University of Gezira

Drinking Water Quality: A Case Study of Zalingei Town, West Darfur State, Sudan (2017)

Abdullah Hussein Adam Manie

February/2018
Drinking Water Quality Assessment: A Case of Zalingei Town, West Darfur State, Sudan (2017)

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Water Management and Irrigation Institute

February/2018
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Date: February/2018
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DEDICATION

This Humble Task

Fruit of my thoughts and study

To My

Loving and Sweet Parents Hussein and Khajia and

To My Wives and My Daughters Wesal and Aya and

My Brothers and Sisters and all people who helped me in this

Research Study.
ACKNOWLEDGMENT

Thanks to Allah for his mercy and help without which I could not complete this work. I would like to express my sincere appreciation and deep gratitude to my supervisor Dr. Eltigani Elnour Bashir for his supervision, help and continuous support as well as his valuable suggestions and ideas throughout the study.

My thanks and deep gratitude to my family and my two Wives for their patient and continuous encouragement and support during my study period.

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Drinking Water Quality: A Case Study of Zalingei Town, 
West Darfur State, Sudan (2017)

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ABSTRACT

This study was done to investigate the drinking water quality of Zalingei town of central Darfur State. Different water sources were selected comprising six deep ground water sources and six shallow water open hand dug wells. Number of 271 households were interviewed and assessed to test water quality. Ground water samples from shallow water open hand dug wells were collected during the period from December to July 2017. Samples were subjected to physical, chemical and micro-biological examination and analyzed to investigate the level of the expected health hazards. The results obtained indicated that the turbidity level ranged from 4 to 10.8 NTU thus exceeding the permissible level of WHO (1993) standards of 5 NTU. The concentration of minerals such as chloride ranged from (0.59-6.6 mg/L), pH (5.82-7.8), sulphate (8-35 mg/L), calcium (9.6-23.0 mg/L), alkalinity (74-286.4 mg/L), fluoride (0.47-1.1 mg/L), magnesium (3.2-7.0 mg/L), ammonia (0.01-0.023 mg/L), TDS (52-467.8 μs/cm) and hardness (82–237.4 mg/L). Electrical conductivity levels were (191-345 μs/cm), Carbonate (0-141.6 mg/l), bicarbonate (0-144.82 mg/l) and iron (0-0.23 mg/l). All these values were below thresholds value of national and international standards of WHO and Sudanese Standards and Metrology Organization (SSMO) standards except fluoride was above Sudanese standards of 1.0 mg/l). Bacteriologically, the E. coli presence quantity ranging (0.- 49) in 100ml sample of water and fecal total coliform quantity ranging (0-51) in 100 ml sample of water. These values were above thresholds value of national and international standards of WHO and SSMO standards of Ecoli. Thus, biologically water in Zalingei is unfit to human consumption.
تقويم جودة مياه الشرب: دراسة حالة مدينة زالنجي، ولاية وسط دارفور، السودان (2017)

عبد الله حسين آدم مني

ملخص الدراسة

أجريت هذه الدراسة على مياه الشرب بمدينة زالنجي، تم أخذ العينات من أثني عشر موقع جغرافيا مختلفة، ستة منها مصادر لمياه غوفية محمية (مضخات، أنابيب أرتوازية) وستة مصادر لمياه سطحية غير محمية (أبار مفتوحة)، وأجريت عليها تحليلات فيزيائية وكيميائية وبيوكيميائية لتتأكد من صلاحية الماء للإستهلاك الأدمي، ولأقد أوضحت الدراسة على أن نسب المعادن والملوثات الموجودة في مياه زالنجي على النحو التالي: مستوى العكارة لأتي عشرة موقع تتراوح ما بين (4-10.8) وحدة قياس العكارة، الكلور (0.59-6.6) مجم/ل، الأس الهيدروجيني (5.82-7.8)، الكربونات (8-35) مجم/ل، الأمونيا (0.01-0.023) مجم/ل، عسر الماء (32-237.4) مجم/ل، الأملاح الذائبة (52-467.8) مجم/ل، الكالسيوم (9.6-23) مجم/ل، الأملاح الموصولة (75-668) مجم/ل، الكربونات السجمت (0.0-141.62) مجم/ل، البيكربريتات (0.0-144.82) مجم/ل، الحديد (0-0.23) مجم/ل، كل هذه المعادن دون مواصفات منظمة الصحة العالمية والمواصفات السودانية، التحليل البكتيري سجلت التلوث البكتيري لبعض العينات، ولهذا فإن المياه في زالنجي بيولوجيا غير صالحة لاستخدام الإنسان.


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CHAPTER ONE
INTRODUCTION

1.1 Introduction
According to the World Health Organization (WHO), 1.1 billion people did not have access to an improved water supply in 2002, and 2.3 billion people suffered from diseases caused by contaminated water. Each year 1.8 million people die from diarrheal diseases, and 90% of these deaths are of children under five. Besides causing death, water-related diseases also prevent people from working and leading active lives (WHO/UNICEF 2004).

In 2000, 189 nations adopted the United Nations Millennium Declaration, and from that, the Millennium Development Goals (MDGs) were derived. The MDGs include 8 main goals, 18 targets, and more than 40 indicators. Their purpose is to focus efforts, promote study, raise awareness, and encourage strong alliances. Goal 7 addresses environmental sustainability, and Target 10 is to “halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation” (UN-NGLS 2006). According to the United Nations report, 80% of the world’s population used an improved drinking water source in 2004, up from 71% in 1990. Although improvement has been made, there will be challenges as populations increase. A large number of people still will not be covered by Target 10, and, significantly, an improved water supply is not necessarily a safe water supply. In recent years, the WHO has moved away from defining set values for microbiological water quality levels, to providing recommendations using a more realistic risk-based approach. It is highly recommended that there be an E. coli count of zero colony forming units (CFU) per 100 ml water. In many cases, particularly in the developing world, this is difficult to achieve, making the above guidelines particularly useful (Sophie M. Johnson 2006).

Water, the universal solvent as they call it, is absolutely essential for all forms of life, not only for human life but also for animals and Vegetation. Indeed, it is a part of the life itself, since the protoplasm of most living cells contains about 80 percent water, and only substantial reduction in this amount occurs during the metabolism and growth of living cells. The problem of supplying adequate amount of safe water for distribution to the public does not end with the constriction of water works. It has been estimated that half of the world’s population has
suffered from diseases caused by polluted water (Barbaras, 1986). Water related diseases and illnesses are responsible for the loss of productivity and deaths of millions, perhaps even billions of people in the developing world. It has been reported that the death of most of the children in Africa who die under the age of 5 is caused by inadequate and safe water Supplies (Loucks, 1994). The faecal-oral disease includes the well-known water diseases that are often fatal, such as cholera and typhoid fever, but also the many common diarrhea diseases. Diarrhea affects young children in developing countries, contributing to malnutrition and death in fact, these diarrheal diseases are often responsible for more child mortality than any other cause of death (West, 1991).

Another important disease which makes big problems is the goiter or thyroid gland which makes a big problem to the human health and this thought due to iodine deficiency. Monitoring the quality of water and applying corrective measures to polluted water before discharging into the Stream River and lakes …etc. are some of the very important aspects in controlling or managing the water quality (Balek, et al., 1994).

In the past decade groundwater quality monitoring networks have been implemented in several countries in Europe and the USA (Jedlitschka, 1996; Sanchez, 1996; Pebesma, 1997 and Beretta et al., 2000). This development is related to the greater attention that has been given to quality aspects of groundwater in general and pollution issues specifically. The increase of attention that has been paid to pollution issues also contributed to better defined objectives of different groundwater monitoring network.

Initially, many national monitoring programs did not have clear objectives or some of the objectives were too general. Without well-defined objectives, monitoring programs tend to become inefficient and the responsible organizations are faced with an abundance of unused data. Monitoring involves designing strategy and methodology of field surveys for choosing the most reliable possible data. The process of groundwater quality and quantity are fully and continuously interactive. Therefore, from technical and economical point of view proper management of groundwater requires full understanding of both processes. (Mohamed A. Dawoud, June 2003).
Moringa oleifera is the most widespread species, which grows quickly at low altitudes in the whole tropical belt, including arid zones (Morton, 1991; Verdcourt, 1985; John, 1986). It is generally known in the developing world as a vegetable, a medicinal plant and a source of vegetable oil. However, in the Sudan it has been traditionally used in water purification (John and Hamid, 1979; John, 1981).

Water quality monitoring system is underdeveloped, and in remote rural areas, is non-existent. The Sudan Ministry of health (SMOH) with World Health Organization (WHO) support had established basic Water Quality Laboratories as part of public health laboratory in each Darfur state with trained personnel. Their functioning is hampered by the lack of adequate governmental operational costs allocation, and largely depends on the humanitarian funding. In all Darfur states, the water quality monitoring mechanism at locality level is non or poorly functioning; for emergency situations (outbreaks, new displaced people gathering and camps) outside of the already existing humanitarian case-load, field missions from the State Laboratory and MOH environmental department, mostly supported by WHO, are organized to take water samples, assess the availability of water and conduct sanitary inspection of water sources and distribution. The system is costly, time consuming and unsustainable. Some portable water quality testing kits have been donated to be distributed at locality level and people have been trained, but as long as they are not powered by an alternative, sustainable source of electricity (such as solar panels), their use at locality level has proved to be unfeasible. So far, the humanitarian organizations and governmental investment has been largely inadequate to enable the establishment of an effective drinking water quality management framework with a surveillance and monitoring system that is coordinated with, and complements the mandates and actions of, other institutions and organizations.

Traditional hand-dug wells are open, usually untreated and are therefore frequently polluted. Around 20% of the water sources are not monitored through laboratory testing and more than one third of monitored sources show significant contamination with Escherichia coli and Hepatitis E virus. Lack of regular chemical and biological testing of the water sources that should raise alerts on contamination and direct the implementation of active corrective measures, such as chlorination and better maintenance of water sources, is one of the main gaps identified in Darfur states. Effective water quality surveillance is essential for, and part of any intervention aiming at water safety management and, at a grander level, the establishment of an
The integrated water resources management (IWRM) approach and tools. The process should be based on an in-depth study/assessment of the present situation, necessary conditions (policies, standards, responsibilities) to inform the development of a feasible balanced plan that is well integrated into, and contributes to, a broader sector strategic plan. The clear commitment of MOH (at all levels) to develop and implement a plan for the establishment of effective water quality surveillance at all levels it is one of the strengths that should be utilized (UNICEF, 2014). Wadi Azoum provides a large volume of storage for Zalingei so overall supplies should be reliable. In Zalingei however, areas away from the Wadi may be short of water in a drought year. Therefore, a drought preparedness plan should be prepared for the town as a whole. Rural areas will be addressed under the IWRM project. Priority for drought preparedness should be given on the basis of environmental vulnerability and population. The work should form part of integrated drought cycle management planning (UNEP, March 2008).

