Sudan University of science & Technology

College of Graduate Studies

The quality of Water in the Traditional Mining Zone at Sodari Area

جودة المياه فى منطقة التعدين الأهلي فى منطقة سودري

A Thesis Submitted in Partial Fulfillment of the Degree of Master of Science in Chemistry

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DEDICATION

To my,

Parents Izzeldeen and Awatif

& my sister.

Acknowledgments

Above all, my thanks to almighty Allah for giving me strength, good health and sound mind to accomplish this work.

I am deeply indebted to my supervisor Dr. El Mugdad Ahmed Ali, for offering his time, inspiration, encouragement and support that enabled me through my research work and studies.

My thanks also go to all the people who contributed immensely in one way or another to the success of this work and my studies especially my uncle Elgezoli Edris Ahmed, also. I thank my friends for their abundant support both financially and morally. I will not forget to thank all my colleagues whom we spent together and had wonderful times during our studies. Special thanks go to my friends and to all those people whom I did not mention their names, I say thank you very much.

Abstract

This study is done to investigate the quality of water in Sodri in North of Kordfan and to see the effect of traditional mining on it̓s quality.

Three samples of groundwater were collected according to standards methods:- One sample from the hafir and two samples from the wells.

Samples were analyzed for physical and chemical parameters. A number of analytical techniques were used. Atomic Absorption Spectroscopy was used for quantification of elements namely iron, zinc, manganese and copper. Spectrometry was used for measuring nitrate and nitrite.

Flame photometer was employed for analysis of sodium, potassium, calcium and magnesium.

The pH results were found to be 7.69, 7.89 and 8.19; the electric conductivity 250 µs/cm , 2400 µs /cm and 2500 µs /cm; the total dissolved solid 150 mg/l, 1445 mg/l and 1500 mg/l; nitrate mg/l, 74 mg/l and 230 mg/l; chloride 14 mg/l, 115 mg/l and 170 mg/l.The results were recorded for the major elements; sodium 39.12 ppm, 507.7 ppm and 539.6 ppm; potassium 19.89 ppm, 20.69 ppm and 47.82ppm; calcium 91.05 ppm, 110.4 ppm and126.3ppm; magnesium 0.046 ppm, 0.332 ppm and 44.33ppm.

The results for trace elements were measured and found to be 0.3 mg/l, o.31 mg/l and o.5mg/l for Iron and 0.0034 mg/l, 0.0034 mg/l and 0.005mg/l; for manganese, 0.012 mg/l, 3.264 mg/l and1.597 mg/l for zinc; 0.703 mg/l, 75.16 mg/l and143.5 mg/l for copper. All the samples of water were turbid.

The results were compared with WHO and SSMO and were found not acceptable and chemically unfit for human consumption.

The deviation of the values for most constituents from these accepted and the change in these values indicates that the water was affected by the mining.

المستخلص

تم إجراء هذه الدراسة بمنطقة سودري التي تبعد عن مدينة الأبيض حوالي ٢٣٧ تقريباً كلم اتجاه الشمال الغربى وذلك لمعرفة نوعية المياه فى منطقة التعدين التقليدى وقياس قيم الأملاح المذابة في مياه الآبار والحفائر في المنطقة. باستخدام تقنيات الامتصاص الذري لتحديد كميات الحديد، الزنك، المنجنيز والنحاس و المضوائية الطيفية المرئية لتحديد قيم النترات والنتريت ومضوائية اللهب لتحديد اللهب لتحديد قيم الصوديوم، البوتاسيوم، الكالسيوم الماغنسيوم .

أجريت الدراسة في ثلاث مناطق هي بئرين وحفير لفحص جودة مياه المنطقة بدراسة الخواص الفيزيائية (الرقم الهيدروجينى ،الأملاح الكلية الذائبة و الموصلية الكهربية) والمكونات الكيميائية (الرصاص ، النحاس ، الزنك ، الحديد ، المنجنيز ، النترات ، النتريت، الصوديوم ،البوتاسيوم ،المغنسيوم والكالسيوم) لتلك المياه . لقد اظهرت الدراسة أن كل العينات للمياه تتصف بالعكورة.

أوضحت النتائج أن الرقم الهيدروجينى للعينات كالآتي ٧.٦٩, ٧.٨٩ و ٨.١٩. ونتائج الموصلية الكهربية هي ٢٥٠, ٢٤٠٠ و٢٥٠٠ الميكروسيمنز/ سم ومحتوى المواد الصلبة هو ١٥٠, ١٤٤٥و ١٥٠٠ ملجم/لتر كما أظهرت الدراسة أن كميات قيم عناصر التركيز المكبر التى تشمل الصوديوم وكانت النتائج ٣٩.١٢, ٥٠٧.٧ و٥٣٩.٦، البوتاسيوم٢٠.٦,١٩.٨٩ و٤٧.٨٢ جزء من المليون، الكالسيوم ١١٠.٤,٩١.٠٥ و ١٢٦.٣ جزء من المليون والمغنسيوم ٠.٣٣٢,٠.٠٤٦ و٤٤.٣٣ جزء من المليون و العناصر النزرة والتى تشمل الحديد ٠.٣, ٠.٣١ و ٠.٥ المنجنيز ٠.٠٠٣٤ ٠.٠٠٣٤ ٠. ٠.٠٠٥ ملجم /لتر الزنك ٠.٠١٢ , ٣.٢٦٤ ١.٥٩٧ ملجم/لتر والنحاس ٠.٧٠٣, ٧٥.١٦ ١٤٣.٥ ملجم /لتر ;و بينت أن قيم الرصاص في كل العينات أقل من ٠.٠١٥٠ ملجم /لتر

قامت الدراسة بمقارنة تلك النتائج مع منظمة الصحة العالمية (١٩٩٣) وهيئة المواصفات والمقاييس السودانية(٢٠٠٢) وكانت النتائج عالية فاقت الحدود المسموح بها ونتيجة لذلك هذه المياه غير صالحة لاستخدام الانسان.

النتائج العالية للعناصر مقارنة بقيم منظمة الصحة العالمية وهيئة المواصفات والمقاييس السودانية والتغير فى قيم العناصرفى المياه يدل على تأثير التعدين التقليدى على جودة المياه.

وتوصي الدراسة على الجهات المختصة اعادة الاعتبار والنظر في أثار التعدين الأهلي علي المياه والسعي للمعالجة أو ايجاد البديل المناسب والأفضل وذلك للحفاظ على سلامة الإنسان وصحته .

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Abbreviations

AAS	Atomic Absorption Spectrometer
A MIW	Acid Mine Influenced Water
BGS	British Geological Survey
B.P	Boiling Point
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPA	Engineering Consultant Ltd
FIg	Figure
GEF	Global Environment Facility
ILO	International Labour Organization
ML	Metal Leach
MIW	Mine Influenced Water
meq/l	Milli equivalents Per Liter m eq/dm^3
mg/l	Milligrams per Liter mg/ dm^3
M.P	Melting Point
ppm	Parts Per Million
SSMO	Sudanese Standard and Meteorology Organization
TH	Total Hardness
TDS	Total Dissolved solids
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization

CHAPTER ONE

1-Introduction &Literature Review

1.1The Chemistry of Water

Water has a simple molecular structure. It is composed of one oxygen atom and two hydrogen atoms. Each hydrogen atom is covalently bonded to the oxygen via a shared pair of electrons. Oxygen also has two unshared pairs of electrons. Thus there are 4 pairs of electrons surrounding the oxygen atom, two pairs involved in covalent bonds with hydrogen, and two unshared pairs on the opposite side of the oxygen atom. Oxygen is an "electronegative" or electron "loving" atom compared with hydrogen.

