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DECLARATION

I declare that, this research work has been carried out by my own self as part of the requirements for the award of PhD Geography (Natural Resources) in the Department of Geography and History, Faculty of Education, University of Gezira, Sudan.

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DEDICATION

This research thesis is dedicated to my parents, my humble family members, friends, well wishers and the entire Muslim ummah.
ACKNOWLEDGEMENTS

All praise is due to Allah the lord of all that exist and to whom all dignity, honour and glory are due. May the peace and blessings of Allah be upon all the prophets and messengers, especially on the greatest of the prophets and messengers, our prophet Muhammad, his family, his companions and on all that follow him in righteousness until the day of recompense. All praise is to Allah who created us and sustained our life up to the time of the conduct of this study. Thanks also are to Allah for his mercy in giving me opportunity to carry out this research work up to the stage of completion.

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I would like to use this medium to express my gratitude to the management of Isa Kaita College of Education Dutsinma and Tertiary institutions Trust Fund (TETUND) for giving me the opportunity and scholarship to undertake PhD programme.

Lastly, my profound gratitude and appreciation goes to my wife Asma’u Aliyu for her courage, advice, care and concern towards the success and achievement of my noble goals. May Allah (S.W.T) guide us throughout our lives and reward all of us with Jannatul Firdaus ameen.

Shamsuddeen Idris

Abstract

Water is one of the most important natural resources that man and other living creatures rely upon for their survival. Studies of water quality issues such as the prevention of water contamination are of great concern nowadays. The study aimed at determining seasonal variability of four sources of portable water i.e., treated tap-water, boreholes, hand-pumps and well-water, in Dutsinma town. The study also aimed at scrutinizing water in the area of study in terms of colour, taste, turbidity and total suspended solids such as nitrate and sulphate in the wet and dry seasons. The study adopted the quantitative and experimental method. Data were collected through field and laboratory works and were analyzed by using T-test as a statistical method in order to ascertain the effect of seasonal changes on the suitability of water for consumption. That was ascertained by comparing the result obtained with the water quality standard set by the Nigerian Industrial Standards NIS (2007) and World Health Organization WHO (2006). The study revealed a number of results, most importantly: The quality of water varies slightly with regard to different seasons. Some parameters record their maximal level in the rainy season. Average values are recorded as follows: pH (6.8), turbidity (7.5NTU), hardness (124.1mg/L), totally dissolved solids (259 mg/L): nitrate (9.38 mg/L), fluoride (1.48 mg/L) and phosphate (0.3 mg/L). In the present study, results of parameters compared to the water quality standards which are recommended by WHO (2006), NIS (2007) revealed that most of the water quality parameters studied were found to be within the recommended level. Consequently, most of the water sources were safe for human consumption. The study recommends regular monitoring and evaluation of water quality parameters especially during the rainy season, in order to confirm their suitability for human consumption. Moreover, the study also recommends proper coverage of wells and proper treatment of well-water before consumption. Further, regular maintenance of boreholes is recommended as well. The study suggests carrying out of more researches in other parameters that have not yet been covered in the study area.
تحدد التغيرات الفصلية لمواصفات مياه الشرب في مدينة دتسينا حاضرة ولاية كاتسينا النيجيرية

(2015-2018) شمس الدين إدريس

ملخص الدراسة

يعتبر الماء من أهم المصادر الطبيعية التي يعتمد عليها الإنسان وغيره من المخلوقات الحية في حياتهم. لذلك فإن دراسة المياه التي تعني بموضوع نوعية المياه ومكافحة التلوث من الأمور التي تجد اهتماماً كبيراً في أيامنا هذه. هدفت الدراسة إلى تحديد التغيرات الموسمية لأربع مصادر مياه الشرب وهي المياه المعالجة، الأبار السطحية، صنابير الدفع اليدوي والمياه الجوفية بمدينة دتسينا. كما هدفت إلى الوقوف على مواصفات المياه في منطقة الدراسة من حيث اللون، الطعم، العكورة والعوالق الصلبة ووجود النترات والكربونات وغيرها من المواصفات في الفصول الجافة والمطيرة. اتبعت الدراسة المنهج الكمي والتجريبي. وتم جمع العينات ميدانياً واختبارها عملياً وعملياً ومن ثم تحليلها باستخدام B-score بطريقة إحصائية للحصول على تأكدات على أثر تغير المياه وصعوباتها للاستهلاك. ثم الحصول على هذه التأكدات بواسطة النتائج العملية والميدانية ومقارنتها مع معايير جودة المياه التي وضعتها الصناعة النيجيرية لسنة 2007. ومنظمة الصحة العالمية لسنة 2006. توصلت الدراسة إلى عدة نتائج

أهمها: هناك تغيرات طفيفة لمواصفات المياه حسب اختلاف الفصول. بعض مواصفات المياه سجلت مستوى أعلى في الفصل المطير. وكانت المتوسطات المسجلة كما يلي: (6.8) mg/L (H+), (7.5) NTU, (9.38) mg/L (العكورة), (0.3) mg/L (فلاورايد), (124) mg/L (المواد الصلبة), (259) mg/L (العوالق الصلبة), (1.48) mg/L (المواد القلوية). أن أغلب مواصفات المياه التي تم دراستها تتماشى مع مستوى المعايير الموصى بها. نتيجة لذلك فإن أغلب مصادر المياه آمنة للاستهلاك الآدمي. توصي الدراسة بالمراجعة والتقويم الدوري لمواصفات جودة المياه خاصة أثناء الفصل المطير لتتأكد مدى صلاحية المياه للاستهلاك الآدمي. كما توصي الدراسة أيضاً بتغطية الأبار ومعالجة المياه بصورة مثل قب الاستخدام. بالإضافة للقيام بصيانة دورية للأبار. تقتراح الدراسة القيام بمزيد من الدراسات لمناطق أخرى لم يتم دراستها بعد.
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CHAPTER ONE

1.1 General Introduction

Water is one of the most vital natural resources for all lives and living creatures on earth. It is an essential and most precious commodity for life (Das, Boruah and Kar, 2014). The main availability and quality of water always plays an important part in determining not only where people can live but also their quality of life. Even though, there has always been plenty of fresh water on Earth, water has not always been available when and where it is needed, nor it is always of suitable quality for all users (Federal Environmental Protection Agency Nigeria, 1996).

Water is undoubtedly connected to life without which there is no life. This is the reason for which water must be given necessary attention at all times. Good drinking water is not a luxury, it is one of the most essential amenities of life itself (Adetunde and Glover, 2010). According to Egbai, Adaikpoh and Aigbogun (2013), water is an essential element for life and it is used for numerous purposes by man and therefore must be of acceptable quality for human consumption and should be of adequate quantities for livestock and industrial uses.

Water quality is a term used in describing the chemical, physical and biological characteristic of water, usually in respect to its suitability for an intended purpose (Kiyawa, 2009). These characteristics are affected by both natural processes and human activities; generally, natural water quality varies from place to place depending on climatic changes, types of soil, rocks and surfaces through which it moves. A variety of human activities such as agriculture, mining, urban and industrial development and recreation significantly alter the quality of natural water and change the water use potentially (Federal Ministry of Environment FEPA, 1996). The key to sustainable water resources is therefore, to ensure that the quality of
Water resources is suitable for an intended use while at the same time maintaining the quality after use. Natural water quality varies from place to place with the seasons, with climate and with the types of soils and rocks through which water moves. When water from rain or snow moves on the land, and through the ground, the water may dissolve minerals in rocks and soils, percolate through organic materials such as roots and leaves and react with algae, bacteria and other microscopic organisms. Water may also carry plants, debris, silt and clay to rivers and streams making the water appear muddy or turbid. When water evaporates from lakes and streams, dissolved minerals are more concentrated in the water that remains. Each of these natural processes changes the quality and potentiality of the natural water (United States Environmental Protection Agency, USEPA, 2006).

Water must be considered as a finite resource that has limits and boundaries to its availability and suitability for use (Bhatia, 2006). Toxic and hazardous substances such as heavy metals and pesticides are introduced into the aquatic environment principally from anthropogenic sources. Population explosion, haphazard rapid urbanization, industrial and technological expansion, energy utilization and waste generation from domestic and industrial sources have rendered many water resources unwholesome and hazardous to man and other living resources (FEPA, 1996).

Dutsin-ma town is blessed with both surface and underground water which its inhabitants use for domestic purposes including drinking. The water in the town tends to be contaminated or polluted as water borne disease prevails in the town (Idris, 2011). The water might be contaminated through a number of factors such as disposal of domestic waste into the streams that drain to the main reservoir, pollution from decaying algae, dead leaves, human and animal faecal waste and agricultural activities. Seepage from septic tanks, pit latrines and waste dump
site, leaching processes may lead to ground water contamination in the town. In addition to these, physical expansion as well as population growth in Dutsin-ma Town also combined to place a lot of pressure on treated water supplies by the water treatment plant that is why in some cases the treated water has varied taste and clarity with high level of turbidity (Idris, 2011).