Therefore, the present investigation was carried out in an attempt to study the drinking water quality assessment in Zalingei Town at different locations during the period of studies, different water sources (Boreholes and Open hand dug wells) and household with the objectives of investigating the physical, chemical and bacteriological parameters of drinking water.

1.2 Statement of the Problem

The problem of supplying adequate amount of safe water for distribution to the public does not end with the construction of water works. It has been estimated that half of the world’s population has suffered from diseases caused by polluted water (Barbaras, 1986). Water related diseases and illnesses are responsible for the loss of productivity and deaths of millions, perhaps even billions of people in the developing world. It has been reported that the death of most of the children in Africa who die under the age of 5 is caused by inadequate and safe water supplies (Loucks, 1994). The faecal-oral disease includes the well-known water diseases that are often fatal, such as cholera and typhoid fever, but also the many common diarrhea diseases. Diarrhea affects young children in developing countries, contributing to malnutrition and death in fact, these diarrheal diseases are often responsible for more child mortality than any other cause of death (West, 1991). All of these health impacts are associated with poor water quality.
1.3 Research Objectives

The overall objective is to provide sufficient data to allow a water quality assessment of Zalingei Town of Central Darfur state. Specific objectives of the monitoring program are:

- To assess water quality in Zalingei
- To set background or reference to water quality.
- To better, understand seasonal water quality variations.
- To provide water quality information to support management activities.
- To raise awareness of water related disease among the community.
2.1 Importance of Water

Water is indispensable and irreplaceable for life. The use of water by man, animals and plant is universal. It is known that water quantity and quality are ever controlling the size and the shape of human Settlement. In addition to the direct use of water in our homes, there are many indirect ways in which water is increasing rapidly with our growing population; forest reported that there are acute shortages in both surface and underground waters in many regions in the world. Careless pollution or contamination of our streams, lakes and underground sources has greatly impaired the quality of the available water. It is therefore of at most importance for future that good conservation and sanitary measures be practiced to insure enough water supply (Sara Sidig 1992).

2.2 Water Sources and Supply

In nature, water is constantly changing from one form to another. The sun constantly evaporates water into the atmosphere, some of that water is returned as rain and snow. Part of this water, rapidly evaporates lack into the atmosphere. Some drains into lakes and rivers to carry ice a journey back to sea. Under natural conditions, the groundwater gradually works its way back into surface waters and makes up to sea. Some infiltrates into the soil to become soil moisture or ground water, under natural condition, the ground water gradually works its way back into surface water and makes up the main source of dependable rivers flow. In the Sudan, the rural population constitutes about 80% of the country’s total population (Abdelmagid, 1984). Most of the year these people use untreated water directly from sources such as traditional surface, deep bores, rivers, intermittent rainy season streams "Khors", natural rain ponds and artificial rain water catchments "Hafirs" (Abdelmagid, 1984).
2.3 Location of Study Area

This study was conducted in Zalingei, Central Darfur State, Sudan located between latitudes 12°30’ and 13°30’ N and longitudes 23°30’ and 23°45’ E (Thabit and Adam, August 2015) (Figure 2.1). The population for the study comprised small-scale farmers in Zalingei area. Rain-fed farming is the most common practice. The major crop grown in this area includes millet, sorghum groundnut, and cowpeas summer crops, where vegetables such as tomatoes and hot pepper are grown as winter crops on valley's banks. The farmers in the study area use simple farm implements such as hoes, cutlass and family labour mostly, this study was carried out on drinking water samples collected from different water sources, household and tea ladies market water containers in Zalingei town, capital state of Central Darfur (Thabit and Adam, August 2015).

The annual rainfall in Zalingei varies between 350 and 750 millimeters (Figure 2.1). The mean average temperature ranges between 20°C and 30°C, (Abdallah, Dawi 2012). Average rainfall recorded for years from 1989 to 1998 was 525.14 mm which is in between 350 mm and 750 mm found in previous studies in the area (Jebel Marra project, Haroun Sudani 2016). Zalingei population about 283,664 individuals with growth rate of 2.6, total population is 291,039 at least 58208 households according to 2008 census allocated in 18 residential clusters (Sudan Central Statistic Ministry of cabinet, 2008), the geographical area of Zalingei and the bordering States see the Figure (2.2) below.
Figure (2.1): Map Zalingei

Average rainfall monthly recorded for years from 1989 to 1998 was 525.14 mm which is in between 350 mm and 750 mm found in previous studies in the area (Jebel Marra project, Haroun 2016).

Figure (2.2): Average rainfall in Zalingei 42 years
Water borne illness remains a major source of worldwide human morbidity and mortality (Mc Festers and Singh, 1991) and that one-half of the world’s population has suffered from diseases caused by polluted water (Barbaras, 1986) and that pathogenic bacteria when present in potable waters cause typhoid fever, bacillary dysentery and cholera (WHO, 1964). However, with improvements in epidemiological surveillance and in clinical diagnosis of bacterial and non-bacterial gastroenteritis there has been over the last two decades an emergence of new forms of water-related illness (West, 1991; Degner et al., 1983). Table (2.1) shows water borne diseases in Zalingie.

Table (2.1): Show water related diseases in Zalingei Town

<table>
<thead>
<tr>
<th>Water borne diseases</th>
<th>Cases</th>
<th>Years</th>
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<tr>
<td></td>
<td></td>
<td>2017</td>
<td>2016</td>
</tr>
<tr>
<td>Typhoid</td>
<td>35</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>Dysentery</td>
<td>65</td>
<td>2820</td>
<td>1560</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>112</td>
<td>9968</td>
<td>11267</td>
</tr>
<tr>
<td>Malaria</td>
<td>235</td>
<td>13310</td>
<td>12230</td>
</tr>
</tbody>
</table>
Acute watery Diarrhea   | 454 | 0 | 0 | 0 | 454
Thyroid gland          | 12  | 0 | 3 | 2 | 17  
Total                  | 3113| 26108 | 25095 | 19773 | 71891

Several pathogenic strains of Escherichia coli in drinking water and food have been implicated in intestinal complaints of humans (Kurl, 1972, Madigan et al., 1997). History of water borne diseases shown in Table (2.1). Most coliform bacteria are not harmful themselves, but point to an unsanitary condition and possible presence of disease-causing organisms. The coliform bacteria may not form disease but can be used as an indicator of pathogenic disease (Sharon, 2004). (Skipton et al., 2004) recommended that drinking water from private wells should be tested for the presence of bacteria at least once a year or when work has been done to the water supply system or when there is any time a change in the any of the water quality parameters (taste, colour, turbidity … etc). The drinking water quality standard for coliform bacteria is set at less than one coliform organism per 100 ml of water. Among the chemical toxin, which can endanger human health, are those substances, which can be present in water as decomposition products of organic compounds (Kurl, 1972). Nitrates are worthy of special mention in this group. If present in too high concentrations, they can lead to methaemoglobinaemia of babies and infants, which in turn can lead to cessation of respiration and death (Mitchell, and Hardin, 1996; Kurl, 1972). In the last acute watery diarrhea (AWD) outbreak in Sudan, Zalingei was among highest rate cities which recorded 454 (57%) cases out 794 cases of whole Central Darfur state and 36 deaths according WHO AWD report central Darfur (WHO, 2017). (Figure 2.5).
Figure: (2.4): Acute water diarrhea cases by locality

Figure: (2.5): Daily cases of AWD in Zalingei

2.5 Physical Parameters of Water

2.5.1 Turbidity

Turbidity is an extremely useful indicator that can yield valuable information quickly, relatively cheaply and on an ongoing basis. Measurement of turbidity is applicable in a variety of settings, from low-resource small systems all the way through to large and sophisticated water treatment plants. Turbidity, which is caused by suspended chemical and biological particles, can have both water safety and aesthetic implications for drinking-water supplies. Turbidity itself does not always represent a direct risk to public health; however, it can indicate
the presence of pathogenic microorganisms and be an effective indicator of hazardous events throughout the water supply system, from catchment to point of use. For example, high turbidity in source waters can harbour microbial pathogens, which can be attached to particles and impair disinfection; high turbidity in filtered water can indicate poor removal of pathogens; and an increase in turbidity in distribution systems can indicate sloughing of biofilms and oxide scales or ingress of contaminants through faults such as mains breaks. Turbidity can be easily, accurately and rapidly measured, and is commonly used for operational monitoring of control measures included in water safety plans (WSPs). It is recommended approach to managing drinking-water quality in the WHO Guidelines for Drinking-water Quality (WHO, 2017). It can be used as a basis for choosing between alternative source waters and for assessing the performance of a number of control measures, including coagulation and clarification, filtration, disinfection and management of distribution systems. Turbidity is also an important aesthetic parameter, with turbidities of 4 nephelometric turbidity units (NTU) and above being visible, and affecting the appearance and acceptability of drinking-water to consumers. Although turbidity can be used in multiple ways within WSPs, this versatility can cause confusion and misinterpretation.

**2.5.2 PH**

PH is the negative common logarithm of the hydrogen ion activity. 15 PH values were measured by pH meter. The pH meter was calibrated by the standard solutions of pH 4, 7 and 9 at 25°C. Temperature plays a role in the determination of pH at which neutrality occurs. The pH values of samples were then recorded. The previous studies (Sinada and Abdel Karim, 1984) showed that, the PH in Zalingei water varies between 7.2 and 6.6, which indicate that all the samples fall in the neutral and acidic side. Therefore, the pH values obtained were within the WHO standards.

**2.5.3 Electrical Conductivity (E.C)**

Electrical conductivity is the measure of the ability of water to conduct an electrical current. The specific electrical conductance is defined as the conductance of a cubic centimeter of any substance compared with the same volume of water. The Electric conductivity (EC) in mmhos per cm (μS/cm) was measured at 25°C using sension 7 conductivity meter (HACH, 2002). Pure water has very low electrical conductance and conductivity of water will increase with the
presence of dissolved minerals. Water with high specific conductance can cause corrosion of iron and steel. Electrical conductivity is expressed in micro mhos per centimeter (μmohs/cm).