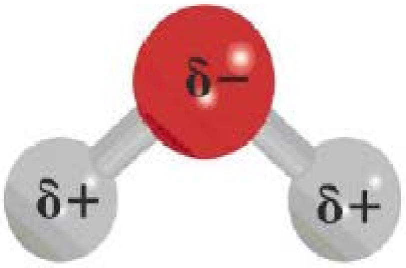

Fig (1)shape bent

1.1.1 The polarity of Water

Water is a "polar" molecule, meaning that there is an uneven distribution of electron density. Water has a partial negative charge (δ-) near the oxygen atom due the unshared pairs of electrons, and partial positive charges (δ-+); near the hydrogen atoms The H–O–H bond angle in water is 104.5, which means that the molecule has a bent shape. This bent geometry and the accumulation of electrons on the oxygen side of the molecule cause the water molecule to have a negative charge on one side, the oxygen side, and a positive charge on the other side, the hydrogen side. Molecules with negative regions and positive regions are called polar molecules.

1.1.2 Hydrogen Bond

An electrostatic attraction between the partial positive charge near the hydrogen atoms and the partial negative charge near the oxygen results in the formation of a hydrogen bond between molecules as shown in fig (2)

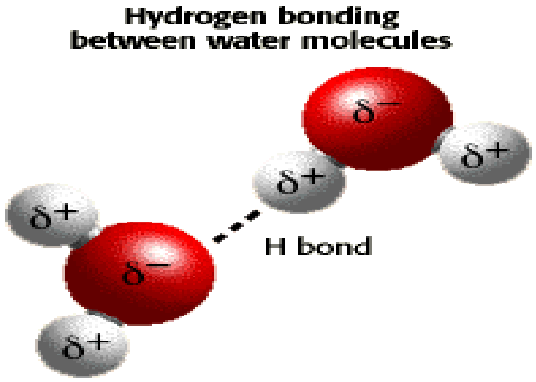

Fig (2) Hydrogen bonding between Water molecules

1.1. 3 Acids and Bases, Ionization of Water

$$H_2O \xrightarrow{\text{Limited}} H^+ + OH^-$$

- Acid release H^+
- Bases accept H^+

Amphoteric properties of water

We define the pH of a solution as the negative logarithm of the hydrogen ion concentration.

- at pH 7.0, a solution is neutral
- at lower pH (1-6), a solution is acidic
- at higher pH (8-14), a solution is basic

Amphoteric properties of water

1.1.4 Physical Properties of Water:

1.1.4.1 Odor

Odor can serve as a guide to gross pollution of water. For example, characteristic odors are associated with chlorination plants, untreated sewage and chemical industry effluents. Anaerobic conditions are also indicated by the smell of hydrogen sulphide, especially near boggy areas. It is not practicable to measure odor quantitatively but it is useful as an indicator of particular conditions.

1.1.4 .2Color

Even pure water is not colorless; in water may be a true color due to dissolved material or an apparent color when suspended material is present(Sawyer 1967). The latter is quite common in natural waters. In the case of drainage waters from peat or humus the brown color may be true or apparent. Similarly an orange color may be present in waters that have passed over iron – rich sediments or mine workings and some colors are associated with various industrial effluents. Color is measured visually against colored glass standard using a comparator or photo metrically with spectrophotometer.

1.1.4.3 Turbidity

May be used as an estimate of undissolved substances in the sample. It is generally measured by visual comparison with standards or photometrically, using a nephelometer or spectrophotometer (Stewart 1989).

1.1.4.4 Density

The density of water is the weight of the water per its unit volume, which depends on the temperature of the water. The usual value used in calculations is 1 gram per milliliter or 1 gram per cubic centimeter.

The density of pure water actually 1 g/cm^3. The maximum density of water occurs around 4 degrees Celsius. Ice is less dense than liquid water, so it floats.

1.1.4.5 Temperature

Technically, heat is an indicator of the kinetic energy of water, or energy of motion. Increasing temperature indicates increasing energy, or molecular motion, of water. Water temperature affects the growth and reproduction of living organisms. Water temperature has a tremendous impact on water density. Differences in water temperature and density cause stratification.

Water temperature can be measured with a thermistor, usually expressed in degrees Fahrenheit or Celsius.

1.1.4.6 Conductivity

Conductivity is a property of water governed by the total ionic content. It is often measured because of its value in characterizing waters. It expresses in resistance of 1 cm^3 of water to the passage of a current usually at 25 ^{o}C. The specific conductance is the reciprocal of the resistance (1/R) in Siemens (S) or more exactly C/R for a given cell expressed as Siemens per cm (S cm^{-1}). The digital readout of modern conductivity meters is in C/R units recorded as microsiemens per cm (µS cm^{-1}) for most fresh water but often millisiemens per cm (ms cm^{-1}) for a brackish sample. Conductivity measures the ability of water to conduct an electrical current and is directly related to the total dissolved salts (ions) in the water (Stewart 1989).

1.1.4.7 Surface Tension

Water has a very high surface tension. In other word, water is sticky and elastic, tend to clump together in drops rather than spread out in thin films. Surface tension is responsible for capillary action which allows water (and in it dissolved substance) to move through the roots of plants and through the tiny blood vessels in our bodies. The highest surface tension 73 dyne /Cm is at $20C^0$and 1atmosphere (Sawyer 1967).

1.1.4.8 Radioactivity

Water may contain trace amount of radioactivity caused by naturally occurring radioactive isotopes such as potassium (^{40}k), (Tebbutt 1998).

1.1.4.9 Viscosity

The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. For liquids, it corresponds to the informal concept of "thickness"; for example, honey has a much higher viscosity than water. Water has low viscosity.

1.1. 5 Chemical Properties of Water

Chemical characteristic tend to be more specific in nature than some physical parameter and are thus more immediately useful in assessing the properties of sample (Tebbutt 1998).

1.1.5.1 pH of Water

The technical definition of pH is that it is a measure of the activity of the hydrogen ion (H^+) and is reported as the reciprocal of the logarithm of the hydrogen ion activity. Therefore, water with a pH of 7 has 10^{-7} moles per liter of hydrogen ion. The pH ecological significance is wide because the behavior of many ions and organic compounds can be related directly to it. It is measured using a pH selective ion electrode. The pH scale ranges from 0 -14.In general, water with a pH < 7 is considered acidic and corrosive. This water with a low pH could contain elevated levels of toxic metals, cause premature damage to metal piping, and have associated aesthetic problems such as a metallic or sour taste. A water with a pH>7 is considered basic and hard. Hard water does not pose a health risk, but can cause aesthetic problems such as an alkali taste. Water can be softened through the use of ion-exchange or the addition of a lime-soda ash mixture, but both processes increase the sodium content of the water (Driscoll 1986).

The normal range for pH in surface water system is 6 to 7.5 and for ground water systems 6.5 to 8.5.

1.1.5.2 Dissolved Oxygen (DO):

The oxygen is a most important element in water quality control ,It's presence is essential to maintain the higher forms of biological life .The effect of a waste discharge in to rivers is largely determined by the biological system .unfortunately oxygen is slightly soluble in water (Sawyer 1967).

The solubility of oxygen in water decreases at higher temperature and becomes almost 0 at the boiling point. The oxygen content of ground water of depth greater than 100 ft is generally considered quite low. Water with dissolved oxygen corrodes metals more rapidly when the pH is low. However, water with some dissolved oxygen and relatively highly electrical conductance will be corrosive even though the pH may be 8 or more. Susceptible metals to corrosion include, iron, steel galvanized iron, and brass; the rate of corrosion tends to increase directly with temperature, but the amount of oxygen in solution decreases with increasing temperature. Therefore, corrosion rate may not vary significantly unless the heated water is under pressure.