1.2 Problem Identification and Justification

Water is one of the most important natural resources that man and other living creatures rely upon for their survival. Man survive longer without food than water, he requires it for domestic purposes and for growing his crops and running of his factories. In fact everything on earth needs water to survive and water is virtually important in every aspect of our lives. In view of the importance of water towards the survival of man and other living creatures on earth, it is pertinent to say that, the importance of studying and monitoring the quality of water for different uses cannot be over emphasized. According to Idris (2011), the incidences of water borne diseases and epidemics in Dutsin-ma town arising from drinking water of doubtful quality have become a great concern. According to General Hospital Dutsin-ma Medical Records, there were over 300 reported cases of water borne disease cases including typhoid, dysentery and cholera from January 2010 to June 2010 and many of these cases have been recorded in the previous years (Idris, 2011). Occurrences of such water borne diseases over the years in the town might have resulted from drinking water that is not safe for human consumption. Water contamination in the town might be attributed to number of factors such as water pollution from decaying algae (some release toxic substances), dead leaves, human and animal faecal waste, disposal of untreated domestic waste into the streams that drain to the main reservoir. In addition to this, agricultural activities such as soil fertility remediation (manuring and fertilization) and application of pesticides are on increase around the town and might have contributed to water
quality deterioration in the town. Another factor is the drilling of boreholes in some cases sited close to septic tanks, pit latrines and waste dump sites, this may lead to ground water contamination through seepage and leaching processes (Idris, 2011).

Physical expansion and population increase in the town placed a lot of pressure on water in terms of quality and supply; and also makes it difficult for the water treatment plant to treat the water as appropriate as possible prior to supply to the consumers. This might be the reason why water supplies by the water treatment plant has varied taste and clarity with high degree of turbidity, that water if allowed to stand for some hours, some residues are usually observed at the bottom of the containers (Idris, 2011).

**Justification of the Study**

The research would address an important issue (portable water quality) that significantly influences developmental processes in any society. It would help in minimizing the cases of water borne diseases in the study area by ensuring that the recommended water quality standards are met. It would also create a sort of balance in drinking water quality between the two seasons. It provides a bench mark for other related studies. The influence of this study is broad, its diversification will open more chances to interested researchers and water users. Furthermore, the Study will help protect our water ways from pollution as water quality evaluations help immensely in controlling pollution levels in our water systems thereby reducing the risk of contacting water borne diseases. It would also help us to understand how we impact our water supply and help us understand the important role we all play in water conservation. Water quality issues influence human and environmental health, so the more we study, assess, evaluate and monitor our water, the better we will be able to recognize and prevent contamination problems.
1.3 Research Objectives

General Objective

The aim of the research is to analyse seasonal variability in water quality of four sources of potable water in Dutsinma town (treated tap water, bore holes, hand pumps and hand dug wells) and to offer recommendations that can be applied.

Specific Objectives

Below are the specific objectives:

1- To test for some biological and physiochemical parameters from the samples of four sources of potable water collected in the city in rainy season.

2- To test for some biological and physiochemical parameters from the samples of four sources of potable water collected in dry season.

3- To compare the results of the parameters tested with standards of water quality for drinking set by Federal Ministry of Environment (FME, 1997), World Health Organization (WHO, 2006) and Nigerian Industrial Standards (NIS, 2007).

4- To determine whether the quality of four sources of drinking water is safe for human consumption.

5- To determine whether the quality of the four sources of water varies with season or not.

6- To offer recommendations for solution based on the findings.
1.4 Scope and Limitation

In terms of the scope and limitation, the research will cover only Dutsinma town, Katsina state, Nigeria, and it will be limited to the four sources of potable water in the town which include treated tap water, bore hole water, hand pump water and open well water. Due to the time factor and resources available, the research did not cover all the water quality parameters, as such, the following physiochemical and biological water quality parameters were considered. These parameters include biological (total Coliforms and fecal coliforms) and physiochemical (temperature, pH, odour, colour, taste, turbidity, Hardness, total suspended solids, total dissolved solids, nitrate, sulphate, chloride, fluoride phosphates, magnesium, iron, COD, and BOD).

1.5 Research hypothesis

1- There is no significant difference in the quality of potable water in Dutsinma metropolis between the two seasons (rainy and dry season).

2- The sources of potable water in Dutsinma metropolis are not safe for human consumption

3- There is significant difference in the quality of potable water in Dutsinma metropolis between the two seasons (rainy and dry season).

4- The sources of potable water in Dutsinma metropolis are safe for human consumption

1.6 Research Questions

1- How many sources of potable water do we have in Dutsinma city?

2- What are the sources of potable water in Dutsinma city?

3- Are the sources of potable water safe for human consumption?

4- Why are the sources of water not safe for human consumption?
5- Does water quality changes with the season?

6 – What are the probable causes of seasonal change in water quality?

7 – What measures can be taken to ensure the suitability of water for consumption

8 – How many boreholes do we have in Dutsinma city?

9 – Are all the boreholes in Dutsinma city functional?

10 – How can functionality of boreholes be maintained?
CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

‘’We have made from water every living thing’’ (Qur’an 21:30). Water is the chemical compound obtained from the fusion of two atoms of hydrogen and one atom of oxygen (H\textsubscript{2}O). It is the only element that occurs naturally in the three states which matter exists (solid, gas and liquid), the boiling point of water is 100\textdegree C while the freezing point is 0\textdegree. Water is a universal solvent dissolving a great many substances and its solubility increase with increasing temperature. Water is also a remarkable catalyst, so many reactions may be slowed down or totally inhibited by lack of water (Ayoade 1988, Oluyemi et al., 2010 and Agbaire et al., 2014). Water makes life possible as without it life and civilization cannot develop or survive. Water forms the largest part of most living matter. An average man is two-third water and would weigh only 13kg when completely without water (Ayoade 1988). Water is one of the most important as well as one of the most abundant compounds on earth and is vital for the survival of any organism (Tortora et al., 2002) in (Onilude et al., 2013). Water is an essential natural resource for sustainability of life on earth (Chinedu et-al, 2011). Humans may survive for several weeks without food, but barely few days without water because constant supply of water is needed to replenish the fluids lost through normal physiological activities such as respiration, perspiration and urination (Murray et-al., 2003) in (Chinedu et al., 2011). Water is of fundamental importance to human life, animals and plants, it is of equal value with the air we breathe in maintaining the vital processes of life and it makes up about 60\% of body weight in human body (Odikamnoro, Omowaye and Aneke 2014). Drinking water must be free from components which
may adversely affect human health, such components include minerals, organic substances and disease causing organisms (Haydar, Arshad and Aziz 2009).

According to Tukur and Abdulkarim (2008), water is essential for life on earth, within organisms. Water provides the medium within which the complex metabolic process necessary for the life takes place, organism simply cannot function without water and if deprived will die quickly. Drinking water for human beings and other organisms must be potable in nature. Before water can be described portable, it has to comply with certain physical, chemical and biological standards, which are designed to ensure that the water is potable and safe for drinking (Tebutt, 1983) in (Eze and Madumere, 2012). Potable water is water that is free from disease producing microorganisms and chemical substances disastrous to health (Ihekoronyo and Ngoddy, 1985). Onwughara et al, (2013) maintained that, potable water is an essential ingredient for good health and the socio-economic development of man. Clean water is essential to human life; safe quality water supplied to communities is an important consideration in the protection of human health and well-being. Without water, life cannot be sustained beyond few days and the lack of access to a safe water supplies leads to the spread of water borne diseases (Omer and Salam, 2012). According to Amira, Abdelmoneim and Elamin (2010), people can survive weeks or months without food but only about four days without water, although an absolute necessity for life can be a carrier of many diseases.
2.2 Water Availability

Fleishmann (1980) reported that, water covers about 70% of the total earth surface, but the proportion portable is negligible as low as 0.01%. An enormous quantity of water is present on our planet. Of the total estimated water on earth and in its atmosphere, 95% is locked in the atmosphere and sedimentary rocks only 5% is actually available for free circulation and about 99% of free water is in oceans. (Asthana and Asthana, 2005). UNESCO (2003) in Makwe and Chup (2013) estimates that globally, ground water provides about 50% of current portable water supplies, 40% of the demand for domestic use, 40% for industrial use and 20% of the water use in irrigated agriculture. Much of the available water therefore is of little use to the mankind as it contains a high percentage of salts. It is mainly the precipitation over land surface in the form of rains, dew, snow which is the most source of fresh water to the terrestrial life. The total amount of available fresh water on our planet is about 84.4 million km$^3$ (Asthana and Asthana, 2005). Wilson (1978) in Chinedu (2011) revealed that, though the hydrosphere is estimated to contain about 1.36 billion Km$^3$ only about 0.3% of the water, existing as fresh water in rivers, streams, springs and aquifers is available for human use, the remaining 99.7% is locked up in oceans and seas. Kumar, Manjunatha and Manjunatha (2013) revealed that, the earth has enormous water resource amounting to about 13,48196000 KM$^3$, out of this amount, 97% is salt water and only 3% is fresh water. Even this small fraction of fresh water is not available to us as most of it is locked up in the polar ice caps and just about 0.003% is readily available to us in the form of ground water and surface water.

