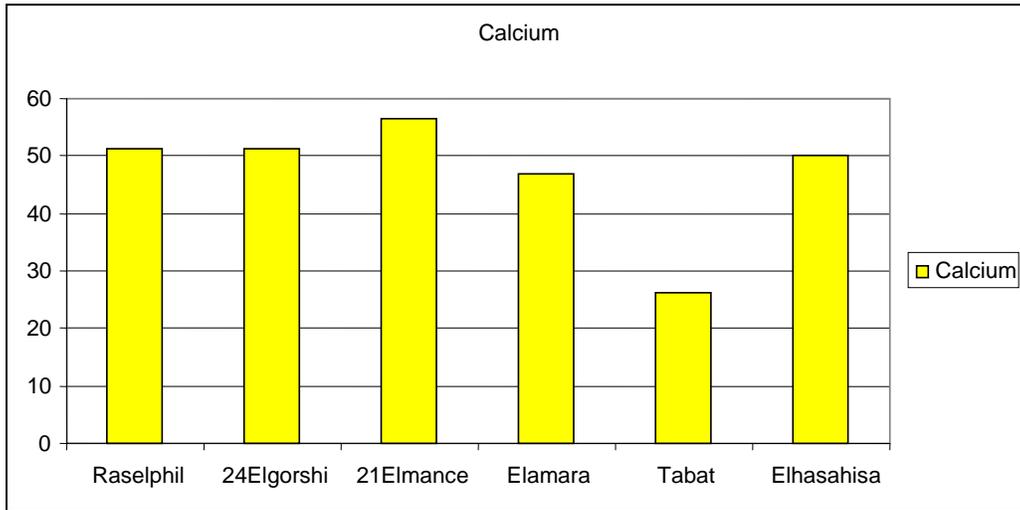
**Total dissolved solids in study area.**



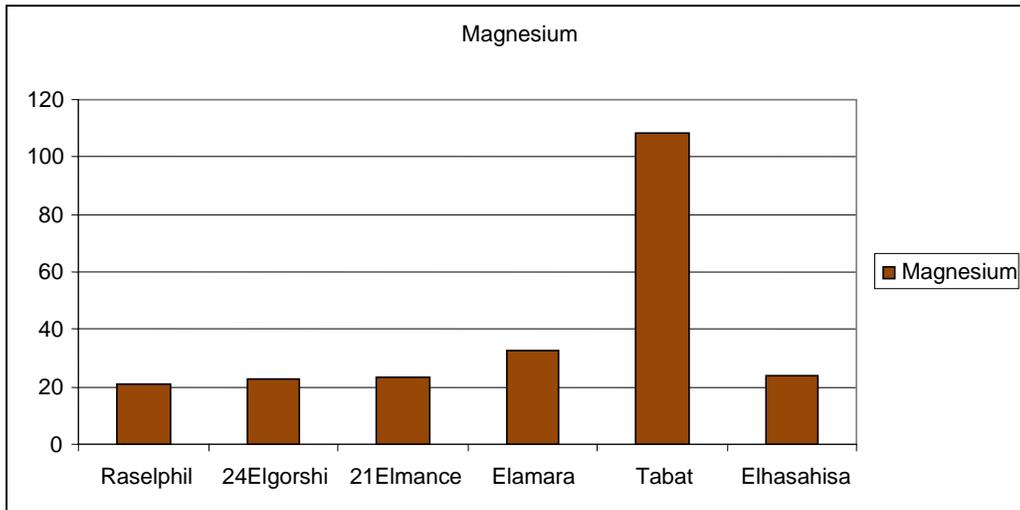
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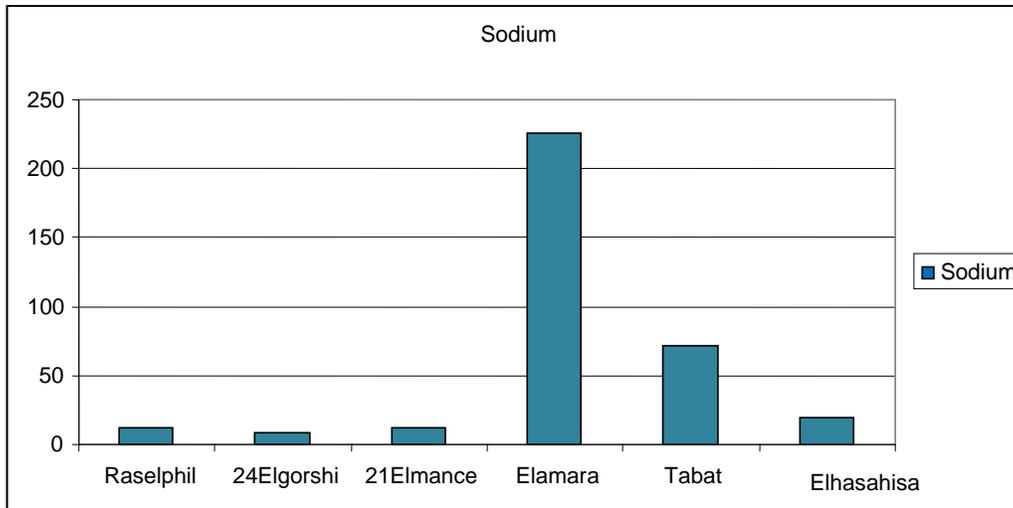