1.1.5.3 Alkalinity

Alkalinity is almost entirely due to bicarbonate $(HCO_3)^-$carbonate $(Co_3)^{2-}$ or hydroxide $(OH)^-$ ions in natural water, usually in association with calcium, magnesium, sodium and potassium. Most the natural alkalinity in water is duo to (HCO_3) produced by the action of ground water on limestone or chalk.

$$\begin{array}{ccc} CaCO_3 & + H_2O+CO_2 \rightarrow & Ca\,(HCO_3)_2 \\ \downarrow & \downarrow & \downarrow \\ \text{Insoluble} & \text{from Soil Bacteria} & \text{(aq)} \end{array}$$

Alkalinity is useful in water and waste as it provides buffering resist changes in pH. pH is normally divided into caustic alkalinity above pH 8.2 .Therefore alkalinity can exist down to this pH because of the fact that HCO_3 is not completely neutralized until this pH is reached (Taylor1958).

Alkalinity range between pH 9.4 and 10.0 is due to caustic hydroxide alkalinity.

1.1.5.4 Hardness

This property of water prevents lather formation with soap and produces scale in water system. It mainly due to the metallic ions Ca^{++} and mg^{++}. The metals are usually associated with HCO_3^-, $SO4^{2-}$, SO_3^{2-} and NO_3^-.There is no hazard on hardness, but economic disadvantage of hard water include increased soap consumption and high fuel costs (Taylor1958).

1.1.5.5 Acidity

Most natural water and domestic sewage are buffered by $CO_3{}^{2-}$/ HCO_3^- system. Carbonic acid H_2CO_3 is not fully neutralized until pH below 4.5 thus CO_2 acidity is in pH range 8.2 to 4.5. Mineral acidity, usually due to industrial waste occurs below PH 4.5. (Tebbutt 1998).

1.1.6 Importance of Water

Water is vitally important for life maintenance. Over years, water quantity and quality has been regarded as limiting factor in controlling the size and shape of human settlement. Water is so important, because, of many reasons. Basically in biochemistry water is an excellent stable solvent needed for dehydration synthesis and hydrolysis. On the other hand there is a surprising connection between quality of drinking water and health. As a waste carried it can be responsible from many water born diseases such as cholera and typhoid fever (Imad 1993).

1.1.7 Water Resources

Water resources are useful to human, animals and plants. Many uses of water including agricultural, industrial, household, recreational and environmental activities virtually require fresh water. Only 3% of water on the earth is fresh water and over two third of this is frozen in glaciers and polar ice caps.(Mark 1981).Water demand already exceeds supply in many parts of the world and more areas are expected to experience this imbalance in the near future .The framework for allocating water resources to water users is known as water rights. (Mark 1981)

1.1.8 Drinking Water

Drinking water or potable water is water pure enough to be consumed or used with low risk of immediate or long term harm. The most developed countries the water supplied to household, commerce and industry is all of drinking water standard.

1.1.9 Ground Water Occurrence

Groundwater may be found almost anywhere in the world and in almost all types of geological formations however, its distribution in terms of quality and quantity varies from one place to another and from one geological formation to another (Fetter1994). (Freeze and Cherry 1979) noted that there are at least three factors that influence groundwater occurrence: hydraulic properties of the geological formations, geological framework, and climate.

1.1.10 Water Quality:

Criteria and standards of water quality are exposure limits for bacteriological, viral and chemical and physical and agent and that have been adopted by government or appropriate authorities therefore have legal force. The purpose to standards is to minimize all known health hazard, since it is obviously impossible prevent all pollution. The WHO has published in 1993vol.1 and in 1996 vol.2 of second Edition of guideline for drinking water quality indented for use by countries as a basis for the development, will ensure the safety of drinking water supplies. In order to define standards, it is necessary to consider these recommendations in the context of prevailing environmental, social, economic and cultural conditions. These guidelines for drinking water. The guidelines:

A- Acceptability aspects.

B- Microbiological aspect

C- Chemical aspect

D- Radiological aspect

1.2 Chemistry of Gold (Au):-

B.P (2,700C°)

M.P (1,064 C°)

Atomic Number: 79

Atomic Mass: 196.9665

Gold was discovered in as shining yellow nuggets and is undoubtedly the first metal known in early civilianization. The symbol drives from the Latin word aurum, which is related to the goddess of dawn, Aurora.

The electronic configuration of gold is $5d^{10}$ $6s^{1}$; for gold (I) it is $5d^{10}6s^{0}$ and for the gold (-I)anion it is $5d^{10}6s^{2}$.These configurations would justify the relative stability of gold (I) compound, with 10 electrons in a closed set of 5d orbital's even to some extent.

The color and luster of gold are what make this metal so attractive .Gold is found as the free metal and in tellurides. It is widely distributed and almost always associated with pyrite or quartz. In the mass, gold is yellow –colored metal, although it may be black, ruby, or purple .Gold is a good conductor of electricity and heat. It is not affected by exposure to air or to most reagents. It̓s inert and a good reflector of infrared radiation. Gold is usually alloyed to increase its strength pure gold is measured in to Ton weight, but when the gold alloyed with other metals term of karat is used to express the amount of gold present.

Gold uses extensively in jewellery, either in its pure form or as an alloy. And also it is used for coinage.

1.2.1 Gold Mining:

Gold mining from alluvium ores was once achieved by techniques associated with placer mining such as simple gold panning and sluicing, resulting in direct recovery of small gold nuggets and flakes. Placer mining techniques since the mid to late 20th century have generally only been the practice of artisan miners. Hydraulic mining was used widely in the Californian gold rush, and involved breaking down alluvial deposits with high-pressure jets of water. Hard rock ores have formed the basis of the majority of commercial gold recovery operations since the middle of the 20th century where open pit and or sub-surface techniques are used. Once the ore is mined it can be treated as a whole ore using a dump leaching or heap leaching processes. Normally, the ore is crushed and agglomerated prior to heap leaching. High grade ores and ores resistant to cyanide leaching at coarse particle sizes require further processing in order to recover the gold values. The processing techniques can include grinding, concentration, roasting, and pressure oxidation prior to cyanidation.

1.2.1.1 Industrial Scale

The solubility of gold in a water and cyanide solution was discovered in 1783 by Carl Wilhelm Scheele, but it was not until the late 19th century, that an industrial process was developed. The expansion of gold mining in the Rand of South Africa began to slow down in the 1880s, as the new deposits being found tended to be Pyritic Ore. The gold could not be extracted from this compound with any of the then available chemical processes or technologies. In 1887, John Stewart Mac Arther, working in collaboration with brothers Dr Robert and Dr William Forrest for the Tennant Company in Glasgow, Scotland developed the MacArthur-Forrest Process for the extraction of gold ores. By suspending the crushed ore in a cyanide solution, a separation of up to 96 percent pure gold was achieved.

1.2.1.2 Heap Leaching

Heap leaching was introduced in the 1970's as a means to drastically reduce gold recovery costs. This process has literally made many mines by taking low grade geological resources and transforming them to the proven ore category. Ore grades as low as 0.01 oz Au per ton have been economically processed by heap leaching.