Igwemmar, kolawole and Okunoye, (2013), revealed that, about 80% of the earth’s surface is covered by water out of which only a small fraction is available for consumption. The rest is locked up in oceans as salt water, polar ice caps, glaciers and underground. Underground
water is a key source of fresh drinking water essential for life over the globe. It is found in aquifers, which are rocks that have the capacity of both storing and transmitting groundwater in significant quantities (Todd, 1980) in (Ayuba, Omonona and Onwuka, 2013). Groundwater is a reliable source of water supply, because it is often unpolluted due to restricted movement of pollutants in the soil profile. According to NWSSP (2000) in Muhammad (2012), Nigeria is endowed with about 52 billion cubic meters of ground water annually. Despite the abundance of ground water the average national water supply coverage was about 57% (about 60% for urban areas, 50% for semi-urban areas and 55% for rural areas (Muhammad 2012). Many water resources in developing countries are unhealthy because they contain harmful physical, chemical and biological agents (Adetunde, Glover and Oguntola, 2011).

**Table 1: Global Distribution of Fresh Water**

<table>
<thead>
<tr>
<th>Fresh water</th>
<th>Quantity in km$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Water in snow, caps, ice sheets, glaciers etc.</td>
<td>24,000,000</td>
</tr>
<tr>
<td>2- Surface ponds, lakes and reservoirs</td>
<td>280,000</td>
</tr>
<tr>
<td>3- Water in stream and rivers</td>
<td>1,2000</td>
</tr>
<tr>
<td>4- Water present as soil moisture</td>
<td>85,000</td>
</tr>
<tr>
<td>5- Ground water</td>
<td>60,000,000</td>
</tr>
<tr>
<td>Total amount of fresh water on our planet</td>
<td>84,377,200</td>
</tr>
</tbody>
</table>

Adopted from Asthana and Asthana (2005).
2.3 Man’s Water Requirement

According to 1970 estimates, about 3500 cubic kms of water are drawn for human use every year, 76% of this total is for agriculture, 6.2% for power generation, 5.7% for industries, 4.3% for domestic requirement and live Stock management. The amount of water drawn is never used completely (Asthana and Asthana, 2005).

Yelwa (1997) in Umar (2003) observed that Nigeria has more than 2,673.3 billion cubic metres ($m^3$) of surface water potential and about 51.96 billion cubic metres ($m^3$) of underground water. National water supply production average levels are only 39% in the rural communities, and 52% in the urban centers. Water has always been an important and life sustaining substance to humans and is essential for the survival of all living organisms (Igwemmar, Kolawole and Okunoye, 2013). Water according to them accounted for about 70% of the weight of human body.

2.4 Demand and Supply of Water

Demand for water increases with increasing population. In the last few decades, there has been tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated face of industrialization (Mohammed and Nur, 2013). Umar (2003) observed that, the usual demands are for domestics, agricultural and industrial. In the past, quantity of water matters but now the quality of water also matters a lot to all users. Studies of water supply and demand in various part of the country have shown that municipal water supplies are grossly inadequate and unreliable, (Oyebande, 1978, Akintola and Areola, 1980 and Ayoade, 1981) in Ayoade et al (1998). These studies among others indicated that, Nigeria’s available water resources, both surface and underground, though Subject to seasonal and spatial variation are
quite abundant and can satisfy the country’s demands for water in the foreseeable future. What is needed is proper planning and management to ensure convergence between supply and demand over time and space. The various studies also indicated the need for evaluation of the countries resources including assessment of water quality in view of increasing incidents of water pollution arising from human activities in various part of the country.

Water resources evaluation is done with the primary objective of meeting the quality and demand for water for various uses and by various users. According to Ayoade (1988), the major abstractive of water are for irrigation and water supply for domestic and industrial uses. The water demands or requirement for these purposes now and in the future must be known in order to facilitate rational planning and optimum utilization of the available water resources. It is universally accepted that an adequate supply of water for drinking, personal hygiene and other domestic purpose is essential to public health and well being (Oguntoyinbo et al 1983). The state of water supply provision in developing countries is far from satisfactory and is a major source of disease and poor health in this part of the world (Ayoade 1988). World Health Organisation (WHO) survey on the availability of potable water in 67 developing countries in (1975) in Ayoade (1988) showed the following; in urban communities only 57% of the population had house connections while 18% have reasonable access to stand pipes. In rural areas, only 20% of the population had reasonable access to safe water. If both rural and urban populations are considered together, only 35% of the populations were adequately served with portable water (Biswas 1978) in Ayoade (1988). As a result of this situation, water related diseases are rampant; in addition, valuable man’s times are spent on fetching water often of doubtful quality from distant sources. According to UN reports (2005) in Boamah et al. (2011), about 20% of the world’s population does not have access to safe drinking water and most of
these communities are found in Asia and Sub-Saharan Africa. Water related diseases such as infectious diarrhea, microbial dysentery and cholera are found in these communities.

The water supply situation in the rural areas is worse than in the urban areas. Very few rural areas can boast of safe sources of water supply in the tropics. Most rural areas do not have access to good quality water, they depend on traditional sources of water supply such as rain, spring, streams, ponds and hand dug well. Rain water and spring water are normally of high quality but the water is usually contaminated during collection and storage. Apart from the unreliability of supplies, there is a problem of pollution and contamination by household and human waste. The water may be contaminated at source or during storage; water borne diseases are therefore rampant (Oguntoyinbo et al 1983). Access to source of water in Nigeria shows that, 48% (about 67 million Nigerians) depend on surface water for domestic use, 57% (79 million) use hand dug wells, 20% (27.8 million) use harvest rain, 14% (19.5 million) have access to pipe borne water and 14% have access to borehole water sources (FGN, 2007). Globally, about 80% of all diseases and death in developing countries are water-related as a result of polluted water (Ayeniyi et al., 2011, Aderibigbe et al, 2008) in (Aketeyon and Soladoye, 2011).

### 2.5 The Quality of Water

Water is precious values of human life and should be of good quality, safe and suitable for drinking (Homaida and Goja, 2013). Water of good drinking quality is of basic importance to human physiology and man’s continued existence depends very much on its availability (Ogueke, Owuamanam and Ezekiel, 2014). The source of water for any purpose is not as important as the quality of the water for the desired purpose (Amos and Joshua, 2014). The quality of drinking water is a powerful environmental determinant of health (WHO, 2010). It is
an important criterion for evaluating the suitability of water for drinking and irrigation (Nirmala et al., 2012). Water plays an indispensable role in sustenance of life and it is a key pillar of health determinant, since 80% of diseases in developing countries are due to lack of good quality water (Cheesbrough, 2006) in Isah et-al, 2013. Water meant for drinking should be free from harmful microorganisms, harmful chemicals, suspended materials, undesirable test, colour and odour (Leton and Umesi, 1990) in obinna, Ezebasili and Okoro, (2014). The microbiological quality of drinking water is a concern to consumers, water suppliers, regulators and public health authorities alike (Yagoub and Ahmed, 2009). Drinking water quality management has been a key pillar of primary prevention for over one and half centuries and it continues to be the foundation for the prevention and control of water borne diseases (WHO, 2010). Water quality is the physical, chemical and biological characteristics of water (Mary-Helen et al., 2011). It is most frequently used by reference to a set of standard against which compliance can be assessed. The quality of water is use to express the suitability of water to sustain various uses or processes (Abdelmoneim, Amira and Elamin, 2009). Water quality varies significantly due to different environmental conditions, ecosystems and intended human uses. Basically good quality water is convenient and safe to use, and palatable for drinking purposes. It should therefore be clear, tasteless, colourless, and free from poisonous corroding, and staining substances as well as disease-causing organisms (NEST 1991). The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem and the suitability for human use (Lianthuamluapia et-al 2013). Good quality water according to Ibe and Okplenyce (2005) is one that is colourless, tasteless, odourless and free from faecal contamination and chemicals in harmful amounts. Water of good drinking quality is of basic importance to human physiology and man’s continued existence depends on both its quality and availability.
(Bisi-Johnson et-al, 2013). Water which is a vital resource of life, its quality is increasingly being polluted in the wake of modern civilization, industrialization, urbanization, population growth, poor land use system and agricultural activities had lead to fast degradation of our surface and ground water quality ( Adeyede and Abolude, 2004).