2.6 Chemical Parameters of Water Quality

2.6.1 Chloride

Chloride is dissolved from most rocks and soils. Waters in humid regions are usually low in chloride content. Arid/semi-arid regions often contain high levels (UWP, 1999). Low to moderate concentrations of both chloride and sulphate ion added palatability to water. In fact, they are desirable for this reason. Excessive concentration of either, of course, can make water unpleasant to drink. The United State Environmental Protection Agency (U.S.EPA, 1996) secondary drinking water regulations recommended a maximum concentration of 250 mg/L for chloride ions. (Al-Redhaiman and Abelmagid, 2004) studied the water of El Gassim region in Saudi Arabia and found that the chloride content ranged from 18 to 1737 mg/L. Chloride is the major anions in water. Chlorides are present as sodium chloride (NaCl, common salt) and to readily dissolve from rocks rich in calcium minerals particularly as carbonates and sulphate. The taste threshold for the calcium ion is in the range (100g/L-300 m/L) depending on the associated anions (WHO, 1995). A50 ml water sample was placed in a 250 mls conical flask; pH was adjusted to 12-13 by addition of 2 ml ammonia solution; one tablet of murexide indicator was added while stirring; the solution was then titrated with Ethylene Diamante Traacetic Acid (EDTA) solution, until the color change from pink to purple.

2.6.2 Sulphates

The concentration of sulphate in natural water can be found in various ranges from a few mg/L to several thousand mg/L ((Jamal and Mohammed, 2013). The highest level usually occurs in ground water. The sources of sulphate are the solutions of minerals containing sulphates and oxides of sulphur, sulphides and thiosulphates. The presence of sulphate in drinking water can cause noticeable taste. The taste varies with the associated cation. Taste threshold has been found to range from 250 mg/L for sodium sulphate to 1000 mg/L for calcium sulphate, Sulphate in domestic water contributes the major source for permanent hardness. High levels can impart taste and when combined with magnesium or sodium can have laxative effective effect, (Jamal and Mohammed, December 2013).
2.6.3 Calcium
Calcium is the fifth amongst the elements in order of abundance (Jamal and Mohammed, 2013). It is present in water as Ca$^{2+}$ and is readily dissolved from rocks rich in calcium minerals particularly as carbonates and sulphate (Allen, and Mancy, 1972). The taste threshold for the calcium ion is in the range (100g/L-300 mg/L) depending on the associated anions (WHO, 1995).

2.6.4 Alkalinity
Alkalinity is a measure of an aggregate property of water and can be interpreted in terms of specific substance only when the chemical composition of the sample is known. Alkalinity is significant in many uses and treatments of natural and wastewaters. Because the alkalinity of many surface waters is primarily a function of carbonate, bicarbonate and hydroxide content, it is taken as an indication of the concentration of these constituents. Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation, alkalinity measurement is used in the interpretation and control of water and wastewater treatment processes (APHA, 1980). (Rodenburg, 1985) reported that water alkalinity is ppm assayed as CaCO$_3$ and water of less than 500 ppm alkaline and pH 6.8 to 8 its nature of alkalinity is the presence of bicarbonate is not harmful.

2.6.5 Fluoride
Epidemiological studies in many parts of the world have established beyond doubt that where the natural water supply contains fluorine in amounts of 1 ppm or more, the incidence of dental caries is lower than in comparable areas where the water contains only traces of the element. Water containing fluoride exceeding 1.5 ppm can cause dental defects if consumed during the calcification or formation of teeth (UWP, 1999).

2.6.6 Magnesium
All human tissues contain small amounts of magnesium (Sara, 1992). The whole adult body contains about 25 g of the metal. The greater part of this amount is present in the bones in combination with phosphate and bicarbonate. It seems likely that the bones provide a reserve supply of magnesium as of calcium and sodium, which is available when there is short gate elsewhere in the body (Sara, 1992).
2.6.7 Ammonia

Ammonia nitrogen includes nitrogen in the form of NH3 and NH4+. As a component of the nitrogen cycle, it is often present in water, from natural sources, but usually in only small amounts. There is no evidence that ammonia nitrogen in water is physiologically significant to man or livestock. Ammonia decreases the ability of hemoglobin to combine with oxygen (GSWS, 1960).

2.6.8 Total Dissolved Solids

All natural waters contain sodium and potassium, but usually only in small amounts in natural or unpolluted surface waters in humid regions. In arid regions, or areas of limited rainfall water may contain larger amounts of sodium. Moderate amounts of sodium and potassium have little effect on the usefulness of water, except that potassium is a requirement for plant growth (Robertson et al., 1979). Jamal and Mohammed (2013) found that the TDS varied widely from 281 to 720 mg/L with a mean of 500.5 mg/L.

2.6.9 Hardness

Water hardness was understood to be a measure of the capacity of water to precipitate soap. Soap is precipitated chiefly by the calcium and magnesium ions present. Other polyvalent cations also may precipitate soap, but they often are in complex forms, frequently with organic constituents and their role in water hardness may be minimal and difficult to define (Sir Stanley, 1963). Wilkins et al. (1981) reported that healthy water criteria hardness is 170 mg/L and TDS 300 mg/L. Sharratt et al. (1980) stated that hard drinking water generally contribute small amount towards total calcium and magnesium human dietary needs. They further stated that in some incidence, where dissolved calcium and magnesium are very high, water could be major contributor to calcium and magnesium to the diet. Bragg and Bragg (1986) noted that mineral in drinking water are more easily and better absorbed than mineral from food. Numerous studies suggest a correlation between hard water and lower cardiovascular disease mortality (Herman et al., 1996). Research on heart disease and cancer shows a healthy water is hard water and moderately high in TDS (Bragg and Bragg, 1986). Experimental evidence shows hard water actually contributes to the prevention of certain types of calculi (Kidney stones or water belly) formation (Guyer, 1977).
2.6.10 Iron
Iron is an essential component of three different processes involved in transfer of oxygen and hence is of great importance in human nutrition. High concentration of iron as low as 3 ppm will leave reddish-brown stains on white porcelain, enameled ware, fixtures and fabrics (Elgeed, 2006). Iron bearing waters tend to stain or impart unpredictable colours and are therefore unsatisfactory for many industrial purposes. Small quantities of iron are essential for plant growth and development, however, toxicity occurs when concentrations exceed 5 ppm (UWP, 1999).

2.6.11 Carbonate and Bicarbonate
Generally, the concentration of carbonate and bicarbonate of Zalingei water is in previous studies showed that the concentrations of CO\textsubscript{3}^-\textsubscript{2} were lower than those of HCO\textsubscript{3}^-\textsubscript{2}. Samples from Forest and Wahida wells had lower concentrations than samples Aribo and Azom River. This is due to the concentrations of carbonic acid in the air that result from rainwater and carbon dioxide interaction.

2.6.12 Nitrate
Nitrate is a colourless, odourless and tasteless compound that is present in some groundwater. Nitrate cannot be detected unless water is chemically analyzed. Nitrate can be expressed as either NO\textsubscript{3} (nitrate) or NO\textsubscript{3}N (nitrate-nitrogen). Nitrate levels above the Environmental protection Agency (EPA) maximum Contaminant Level of 10 mg/L NO\textsubscript{3}-N or 45 mg/L NO\textsubscript{3} may cause methemoglobinemia in rats (Self and Waskom, 1998).

2.7 Biological Parameters of Water Quality
The importance of the biological methods in the assessment of water quality cannot be neglected. In many instances degradation of water quality is a biological phenomenon. Chemical methods measure the concentration of pollutants responsible and biological indicators show the degree of ecological imbalance (Mahgoub, 1984). One of the major biological parameters is the microbiological count for measuring levels of fecal contamination.

2.8 Bacteria as Indicators of Water Sanitary Quality
A direct examination for the various pathogenic organisms that may be present in drinking water is difficult and time consuming (Madigan et al., 1997). Other means are therefore to insure that drinking water is free of pathogenic. Indicator bacteria are used to evaluate the portability of drinking water. Packer et al. (1995) reported that the presence of coliform organisms in drinking water is used as an indicator of fecal contamination since they are the most sensitive indicator bacteria for demonstrating excremental contamination. In his review (Jay, 1986) reported that the indicators of sanitary quality know employed consists of two groups of bacteria, namely, the coliforms and enterococci, in addition total bacterial numbers are also useful in this regard.

2.8.1 Coliform Bacteria
The coliform group of bacteria has remained the corner stone of the national drinking water regulations all over the world and is used in the water supply industry as criteria of operational parameters. This group is defined in water bacteriology as the aerobic and facultative anaerobic, gram-negative, non-spore-forming, rod-shaped. Bacteria that ferment lactose with gas formation within 48 hr at 35°C (Madigan et al., 1997) According to these authors the coliform group includes the organism Escherichia coli (a normal inhabitant of vertebrate intestinal inhabitant) and the species Enterobacter aerogenes (not generally associated with intestine). The coliform group was proposed as an indicator; mainly because of it is a common inhabitant of man and animal's intestines, and because of its presence in the intestinal tract in large numbers, (Buttiaux and Mossel, 1961). Since the water borne disease is generally intestinal diseases, the existence of pollution is taken to indicate the possibility that the etiologic agents of these diseases may be present (Jay, 1986). Kabler et al. (1960) emphasized that the presence of any member of organisms from coliform group in treated potable water is not acceptable regardless of their source, and that their presence in potable water indicates important practices.

2.8.2 Fecal Coliform Bacteria
The coliform group has long been routinely employed to indicate the sanitary quality of water. Recently, an-emphasize has been placed only on determining the presence of Escherichia coli since it is considered the principle fecal coliform (Fish, et al., 1995). Since Escherichia identified E. coli as an indicator of fecal pollution, attempts have been made to define the sanitary significance of this microorganism (Jay, 1992; Krumper, 1983). One of the attractive
properties of E. coli as a fecal indicator for water is its period of survival (Jay, 1992). The native habit of E. coli is the enteric tract of humans and other warm-blooded animals (Krumper, 1983). Bardsley (1938) reported that the dominant and most numerous types of coliform in the feces is E. coli type I. Although several studies have suggested that the fecal coliform methods for assaying microbiological contamination level of different types of water are more specific and less ambiguous than the total coliform method, the drinking water regulations in most countries are still based on total coliform assays (Mercado and Hazen, 1987).

2.9 Contamination of Drinking Water
The term contamination is defined as the presence of bacteria in water from the intestinal tract of worm-blooded animals including man. The presence of such bacteria means that the water may carry human disease germs. The fact that water looks clear and sparkling is no assurance of its purity. Disease germs are invisible to the unaided eye (Forrest, 1956). The movement of animal wastes into the surface water is often cited as a major factor contributing to the pollution of available water in many rural areas (Doran, 1979 and Fernandez et al., 1991). El Shazali and Erwa (1971) reported that studies in the Sudan have clearly demonstrated the close association of biological contamination of drinking water with the high prevalence of diarrheal diseases and certain enteric pathogens.