Heap leaching involves placing crushed or run of mine ore in a pile built upon an impervious liner. Cyanide solution is distributed across the top of the pile and the solution percolates down through the pile and leaches out the gold. The gold laden pregnant solution drains out from the bottom of the pile and is collected for gold recovery by either carbon adsorption or zinc precipitation. The barren solution is then recycled to the pile. Heap leaching generally requires 60 to 90 days for processing ore that could be leached in 24 hours in a conventional agitated leach process. Gold recovery is typically 60-80% as compared with 85-95% in an agitated leach plant.

1.2.1.3 Sodium Cyanide Hazards

There is no potential interaction between wildlife and process solution containing sodium cyanide in the Heap Leach Facility in-heap pond as process solution is contained within the ore pore space and will be irrigated via buried drip emitters. Therefore, the in-heap pond will not include open solution accessible to wildlife. However, there is some risk to wildlife from cyanide containing process solution that may be temporarily stored in events ponds. To mitigate the potential for wildlife to be exposed to open ponds containing dilute sodium cyanide solution, the events ponds will be fenced, vegetation will be controlled, and Bird Balls, netting or reasonable alternatives will be used to deter waterfowl or other birds from landing on the ponds.

1.2.2 Traditional Mining

Traditional mining, also known as old-school mining, is a mining method involving the use of simple manual tools, such as shovels, pickaxes, hammers, chisels and pans (Areey2003) It is done in both surface and underground environments. Until the early 1900s, traditional mining was widely used throughout the world. It is still a used mining method in some countries, including Colombia and Peru in South America and Niger in Africa. In traditional surface and underground mining, hammers and chisels with pickaxes and shovels are used. Mine cars are used to move ore and other materials in the process of mining.(ILO 2005) Pans are used for placer mining operations, such as gold panning.

The traditional method of cracking rock was fire-setting, which involved heating the rock with fire to expand it. Once the rock was heated by fire it was quenched with water to break it. Fire-setting was one of the most effective rock-breaking methods until 1867 when Alfred Nobel invented dynamite.

Traditional mining operations have created some of the largest handmade features on earth, such as the Big Hole open pit mine in South Africa, which is claimed to be the largest hole on Earth excavated by hand.

Sudan experienced at least 5major episodes of mining boom :3000-1500BC:The ancient gold ,iron ore and copper mining activities in Nubia in northern and central Sudan around 10th Century Nuba, Beja, Arab and other tribes produced substantial gold in the Red Sea hills, Nubian desert, south Blue Nile, and Nuba mountains19th Century The Ottoman Empire gold quest in Sudan 1900 -1953 The Colonial gold mining in the Red Sea Hills, Northeastern Sudan 2005 Present The Recent gold mining boom in all Sudan,(Suliman 2015)

Artisanal scale mining is a gold focused activity in Sudan limited artisanal activities on chromite, limestone, and salt

Over 1 Million miners participate in gold mining and extraction, about 4 million dependents directly benefit from the activities, Activities cover 14 of the 18Sudanese states Artisanal gold mining accounts for 85% of the total gold extracted (2010 present).

1.2.3 Mercury

Mercury exists in both inorganic and organic compounds. Methylation of inorganic mercury into organic mercury occurs in micro-organisms under anaerobic conditions, for example, in underwater sediments. Organic mercury is highly poisonous and is easily absorbed by the gastric and intestinal organs, and it is carried by blood into the brain, liver, kidney and even foetus. For centuries, mercury has been used in the amalgamation of gold (Au). It is estimated that about 1.32 kg of Hg is lost for every 1 kg of Au produced (Harada et al. 1997). About 40% of this loss occurs during the initial concentration and amalgamation stage of Au. The lost Hg is released directly into the soil, streams and rivers, initially as inorganic Hg, which later converts into organic Hg. This is then taken up into the food chain, mainly by fish and other aquatic life. There mining 60% Hg is released directly into the air when the Hg–Au amalgam is heated during the purification process and is often inhaled. Mercury is a very volatile element, thus dangerous levels are readily obtained in air. Safety standards require that Hg vapor should not exceed 0.1mg/m^3 in air.

1.2.3.1 Mercury Use

Mercury is one of the pollutants that are causing growing concern due to its long term impacts on ecosystem and human health. Though the use of mercury is illegal in most countries, artisanal and small-scale mining remains a dangerous source of mercury pollution affecting all developing countries where gold is produced

(Veiga1997).Mercury is used to separate gold from ore and is leaked to the environment in many ways during the amalgamation process: unintentional spillage, discharge with other wastes into inadequate tailings ponds, direct discharge into rivers and waterways, or vaporization into the atmosphere. Gold in the ore sludge is mixed with mercury into an amalgam, which is then separated by heating into mercury vapors and gold. It has been found that an estimated two grams of mercury are released into the environment for each gram of gold recovered (UNIDO2001; Limbong et al. 2003). The negative impacts of gold mining due to the use of mercury amalgamation have been well documented all over the developing world. The Global Mercury Project, a joint effort of the Global Environment Facility (GEF), United Nations Development Programme (UNDP) and United Nations Industrial Development Organization (UNIDO), began in 2002 to address the environmental and health impacts from the use of mercury in small-scale gold mining. The Project focuses on six countries: Brazil, Sudan, Tanzania, Zimbabwe, Laos and Indonesia and was initiated to help demonstrate ways to overcome the barriers to the introduction of cleaner artisanal gold mining and extraction technologies. Preliminary investigations in these six countries were undertaken to establish the intensity of artisanal mining activities and their impacts on international water bodies (GEF et al. 2003).The extent of mercury lost depends on which of a variety of mining and amalgamation methods are used, along with the fate of contaminated tailings and Au-Hg separation methods. When mercury is placed on sluice boxes or spread on the ground to amalgamate the whole ore, losses can be 3 times the amount of gold recovered. When just the gravity concentrates are amalgamated, the mineral portion is separated from the amalgam by panning, forming an amalgamation tailing which is then usually dumped directly into a water stream creating a “hot spot” of mercury contamination (Veiga 1997).

1.2.3.2 Mercury in Water

Once it is in the water, mercury attaches to sediment and is transported downstream. Larger sediment sinks to the bottom but later re-enters the aquatic system when channel or floodplain materials are reworked by erosion (Miller and Lechler 2003).Mercury is also able to persist in surface waters for decades, which means that mercury use today will still impact these communities for years to come .It is widely recognized that cleaner production methods for artisanal and small-scale gold mining are needed to reduce the negative impacts on environment and health and to achieve legitimacy of the sector as a means of poverty alleviation and sustainable development. The technologies that are developed must satisfy certain criteria in order to be viable for the sector: economically beneficial, simple and expedient (Hinton and Veiga 2003).

1.2.3.3 Health Effect of Mercury

While most mercury released into the environment is in the form of elemental or inorganic mercury, it is organic mercury in particular, methyl mercury that poses the greatest threat to humans and wildlife. A potent neurotoxin, exposure to methyl mercury impairs the brain, kidneys, and liver, and causes developmental problems, reproductive disorders, disturbances in sensations, impairment of speech and vision, hearing and walking difficulties, mental disturbances, and death. A person with methyl mercury poisoning has five typical symptoms: visual constriction, numbness of the extremities, and impairment of hearing, speech and gait (Veiga1997).In a number of studies undertaken in artisanal and small-scale mining communities, neurological problems have been found in miners and surrounding communities due to inhalation of vapors when the amalgam is heated. Thus, mercury affects not only the miners themselves, but surrounding communities and communities downstream from the mining locations as well. Previous studies on

Hg pollution in Ghana dealt with research data on some of the rivers draining south-western Ghana.Adimado and Baah (2002) studied Hg concentrations in human blood, urine, and fish from a kobra and Tano rivers. Bannerman et al. (2003) reported Hg and as contaminations in sediments and water in gold mining regions in the kobra river basin. Similarly, Bonzongo et al. (2003) investigated water, soil and sediments from artisanal gold mining areas, and reported high Hg and toxic element concentrations.