Water quality is deteriorated in less developed countries through seepage from septic tanks, discharge of untreated effluent directly into rivers, and water ways (Garret, 2000). The most common form of water pollution is organic matter from domestic sewage municipal waste and agro industrial effluent. This organic matter includes fecal materials, viruses, bacteria and other biological organisms. Water borne infections include schistosomiasis, hepatitis and gastro enteritis etc. These pathogens come from the sewage discharged directly into water but can also come from storm run-off, landfills and agricultural areas (Garret 2000). According to Tortora et-al (1998) in Adetunde and Glover ( 2010), the most dangerous form of pollution occurs when faeces enter the water supply and results in perpetuating many water borne diseases. Microorganisms of concern in water quality as pointed out by Birmingham et-al (1997) in Ibe and Okplenye (2005) include the following bacterial agents of diarrhea and gastroenteritis namely: salmonella sp., Shigella sp., Escherichia coli Vibro cholerae. Protozoal agents of diarrhea include Entamoeba histolytica, Giardia lamblia, Balantidium coli, and Cryptococcus pervum. Enteroviruses causing various clinical ailments, not necessarily diarrhea, but are transmitted by water include poliovirus, Rotavirus, Hepatitis A virus and Hepatitis E virus (Benjelloun et-al, 1997) in ( Ibe and Okplenye, 2005). Many of the organisms that cause serious diseases such as typhoid fever, cholera and dysentery can be traced directly to polluted drinking water, these disease causing organisms called pathogens are discharged along with faecal wastes and are difficult to detect in water supplies ( Vagalari et al., 2011).
Microbiological contamination of drinking water quality may also occur between the collection point and the point of usage (Lamikanra, 1999 and FAO, 1997) in (Bisi-Johnson et-al, 2013). To improve the microbiological quality and reduce the potential health risk of water, intervention strategies are needed that are easy to use effectively, affordably, functionally and sustainably. (Bisi-Johnson et-al, 2013). According to Shrivastava, Chandra and Yadav (2014), the microbial, especially bacteriological impurities caused by the presence of pathogenic or disease producing bacteria make water dangerous for human consumption and these bacteria capable of producing disease in humans are obtained from waste water of corporations, municipalities and other household activities. The portable water contaminated with municipal sewage is the root cause of dangerous diseases in human beings. The disease causing organisms present in the faeces of infected people get ultimately mixed with the water supply there by spreading chronic diseases (Shrivastava, Chandra and Yadav 2014).

Other causes of water quality deterioration were outline by many personalities. Maigari (2002) identified the causes as industrial activities, agricultural practices, municipal waste generation and mode of disposal, land erosion etc. According to Uchegbu (2002), various sources of water pollution are organic and inorganic waste from industrial plants, municipals waste, and sediments from land erosion, oil spills and contribution from routine operations.

According to Bhatia (2006), quality of drinking water has been a factor in determining human welfare, fecal pollution of drinking water has frequently caused water borne disease that have decimated the population of whole cities. Unwholesome water polluted by natural sources has cause great hardship for people forced to drink it.
Feachman (1977) in Kiyawa (2009) indicated that 80% of the ailments humans beings suffer are water borne infectious disease and other emerging affliction of global or specific regional prevalence are usually identified not only with food, soil and atmosphere but most of all water. Parasitic organism such as bacteria, fungi, protozoa worms and viruses are usually associated with water quality. Throughout the world, the quality of ground water is getting degraded by human activities, over exploitation, over pumping and percolation of effluents, residues and pathogen (Gummadi and Swarna, 2013). According to USEPA (1995) and WHO (2006) reports, most tap, boreholes, streams and rivers water in use are not safe for drinking due to heavy industrial and environmental pollution. Toxic chemicals, heavy metals and bacteria in water make people sick and expose them to long term health condition. Water quality should be controlled in order to minimize acute problems of water related diseases which are endemic to man (Okonko et al., 2008).

**Table 2: Common Water Quality Parameters with Associated Water Sources**

<table>
<thead>
<tr>
<th>S/No</th>
<th>Water sources</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Deep ground water (Boreholes)</td>
<td>Fe, Mn, colour, H₂S, NO₃, (PH)</td>
</tr>
<tr>
<td>2</td>
<td>Shallow ground water (open wells)</td>
<td>Fe, micro organisms, NO₃, NH₃</td>
</tr>
<tr>
<td>3</td>
<td>Spring water</td>
<td>Fe, CO₂, (PH), micro organisms</td>
</tr>
<tr>
<td>4</td>
<td>Rain water</td>
<td>Constituents of atmospheric pollution, CO₂(PH)</td>
</tr>
<tr>
<td>5</td>
<td>Surface water (Streams river, lakes and reservoirs)</td>
<td>Suspended solids, micro organisms, colour, algae, taste, odour, organic matter, NO₃, NH₃ etc.</td>
</tr>
</tbody>
</table>

*Source: Adopted from Umar (2003).*
Table 3: Possible Characteristics of Water from Different Sources.

<table>
<thead>
<tr>
<th>Sources</th>
<th>Characteristics</th>
<th>Radioactive matter</th>
<th>Organic matter</th>
<th>Inorganic matter</th>
<th>Microbial count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep well</td>
<td>Nil</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Shallow well</td>
<td>Very low</td>
<td>Variable</td>
<td>Low</td>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td>Surface water</td>
<td>Variable</td>
<td>High</td>
<td>Low</td>
<td>Generally contaminated</td>
<td></td>
</tr>
</tbody>
</table>

Source: Adopted from Kiyawa (2003)

2.6 Global Water Quality Issues

Water quality issues have received considerable attention worldwide recently. Several research findings both published and unpublished revealed increasing concentration of varied chemical substances and biological germs in both surface and ground water due to increase in population and the attendant economic and social activities. For instance, in Europe World Water & Environmental Engineer WW & EE (1991) in Umar (2003) observed heavy contamination of ground water with domestic sewage and pesticides from farm in East Hungary. Similarly UNDP (1990) in Umar (2003) reported feacal contamination of wells in Congo and Zaire. IDB (1992) in Umar (2003) reported the spread of cholera infection from Peru to Chile, Ecuador, Columbia, Brazil and Mexico, over 300,000 cases with 3,170 death were recorded. The causative bacteria were transmitted through water, food and human faeces. Another report by WHO (1992) revealed concentration of heavy metals which reached three times allowed limits in Han river.
According to population reports (1992), water borne diseases caused or aggravated by polluted drinking water kill an estimated 10 to 25 million people globally each year. Most of these deaths could be prevented if sanitation and living conditions improved. In Africa, UNWD (1989) in Umar (2003) reported high concentration of salt and fluoride in surface and ground water; such as in Morocco, Tunisia and Algeria. WHO (1989) reported similar cases in Senegal and Chad area. The work of Boamah et al.,(2011) in Kumasi Ghana, that of Amira et al., (2009, 2010) in Wad-Medani, Khartoum and Central Sudan, and the work of Hamoun and Arafat (2013) in Ed-Dueim, Sudan revealed high bacterial contamination in most of the water samples studied.

2.7 Water Quality Monitoring

Water quality monitoring is important in water for drinking and other uses to ascertain the level and nature of pollution. Any information derived from monitoring exercise will subsequently guide in determining the type and degree of treatment required to make the water portable and to guarantee health and safety.

According to Federal Ministry of Environment Nigeria FME (1997) water quality monitoring includes watching, observing, checking, keeping track of, regulating and controlling the different water bodies for various use categories in the different sectors of the economy, not only for safety purpose but for ascertaining suitability for use. Water quality monitoring studies are centered mainly on physio-chemical, chemical and bacteriological analysis of water samples from various sources.

2.8 Significance of Water Quality Monitoring

FME (1997) stated that, water quality monitoring is important for various reasons among which are:

I-To establish base line data: water quality monitoring provides a base line data which can be used as a basis for comparison with other monitoring exercises. In other word, the data base serves as data bank to support periodic water quality monitoring.

II- To detect and evaluate trends: identification of the general trend is possible through quality monitoring as the recorder is informed routinely whether or not certain water quality variables are showing improving magnitudes or deteriorating ones.
III- To provide basis for and guide implementation of corrective contingency plans against pollution and to support proper maintenance culture and sustainable water quality management.

IV- To detect accidental, critical events including their sources that may result in quick and unusual amount of pollutants into the environment, so that the public may be advised appropriately when necessary.

Water monitoring activities generate information, such information are stored and retrieved for evaluation of effectiveness of treatment methodology and for planning and policy review purpose.

2.9 Water Quality Parameters

Water quality parameters are the measurable attributes of physical, chemical and biological characteristics of the water upon which water is assessed for quality and upon which water standard are set.

According to Kiyawa (2009) water parameters include:

- Physical parameters which are impurities that affect the aesthetic quality of water making it undesirable for human consumption. These parameters include temperature, colour, odour, turbidity, taste, total suspended solid etc.

- Chemical parameters are chemical constituent present in water. Their presence in high concentration could change the physical appearance of the water and cause serious health risk. They include those that are naturally occurring in the water and those that are present due to land use in or around the area. These include pH, magnesium, chloride, alkalinity, nitrate, Iron, sulfate, calcium and manganese.
Biological quality is determined by the presence of organisms of the coli-form group or pathogen organism used as indicators of pollution and contamination which may or may not have health significance.

Ayoade (1988) observed that, the most important characteristics that determine water quality are:

- Physical characteristics – colour, clarity, taste, odour, temperature, amount of suspended solid.

- Chemical characteristics – Reaction, amount of dissolved solid hardness, amount of nitrogenous matter.

- Biological characteristics – Bacteriological content, amount of dissolved oxygen and biochemical oxygen demand.

Parameters selected for the research were described below.

- **Temperature**: temperature is the measure of hotness or coldness of water at the time of sample collection. Temperature in general affects the rates of chemical reactions in water, such reactions decrease with decreasing temperature (WHO 1984) in kiyawa (2009). As such a measure of the temperature at which the water samples are collected is of paramount important. Maria (1976) observed that in waters with higher temperature, the multiplication of bacteria is more rapid than in the waters with a lower temperature. Temperature results may lead to the discovery of an unsuspected source of pollution. The temperature of the water should be observed at the time of collection of the sample.