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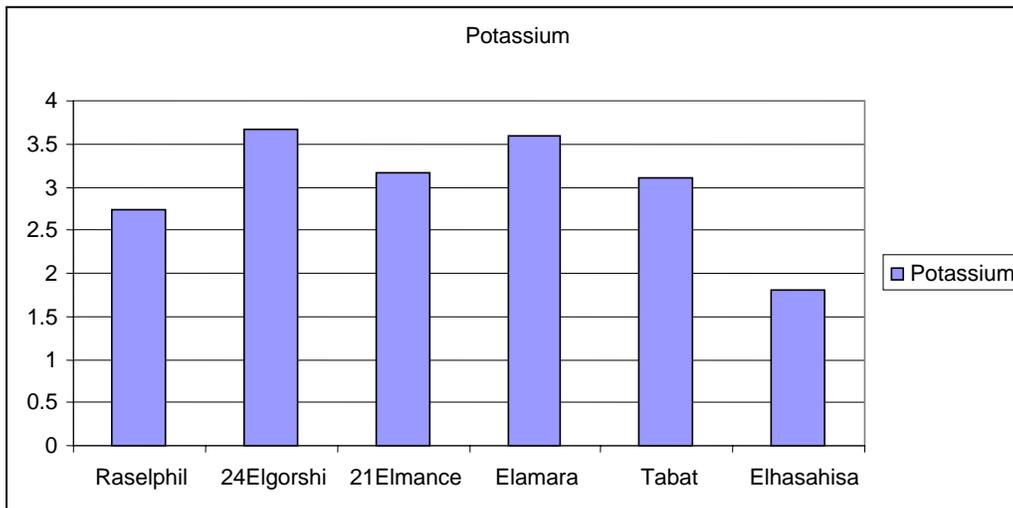
**Calcium levels in study area.**



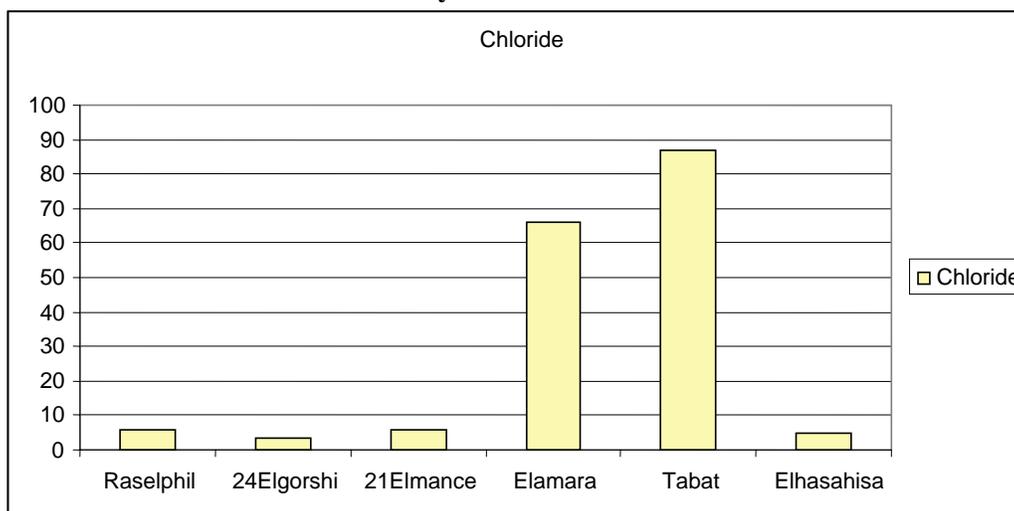
**Magnesium concentration in study area.**



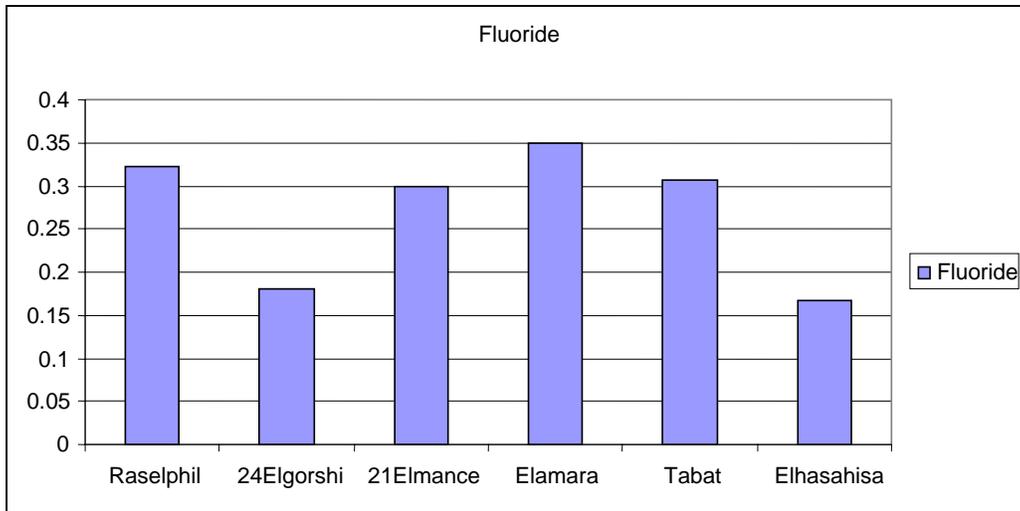