1.3 Literature Review

1.3.1 Definition of Mine Influenced Water

A Mining influenced water (MIW) as any water whose chemical constituents.MIN refer commonly to ground water of surface drainage containing mainly up normal levels of acidity or alkalinity, iron, calcium, manganese, zinc, magnesium and anions like chloride ,fluoride (Harries1997). Rock-drainage is another term for MIW, because it is a consequence of the interaction of rock and minerals with the water MIW can be acidic mine, neutral, or alkaline according o the type of interacting rocks and minerals. It is natural consequence of mining activities or any other large earth disturbance which exposes sulpher containing minerals to oxygen, water and microorganism (Stephen1999). Acid rock-drainage is the most descriptive terminology of acidic water that originated from acidic rock, because the generation of acidic water can occurs naturally without mining or any other anthropogenic earth disturbance, which can be greatly accelerated by mining or any other anthropogenic activities due to increased exposure of sulphide minerals to air and water abandoned Mine drainage.

The mine acidic water originated as result of sulphide minerals oxidation.

Table (1) the common sulphide minerals

No.	Mineral	Chemical composition
1	Pyrite	Fe S_2
2	Marcasite	Fe S_2
3	Chalcocite	$Cu2_S$
4	Sphalerite	Zn S
5	Cinnabar	Hg S

The oxidation produces acidity (H^+), this oxidation is highly accelerated by the presence of some type of microorganism when these minerals are exposed to oxygen by any natural or anthropogenic reasons, combination of auto- oxidation and microbial oxidation.

Chemistry of mine influenced water

The oxidation products are sulphuric acid, ferrous ion and in addition to heavy metals found in the parent minerals rock. The overall equation production can be summarized in the following equation

$$4\ FeS_2\ (s) + 150_2 + 14\ H_2O \rightarrow 4\ Fe(OH)_3 + 8\ H_2SO_4\ (aq).$$

Elements such as copper zinc and manganese commonly found in the rock adjacent to MIW.

1.3.2 Impact on Water Resources

Perhaps the most significant impact of a mining project is its effects on water quality and availability of water resources within the project area. Key questions are whether surface and groundwater supplies will remain fit for human consumption, and whether the quality of surface waters in the project area will remain adequate to support native aquatic life and terrestrial wildlife.

The impacting untreated mine water on aquatic communities may not be immediately apparent, but possibly severe. The greatest impact of mine water pollution occurs in small streams.

1.3.3 Acid Mine Drainage &Contaminant Leaching:

Acid mine drainage is considered one of mining’s most serious threats to water resources .Amine with acid mine drainage has the potential for long-term devastating impacts on rivers, streams and aquatic life. Because during mine operations and ore mental impacts on both the natural and social environments.

Reclamation, rocks and other cuttings are left exposed to air, and rainwater react with exposed natural metals and create soluble acids which intern will move with rainwater to the surrounding water streams. Heavy metals are persistent material and they will stay in water stream for ages causing damage to aquatic life as well as people and animals that drink from these water sources. As discussed in the baseline chapter, the water resources in the study area are limited to rainwater and groundwater and both sources need to be preserved during mining operations.

1.3.4 Effect OF Metals Ions on Macro-Invertebrate

Heavy metals act as metallic poisons and increase the toxic iron, manganese are among metals that have severe impact on aquatic life.

These trace metals such as Zn, Cu, which often present in high concentration are toxic at extremely low concentration and may act synergic ally to suppress a algal metals growth and effect fish and aquatic insect.

1.3.5 Prediction of AMIW

Mining activities throughout the world is associated with acid rock- drainage and metal leaching (ML) which are considered to be the most problematic environmental challenges facing mining, public, governmental and environmental.

1.3.6 Treatment of MIW

Treatment of MIW is the final step carried after the control and prevention methods and techniques failed to stop or reduce the leached metal and acidic mine drainage.

Treatment or remediation solution of MIW should consider many integrated factor which increase the effectiveness of treatment method use, these method should be environmentally friendly and avoiding incorporation of foreign pollutant to the environment's by-products of the treatment in addition to its main function in removing toxic material.

The removal of metals is based on mechanical, chemical and biological process.

The treatment technology must be flexible and can be adapted to scientific and technological advances that will be made in the future (Sheldon 2004).

1.3.7 Statement of Problem

The chemical quality of water resources in the Sudan has been little documented (BGS, 2004). From the limited information available, the resources compositions appear to be spatially variable and highly dependent on geological properties natural of area generally. A large proportion of the population of North Kordofan relies on groundwater and Hafirs for domestic use and livestock. However treated borehole water supplies for natural chemicals and by accredited water utilities are not available (Pritchard et al. 2007). There is health problems associated with intake of water with high concentrations of chemical compounds from groundwater (EPA, 2008). Dental fluorosis is common in some parts of Sudan but studies on fluoride levels of drinking water sources have not been adequately done. In small doses (0.5-1.5 mg/l), fluoride helps prevent dental carries but in doses above 1.5mg/l fluoride causes teeth and bone fluorosis (WHO, 2008). EPA (2008) observes that the short-term problems associated with excessive levels of nitrate in drinking water are serious illness and sometimes death especially in infants. These problems range from an acute condition in which health deteriorates rapidly over a period of days. Long-term intake of nitrates and nitrites has the potential to cause dieresis, increased starchy deposits and hemorrhaging of the spleen (EPA, 2008).

1.4. Aims &Objectives

- **The main objectives of this study can be summarized as follows:-**
  - To analyze and determine the chemical quality of groundwater and hafirs for drinking in Sodari area in North Kordfan and comparing them with WHO guidelines , and Sudanese standards to identify areas with critical quality issues and suggest possible interventions .
  - To determine the chemical quality of groundwater by measuring TDS, hardness, calcium, sodium, potassium, magnesium, chloride, electrical conductivity, pH, nitrate, nitrite, iron and. to compare with the WHO guidelines and Sudanese standards.

CHAPTER TWO

2. Materials & Methods

2.1 Study Area

2.1.1 Location\Selection of Water points

Study area is geographically located between 29^0 07’ 52.90’’ and 29^0 08’ 02.40’’ east longitude, 14^0 24’ 19.8 and14^0 24’ 20.1’’ north latitude in north Kordofan state, Sudan **Table (2).**

The licensed area cover an area of about 105,000 square meters and is accessible by paved road from Khartoum to Obied about 340 Km and then by unpaved road to Sodari locality of about 200 Km of unpaved road.

The study was conducted in Sodari in north Kordofan state, to investigate water quality in the area of traditional gold mining .The area was selected because of its position in relation to groundwater morphometry and it is very necessary to assess water quality.

Table (2): coordinate the study area

Point	N coordinate	E coordinate
A	14^0 24’ 29.80’’	29^0 08’ 02.40’’
B	14^0 24’ 19.80’’	29^0 08’ 02.40’’
C	14^0 24’20. 10’’	29^0 07’ 52.90’’
D	14^0 24’ 19. 90’’	29^0 07’ 52.90’’

2.1.2 Climate

Although Sudan lies within the tropics, the climate ranges from arid in the north to tropical wet-and-dry in the far south west .North kordfan region characterized by semi-desert climatic conditions, where long hot summer, cold winters and short rainy seasons from July to September with low rain fall rates prevail. Semi-desert climate of the region where temperature in summer reaches almost 39^0C & goes down in January to 13.5^0C.The climate specifically in this period is cold or medium; rainfall range in the period July- September is150-250 mm.