- **pH**: denotes hydrogen-ion index. The pH scale is a convenient means of expressing acidity and alkalinity in liquids. pH is a measure of acidity of water, and is important in understanding the
chemical balance of the water. pH below 7 indicates acid conditions, 7 represents the condition of pure water while pH above 7 indicates alkaline condition. pH is a strong determinant of the solubility and availability of both nutrients and pollutants. pH is an indicator of the existence of biological life as most of them thrive in a quite narrow and critical pH range. Most natural water bodies will have pH close to 7, depending on the local geochemistry. Very low pH (less than 6) can come from acid rain, industrial sources or mine drainage (Zaslow and Herman 1996).

Basically, the pH values determine whether the water is soft or hard. Water with a pH of lower than 7 is considered to be acidic, soft and corrosive, water with pH greater than 8.5 indicates hard, alkaline water. Hard water poses no health risk. (Apec, 2006) in Kiyawa (2009).

- **Colour, Taste and Odour:** - pure water is said to be colourless and odourless. Colour, odour and taste are parameters to either qualify or disqualify water for drinking purposes; and it is immaterial whether or not the water is clean (Uchegbu 1998) in (kiyawa ,2009). Colour is vital as most water users, be it domestic or industrial, usually prefer colourless water. Determination of colour can help in estimating costs related to discolouration of water. The colour of water is commonly caused by the extraction of colouring materials from the humus of forest or the deposit of vegetable matter in swamps and low-lying areas. In certain cases colour may be imparted to water by dissolved iron or by the discharge of industrial wastes, but generally, colour has little relation to pollution except as indicating surface water is reaching water supplies (Maria 1976). The removal of colour in water is a function of water treatment; therefore, the decrease of colour is a measure of treatment plant’s efficiency.

Odour and taste problems in drinking water supplies account for the largest single class of consumer complaints, some are due to natural causes while others to man’s industrial activities,
Odours in the water are caused by extremely small concentrations of volatile compounds. Some of these compounds are produced when organic matter decomposes and are, therefore, likely to be present in surface waters because of the presence of organic matters from surface wash. Some odours of surface water are produced by pollution from industrial waste and by plankton (free moving microscopic organism), or by addition of chlorine to water (Maria 1976).

Taste in water is generally closely related to odour and is caused by the same condition, but odourless water may have a distinct taste. Metallic ions such as copper, zinc or iron may cause metallic taste. Some waters may have a flavour which can be surmised from the saline constituents.

- **Turbidity:** turbidity is a measure of the cloudiness of water that is used to describe the suspension of particles in water which interferes with the passage of light. It is used to indicate water quality and filtration effectiveness. Turbidity may be caused by silt extracted from soil, suspended organic and mineral matter, precipitated calcium carbonate in all waters, aluminium hydrate in treated waters, iron oxide in corrosive water and microscopic organisms (Maria 1976). Turbid water is undesirable from an aesthetic point of view in drinking water. Higher turbidity levels are often associated with higher levels of disease causing organisms such as viruses, parasites and some bacteria. They cause symptoms such as nausea, cramps, diarrhoea and associated headaches (USEPA 2006).

- **Hardness:** hardness in water is caused by dissolved calcium and to a lesser extent magnesium expressed as the equivalent quantity of calcium carbonate (Ca, Mg and CaCO₃). Water is a universal solvent and dissolves varying amounts of different substances.
substances producing hardness do not affect the sanitary quality but are of importance in the
domestic use of water particularly for laundry and boiler purposes. (Maria 1976). Calcium and
magnesium salts, the principal mineral constituents consume soap and precipitate as insoluble
compounds. Calcium and magnesium generally are dissolved as soluble bicarbonates but may
change to soluble carbonate.

- **Total Suspended Solids**: - according to Umar (2003) suspended solids refers to the
quantity of organic materials and minerals in suspension in water. Suspended solids may be
derived from mineral and organic materials transported into water by erosion. High suspended
solids in any water body may be aesthetically unsatisfactory for bath and other domestic uses.
Total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates,
manganese, organic matter, silt and other particles (Agbaire et al., 2014).

- **Total dissolved solids**: - total dissolved solids (TDS) is defined as the concentration of
all dissolved minerals in water. Natural waters contain a variety of both ionic and uncharged
species in various amounts that constitute total dissolved solids (Agbaire and Oyibo, 2009).
Total dissolved solids in water consist of inorganic salts and dissolved materials. Total dissolved
solids indicate the general nature of water quality and salinity. Water samples containing more
than 500mg/l of TDS is considered undesirable for domestic uses but unavoidable cases of
1500mg/l is also allowed. Hence 500mg/l is desirable limit and 1500mg/l is the maximum
permissible limit (Nwaici et al., 2007). Total dissolved solids in water composed mainly
carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium,
potassium, manganese and organic materials (Agbaire et al., 2014).
- **Nitrates**: relatively little of nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former waste discharge and the latter chiefly artificial fertilizers. However, bacterial oxidation and fixing of nitrogen by plants produce nitrates (EPA, 2001). High levels of nitrate in waters to be used for drinking will render them hazardous to infants as they induce the blue baby syndrome. The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite. The study of nitrate content in water is of importance since it is the final product of ammonia (Agbaire et al., 2014). The standard permissible value of nitrate for public water supplies ranges from 40-70mg/l.

- **Iron**: iron is present in significant amount in soils and rocks, principally in soluble forms. However, complex reaction which occur naturally in ground formation can give rise to more soluble forms of iron which will therefore be present in water passing through that formation (EPA, 2001). Appreciable amount of iron may therefore be present in ground water. Severe problem can be caused in drinking water supplies by the presence of iron. Although there are normally no harmful effects on consuming waters with significant amount of iron, rather the problems are principally aesthetic. According to Rajana (2010) in William (2014), prolong consumption of water that is reddish brown in colour due to ferric hydroxide may lead to liver diseases. Largest contributors of iron in ground water are minerals contained within the underlying bedrock, soil and sand, the most common is ferrous iron, limestone, shale and coal which often contain the iron rich in pyrite. Acidic rain also releases iron into ground water (lentech, 2009) in (William, 2014).

- **Sulphate**: Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They are often derived from sulphides of heavy metals (iron, nickel, copper and lead). Iron sulphides are present in
sedimentary rocks from which they can be oxidized to sulphate in humid climates (EPA, 2001). As magnesium and sodium are present in many waters, their combination with sulphate will have an enhanced laxative effect of greater or lesser magnitude depending on concentration. The utility of water for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 250mg/l.

- **Chloride** :- The presence of chloride where it does not occur naturally indicates possible water pollution (Agbaire, 2014). Chloride contaminates rivers and ground water and can make it unsuitable for human consumption. High level of chloride kills plants and animals. Chloride exists in all natural waters, the concentration varying very widely and reaching a maximum in sea water (up to 35,000 mg/l). In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents. Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability (EPA, 2001). At levels above 250mg/l, water will begin to taste salty and will become increasingly objectionable as the concentration rises further. High chloride levels may similarly render fresh water unsuitable for agricultural irrigation (EPA, 2001).

- **Fluoride** :- Fluoride occurs naturally in quite rare instances. It arises almost exclusively from fluoridation of public water supplies and from industrial discharges. Health studies have shown that the addition of fluoride to water supplies in levels above 0.6 mg/l leads to reduction in tooth decay in growing children and that the optimum beneficial effect occurs around 1.0 mg/l (EPA, 2001). At levels markedly over 1.5 mg/l an inverse effect occurs and mottling of teeth (or severe damage at gross levels) will arise. For this reason there is a constraint on fluoride levels, the effect of which varies with temperature.
- **Phosphates** :- Phosphates occurs widely in nature in plants, in micro-organisms, in animal wastes and so on. They are widely used as agricultural fertilizers and as a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are thus important contributors of phosphorus to surface water (EPA, 2001). According to Agbaire (2014) phosphates are only toxic to both plants and animals when present in high levels. Levels of phosphates greater than 1.0 mg/l may interfere with coagulation in water treatment plants. In this case, the organic particles that are present in micro-organisms may not be completely removed before water distribution. Phosphates occur in natural waters in low quantity as many aquatic plants absorb and store phosphorus many times their actual immediate needs.

- **Magnesium** :- Magnesium is a salt that contribute to the hardness and taste of water. Excessive magnesium may give water a bitter taste, but is normally not a health hazard (Igwemmar, Kolawale and Okunoye 2013). Like calcium, magnesium is abundant and a major dietary requirement for humans (0.3-0.5g/day). It is the second major constituent of hardness and it generally comprises 15-20% of the total hardness as CaCO$_3$ (EPA, 2001). It is concentration is very significant when considered in conjunction with that of sulphate.

- **Chemical Oxygen Demand (COD)**:- Cunningham and Cunningham (2006) regarded chemical oxygen demand as the measure of all organic matter in water derived from sewage, agricultural run-off paper mills waste & food processing waste. COD values are always higher than BOD values because nearly all organics are oxidized in the chemical oxygen demand test against BOD test in which only some organics are decomposed. (Uchegbu 1998) in kiyawa (2009).
- **Biochemical Oxygen Demand (BOD)**: This is simply the rate of oxygen use. It is the measure of the amount of oxygen required by bacteria and other microorganisms to stabilize degradable organic matter and not a measure of some specific pollutants. According to Zaslow and Herman (1996), chemical oxygen demand measures how much oxygen is consumed by bacteria as they breakdown pollution and organic matter in the water. Cunningham and Cunningham (2006) also maintained that biochemical oxygen demand BOD is the amount of dissolved oxygen consumed by aquatic microorganisms and is a standard measure of water contamination. If the oxygen is low, it could be because the water is clean, available microorganism are not interested in consuming organics or the microorganism are dead or dying.