**Sodium concentration in study area.**



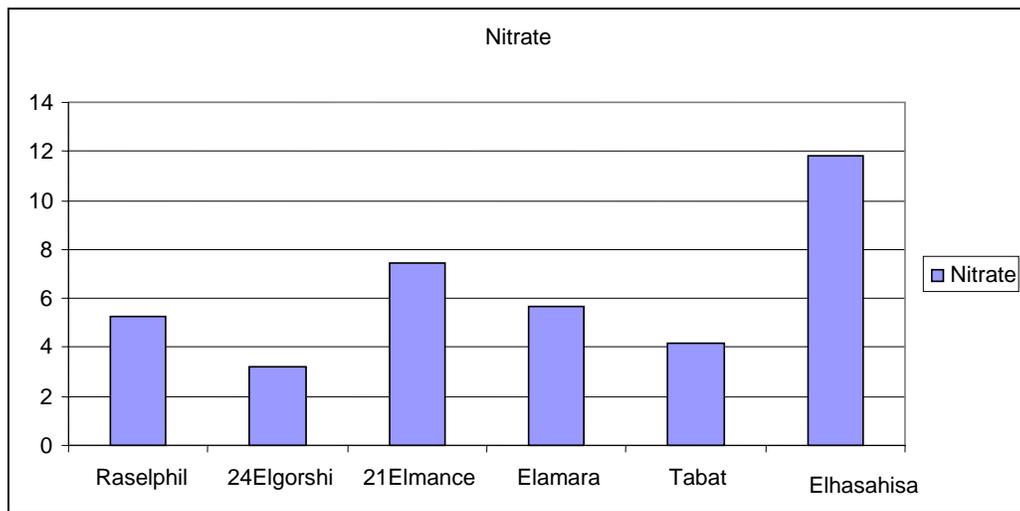
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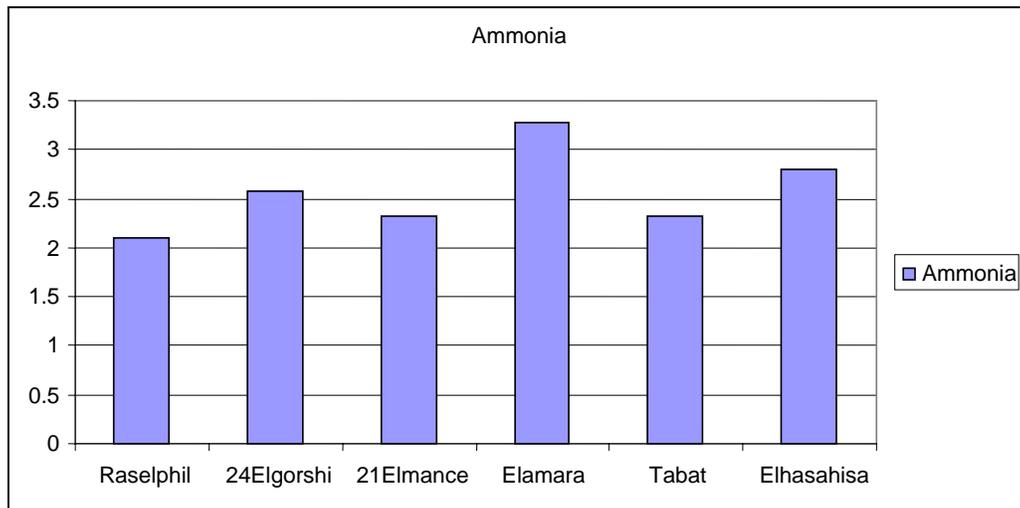
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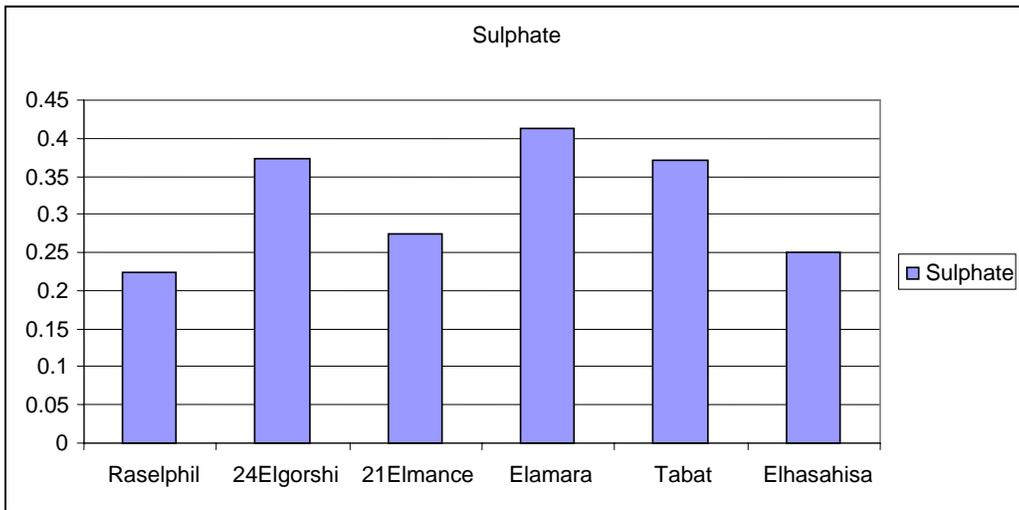