2.10 Water Pollution
The more acceptable definition of water pollution is that given by FAO (1979): "The presence of any substance (organic, inorganic, biological, thermal or radiological) in water at intensity levels which tend to impair, degrade, or adversely affect its quality or usefulness for specific purposes". Here contamination is synonymous with the degradation of water quality. The early studies on water pollution were motivated primarily by public health considerations and were largely bacteriological investigations. Although the terms contamination and pollution are often used synonymously, health authorities make the definition of water pollution as any undesirable quality of water other than contamination. Dirt, silt, organic matter, minerals, objectionable colours, odours or tastes, acidity and alkalinity are causes of pollution. Although pollution is not necessarily a health hazard, it is often accompanied by contamination which is a health hazard (Forrest, 1956).
The most common pollutants are bio-degradable organic matter, suspended solids, ammonia, nutrients, heat and bacteria from industrial, agricultural and sewage waste effluents and land run-off. Many other pollutants such as solids (e.g. wood), detergents, phenols, cyanide, metals, acids, alkalis, pesticides, oils, boron, complex industrial chemicals and biological contaminations (e.g. viruses) may be present. Pollution (e.g. by pesticides) of reservoirs and boreholes occasionally causes local problems. Where possible the water undertaking will switch to alternative supplies until the pollution is eliminated. However, concern has been expressed about longer-term pollution of ground waters, which feed boreholes and other sources, by the use of old mines and quarries for the disposal of liquid chemical wastes. System pollution by cross-contamination (e.g. between water and sewage pipelines) is uncommon and transitory. The leaking of metals from metal piping may occur, however, especially in soft-water areas. Old lead piping is particularly troublesome; contributing locally substantial additions to the total lead intake of human populations (Saunders, 1976).

Some of the forms this pollution takes include untreated sewage, industrial discharges, leakage from oil storage tanks, mine drainage and leaking from mine waste and drainage from the residues of agricultural fertilizers and pesticides. The release of heavy metals such as lead, mercury, silver and chromium—which are highly toxic to aquatic life, is one of these inherited problems. Many of the 100,000 or so commercial chemicals employed in the world today create difficulties if they are released into aquatic ecosystems, as happens in accidental spills. Another set of problems results from wet and dry deposition of materials transported during the atmosphere. In the Sudan, a particular point source of pollution of the White Nile at Khartoum is the continuously flowing stream of partially treated sewage coming from the city's sewage treatment plant and surroundings (Dirar, 1986).

2.10.1 Sources of Pollution
The nature, man, domestic routine activities, agriculture and industry all contribute to the degradation of our water quality.

2.10.2 Sources of Natural Degradation
FAO (1979) reported that most ground 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 vegetation 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 as a function of nature, not of man; and is generally referred to as a background level of quality.

2.10.3 Sources of Man-made 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 of subsurface water environment. According to the FAO (1979) and Katz (1971), there are four main sources of water pollution comprising, agriculture (animal and crop waste, pesticides, fertilizers, etc. …), industry (serves as another originator of chemicals), waste generated domestically and 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 underground 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.

2.11 Water Treatment
For small communities, it is generally preferable to protect a groundwater source that requires little or no treatment than to treat surface water that has been exposed to faecal contamination and is usually of poor quality. In many circumstances, however, surface water is the only practicable source of supply and requires affordable treatment and disinfection. The range of treatments available for small-community supplies is necessarily limited by technical and financial considerations; the most appropriate and commonly used treatments are summarized below. Installation of packaged treatment plants is not a suitable means of dealing with the typical water-quality problems that prevail in rural areas (WHO, 2004). Guideline value cannot be met with the existing system, then additional treatment may need to be considered, or water should be obtained from alternative source. The cost of achieving a guideline value will depend on the complexity of any additional treatment of other control measures required. It is not possible to provide general quantitative information on the cost of achieving individual guideline values.
2.11.1 Chlorination

Chlorination can be achieved by using liquefied chlorine gas, sodium hypochlorite solution or calcium hypochlorite granules and onsite chlorine generators. Liquefied chlorine gas is supplied in pressurized containers. The gas is withdrawn from the cylinder and is dosed into water by a chlorinator, which both controls and measures the gas flow rate. Sodium hypochlorite solution is dosed using a positive-displacement electric dosing pump or gravity feed system. Calcium hypochlorite has to be dissolved in water, and then mixed with the main supply. Chlorine, whether in the form of chlorine gas from a cylinder, sodium hypochlorite or calcium hypochlorite, dissolved in water to form hypochlorous acid (HOCl) and hypochlorite ion (OCI) (WHO, 2004).

Different techniques of chlorination can be used, including breakpoint chlorination, marginal chlorination and superchlorination/dechlorination. Breakpoint chlorination is a method in which the chlorine dose is sufficient to rapidly oxidize all the ammonia nitrogen in the water and to leave suitable free residual chlorine available to protect the water against reinfection from the point of chlorination to the point of use. Superchlorination/dechlorination is the addition of a large dose of chlorine to effect rapid disinfection and chemical reaction, followed by reduction of excess free chlorine residual. Removing excess chlorine is important to prevent taste problems. It is used mainly when the bacterial load is variable or the detention time in a tank is not enough. Marginal chlorination is used where water supplies are of high quality and is the simple dosing of chlorine to produce a desired level of free residual chlorine. The chlorine demand in these supplies is very low, and a breakpoint might not even occur (WHO, 2004).

Chlorination is employed primarily for microbial disinfection. However, chlorine also acts as an oxidant and can remove or assist in the removal of some chemicals-for example, decomposition of easily oxidized pesticides such as aldicarb, oxidation of dissolved species (e.g., manganese (II)) to form insoluble products that can be removed by subsequent filtration; and oxidation of dissolved species to more easily removable forms (WHO, 2004).
disadvantage of chlorine is its ability to react with natural organic matter. However, byproduct formation may be controlled by optimization of the treatment system (WHO, 2004).

2.11.2 Ozonation
Ozone is a powerful oxidant and has many uses in water treatment, including oxidation of organic chemicals. Ozone can be used as a primary disinfectant. Ozone gas (O3) is formed by passing dry air or oxygen during a high-voltage electric field (WHO, 2004). The resultant ozone-enriched air is dosed directly into the water by means of porous diffusers at the base of baffled contactor tanks. The contractor tanks, typically about 5 m deep, provide 10-20 min of contact time. Dissolution of at least 80% of the applied ozone should be possible, with the remainder contained in the off gas, which is passed during an ozone destructor and vented to the atmosphere (WHO, 2004).

The performance of zonation relies on achieving the desired concentration after a given contact period. For oxidation of organic chemicals, such as a few oxidizable pesticides, a residual of about 0.5 mg/Litre after a contact time of up to 20 min is typically used. The doses required to achieve this vary with the type of water but are typically in the range 2-5 mg/Litre. Higher doses are needed for untreated waters, because of the ozone demand of the natural background organics (WHO, 2004). Ozone reacts with natural organics to increase their biodegradability, measured as assailable organic carbon. To avoid undesirable bacterial growth in distribution, zonation is normally used with subsequent treatment, such as filtration to remove biodegradable organics, followed by a chlorine residual, since it does not provide a disinfectant residual. Ozone is effective for the degradation of a wide range of pesticides and other organic chemicals (WHO, 2004).

2.11.3 Filtration
Particulate matter can be removed from raw waters by rapid gravity horizontal, pressure or slow sand filters. Slow sand filtration is essentially biological process, whereas the others are physical treatment processes (WHO, 2004). Rapid gravity, horizontal and pressure filters can be used for direct filtration of raw water, without pretreatment. Rapid gravity and pressure filters are commonly used to filter water that has been pretreated by coagulation and sedimentation. An alternative process is direct filtration, in which coagulation is added to the water, which then passes directly onto the filter where the precipitated flock (with
contaminants) is removed; the application of direct filtration is limited by the available storage within the filter to accommodate solids (WHO, 2004).

2.11.4 Rapid Gravity Filters
Rapid gravity sand filters usually consist of open rectangular tanks (usually < 100 m²) containing silica sand (size range 0.5-1.0 mm) to a depth of between 0.6 and 2.0 m (WHO, 2004). The water flows downwards, and solids become concentrated in the upper layers of the bed. The flow rate is generally in the range 4-20 m³/h. Treated water is collected via nozzles in the floor of the filter. The accumulated solids are removed periodically by backwashing with treated water, sometimes preceded by scouring of the sand with air. A dilute sludge that requires disposal is produced (WHO, 2004).

In addition to single-medium sand filters, dual-media or multimedia filters are used. Such filters incorporate different materials, such that the structure is from course to fine as the water passes during the filter. Materials of suitable density are used in order to maintain the segregation of the different layers following backwashing. A common example of a dual-media filter is the anthracite-sand filter, which typically consists of a 0.2 m deep layer of 1.5-mm anthracite over a 0.6 m deep layer of silica sand. Anthracite, sand and garnet can be used in multimedia filters. The advantage of dual and multimedia filters is that there is more efficient use of the whole bed depth for particle retention – the rate of head loss development can be half that of single-medium filters, which can be allow higher flow rates without increasing head loss development (WHO, 2004). Rapid gravity filters are most commonly used to remove floc from coagulated waters. They may also be used to reduce turbidity (including adsorbed chemicals) and oxidized iron and manganese from raw waters (WHO, 2004).

2.11.5 Pressure Filters
Pressure filters are sometimes used where it is necessary to maintain head in order to eliminate the need for pumping into supply. The filter bed is enclosed in a cylindrical shell. Small pressure filters, capable of treating up to about 15 m³/h, can be manufactured in glass-reinforced plastics. Larger pressure filters, up to 4 m in diameter, are manufactured in specially coated steel. Operation and performance are generally as described for the rapid gravity filter,
and similar facilities are required for backwashing and disposal of the dilute sludge (WHO, 2004).

2.12 Public Health Significance of Drinking Water Treatment

Until the 20th century, effective water treatment practices did not exist, while there were no bacteriological methods of evaluating the health significant of polluted drinking water, (Madigan et al., 1997). The degree and type of treatment depends on the character of the water and on the degree of pollution of public health significance. Thus, many well waters are of satisfactory physical and chemical quality and required treatment only by chlorination to protect against known or potential bacteriological pollution (Forrest, 1956). At the other extreme are those surface waters which are exposed to direct pollution and which usually do not meet the standards of quality of potable waters (Kurl, 1972).

Treatment involving physical, chemical and biological changes of surface waters is therefore necessary. Madigan et al. (1997) reported that turbidity removal by filtration provides a significant decrease in the microbial load of water, and so filtration did play a part in providing safer drinking water. The clear water should often be disinfected because many organisms can pass during the filters. It was the discovery of chlorine, the cheapest and most effective water disinfectant, in about 1910, which had a major impact on water treatment (Madigan et al., 1997). Chlorine is a very useful disinfectant for drinking water and is effective against the bacteria commonly associated with water borne diseases. A dramatic improvement in the health of the American people during the early part of the 20th century was due to a large extent to the establishment of satisfactory water treatment processes (Madigan et al., 1997).