Bellamy (2007) opined BOD to be the amount of dissolved oxygen required by microorganisms in water for aerobic decomposition of organic matter present in water. BOD values can be used as a measure of waste strength and degree of pollution. As the amount of organic waste in water increase, more oxygen is used resulting in a higher BOD values.

- **Coliform bacteria and Eschericia coli (E-coli)**: Coliform bacteria are bacteria that grow in the digestive tracts of humans and other warm blooded animals and indicate the presence of sewage and other sources of fecal pollution. (Zaslow and Herman 1996 and Sunday et al., 2014). Coliform bacterium is not a health threat itself, it is used to indicate whether other potentially harmful bacteria may be present in water. Coliforms are naturally present in the environment as well as faeces. Cunningham and Cunningham (2006) revealed that, if any coliform bacteria are present in a sample of water, infectious pathogens are usually assumed to be present also, therefore, the United States Environment Protection Agency (EPA) considers water with any coiliform bacteria at all to be unsafe for drinking. Fecal coliforms and Eschericia coli (E-coli) come from human and animal faecal waste. The highest level of which is allowed in drinking
water is 5% while the level in drinking water below which there is no known or expected risk to health is zero (USEPA 2006).
CHAPTER THREE

PHYSICAL AND HUMAN CHARACTERISTICS OF THE AREA

3.1 Study Site description

Situation and Location

Dutsin-ma Local Government is located in the Sudan Savannah Zone of central part of Katsina State. It is relatively bounded by Safana and Dan-musa local governments by the west, Kurfi and Charanchi Local Governments by the north, Kankia by the east, Matazu and Dan-musa local governments to the south. In absolute terms, Dutsin-ma town is found within latitude 12°27'10" N and 12°27'16" N and longitude 07°29'56" E and 07°30'04" E.

Geology, Relief and Soil

Dutsin-ma town is underlain by the basement complex area of Katsina State which is of crystalline origin Tukur, (2010). There are numerous quazatic and granitic hills, which rise 60-200meters above the surrounding plains. These hills are probably the result of the intrusion of older granites into the basement complex, which have undergone long period of denudation (Adamu, 2000) in Tukur (2010). Prominent one among them is Ma-rock known as DUTSIN-MA. Thus, name of the town. Dutsin-ma is on a moderately rolling undulating plain (Perkins and Stembridge 1970) in Tukur (2010).
Fig. 1: Map of Katsina State Showing Dutsinma L.G.A. and the Study Location.
Source: GeoEye Image 2014.
Generally, in Katsina State, sandy “drift” deposits laid down during the last arid phase about twelve thousand years ago overlie underlain rocks. In the southern part of the state, the soil is largely clayey soils of about five Meters in depth and very fine in texture (Adamu, 2000) in Tukur (2010). The soil tends to be water logged with heavy rainfall and to dry out and crack during dry season. The soil is difficult to work; in addition, it is suitable for the cultivation of such crops maize, guinea corn and cotton. While in the northern part of the state, the soil (drift deposits) is coarser. This result to high sandy soils of reddish colours and low or medium fertility. These soils are easily worked and well suitable for the cultivation of crops like millet, cowpea and peanut, which are less demanding in nutrients as compared to maize, cotton and guine corn (Adamu, 2000) in Tukur (2010). Since Dutsin-ma is located within the transition zone between the basement complex region and sandy formation zone, it combines two soil characteristics, the sandy and clay soils.

Generally, the soil of the area is the tropical ferruginous red and brown soil of the basement complex. The soil forming materials are rock and sand materials. Brown to orange color soils consisting of sandy clay loam, overlying lateritic ironstones are found on the interfluves and upper slopes of undulating area, while on the seasonally flooded river valley floors, highly clay content heavier grey soils occur (Oguntoyinbo et al, 1983).

**Climate**

The climate of the area is semi arid classified as tropical wet and dry climate (AW), as classified by W. Koppens. Two major factors influence the climate of the area, latitudinal location and continentality (distance from the sea),
Temperature

April is the warmest month of the year and January is the coldest month of the year in Dutsinma area. The Temperature in April averages 30.8°C. In January, the average temperature is about 21.2°C (Isa Kaita College of Education, Weather Station 2017). Between March and May the area, experience a hot dry season climate. A warm wet season is experience from June to September. Towards the end of the year, the area experience a less marked season after rains, which is characterize by a decreasing rainfall and a gradual lowering of temperature. Temperature is higher during in the dry season (March to June) than in rainy season and this affects temperature of the water and other processes that requires higher temperature.

**Table: 4 Mean Monthly Temperature of Dutsinma from July 2016 – June 2017**

<table>
<thead>
<tr>
<th>Months/ Year</th>
<th>Temperature °C</th>
<th>Temperature °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>July (2016)</td>
<td>25.8</td>
<td>78.4</td>
</tr>
<tr>
<td>August (2016)</td>
<td>24.8</td>
<td>76.6</td>
</tr>
<tr>
<td>September (2016)</td>
<td>25.8</td>
<td>78.4</td>
</tr>
<tr>
<td>October (2016)</td>
<td>26.7</td>
<td>80.1</td>
</tr>
<tr>
<td>November (2016)</td>
<td>24.3</td>
<td>75.7</td>
</tr>
<tr>
<td>December (2016)</td>
<td>21.2</td>
<td>70.2</td>
</tr>
<tr>
<td>January (2017)</td>
<td>21.2</td>
<td>70.2</td>
</tr>
<tr>
<td>February (2017)</td>
<td>23.8</td>
<td>74.8</td>
</tr>
<tr>
<td>March (2017)</td>
<td>28.2</td>
<td>82.2</td>
</tr>
<tr>
<td>April (2017)</td>
<td>30.8</td>
<td>84.7</td>
</tr>
<tr>
<td>May (2017)</td>
<td>30.7</td>
<td>87.3</td>
</tr>
<tr>
<td>June (2017)</td>
<td>28.8</td>
<td>83.8</td>
</tr>
</tbody>
</table>

**Source: Isa Kaita College of Education Dutsinma Metrological Station 2017**
Wind

Dutsin-ma area is affected by two main winds (air masses). These are tropical continental and tropical maritime air masses. The former is associated with dry wind and dusty harmatan from the Sahara desert, while the later is associated with rain bearing southwest winds from the Atlantic Ocean that affect the whole country (Udoh, 1970). Wind speeds are higher in the month of January (16mph). Lower wind speeds of about 10mph are common in the month of April.

Table: 5 Wind Speed of Dutsinma from July 2016 – June 2017

<table>
<thead>
<tr>
<th>Months/ Year</th>
<th>Wind Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July (2016)</td>
<td>12</td>
</tr>
<tr>
<td>August (2016)</td>
<td>11</td>
</tr>
<tr>
<td>September (2016)</td>
<td>10</td>
</tr>
<tr>
<td>October (2016)</td>
<td>12</td>
</tr>
<tr>
<td>November (2016)</td>
<td>15</td>
</tr>
<tr>
<td>December (2016)</td>
<td>16</td>
</tr>
<tr>
<td>January (2017)</td>
<td>17</td>
</tr>
<tr>
<td>February (2017)</td>
<td>12</td>
</tr>
<tr>
<td>March (2017)</td>
<td>10</td>
</tr>
<tr>
<td>April (2017)</td>
<td>10</td>
</tr>
<tr>
<td>May (2017)</td>
<td>09</td>
</tr>
<tr>
<td>June (2017)</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: Isa Kaita College of Education Dutsinma Metrological Station 2017
Rainfall

According to Adamu (2000) in Tukur (2010) the climate of Dutsin-ma could be described as tropical continental, with annual rainfall of about 800mm. the climate of the area differs considerably according to the month and season. From December to February is a period of cool and dry (harmattan) season. Rainfall distribution in the area never exceeds five to six months. August happen to be the wettest month of the year in the area, when an average rainfall reaching up to 175mm is recorded. The least rainfall amount in the area is in March, April and October with less than 10mm. Generally, the total annual rainfall in the area is about 846mm. But records show that there are wetter years, for example, 1999 which records about 1224mm, while on the other hand there are drier years, for example 1996 which records about 459.4mm of rainfall and 2007 records about 420mm of rainfall (Isa Kaita College of Education Meteorological Station 2017).