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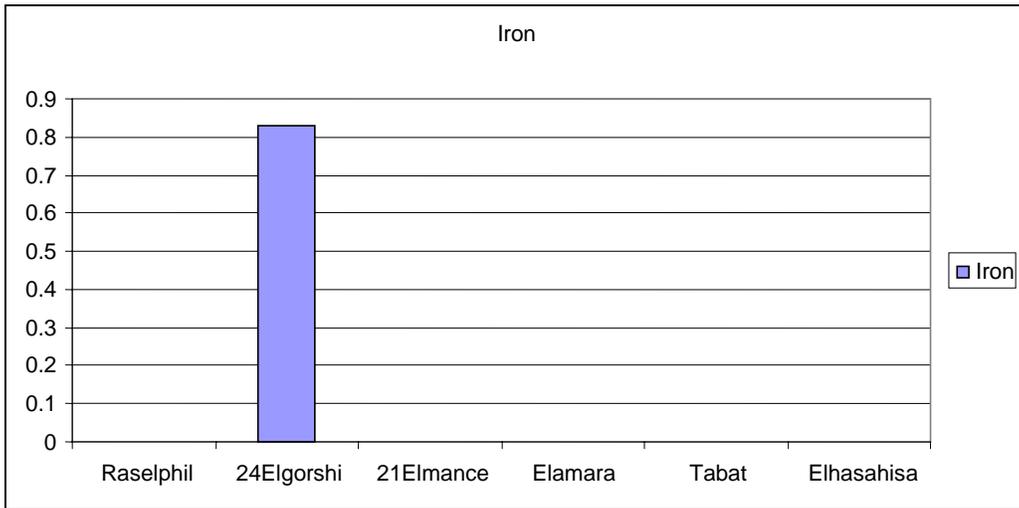
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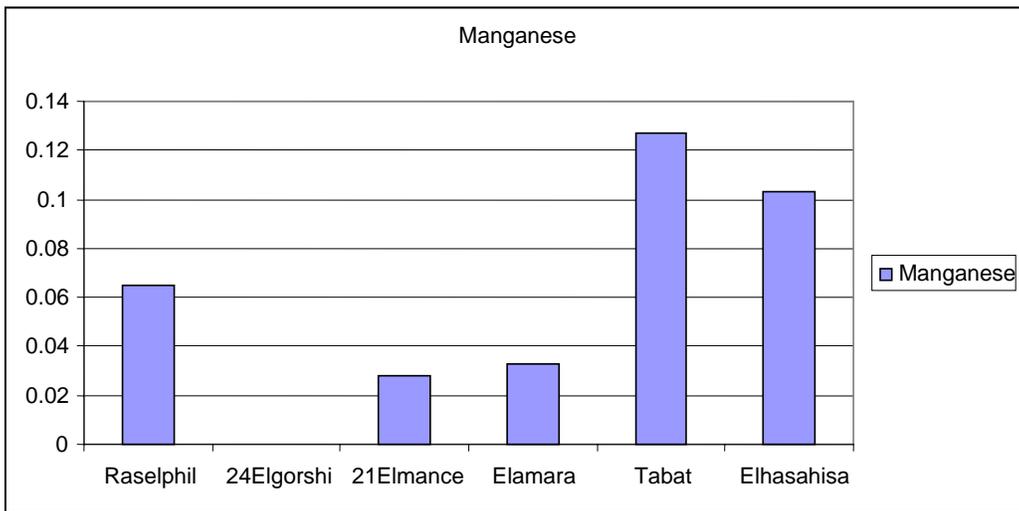
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