2.13 Standards of Potable Water Quality

According to James (1979) the terms "Criterion", "Guidelines" and "Standard" are frequently used but indiscriminately, but it is necessary to understand critical differences between the meanings of these words. "A criterion" is defined as a quantifiable relationship between the density of some indicator of quality of the water on one hand, and the health risks associated with its recreational use as measured by illness or symptomatology on the other hand. The diseases are usually infectious in nature and the activities include all those in which there is
significant exposure of the head to the water. A "Guideline" derived from such a criterion is a suggested upper limit for the density of the indicator in the water which is associated with health risks which are considered unacceptable. A "Standard" is a definite rule, principle or measure established by an authority; because something may be termed "a standard" but this does not necessarily mean that it is rationally based on the best scientific knowledge and engineering practice (FAO, 1986).

Minimum standards to all surface water for all uses are as follows:

- Free from substances that will settle to form sludge deposit.
- Free from floating debris, oil scum and other materials.
- Free from materials producing colour, odour or other in such a degree to cause a nuisance (Feachem et al., 1977). International standards for drinking water set by public health agencies include specific rules defining bacteriological quality and acceptable limits of significant physical and chemical characteristics of water delivered to consumers.

2.14 Bacteriological Quality Standards

Effective chlorination yields water which is virtually free from coliform organisms, i.e. these organisms are absent in 100 ml portions. A standard demanding that coliform organisms be absent from each 100 ml sample of water entering the distribution system—whether the water be disinfected or naturally pure— and from at least 90% of the samples taken from distribution system can be applied in many parts of the world. For each individual sample, coliform density is estimated in terms of the "most probable number" in 100 ml of water or MPN index (Table 2.2). The following bacteriological standards are recommended for treated and untreated supplies for present use during the world:

2.14.1 Treated Water

In 90% of the samples examined during any year, coliform bacteria shall not be detected or the MPN index of coliform microorganisms shall be less than 1.0 per 100 ml. None of the samples shall have an MPN index of coliform bacteria in excess of 10 in 100 ml samples (WHO, 1964).

2.14.2 Untreated Water
In untreated water which is naturally pure, the standards are the same as above but it is stated that none of the samples should show an MPN index greater than 20 per 100 ml (WHO, 1964). When samples are taken from the distribution system they should be free from coliform organisms. In practice, this cannot always be attained and the standard applied should ensure that during the year 95% of the samples should not contain any coliform organisms of E. coli in 100 ml (Dart and Streton, 1980).
Table (2.2): Bacteriological drinking-water quality standards in the Sudan compared with WHO guidelines.

<table>
<thead>
<tr>
<th>Country/Organization</th>
<th>Name of Standard</th>
<th>E. Coli or Thermo Tolerant Coli form Bacteria</th>
<th>E. coli or Thermo Tolerant Coli form Bacteria</th>
<th>Total Coli form Bacteria</th>
<th>E. Coli or Thermo Tolerant Coli form Bacteria</th>
<th>Total Coli form Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td>Guidelines for drinking-water quality, THIRD EDITION, Volume 1, Recommendations. WHO, Geneva, 2004.</td>
<td>Must not be detectable in any 100 mL sample.</td>
<td>Must not be detectable in any 100 mL sample.</td>
<td>Must not be detectable in any 100 mL sample.</td>
<td>Must not be detectable in any 100 mL sample.</td>
<td>Must not be detectable in any 100 mL sample.</td>
</tr>
</tbody>
</table>
| Sudan                | Drinking-water Standard ICS 13.060.00.                                           | 1. E. coli or thermo tolerant coli form bacteria: Must not be detectable in any 100 mL Sample.  
2. Pathogenic intestinal protozoa: Must not be detectable in any 100 ML Sample | E. coli or thermo tolerant coli form bacteria: Must not be detectable in any 100 mL sample. Pathogenic intestinal protozoa: Must not be detectable in any 100 mL sample. | TCC: Must not be detectable in any 100 mL sample. | E. coli or thermo tolerant coli form bacteria: Must not be Detectable in any 100 mL sample. Pathogenic intestinal protozoa: Must not be detectable in any 100 mL sample. | TCC: Must not be detectable in any 100 mL sample. |
2.15 Guidelines for Physical and Chemical Parameters

Water quality is defined by physical, chemical and biological parameters, but also on the characteristics of the water resource, the supply system and the final utilization. Water quality standards depend on the intended use of the water: human consumption (for drinking, cooking, domestic and personal hygiene), food production (crops or livestock), industry and the environment. However, in humanitarian programmers, water quality aspects related to human consumption are the most important, because of their implications for health. Different sets of standards exist, and many countries have their own reference standards, but the most widely recognized worldwide guidance on water quality standards is provided by the world health organization (WHO). Respecting water quality standards may be difficult and may require the development of no sustainable systems for a community. In these cases, a system that produces less than perfect quality water may be appropriate, and certain critical quality parameters should be met to cope with major health risks. Having water in sufficient quantity must be the first priority, to allow water consumption, food production and hygiene activities to be undertaken.

2.16 Water Quality Monitoring

A specific definition of water quality monitoring is given by the U.S Environment Protection Agency in this terms “Monitoring of water quality might be defined as a scientifically designed program of continuing surveillance, including direct sampling and remote quality measurements, inventory of existing and potential causes of change, and analysis of the cause of past quality changes and prediction of the nature of future quality changes”. Following this definition, the main purpose in monitoring water quality can be described as to obtain an early warning of water pollution and/or determine the progress of pollution or changes in water composition (FAO, 1979). The first short-term research monitoring type in the Sudan was carried out by Dirar (1986), it comprised and around the year survey of two biological and one physical parameters of the Blue, White and Main Nile’s water. Parameters surveyed where the coliform and fecal coliform counts were much higher in the Blue Nile during the year than the White Nile. When dominated by the Blue Nile water, the Main Nile showed more contamination than the White Nile.
CHAPTER THREE
MATERIALS AND METHODS

3.1 General
This study was conducted in Zalingei, Central Darfur State, Sudan located between latitudes 12°30’ and 13°30’ N and longitudes 23°30’ and 23°45’ E. The population for the study comprised small-scale farmers in Zalingei area. Rain-fed farming is the most common practice. The major crop grown in this area includes millet, sorghum groundnut, and cowpeas summer crops, where vegetables such as tomatoes and hot pepper are grown as winter crops on valley's banks. The farmers in the study area use simple farm implements. This study was carried out on drinking water where samples were collected from different water sources (Borehole and open hand wells) in Zalingei town, capital state of Central Darfur. The annual rainfall in Zalingei varies between 350 and 750 millimeters. The mean average temperature ranges between 20 °C and 30 °C, (Abdallah, Daw 2012). Average rainfall recorded for years from 1989 to 1998 was 525.14 mm, which is in between 350 mm and 750-mm. Zalingei population about 58208 households according to 2008 census allocated in 18 residential clusters (Sudan Central Statistic Ministry of cabinet, 2008).

3.2 Sampling
Samples were collected from different sources of drinking water that supply Zalingei. Twelve samples were taken, six samples from shallow water open hand dug wells and six samples from ground water sources (piped water taps and hand pumps). The data was collected during the period between December 2016 and July 2017.

3.3 Sampling Techniques
500 ml of water samples were collected aseptically in sterile Bottles. The opening of the tap was cleaned, sterilized by alcohol, and flaming. The tap was then opened, first stream was discarded, and after 2 minutes, the target sample was collected in sterile bottle. The bottle was tightly closed and immediately transported to laboratory for chemical and bacteriological analysis. The chemical and bacteriological analysis was carried out in Water, Environmental and Sanitation Project (WES) Zalingei Analysis Laboratory.
3.4 Determining of the Sample Size to be interviewed for Household Water Treatment

The sample size selected for this survey was determined using standard statistical online software. This software provided the sample size that was interviewed for the given population of 291039. For the purposes of this survey a confidence of 95% was chosen with an acceptable margin of error set at 5%. This was noted as a fair choice for the sample population requirement and the assumption is that the population presents a normal statistical distribution. The number of households interviewed was 271 in Zalingei town and surrounding IDPs camps.

3.5 Physical and Chemical Techniques

The physical and chemical contaminants analysis methods and procedures were adopted from Greenberg et al, 1998). The results were compared with WHO and Sudanese Standards. (Table 3.1).

Table (3.1): shows Sudanese drinking water standards compared with recommended by world health origination (WHO) and Sudanese standards. (1998)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>WHO standards</th>
<th>Sudanese standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dissolved solid (TDS)</td>
<td>1000 ppm</td>
<td>1000 ppm</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>Sulphate</td>
<td>250 mg/l</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>Nitrate as NO3</td>
<td>50 mg/l</td>
<td>50 mg/l</td>
</tr>
<tr>
<td>Sodium</td>
<td>200 mg/l</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>Fluoride</td>
<td>1.5 mg/l</td>
<td>1.5 mg/l</td>
</tr>
</tbody>
</table>

Physical and chemical tests we carried out as shown in Table (3.2 and 3.3) and biological measurement shown in Table (3.4)
Table (3.2): Physical Tests

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Method</th>
<th>Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>The water turbidity was measured by nephelometric method, this method was based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by standard reference suspension.</td>
<td>The turbidity was measured using HACH (2000) turbidity meter and the results were reported in nephelometric turbidity units (NTU).</td>
</tr>
<tr>
<td>pH</td>
<td>The pH was measured by direct reading using sension 3 Millimeter (HACH, 2002).</td>
<td>1. At first the apparatus was standardized as Greenberg et al. (1998) described. Sufficient amount of the sample was poured into the beaker to allow the tips of the electrode to be immersed to 2 cm height and 1 cm away from the sides and bottom of the beaker. 2. Temperature was checked so as not to be too high, and then the pH meter was turned on. 3. The temperature and pH of the water sample were recorded.</td>
</tr>
<tr>
<td>Electric conductivity</td>
<td>The Electric conductivity (EC) in mmhos per cm (μS/cm) was measured at 25°C using sension 7 conductivity meter (HACH, 2002).</td>
<td>1. Water sample conductivity was measured by rinsing out the conductivity cell with at least three portions of the water sample under study. 2. The temperature of a portion of the sample was adjusted to 25°C +0.1°C. 3. The conductivity cell containing the electrodes was immersed in a sufficient volume of the sample so that the liquid level is above the vent holes in the cell. 4. The temperature of the sample was observed and recorded to the nearest 0.1°C and then the meter was turned on and the reading was recorded. The measuring unit was millisiemens per meter (1 mS/m = 10 μmhos).</td>
</tr>
</tbody>
</table>
### Table (3.3): Chemical Test