Table: 6 Total Annual Rainfall for Some Years in Dutsinma Metropolis

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>650mm</td>
<td>809</td>
<td>706.00</td>
<td>554mm</td>
<td>624mm</td>
</tr>
</tbody>
</table>

Source: Isa Kaita College of Education Dutsinma Meteorological Station 2017

Relative Humidity

Relative humidity of Dutsin-ma and its environs hardly exceeds 20-28% due to north easterly trade winds, which bring cool, dry and dusty conditions in the month of December to February, where the least relative humidity of less than 18% is recorded. While in the month of
August and September, the maximum relative humidity of about 25-28% is recorded. (Isa Kaita College of Education Meteorological Station, 2017)

**Water Resources in the Area**

Dutsin-ma area is well drained by many rivers, major ones among them include; River Karaduwa, Kagara and Bunsuru which all bring water to Zobe dam, constructed for dry season farming purpose. Small rivers like River Dabawa and Darawa supply water to Dutsin-ma dam constructed for domestic water supply (field observation 2015). There are two major sources of domestic water supply in Dutsin-ma town, these are, surface and underground water. The Dutsin-ma Dam supply water to urban Dutsin-ma and its environs. A dam was constructed and commissioned in 1975 with a water treatment plant that is capable of treating 150m$^3$ of raw water per hour (Ibrahim 2006). Presently the water treatment plant could not sustain water demand of the area due to high population concentration which affects water in terms of quality and supply. As a result boreholes were drilled to supplement treated tap water supply (field work 2015). In addition to this, there is another Dam around the study area called Zobe Dam. It is an a earth-fill structure constructed in 1983 with a height of 19 m and a total length of 2,750 m. Zobe dam has a storage capacity of 179 Mca and irrigation potential of 8,000 hectares. The dam was constructed to supply water for domestic use to many parts of Katsina state including Dutsinma city. Another reason for its construction was for local irrigation and power supply. Currently the dam is under utilized for the purposes to which it was constructed. If this dam is adequately utilized, to would boost domestic water supply in Dutsinma city and neighboring settlements.
Population

Dutsin-ma metropolis is predominantly Hausa-Fulani territory. Majority of the people speak Hausa, but there are small portion of the people that speak Fulani. Large percentages of the people in the area are cultivators, with a few traders. According to the 2006 National Population census, the population figures of Dutsin-ma Local Government reached 169,671 inhabitants. Of this population figure, 52.6% are males and 47.4% are females with 58.8% literacy and 41.2% illiteracy level. In terms of age level, 44.0% of the population aged under 15 years, 43.2% aged between 15-65 years and 2.7% aged above 65 years. (National Population Commission, 2006). The estimate of 2017 puts the population of Dutsinma local government at 220,756 people. (National Population Commission, 2017). As at 2017, the annual increase rate of population was 2.6% and birth rate was about 36.9 births per 1000 population. There is considerable number of migrants from southern part of Nigeria, especially Igbos and Yorubas, in addition to migrants from Niger Republic. As of 2006 population census, the area has a net migration rate of 0.2 migrants per 1000 population.

Economic Activities

Agriculture is the backbone of Katsina State economy as 75% of its people are farmers (Sama’ila, 2002). As such large percentages of the people in Dutsin-ma are farmers. Economically therefore, Dutsin-ma area could be described as an agrarian society, for the fact that majority of the inhabitants are farmers. Food crops such as sorghum, cowpea, maize, millet and peanut dominate crop production. Cotton and vegetables are the only cash crops usually produce in the area. Construction of Zobe Dam along river Karaduwa and Bunsuru by Federal Government in 1983 has greatly boost irrigation farming. This has considerably changed the
socio-economic life of the people in the area (SRRBDA, 1985). Dutsin-ma is blessed with considerable vegetation resources, for example, the Ruma-kukar Jangarai Forest reserve, serves as a grazing land and provides fuel wood to the neighboring villages and town. Apart from agriculture, people of the area engage in other secondary economic activities such as trading, local manufacturing, mining, transportation and the like.
CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Materials and Methods

This chapter presents methods adopted for the collection and analysis of data.

Sources of Data

Two major sources of data were used for this research they were:

Primary sources of data which involved field collection of water samples and analysis of selected water quality parameters using standard laboratory techniques/procedures.

Field work

The field work was divided into Pre-field work which involved reconnaissance survey of the study area to identify different water sources in the metropolis for the selection of the sampling points and main field work which involved collection of water samples and laboratory analysis of the samples collected.

Sampling Design

A purposive sampling technique was adopted and samples were drawn purposefully from the four water sources (treated tap, hand pumps, boreholes and open well water). During reconnaissance survey, eight sampling points were selected; two sampling points for the treated tap water, two for hands pumps, two for boreholes and two others for open wells. The sampling points selected were water treatment plant (production point) and Bayan area (consumption points) for the treated tap, Unguwar Kudu and Low-cost Housing Estate for hand pumps, Sokoto
Rima and Isah Kaita College of Education for Boreholes and police station open well and new market well for the open concrete wells. In the case of sampling points selection, bore holes and hand pumps were purposely selected because they were the busiest ones at the time of sample collection. For the treated tap water, selection was made, because they are the busiest points where people and water vendors source their water, and also to find out probable variation in the extent of water treatment in the area especially, situations between the treatment plant and a way so as to find out if there is spatial difference in water quality between the production and consumption points. In case of well selection, the two wells are among the busiest ones and their water supply is continuous throughout the year.

![Fig 2 Map of Dutsinma City Showing Eight Sampling Points](source)

**Fig 2 Map of Dutsinma City Showing Eight Sampling Points**
Sample Size

Eight water samples were drawn from eight sampling points selected, two samples from treated tap water, two samples from hand pumps, two samples from boreholes and two samples from open wells. Sampling collection was carried out thrice in the rainy season and thrice in the dry season respectively, making a total of forty eight (48) water samples for the study (24 samples in the rainy season and 24 samples in the dry season).

Sample’s Collection

Water samples were collected from tap water, boreholes, hand pumps and open wells. Sample’s collection for the dry season was carried out in the month of January, February and April 2016. For the rainy season, the samples were collected in the month of July, August and September 2016. Water samples were collected using sterilized 2-liter plastic containers, thoroughly washed and acidified with nitric acid and clearly marked and labeled after the sampling points, time and date. The containers were further rinsed with the sample water at the sites of the sample collection before the samples were collected to avoid contamination. This is in accordance with Balarabe, Oladimeji and Abubakar (1998), Nirmala et al, (2012), Abed, Hussain and Pradhan (2011), Agbaire, Akporido and Akporhonor (2014), Nwaichi, Monamu and Njoku (2013) and Makwe and Chup (2013). After sample collection, the sample containers were further placed in black polythene bags to prevent light from getting into the samples which could alter the rate of chemical reactions of the micro organisms. All samples were collected between 8:00am to 10:00am and kept in coolers filled with ice blocks before they were finally conveyed to the laboratory where they were analysed for all the selected parameters.
Laboratory Analysis

Parameters analyzed in the laboratory were biological (total Coliforms and fecal coliforms) and physiochemical (temperature, pH, odour, colour, taste, turbidity, Hardness, total suspended solids, total dissolved solids, nitrate, sulphate, chloride, fluoride, phosphates, magnesium, iron, COD, and BOD).

These parameters were tested using standard laboratory techniques as discussed below. The physiochemical and biological analysis of all the water samples was carried out at Katsina State Water Board Laboratory (Ajiwa Water Treatment Plant Central Laboratory). Six series of results were obtained from laboratory analysis, three results for rainy season and three results for dry season. For each of the two seasons, the average of the three results were taken to serve as the main results for the research, one result for the rainy season and one for dry season.

Methods of laboratory analysis

- **Temperature Determination:** An accurately graduated thermometer designed to measure water temperatures was used to measure the temperatures of all the samples at collection time. The thermometer was put into the water samples at the source of each sample and all the temperature readings were recorded accordingly.

- **pH Determination Using Comparator pH Indicator:** Two test tubes were filled to the 10ml mark with the sample water. An indicator was added to the right hand test-tube and carefully mixed together, while the other test-tube was left blank. A disc was inserted in the lid of lovibond comparator and was gently revolved until the nearest colour match was obtained and the pH was read in the Indicator recess at the bottom right-hand corner of the comparator.
- **Odour Determination using Clean Odour Free Glass Bottles:** 250ml of sample was placed in a 500ml wide-mouthed, Stoppard flask and little potassium hydroxide (KOH) was added. The flask was heated over a water bath until the temperature of between 50 – 60°C was reached. The flask was then shaken, the stopper removed and the nose promptly applied to the aperture of the flask and finally odour was perceived.

- **Taste Determination:** A small quantity of samples was placed into one 50ml beaker and warmed to room temperature. Taste was perceived by tasting the sample on both tip and back of tongue.

- **Colour Determination Using the Hazen Method:** A colourless cylindrical glass tube was filled with water while another was filled with distilled water. The coloured solution was added to the distilled water, a small amount at a time until the colour, on looking vertically down through the tubes corresponded to the colour of the water being examined. The amount of the coloured solution added and the total volume of the distilled water being known, the dilution gave the degree of colour.

- **Determination of Turbidity P.C.I. Turbidity metre Technique:** The interior reservoir of the metre was filled with water and the electrical light was switched on. Multiple reflections were obtained of the original light-spot. The reading was obtained by moving a slider mounted on the cover until the slider gave a direct reading on a scale in units of turbidity.

- **Hardness (mg/l):** Hardness in water is caused by dissolved calcium and to a lesser extent, magnesium expressed as the equivalent quantity of calcium carbonate. The test was carried out
by titration using the following apparatus, delivery tube, counter (table clock), dropper, buffer solution and man – ver – 2 hardness reagents.