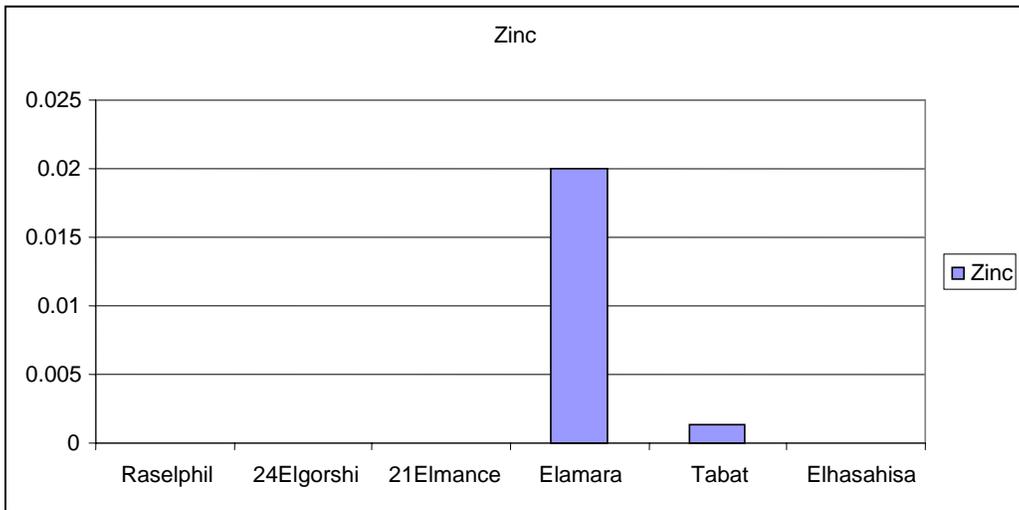
**Sulphate concentration in study area.**



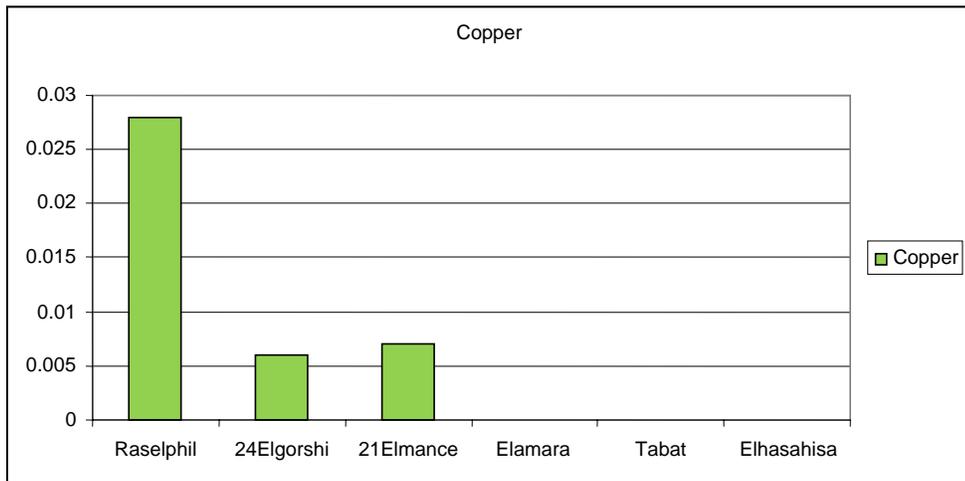
**Iron concentration as mg/L in study area.**



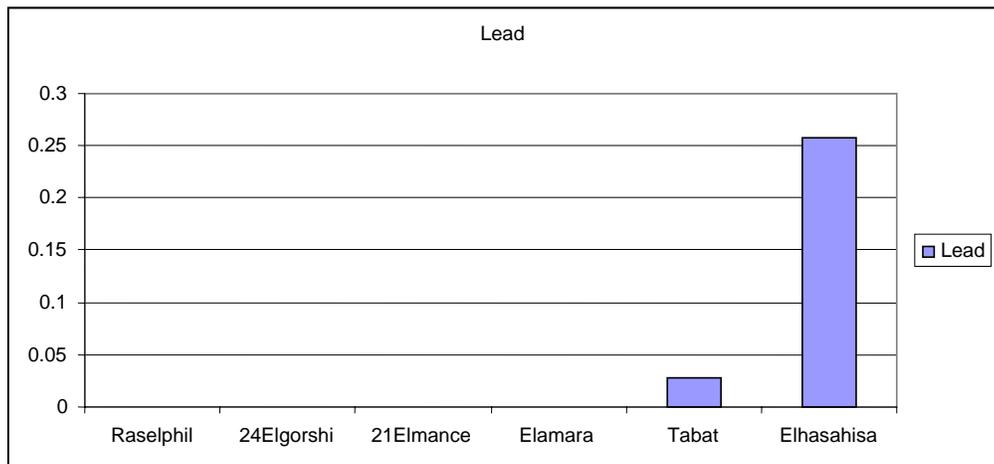