<table>
<thead>
<tr>
<th>Chemical Properties</th>
<th>Method</th>
<th>Procedures</th>
</tr>
</thead>
</table>
| **Chloride**        | Chloride was determined in a neutral or slightly alkaline solution by titration with standard silver nitrate solution using potassium chromate as an indicator. Silver chloride was quantitatively precipitated before red silver chromate were formed. | 1. Sample of 50 ml was measured into porcelain dish and pH was adjusted to about 8.  
2. One milliliter of potassium chromate indicator solution was added and stirred.  
3. The sample was titrated with silver nitrate solution with constant stirring until slight reddish coloration persists.  
4. Steps 1 to 3 were repeated on a 100 ml distilled water blank to allow for the presence of chloride in any of the reagents and for the solubility of silver chromate. |
| **Sulphate**        | Sulphate (using powder pillows): Powder pillows method is used to determine the sulphate concentration in water by direct reading using spectrophotometer DR 3900-HACH programme procedure adjusted to the wavelength 450 nm is used for analysis. | DR 3900-HACH programme procedure adjusted to the wavelength 450 nm is used for analysis. |
| **Calcium**         | Calcium in water is, generally, determined using EDTA Titrimetric method. The general principle is that when adding ethylene diamine tetra acetic acid (EDTA) solution to a water | 1. A colour comparison blank was prepared by placing 50 ml of distilled water in a white porcelain dish.  
2. Then 50 ml of the target were placed in a white porcelain dish.  
3. Two ml of NaOH solution were added to both the sample and the Comparison blank and were stirred, the pH was adjusted to 12 - 13.  
4. Two drops of Murexie indicator solution was added to the blank and stirred. |
| Sample containing calcium and magnesium ions, it reacts with the calcium before the magnesium | then 1 to 2 drops of EDTA titrant from the burette were added each time while stirring till the colour turned from red to an orchard purple.  
5. The burette reading was recorded.  
6. The burette was read and the volume of EDTA titrant used by Subtracting the burette reading from the reading of step (5). Calcium concentration was calculated as follows:  
   \[ \text{Ca} = \frac{A \times C \times 400.8}{\text{ml sample}} \]  
   Where:  
   \[ A = \text{Volume of EDTA titrant used for titration of sample (ml)} \]  
   \[ C = \text{mL of standards calcium solution/ml of EDTA titrant}. \]  
The results were recorded as mg/L. |
| Alkalinity | Alkalinity was determined by titration of the sample with standard solution of a strong acid. The method was that described by Greenberg et al. (1998).  
1. A mount of 50 ml water sample was mixed with two to three drops of phenolphthalein indicator in the porcelain basin. If no colour was produced the alkalinity to phenolphthalein was zero. If the sample turned pink or red, the alkalinity was determined by titration with standard acid until the pink colour disappeared. In all case the determination was continued by using the sample to which phenolphthalein had been added.  
2. A few drops of methyl orange indicator were added, and if the sample was orange without the addition of acid, the total alkalinity was zero and if the sample turned yellow titration with standard acid was done till the first perceptible colour change towards orange took place. |
| Fluoride | The concentration of fluoride in the water sample was measured by spadnos method as described by Greenberg et al. (1998).  
1. Preparation of standards curve: The fluoride standards in the range of 0 to 1.4 mg F-/litre was prepared by diluting appropriate quantities of standard fluoride solution to 50 ml with distilled water. Five ml of each of the Spadnos solution was pipetted and the acid zirconyl reagent or 10.00 ml of the mixed acidzirconyl/ Spadnos, were pipetted and mixed well. Contamination was avoided. The photometer was set to zero absorbance with reference solution |
and the absorbance reading of the standards was obtained. Curve of the relationship between mg fluoride and absorbance was plotted.

2. Sample pretreatment: Residual chlorine was removed if found in the sample by adding 1 drop (0.05 ml) (NaAsO) solution/0.1 mg residual chlorine and mixed.

3. Colour development: A fifty ml sample or a portion diluted to 50ml with distilled water was used; the temperature was adjusted as in the standards curve. Five ml each of Spadnos solution and acidzirconyl reagent were added. The absorbance was read, after setting the reference point of the spectrophotometer at zero. If the absorbance falls beyond the range of the standard curve the procedure was repeated using a diluted sample.

**Magnesium**

Magnesium was determined by subtracting the calcium hardness from total hardness the remained amount contributed to magnesium (Greenberg et al. 1998).

Magnesium hardness was calculated using the following equation:

\[
\text{Total hardness} = \text{Calcium hardness + Magnesium hardness, Magnesium hardness} = \text{Total hardness - Calcium hardness.}
\]

**Ammonia**

Ammonia is distilled from a buffered solution, and an aliquot of the distillate then nesslerized. Essentially, nesslerization is the reaction between potassium mercuric iodide and ammonia which forms a red brown complex of mercuric ammonobasic iodide.

1. Determine the quantity of NH\(_4\) (as X) in aliquot from a plot of absorbencies of standards containing known amounts of constituent. 1 ml distillate

2. ppm Ammonia nitrogen as N = density \(X\) ml aliquot, \(X\) (mgN in aliquot) ppm Ammonia nitrogen as NH\(_4\) = ppm as N \(\times\) 1.288

**Total dissolved Solid (TDS)**

The total dissolved solid (TDS) applies to the dry weight of the material that is removed from a

1. The filter disc was placed on the filter holder; assembled in suction flask apparatus and vacuumed by a vacuum source.

2. The filter disc was washed by distilled water and vacuumed for 2-3 minutes.
| measured volume of water sample by filtration through a standard filter. | 1. After the water passed through the filter. The filtrate was discarded.
2. The filter paper was removed from the filter funnel and placed on supporting surface in a drying oven at 103-105°C for 1 hour.
3. The filter paper was cooled in a desiccator and weighed in an analytical balance.
4. The above was repeated till the weight between two successive series of operations was less than 0.5 mg.
5. The filter paper was stored into a desiccator until required and weighed (W1).
6. Then cooled in a desiccator and weighed (W2).
7. The total dissolved solid equal W2-W1. |
|---|---|
| **Total Hardness** | **The total hardness of a water sample was measured by EDTA Titrmetric method as described by Greenberg et al. (1998).**
1. An amount of 25 ml of the sample was diluted to 50 ml EDTA titrant and titration was completed within 50 ml with distilled water in a porcelain dish
2. Two drops of Erichrome Black T indicator solution were added.
3. Standard EDTA titrant was added slowly with continuous stirring until the last reddish ting disappeared from the solution and the solution became normally blue.
4. A distilled water blank of the same volume as the sample was used identical amounts of buffer, inhibitor, and indicator were added.
5. Two drops of murex ide indicator solution were added to the blank and stirred, and then one to two drops of EDTA titrant from the burette were added each time while stirring until the colour turned from red to an orchard purple. |
<table>
<thead>
<tr>
<th><strong>Bacteriological Examination</strong></th>
<th><strong>Method</strong></th>
<th><strong>Procedures</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enumeration of fecal coliform bacteria</strong></td>
<td>The membrane filtration technique was used for fecal indicator bacteria of all samples. In accordance with standard methods (APHA, 1980).</td>
<td>The membrane filtration technique was used for fecal indicator bacteria of all samples. In accordance with standard methods (APHA, 1980).</td>
</tr>
<tr>
<td><strong>Membrane filter test</strong></td>
<td>All samples were examined according to the standard methods, for total coliform, fecal coliform, total count, by membrane filter technique with the use of millispor broths, membrane filters of pore size 0.45 μm (Millipore Corp., HAWG) were used for the identification tests.</td>
<td>Membrane filter, filter pad and culture media were used to determine total coliform; the samples were incubated in petri dishes upside down at 37 degree centigrade for 24 hours to count total coliform using Delaque water testing kit.</td>
</tr>
<tr>
<td><strong>Total coliform count</strong></td>
<td>Approximately 150 selected bacterial colonies were subcultured from MF plates during the period of the study. These isolates and the typical total coliform isolates were identified in accordance to Brenner (1984). The medium used for total coliform count was Membrane Endo Type. The medium is composed of: Sodium laurel sulphate 00.05 gram and reagent grade water 1.00 liter</td>
<td>Membrane filter, filter pad and culture media were used to determine total coliform; the samples were incubated in petri dishes upside down at 37 degree centigrade for 24 hours to count total coliform using Delaque water testing kit.</td>
</tr>
<tr>
<td><strong>Total Count</strong></td>
<td>The membrane filter (MF) heterotrophic plate count method described by Greenberg et al. (1998) was followed to estimate total bacterial populations in water. A sample volume (5 ml) was passed through a membrane filter with a pore size 0.43 μm which is small enough to retain the bacteria present in the water sample.</td>
<td>Membrane filter, filter pad and culture media were used to determine total coliform; the samples were incubated in petri dishes upside down at 44 degree centigrade for 24 hours to count total coliform using Delaque water testing kits.</td>
</tr>
</tbody>
</table>
The membrane filter was then placed on an absorbent pad saturated with culture medium selective for heterotrophic bacteria growth in Petri dish. The Petri dish containing the membrane filter and the pad was incubated upside down at 44°C. After 24 hours' incubation, the developed colonies were counted. The results were expressed as colonies/5 ml sample.

**Household visit**

The households were determined through random sampling, by spinning a pen and finding the first house in the direction of the pen. A second spin would then be conducted and three households would be skipped before reaching the next household for the interview. In practice this approach encountered some challenges where households were dispersed widely. But generally where conditions prevailed for the appropriate survey techniques this approach was adopted in sampling the households for the interview.

**Data collection method (HH)**

The data analysis template at field level was developed and SPSS data analysis software was used for the analysis of data. Data was collected by the use of a formal structured questionnaire throughout the survey. Informal verbal consent from the respondents was obtained after explaining the purpose of the survey.
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Turbidity

Generally, the result shows significant differences in turbidity among sites. The highest value (10.8 NTU) was reported in July, while the lowest one (4 NTU) was reported in December 2017. The turbidity was high in rainy season and low during summer and winter seasons. The turbidity values were within the WHO and SSMOH standards. There is strong association between high turbidity and poor quality of water.

4.2 pH

Figure (4.1) shows the pH values of the twelve sites. The result shows small differences among sites. The highest and lowest pH was found in December 2017. The highest value was recorded in Taiba (7.8) and the lowest was recorded in Hamiadya (5.82). Both values were below WHO standards.