2.1.3 Hydrology

For much of Kordfan, surface –water supplies collected and stored in hafirs, fulas, and tebeldi trees are almost completely appropriate for present needs, and water from wells must serve as the base for economic and cultural development.

Kordfan in central Sudan lies within the White Nile –Nile River drainage basin. Seasonal rainfall, ranging from 100 mm-250 mm, occurs almost entirely during the summer months, but little runoff ever reaches the Nile River (wadi Elmalik).

2.2 Sample Collection

Water samples were collected according to standard methods from the ground water sources at the traditional mining area, one sample from the hafir and two samples from the hand dug wells in Sodari to determine the quality of drinking water. Samples were submitted to laboratories for analysis.

For the purpose of accomplishment of the stated objectives of this study, a number of analytical techniques have been used.

2.2.1 Sampling

- The cap was removed and mouth of bottle was faced up.
- The plastic bottle was washed 4 times by distilled water.
- The plastic bottle was pushed from horizontal position until was filled, from the hafir and hand dug wells.
- The sample bottle was closed and was labeled with sample code number.

2.3 Chemical

- Ethylene diamine tetra acetic acid solution disodium salt.
- Buffer 10 solution
- 0.014M $AgNO_3$ solution
- Eriochrome Black T solution
- NaCl Solution
- Nitraver 5Tablet (nitrate reagent powder)
- Nitriver 3 Tablet (nitrite reagent powder)

2.4 Instrumentals

- pH/ meter ,HANN, model(301,ITALY)
- Conductmeter (Hach Sens ion712 Metrohm).
- Spectro direct (2005, USA).
- Spectrophotometer, Lovibond (D.R 4000 Hach, 2010 USA).
- Flame photometer (2005, USA)
- AAS, Shimadu, Computerized model (2380, USA).

2.5 Sample analysis

2.5.1 Physical & Chemical Parameters:

After collection, the pH, Total dissolved solid and electrical conductivity were measured.

2.5.2 Determination of Nitrates & Nitrite

The sample of nitrite was acidified with sulfuric acid to form an intermediate diazonium salt. This is salt couples with acid to form colored solution. For nitrate determination, UV spectrophotometer (D.R 4000 Hach cadmium reduction method range 0-30 mg/l) was used; the sample cell was filled with 10 ml of the sample. The content of one nitraver 5 nitrate reagent powder pillows was added to the sample cell and the cell was Stoppard and shaken vigorously. A 5 minute reaction period was started, after which, a second cell was filled with 10 ml deionized water as a blank. The wavelength (λ) 500 nm was automatically selected. The light shield was closed. The result in mg/l nitrate recorded.

For nitrite determination a low range of the stored program number was selected by pressing nitrite setting, the wave

Length (λ) 507 nm was automatically selected. The sample cell was filled with 100 ml of the sample. The content of one nitriver 3 nitrite reagent powder pillows was added to the sample cell and the cell was Stoppard and shaken vigorously. 20 minute reaction period was started, after which, a second cell was filled with 10 ml deionized water as a blank. The result in mg/l nitrite was recorded

2.5.3 Determination of Chloride Concentration

Mohr’s method (titration with silver nitrate) was used for determination of chloride ion concentration. 10 ml of ground water sample was transferred to 250 ml titration flask and titrated against standard silver nitrate solution 0.014M. A precipitate of silver chloride forms according to the reaction;

$$Ag^{+}{}_{(aq)} + Cl^{-}{}_{(aq)} \rightarrow AgCl_{(s)}$$

The end point of the titration occurs when all the chloride ions are precipitated. Then, additional chloride ions react with the chromate ions of the indicator, (potassium chromate) to form a red-brown precipitate of silver chromate:

$$2Ag^{+}{}_{(aq)}+CrO_4{}^{-2}{}_{(aq)}\rightarrow Ag_2CrO_{4(s)}$$

The average volume of silver nitrate measurements for each titration was taken from which the moles of silver nitrate reacting are calculated. The following reaction was used to determine the moles of reacting chloride ions:

$$Ag^{+}{}_{(aq)}+Cl^{-}{}_{(aq)}\rightarrow AgCl_{(s)}$$

The chloride concentration was calculated for each ground water sample in mol\Land then multiplied by the atomic weight to convert to ppm or mg/l.

2.5.4 Determination of Water Hardness (Calcium +Magnesium)

Reagent:

- Buffer 10 solutions.
- EDTA solution consists of (1.179g Ethylene diamine tetra acetic acid (EDTA).
- Indicator solution consists of (Eriochrome Black T 2.36g (0.5g in100mg NaCl)).

Procedure:

Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter. Reactions taking place during titration are:

$$Ca^{2+} + EDTA^{2-} \rightarrow Ca\ EDTA$$

&

$$Mg^{2+} + EDTA^{2-} \rightarrow Mg\ EDTA$$

Calcium hardness determined after removing magnesium interference by adjusting the pH of the sample to 12 with sodium hydroxide. Exactly 50 ml of Filter solution was transferred to 250 ml Erlenmeyer flask and then added 2 ml of ammonia buffer and 3 drops of the indicator Eriochrome Black T solution with NaCl titrated with 0.01M EDTA solution till color changes from violet to blue. As water hardness is usually reported in terms of mg/L of calcium carbonate (even if water contains both calcium and magnesium), that allows direct calculation of calcium carbonate mass for known amount of titrant used strange reaction equation:

$$CaCO_3 + EDTA^{2-} \rightarrow Ca\ EDTA + CO_3^{2-}$$

Magnesium hardness was determined by using mathematical approach by subtracting the calcium hardness from total hardness results reported in mg/l magnesium.

$$MgH\ (mg/L) = Total\ Hardness - Calcium\ Hardness$$

2.5.5 Determination of Sodium & Potassium Using Flame Photometer

In principle, it is a controlled flame test with the intensity of the flame colors quantified by photoelectric cell. The sample was introduced to the flame at a constant rate. Filters select which color the photometer detects and exclude the influence of other ions. Before use, the device was calibrated with a series of standard solutions of the ion to be tested. The solution to be analyzed is discharged through an atomizer in a fine mist into a chamber, whence it is drawn into a flame. By an optical system the light produced by the combustion of the elements in the vaporized solution is conducted through appropriate filters to impinge upon a photoelectric cell which activates a galvanometer. The results from calibration curve were recorded in (ppm) for sodium and potassium

2.5.6 Determination of Trace Elements (Fe, Mn, Zn ,Cu &Pb)

A series of working standard solutions were prepared from the stock solution of each element depending on the sensitivity range specified in the manual of the AAS. The atomic absorption spectrophotometer Shimadu, Computerized model (2380, USA, 1996) was calibrated using these standard solution for each element. Stock standard solutions containing 1000 mg\l of copper, zinc, manganese and iron were obtained from Prim Ag® -Plus Certified reference material. Specifications of these stock solutions are Cu (metal), Zn (metal), Mn (metal), pb (metal) and $Fe(NO_3)_3.9H_2O$ in HNO_3 (0.5M) matrix. About 20 ml of each of the working standard solutions and sample solution were separately placed into 50 ml beaker. After an allowed warming up period for the spectrometer, the blank (zero mg/l standards) was set to zero deflection. Sample solutions were aspirated into the flame under the same conditions as the working standard solutions. The atomization tube was rinsed with distilled water after each sample reading. The calibration curve of absorbance versus concentration was plotted using integrated software program with the instrument for Zn, Cu, Fe, and Mn, and Pb the concentrations of the analyst in (mg/l) **.**

CHAPTER THREE

3. Results, Discussions, Conclusion& Recommendations

3.1 Results

Table (3)

Statistical summary of physical properties electrical conductivity (µs/cm), pH and total dissolved solid (TDS) mg/l in ground water samples collected from wells and hafir located in Sodari aquifer

Parameter	Sample1well	Sample2Well	Sample3Hafir
Electrical conductivity (µs/cm)	2400 µs/cm	2500 µs/cm	250 µs/cm
pH	7.89	7.67	8.19
Total Dissolved Solid (TDS) mg/l	1445	1500	150

Table (3) presents the statistical summary of physical properties measured in groundwater samples collected from hafir wells located in Sodari aquifer. The electrical conductivity (EC) values were found to be 2400, 2500,250 µs/cm. The pH was measured and was found to be 7.89, 7.67and 8.19.