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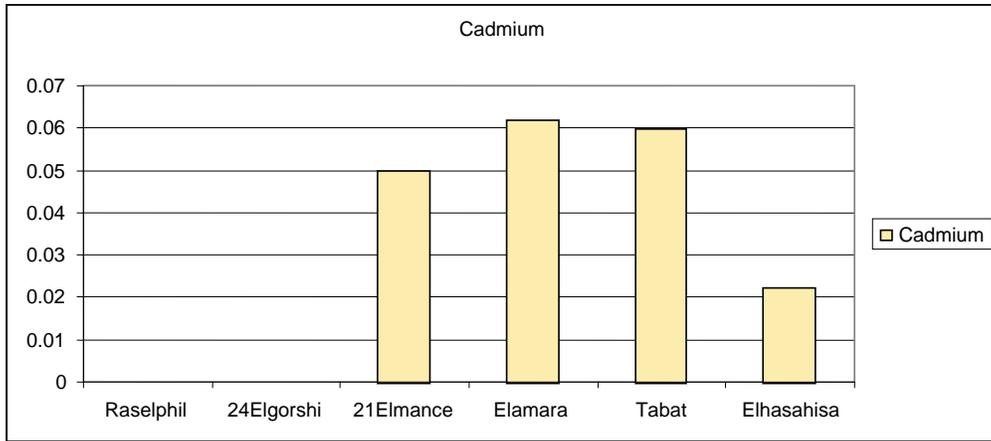
**Zinc concentration as mg/L in study area.**



**Copper concentration in study area.**



**Lead concentration in study area.**



**Cadmium concentration mg/L in study area.**