![Figure (4.1): The pH](image-url)

Figure (4.1): The pH
4.2.1 Electrical Conductivity

Figure 4.2 shows the electrical conductivity levels of the twelve studied sites during the period between December 2016 and July 2017. The results obtained show that the conductivity varied among sites for all locations with the highest value (668 μs/cm) obtained during December and the lowest value (75 μs/cm) obtained during July. The conductivity was high in winter season (December) and low in the earlier rainy season (July). All the readings were below the acceptable level of WHO standards and SSMO standards (1500 μs/cm).

![Figure 4.2: Electrical conductivity (EC) and total dissolve solids (TDS) for Zalingei.](image)

4.3 Chemical Parameters

4.3.1 Chloride

Figure (4.3) shows the chloride level of the six locations. The results show big differences among months. The highest value (6.6 mg/L) was reported during July in Taiba, while the lowest value (0.59 mg/L) was reported during December at Khamsadagaig. All these readings fall below the acceptable level of WHO (1993) standards (250 mg/L) and the SSMO (2002).
Figure (4.3): Results of the concentrations of some anions and hardness

4.3.2 Sulphate

Figure (4.4) shows the sulphate levels of six sites. The data showed large differences among sites. The highest value (35 mg/L) was reported in December, while the lowest value (0 mg/L) was reported in July. All these readings fall below the permissible level of WHO (1993) and SSMO (2002) standards of 250 mg/L.

4.3.3 Alkalinity

Figure (4.4) shows the alkalinity values of the six sites. The data showed differences among months. The highest value (286.4 mg/L) was reported in December, while the lowest one (74 mg/L) was reported in July. All the readings fall below the threshold value of the WHO 1993 standards of 500 mg/L.
4.3.4 **Fluoride**

Figure (4.3) shows the fluoride levels of the six sites during the period of study. The data shows significant differences among sites; the highest value (1.1 mg/L) was reported in December, while the lowest value (0.47 mg/L) was reported in July. All the readings fell below the acceptable level of the WHO (1993) maximum of (1.5 mg/L) and above acceptable of SSMO (2002) (1.0 mg/L).

4.3.5 **Total Dissolved Solids (TDS)**

The data in Figure (4.2) shows the TDS levels of the six sites. The data showed the highest mean value of 467.8 mg/L reported in December and the lowest value of 52 mg/L reported in July. All the readings fall below the threshold value of the WHO (1993) standards (1000 mg/L).

4.3.6 **Hardness**

The data in Figure (4.4) shows the hardness levels of the six sites. The data shows the highest value (237.4 mg/L) in December while the lowest one (82 mg/L) in July. All the readings were felt below the acceptable level of 500 mg/L according to WHO (1993) standards. Previous studies indicated that waters were classified according to degree of hardness, water less than 75 mg/L CaCO3 was considered as soft water and water that contains 75 to 150 mg/L was...
considered as moderate and water that contains 150 to 300 mg/L CaCO3 is considered as hard and water that is greater than 300 mg/L was considered as very hard water (Harris, et al., 1992).

### 4.3.7 Carbonate

The data in Figure (4.5) shows the concentration of carbonate of highest value (141.6 mg/l) in Hamaidya and the lowest value (0 mg/l) in Taiba during December.

### 4.3.8 Bicarbonate

The data in Figure (4.5) shows the concentration bicarbonate, the highest value (144.81 mg/l) was recorded in Hamaidya and the lowest value (0 mg/l) was recorded in Taiba during December.

**Table: (4.1): Physical and chemical parameters**

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Date of Collection</th>
<th>Location</th>
<th>Sample source</th>
<th>pH</th>
<th>Turbidity</th>
<th>TDS</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6/12/016</td>
<td>Hamaidya</td>
<td>HDW</td>
<td>7.6</td>
<td>4</td>
<td>205</td>
<td>293</td>
</tr>
<tr>
<td>2</td>
<td>6/12/016</td>
<td>Hisahisa</td>
<td>HDW</td>
<td>7.4</td>
<td>4</td>
<td>241</td>
<td>345</td>
</tr>
<tr>
<td>3</td>
<td>6/12/016</td>
<td>Alwadi</td>
<td>HDW</td>
<td>7.2</td>
<td>5</td>
<td>134</td>
<td>191</td>
</tr>
<tr>
<td>4</td>
<td>18/7/017</td>
<td>Hamaidya</td>
<td>HDW</td>
<td>7.4</td>
<td>15</td>
<td>205</td>
<td>293</td>
</tr>
<tr>
<td>5</td>
<td>18/7/017</td>
<td>Hisahisa</td>
<td>HDW</td>
<td>7.8</td>
<td>10.8</td>
<td>241</td>
<td>345</td>
</tr>
<tr>
<td>6</td>
<td>18/7/017</td>
<td>Alwadi</td>
<td>HDW</td>
<td>7.6</td>
<td>8</td>
<td>134</td>
<td>191</td>
</tr>
</tbody>
</table>
4.4 Bacteriological Parameters

Table (4.2) shows the total coliform values of the six sites examined from the open hand dug wells during the period of study. The data shows the highest value (51/100 ml) reported in July, while the lowest (0.0/100 ml) was reported in December. July registered higher value because this is the period of incubation where very high turbidity and temperature during the rainy season, while decrease during dry and winter season. The presence of these microorganisms indicates fecal contamination. The SSMO (2002) recommends that the permissible coliform count be around 0.0.

4.4.1 Escherichia Coli (E. coli)

Table (4.2) shows the E. coli count of the six sites examined. The data show variations among sites, the highest value (49/100 ml) was reported in July, while the lowest one (0.0/100 ml) was reported in December. Total coliform and total count isolated from the water system over the study period were cultivated at 37 °C. In case of fecal E. coli (cultivated at 44.5). The bacterial count appeared to be higher in the rainy season, the period of contamination, and decline gradually in the rainy season, and was very low or insignificant in the winter season, when turbidity and temperature were very low.
The microbiological examination of water shows that the un-piped water in Zalingei is generally contaminated by bacteria including coliform and E. coli as their count violated the WHO (1993) and SSMO (2002) standards which state that coliform bacteria must be detectable in drinking water. Moreover, it was observed that no regular chlorination of un-piped drinking water in Zalingei town. Therefore the most vicinity of Zalingei town population are using unprotected contaminated from 16 open hand dug wells the in vicinity of Wadi Aribo. The drinking water transportation system is through donkey carts and truck trailers which is very risk for contamination during transportation before reach the consumers at household. Moreover only 50% of Zalingei town population are including in pipe water distribution system with no regular chlorination, water safety plan or treatment plan for drinking water.

**Table: (4.2) Shows bacteriological result from HDW**

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Date of collection</th>
<th>Location</th>
<th>Samples from hand dug wells</th>
<th>E. coli</th>
<th>Total coliform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6/12/016</td>
<td>Hamaidya</td>
<td>HDW</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>6/12/016</td>
<td>Hisahisa</td>
<td>HDW</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>6/12/016</td>
<td>Alwadi</td>
<td>HDW</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>18/7/017</td>
<td>Hamaidya</td>
<td>HDW</td>
<td>0</td>
<td>51</td>
</tr>
<tr>
<td>5</td>
<td>18/7/017</td>
<td>Hisahisa</td>
<td>HDW</td>
<td>49</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>18/7/017</td>
<td>Alwadi</td>
<td>HDW</td>
<td>1</td>
<td>44</td>
</tr>
</tbody>
</table>

**4.4.2 The Main Water Sources**

In the dry season, 3.7% of the respondents reported to use water from a well with a hand pumps, 46.5% from water taps connected to a borehole and 29.9% from a well with a concrete apron. 20% reported to use unprotected sources such as open wells, rivers and Wadis, as their main water source.
Figure (4.6): Show the main source of drinking water in Zalingei.

4.4.3 Water Storage and treatment
23.2% of households reported to collect water in jerry cans, 29.9% Barrel, and 33.6% leather bag (Griba). The result shows that water treatment knowledge and practices at a household level were very low. Only 17.7% knew how to treat water at home and this is concerning particularly for those households that access water from unprotected sources such as the river and open hand dug wells.

Consequently, there is a need to promote awareness with regard to safe collection, storage and treatment of water at household level. Those that who treats their water at home, the most popular method of treatment was 8.1% boiling, 4.4% adding chlorine or bleach, 3% filtering and 5.2% solar disinfection. 48.2% of respondents said they wash their containers with water only, 28.8 % with water and soap and 8.5 % water, soap and gravel. From the observations, 60.9% observed to clean their water containers, 63.8% cover their container and 65.7% to raise up their water containers above ground level.
Figure (4.7): show the type of the main water storage containers and treatment.

Figure (4.8): Cleaning of water storage containers

4.4.4 Hand Washing Practices

The result shows that 24.4% of the respondents expressed, they washed their hands with water only, 71.6% with soap and water and 4% with water, ash and sand. Only 33.2 mentioned that washed their hands to keep away from germs to prevent diseases 35.1% to avoid bad smell, 55.5% to keep clean and 15.5% for religious reasons.
4.4.8 The Critical Times of Hand Washing

About 26.3% of respondents washed their hands before eating, 21.8% before preparing food, 7.7% after cleaning child, and 7.7%, before feeding child and 36.5 % and after defecation.

**CHAPTER FIVE**

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- The Turbidity of Zalingei drinking water obtained from water sources ranging (4-10.8) and exceeded the levels recommended by the WHO (1993) standards (5 NTU).
- The pH of Zalingei water was within the admissible level of WHO (1993) standards (5.82 – 7.8).
- The electrical conductivity fall within the WHO (1993) standards ((75-668 μs/cm),) and is, therefore, suitable for drinking.
- The concentrations of chloride, sulphate, calcium, alkalinity, fluoride, magnesium, ammonia, TDS and hardness, fall below the thresholds of WHO (1993) and SSMO (2002) standards.
- The water under study was polluted by coliform, bacteria, which were evidently higher in summer and rainy season (July 2017) and lower or disappear during the winter season.
(December 2016), the highest-level 49 recorded in site 5 in Hisahisa. This area is not included in the water network.

- The most common water source are unprotected open hand dug wells, which is very high risk of biological contamination. These values were above thresholds value of national and international standards of WHO and Sudanese Standards and Meteorology Organization (SSMO) standards of Ecoli.
- Generally, it can be concluded that Zalingei drinking water has adequate physical and chemical quality and is suitable for drinking. However, the bacteriological quality needs high consideration.

### 5.2 Recommendations

1. Replaced the old pipelines of the network by new pipeline to avoid water losses and leakage to prevent the contamination.
2. Adequate treatment by adding chlorine to prevent contamination by microorganisms.
3. Checking the efficiency of the water storage tanks frequently for free residual chlorine to guarantee cleanliness and suitability of water for drinking.
4. Removed the current slaughter in Suck Alghanam as it is near by the functioning shallow water sources.
5. Improvement and protection of open hand dug wells in Zalingei town through fencing, lining and covering.
6. Review and reactivation of local water laws, regulations and guidelines to organize the public and private water sector for the safe water handling.
7. Training of water user is including (locality, private sector and community leaders) on water safety plan and hygiene promotion.
8. Expansion of water pipe line to inclusion unnerved residential areas in the town.
9. Strengthen the coordination between service providers and decision makers to meet at least once per month.
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UNICEF (2014). Increased Access to and Use of Sustainable Water, Sanitation and Hygiene (WASH) Services Underpinned by Improved Integrated Water Resources Management (IWRM) in Darfur,.