The total dissolved solid (TDS) ranged from 1445, 1500, t0150mg/l.

Table (4) Statistical summary of concentration (mg/l) of Nitrate &Nitrite and Chloride in ground water samples collected from wells located Sodari as shown in table (4) below

Analyze	Sample1	Sample2	Sample3	WHO-1993	SSMO2002
Nitrate	74	230	5	50	45-50
Nitrite	0.2	0.5	<0.01	0.02	-
Chloride	170	115	14	250mg/l	250mg/l

Table (5)

Statistical summary of concentration (ppm) of major elements in ground water samples collected from hafir and wells located in Sodari aquifer

Element	Sample1 ppm	Sample 2ppm	sample 3 ppm	WHO-1993	SSMO-2002
Na	507.7	539.6	39.12	200	200
K	19.89	47.82	20.69	---	
Ca	126.3	91.05	110.4	---	
Mg	0.046	44.33	0.332	---	

On (Table5) data showed the concentration of potassium ranged from 19.89, to 47.82ppm, calcium concentration ranged from 91.05to126.3ppm and magnesium concentration ranged from 0.332 to 44.33ppm and sodium ranged from 39.12 to 539,6ppm.

Table (6):

Statistical summary of concentration (mg/l) of some trace elements in ground water samples collected from wells located in sodari aquifer

Element	Sample 1	Sample2	Sample3	WHO(1993) mg/l	SSMO(2002) Mg/l
Fe	0.31	0.3	0.5	0.5-50	0.30
Mn	0.0034	0.005	0.0034	0.50	0.50
Zn	1.597	0.012	3.264	3.00	3.0-3,5
Cu (mg/l)	143.5	0.703	75.16	2.00	1.50
Pb(mg/l)	< 0.0150	< 0.0150	< 0.0150	0.01	0.01

AAS, Shimadu, Computerized model (2380, USA, 1996) was used for the measurement of elements concentrations namely Mn, Fe, Cu, Zn and pb in water samples.

3.2 Discussion

This study is done to investigate the quality of drinking water (groundwater) in mining area at Sodari by determination of the physical properties and the chemical analysis.

Three samples were collected from different sources (Hafir and Hand - dugs wells).The physical examinations included the electrical conductivity EC, pH and TDS and chemicals examinations also applied and the results were compared with international drinking water guidelines.

Table (3) presents the statistical summary of physical properties measured in groundwater samples collected from wells located in Sodari aquifer. The electrical conductivity (EC) values are highly scattered ranging between 250 to 2500 µs/cm with an75% of the EC values exceed 1000 µs/cm, the guide-line value specified by WHO (WHO, 1993).

The electrical conductivity (EC) is important because it is a measure of salinity and chloride ion concentration which greatly affects the taste and odor problems. Conductivity can be used as a measure of total dissolved solids (TDS) which is expressed in ppm. These solids are usually composed of sulfate, bicarbonate, and chlorides of calcium, magnesium, and sodium. The conversion factor used for converting EC values into TDS is 0.64. For this reason EC values may, sometimes, be considered to be a measure of water quality.

The total dissolved solid (TDS) ranged from 150 mg/l to 1500 mg/l, which exceeded the permissible level of WHO (1993) standard and SSMO (2002)**.**

The pH range from 7.67 to 8.19 (Table 3). All the samples had pH values within the permissible range of 6.5 – 8.5 (WHO, 1993) and SSMO (2002) organic Statistical significance nitrate–N concentration in wells influences pH values.

The low pH values could affect leaching of metal ions such as iron, manganese, copper and zinc to the aquifer.

The nitrate concentration of the groundwater samples collected from the study area ranged from 74,230 mg/l and 5mg/l as shown in (Table4). which was found that the values obtained were exceeded permissible level WHO guide line for drink water and set for drinking water by the Sudanese Standards and Metrology Organization (SSMO, 2002) guide line for drinking water. The nitrite ion is relatively unstable and can be rapidly oxidized to nitrate and is seldom present in well oxygenated or chlorinated supplies. Chemical and biological processes can result in further reduction to various compounds, including ammonia, or re oxidation to nitrate.

The recommended guide line values for nitrite in drinking water are o.o2 mg/l (WHO 1993) and (SSMO 2002). Accordingly, the nitrite concentrations for the analyzed samples lie far over the maximum levels for WHO and SSMO. The toxic effects of nitrate exposure result from the conversion of nitrate to nitrite Water needs to be treated to be acceptable for drinking. Chloride ion concentration and the cause in the samples highly ranged from 170 mg/l,115 mg/l,14mg/l. Most samples exhibited exceeding guidelines for drinking water of 250 mg/l WHO and (SSMO,2002) 100mg/l. The high concentration of chloride ions is an indication of ground water salinity, and high salinity in the area occurred at well 1.

Data in Table (5) show the concentration of potassium ranging from 19.89ppm to 47.82ppm, calcium concentration ranging from 91.5 ppm to126.3ppm and magnesium concentration ranging from 0.046ppm to 44.33ppm which does not fall within acceptable WHO levels (WHO 1993), sodium ranging from 39.13mg/l to 539.6mg/l the which exceed the limit for drinking water of 200 mg/l(WHO) except sample 3. However, generally sodium concentration is not related to the contamination. That groundwater contamination is related to the distribution of chemical water types.

All Ca subtype water was contaminated with nitrate and bacteria. Temporal fluctuations in nitrate concentrations of Ca subtype water are attributed to seasonal fluctuations in recharge and in plant growth. Ca-Mg water subtype, and Na-HCO_3 and Na-Cl water types were generally not contaminated, and associated with longer residence times and reducing conditions, which allow bacterial die-off and denitrification, respectively. That controls the rate and depth of active groundwater circulation.

Data show that concentration of manganese ranged from 0.0034mg/l to 0.005 mg/l and zinc concentration ranged between 0.012 mg/l to 3.264 mg/l. The measured concentrations of manganese and zinc were less than maximum limits 0.3 mg/l and 5 mg/l, respectively the permissible level of (WHO, 1993) and SSMO (2002) zinc standard is 3.5 mg/l and 3.0mg/l, respectively .This indicates that there are no hazards associated with these two elements. Iron concentration ranged between 0.3 mg/l to o.31 mg/l. it lower than the upper limit recommended by WHO (1993) standard; .these essential elements are needed to maintain the physiological functions. Copper concentration ranged between 0.703 mg/l to 143.5 mg/l. all the samples contained copper concentration then that maximum 2 mg/l allowed by WHO for drinking water ;which although, it had a higher concentration of iron that recommended in some locations ,it is highly needed for haemopyosis. Whereas for manganese, zinc and copper the concentration was found to be within both (WHO 1993) and (SSMO, 2002) limit pb values <o.o150 mg/l less than WHO level o.o1mg/l when EPA has a set the maximum contaminant level for lead at zero because, lead is toxic metal that can be harmful to human health even at low level.

3.3 Conclusion

Based upon the results obtained in this study, the following concluding remarks can be drawn:

1. The electrical conductivity (EC) measurement of the water in wells exceeded the permissible level specified by WHO, and most of these wells are located in north Sodari part of the aquifer. EC results are usually used to measure of TDS.
2. All pH values of water samples of the investigated wells were within the acceptable range except of well No3 which is considered alkaline.
3. Nitrate and nitrite concentration in high of the wells exceeds the maximum permissible limit set for drinking water, and that the majority of these wells are located in north and north-east part of the study area.
4. The chloride ion concentration falls within less than limit for drinking water set by WHO. Potassium, calcium sodium, and magnesium concentrations were found to be exceeded permissible level of WHO drinking water.
5. Manganese, zinc and copper concentrations were found which exceeded permissible level WHO except of the iron sampled sample 3 exceed the WHO limits for drinking water.
6. The chemicals used in mining and processing minerals contaminate the land, water, and air, causing health problems for workers and people living near mines due to toxicity.
7. The analysis of the water samples taken from the above mentioned hafir has proved that its water is chemically fit for human consumption (although it appeared to be alkaline and moderately hard),while water samples taken from hand-dug wells were alkaline and very hard containing high total dissolved solid and nitrate contents ,because unfit for human consumption. In addition to these problems arising from mining processes, mercury has the greatest health hazard risks on the environment generally; air, solid and specifically water.

3.4 Recommendations

1. Further research must consider epidemiological studies as well as setting monitoring program for chemical constituents' concentration to evaluate the progress of pollution.
2. Proper site selection for the location of domestic water wells and proper well construction may reduce potential element contamination of drinking water sources. Careful management of contamination sources (septic systems, fertilizer storage, handling, livestock facilities, silos and exactly mining operation) within several hundred feet from the well is important; the risk of high harmful is minimized.
3. It would be preferable for the local authorities to consider a suitable and affordable method of treatment for reducing harmful elements of water pollution in wells located in Sodari of the aquifer.
4. The water sample taken from hand- dug well have shown high alkalinity and considered as unfit for human consumption.
5. Through mining operation, mining waste contaminates water making it very dangerous for humans and animals' living in the area, therefore all stockholders and authorities must obey the regulations of environmental rules.
6. Use of safe reagents will recommend generally using safe product in mining such as Gold dressing agent (environment friendly gold ore –dressing product) instead of sodium cyanide enjoys several advantages such as low toxicity and need complicated procedures does not belong to adopt of radioactive and toxic environmental protection.

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Appendix

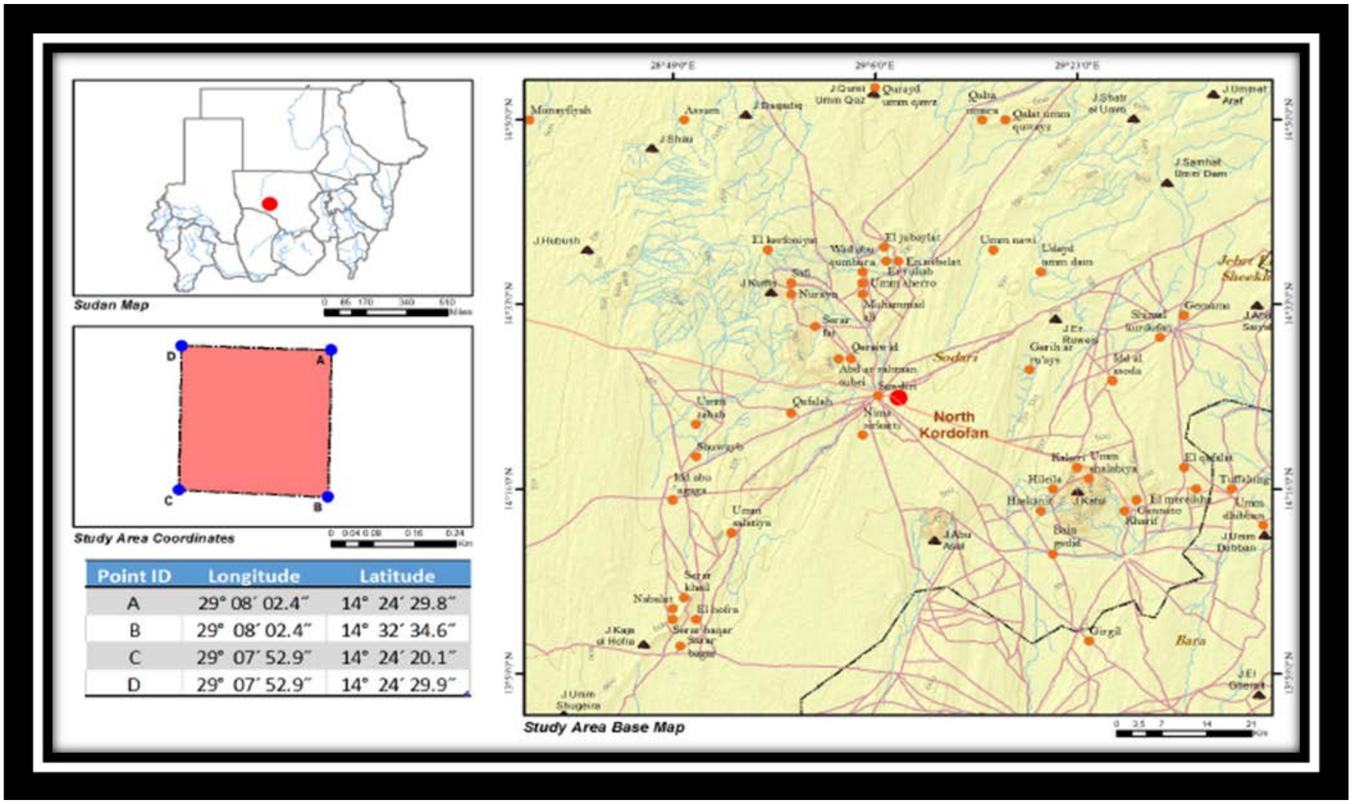
*WHO guideline values (1993) & SSMO (2002) on chemical compounds limit set for drinking water quality

s	Parameter	Unit	Guideline Value	SSMO (2002)
1	Nitrate & Nitrite	mg/l	50 total	45-50
2	Chloride	mg/l	250	100
3	Hardness	as $CaCO_3$	500	1000
4	Iron	mg/l	0.5-50	0.30
5	PH	mg/l	6.5 to 8.5	6.5 to 8.5
6	Sodium	mg/l	200	-
7	Zinc	mg/l	3	3-3.5
8	Ammonia	mg/l	1.5	-
9	Copper	mg/l	2	1.5
10	Manages	mg/l	0.05	0.05

Fig (3) Hand dug wells

Fig (4) **Hafir**

Fig (5) Tailing from Artisanal Miner



Point ID	Longitude	Latitude
A	29° 08′ 02.4″	14° 24′ 29.8″
B	29° 08′ 02.4″	14° 32′ 34.6″
C	29° 07′ 52.9″	14° 24′ 20.1″
D	29° 07′ 52.9″	14° 24′ 29.9″

Fig(6) Sodri Map

Fig(7) **Water harvesting**