UN-NGLS. (2006). the proportion of people without sustainable access to safe drinking water and basic sanitation”.


## ANNEXES

**House Hold Drinking Water Quality Assessment and it is Impact on Community Health in Zalingei Town**

### COMPLETE BEFORE THE INTERVIEW

<table>
<thead>
<tr>
<th>Date</th>
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<tr>
<td>Surveyor’s Names</td>
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<td>Locality</td>
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### SECTION 1 – WATER SOURCES, HANDLING, TREATMENT, STORAGE

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<tr>
<th>Q1.1</th>
<th>What is your main source of drinking water?</th>
<th>ما هو مصدر مياه الشرب الرئيسي؟</th>
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<td>1</td>
<td>Well with hand pump</td>
<td>المضخة مع مضخة يدويَّة</td>
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<td>Water tap connected from borehole</td>
<td>الماء الماسورة من الآبار المفتوحة</td>
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<td>3</td>
<td>Well with concrete apron</td>
<td>الآبار المحمية</td>
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<td>4</td>
<td>Traditional well</td>
<td>الآبار التقليدية</td>
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<td>5</td>
<td>Wadi/River</td>
<td>نهر / الوادي</td>
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<td>6</td>
<td>Haifer/Pond</td>
<td>الترع أو الحفائر</td>
</tr>
<tr>
<td>7</td>
<td>Other (specify)</td>
<td>أخرى ( اكتب الإجابة             )</td>
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<table>
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<th>Q1.2</th>
<th>What type of container do you use to collect your drinking water from the source?</th>
<th>ما هو نوع الأكواب التي تستخدمها لنقل مياه الشرب من المصدر؟</th>
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<tr>
<td>1</td>
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<td>Bucket</td>
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<td>4</td>
<td>Plastic Container ((Khoroje)</td>
<td>حاوية بلاستيكية</td>
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<td>5</td>
<td>Leather bags (Griba)</td>
<td>كارا / فطضاس</td>
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<td>6</td>
<td>Animal drawn cart</td>
<td>كارو/ فنطاس</td>
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<td>أخرى (حدد                                              )</td>
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<th>Q1.3</th>
<th>Do you treat your water in any way to make it safer to drink?</th>
<th>ما هو نوع الشروط الذي تستخدمه لجعل مياه الشرب أكثر أمانًا؟</th>
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<th>Q1.4</th>
<th>If yes, what type of treatment do you practice? (√ All that they say)</th>
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<td>Add bleach/chlorine</td>
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<td>3</td>
<td>Use a filter (cloth, ceramic, or sand)</td>
<td>استخدام فلتر (خليط، ورق، أو الرمل)</td>
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<td>Solar disinfection</td>
<td>تطهير الجراثيم عن طريق الشمس</td>
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<td>5</td>
<td>Let it stand and settle</td>
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### SECTION 2 – HANDWASHING & HYGIENE

**Q2.1** What do you normally use to wash your hands?

- Water only
- Water and soap
- Water and ash
- Water and sand
- Other (specify)

**Q2.2** Why do you wash your hands?

- To keep away germs/prevent disease
- To avoid a bad smell
- To keep clean
- It’s a religious requirement
- Don’t know

**Q2.3** When do you usually wash your hands?

- Before food preparation
- Before eating
- After eating
- After defecation
- After cleaning child from defecation/urination
- Before feeding the child
- Other (specify)

---

**Q1.5** How do you clean your water containers?

- Wash with water only
- Wash with soap and water
- Wash with water, soap and gravel
- Other (specify)

**Q1.6** Observe the water container and the place where the container is kept. Tick if the statement is true.

- The water pot is raised
- The water pot is clean
- The water pot is covered
<p>| Q3.1 | Have any of your family members fallen ill during last 2 weeks? | 1 | Yes |
|      |                                                             | 2 | No  |
| Q3.2 | If yes, what is the type of diseases?                      | 1 | Eye infection |
|      |                                                             | 2 | Bloody Diarrhea |
|      |                                                             | 3 | Dysentery |
|      |                                                             | 4 | Malaria |
|      |                                                             | 5 | Typhoid |
|      |                                                             | 6 | Watery Diarrhea |
|      |                                                             | 7 | Scabies |
| Q3.3 | What causes diarrhea? (✓ All that they say)                 | 1 | Eating dirty/uncovered food |
|      | ما هي مسببات الأسهال؟                                       | 2 | Drinking dirty/uncovered water |
|      |                                                             | 3 | Worms |
|      |                                                             | 4 | Flies |
|      |                                                             | 5 | Malaria |
|      |                                                             | 6 | Certain foods |
|      |                                                             | 7 | Breastfeeding |
|      |                                                             | 8 | Over eating |
|      |                                                             | 9 | Not washing hands |
|      |                                                             | 10| Don’t know |
| Q3.4 | How do you prevent diarrhea? (✓ All that they say)         | 1 | Cover food |
|      | كيف تتجنب الأمراض الإسهال؟                                 | 2 | Clean raw food before eating/ طبخ الطعام جيدا/كل الطعام النظيف |
|      |                                                             | 3 | Wash hands |
|      |                                                             | 4 | Drink water from hand pump or water tap-شرب الماء النظيف |
|      |                                                             | 5 | Use a latrine and keep it clean |
|      |                                                             | 6 | Dispose of rubbish safely |
|      |                                                             | 7 | Prevent flies |
|      |                                                             | 8 | Keep clothes/ body clean |
|      |                                                             | 9 | Safe disposal of child’s faeces |
|      |                                                             | 10| Other (write answer) |
|      |                                                             | 11| (أخرى (حدد)) |</p>
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<th>Mar</th>
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</table>

**Total Rainfall from 1975-2016**

22055

**Average rainfall from 1975-2016**

525.119
### Information at National Level (AWD, 2017-2018)

#### WAD cases at Central Darfur by locality 2017

<table>
<thead>
<tr>
<th>Date</th>
<th>Azum</th>
<th>Mukjar</th>
<th>Nertiti</th>
<th>Umdukhun</th>
<th>Wadi Salih</th>
<th>Zalingi</th>
<th>Golo</th>
<th>Total</th>
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<tr>
<td>Nov 2018</td>
<td>119</td>
<td>1</td>
<td>170</td>
<td>1</td>
<td>29</td>
<td>454</td>
<td>20</td>
<td>794</td>
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#### TODAY (28-Aug-2017)

<table>
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<tr>
<th>State</th>
<th>Total cases</th>
<th>%</th>
<th>Total deaths</th>
<th>%</th>
<th>CFR</th>
<th>First case</th>
<th>Days since first case</th>
<th>Case per day (calculated)</th>
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<tbody>
<tr>
<td>Kassala</td>
<td>744</td>
<td>2.4%</td>
<td>23</td>
<td>3.4%</td>
<td>3.1%</td>
<td>21-Aug-2016</td>
<td>372</td>
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<td>Blue Nile</td>
<td>1,850</td>
<td>6.0%</td>
<td>60</td>
<td>9.0%</td>
<td>3.2%</td>
<td>4-Sep-2016</td>
<td>358</td>
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<td>Rievr Nile</td>
<td>1,534</td>
<td>5.0%</td>
<td>26</td>
<td>3.9%</td>
<td>1.7%</td>
<td>10-Sep-2016</td>
<td>352</td>
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<tr>
<td>Gezira</td>
<td>3,246</td>
<td>10.5%</td>
<td>66</td>
<td>9.9%</td>
<td>2.0%</td>
<td>15-Sep-2016</td>
<td>347</td>
<td>9</td>
</tr>
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<td>Sennar</td>
<td>3,486</td>
<td>11.3%</td>
<td>34</td>
<td>5.1%</td>
<td>1.0%</td>
<td>17-Sep-2016</td>
<td>345</td>
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<tr>
<td>Khartoum</td>
<td>2,214</td>
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<td>32</td>
<td>4.8%</td>
<td>1.4%</td>
<td>25-Sep-2016</td>
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<td>Gedarif</td>
<td>2,219</td>
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<td>33</td>
<td>4.9%</td>
<td>1.5%</td>
<td>16-Sep-2016</td>
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<tr>
<td>Red Sea</td>
<td>1,272</td>
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<td>17</td>
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<td>1.3%</td>
<td>10-Jan-2017</td>
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<td>Northern</td>
<td>840</td>
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<td>15</td>
<td>2.2%</td>
<td>1.8%</td>
<td>12-Feb-2017</td>
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<td>8,574</td>
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<td>885</td>
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<td>11</td>
<td>1.6%</td>
<td>1.2%</td>
<td>19-May-2017</td>
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<tr>
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<td>730</td>
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<td>56</td>
<td>8.4%</td>
<td>7.7%</td>
<td>22-May-2017</td>
<td>98</td>
<td>7</td>
</tr>
<tr>
<td>West Kordofan</td>
<td>340</td>
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<td>33</td>
<td>4.9%</td>
<td>9.7%</td>
<td>24-May-2017</td>
<td>96</td>
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<td>578</td>
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<td>27</td>
<td>4.0%</td>
<td>4.7%</td>
<td>14-Jun-2017</td>
<td>75</td>
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<tr>
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<td>763</td>
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<td>42</td>
<td>6.3%</td>
<td>5.5%</td>
<td>20-Jun-2017</td>
<td>69</td>
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<td>1,002</td>
<td>3.2%</td>
<td>49</td>
<td>7.3%</td>
<td>4.9%</td>
<td>28-Jun-2017</td>
<td>61</td>
<td>16</td>
</tr>
<tr>
<td>West Darfur</td>
<td>341</td>
<td>1.1%</td>
<td>16</td>
<td>2.4%</td>
<td>4.7%</td>
<td>5-Jul-2017</td>
<td>54</td>
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<td>Central Darfur</td>
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<td>18</td>
<td>2.7%</td>
<td>5.7%</td>
<td>2-Aug-2017</td>
<td>26</td>
<td>12</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>30,936</strong></td>
<td>3.5%</td>
<td><strong>670</strong></td>
<td>3.5%</td>
<td><strong>Average</strong></td>
<td><strong>201</strong></td>
<td><strong>10</strong></td>
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</table>

- **39,600,000**
- **0.000781212**
- **0.391%**
- **154,680**