- **Total Suspended Solids (mg/l):** Suspended solids refer to the quantity of organic materials and minerals in suspension in water. The test was carried out by titration method. The method involved separation of suspended solids by titration on glass disc followed by drying at 105°C. The apparatus used include vacuum flask, titration support (stand) with clamps and filters washed dried at 105°C.

\[
\text{Results} = SS = \frac{M1 - Mo \times 100}{V}
\]

Where, 

\[ V \] = measured volume (100ml)

\[ Mo \] = mass

\[ M1 \] = weight of filter, cake and dish

- **Total Dissolved Solids (Mg/l):** Total dissolved solids were determined through HACH titration method with TDS conductivity meter using beaker, distilled water and the sample.

- **Electrical Conductivity.** Electrical conductivity was determined using conductivity meter with scale of 0-20000 units. The measuring cell was cleaned and rinsed with distilled water and with some sample water. The cell was filled with the sample and the connecting cable was plugged into the measuring cell socket. The temperature dial was set to the temperature of the sample and the selector switch was turned to the anticipated range of measurement. The
activator button was held down and the measuring dial was slowly rotated until the balance indicator moved to the center scale. The dial setting was read and multiplied by the range factor.

- **Nitrate (Mg/l):** Nitrate was determined by comparative method using HI 3874-0 reagent. The vessel was filled to 10ml mark with the sample water and one packet of HI 3874-0 reagent. The cover was replaced correctly and the mixture was shaken vigorously for one minute and then waits for four minutes for the colour to develop. The cover of the vessel was removed and colour comparator tube was filled with 5.0ml of treated sample. The colour that matches the solution in the tube was determined. To convert the reading to Mg/l of Nitrate, the reading was finally multiplied with the factor of 1.43.

- **Chloride (Mg/l):** Chloride was determined using Silver Nitrate Solution. 1ml Potassium Chromate K$_2$CrO$_4$ was added to 100ml of water sample and titrated with 0.01ml standard Silver Nitrate solution to a pinkish yellow end point.

\[
\text{Cl Mg/l} = \text{Ml of AgNO}_{3} \times F \times 1000 \text{mg} \times 1000
\]

\[
\text{Ml of Sample}
\]

- **Sulphate (Mg/l):** The amount of Sulphate was determined using HI 38000A-0 Sulphate reagent and complexion reagent. The plastic vessel was filled with 50ml of water sample and a packet of HI 38000A-0 sulphate reagent was added and swirled gently until it dissolved. Two drops of complexion reagent were added and swirled again to mix. Two spoons of HI 38000B-0 reagent were added and swirled to mix and waited for five minutes to allow reaction to occur. The test tube was then placed on a white surface and looked from the top at the black spot at the bottom. Transfer from the vessel to test tube was made
until black spot disappeared completely and finally the concentration of sulphate in mg/l was read in correspondence to the level of liquid.

- **Determination of Fluoride using SPADNS Reagent.** Fluoride was determined by HACH instrument using SPADNS reagent. 10ml of sample was measured into a dry 10ml sample cell (The prepared sample). 10ml of deionized water was measured into a second dry sample cell (The blank). 2.00ml of SPADNS reagent was added into each cell and swirled to mix. The time enter was pressed and one minute reaction period began. When the timer beeps once, the blank sample was placed into the cell holder with the sample cell tightly covered with the instrument cap. Zero was pressed on the instrument and the cursor moved to the right and the display showed 0.00mg/l F. The prepared sample was placed into the cell holder with the sample cell tightly covered with the instrument cap. The read icon was pressed on the instrument and the cursor moved to the right then the result of Fluoride in mg/l was displayed.

- **Determination of Phosphate:** A measured amount of sample water was poured into a mixing tube and ammonium heptamolybdate reagent was added, the tube was then Stoppard and vigorously shaken. A dilute stannous chloride reagent was added. This produced a blue colour due to the formation of molybdenum blue. The depth of the blue colour indicated the amount of phosphate in the water. The absorbance of the blue solution was measured with a colorimeter and the concentration of phosphate from the original solution was calculated.

- **Determination of Magnesium Using EDTA Technique :** 50ml of sample was added to 0.1 N Hcl to decompose bicarbonates. It was then boiled to expel CO$_2$ and allowed to cool before NaoH was added to produce a Ph 12-13. A murexide indicator was
added and the solution was titrated slowly with EDTA titrant to the proper end point. After the end point, 6ml of concentrated ammonium solution was added. It was then titrated again with EDTA until a faint blue colour appeared. The colour of the indicator changed from wine red to blue.

$$\text{Magnesium Mg/l} = \text{EDTA titrant} \times 0.4343 \times 100 \times F \times \text{ml of Sample}$$

- **Determination of Iron**: 25ml of sample was measured into a conical flask. 5ml of Sulphuric acid was then added. The solution was titrated with 0.02N potassium permanganate solution until the colour changed from colourless to faint pink colour.

$$\text{Mg/l Iron} = \text{ml of 0.02N KmnoO}_4 = 5.584 \text{ mg of FE}$$

- **COD (Chemical Oxygen Demand)**: This test indicates the quantity of oxidizable compounds present in water. 100ml of sample was poured into an Erlenmeyer flask and 2ml sodium hydroxide was added and boiled for ten minutes. Immediately, 10ml oxalic acid was added and mixed. Excess oxalic acid was titrated with potassium permanganate and the result recorded as

$$O_2 \text{ (COD)mg/l} = \text{ml of 0.01N Kmno}_4 \times 0.08 \times 1000 \times \text{ml of sample}$$
- **BOD (Biochemical Oxygen Demand):** This test took five days to complete and was performed using a dissolved oxygen test kit. The BOD level was determined by comparing the DO (dissolved oxygen) level of water that has been incubated in a dark location for 5 days. The difference between the two DO levels represents the amount of oxygen required for the decomposition of any organic materials in the samples and is a good approximation of the BOD level.

- **Bacteriological Examination:** The purpose of bacteriological examination is to indicate the degree of sewage pollution of the water at the time of sampling and thus, the possibility that disease may be transmitted by the water. The organisms most commonly used as indicators of pollution are Escherichia Coli (E. Coli) and the Coliform group as a whole.

**Methods of Microbiological Analysis of Water**

- **Standard Test for Coliform Bacteria:** This is the enumeration of mesophilic bacteria (total plate count) based on the assumption that, microbial cells present in a sample mixed with an agar medium form visible separated colonies. 1.0ml of sample water was measured into a test tube containing 9ml buffered peptone water. The test tubes were labeled 10–1 to 10–5 and serial dilution was done. Petri dishes were also labeled 10–1 to 10–5 and pour plating was done. 15ml of the plate count agar was poured into each dish. The contents were allowed to solidify, the dishes inverted and incubated at 30°C for 72 hours. Colonies of bacteria appeared and these colonies were counted and recorded per 100ml of dilution.

\[
CFU = \text{No. of cells} \times \text{dilution factor} \\
\text{Vol. of water used}
\]
- **Gram Staining**: This provides a starting point for classifying, identifying and characterizing bacteria. It helps to determine the source of microbes isolated as contaminants. From the incubated petri-dishes with colonies, a small amount was scooped using sterilized wire loop and transferred onto a slide. Crystal violet was added to stain the cytoplasm purple regardless of the cell type. Iodine was then added as an agent that binds the dye to the cell and helps resist decolorization agent (Alcohol) was added. The purple dye complex was retained by gram-positive organisms but was readily removed from gram – negative cells. Gram-negative cells became colorless. Red dye safranin was applied as a counter stain. It stained the gram-negative cells red while gram-positive remains purple. The slide was placed under a viewing microscope where the bacteria were seen and classified according to their shape, color and occurrence.

- **Enumeration of Coliform Bacteria (Determination of Most Probable Number, MPN)**: Coliform group includes all the aerobic and anaerobic facultative gram negative, non spore forming rod-shaped bacteria which ferment lactose with gas formation within 48hours at 37°C. For each sample, three test tubes were labeled 1:10, 1:100, and 1:1000. Each test tube contained 9ml peptone water. 1ml of the water sample was added to test tube 1:10 and serial dilution was done. For each of the three labeled test tubes, three tubes containing inverted durham tubes and LST broth were arranged. From 1:10 test tube, 1ml was measured and poured into each of the other three tubes labeled 1:10, 1:10 and 1:10. This procedure was done to test tubes 1:100 and 1:1000. The tubes were incubated at 37°C for 48hours. The tubes showing gas formation were recorded. The MPN table was then referred to and the most probable number known. This is the presumptive test.
- **Confirmatory Test for Coliform:** A loop full of gas positive tubes of LST broth was transferred into a separate tube of BGL broth. The tubes were incubated at 37°C for 48 hours. Gas formation confirms the presence of coliform bacteria.

- **Confirmatory Test For E. Coli:** A loopful from gas tube of LST was transferred into a separate tube of EC broth. The tubes were incubated for 48 hours at 44.5°C. A plate was streaked with L-emb agar from the positive tubes in a way to obtain discrete colonies and incubated at 35°C for 18 – 24 hours.

The secondary sources of data was generated through consultation of relevant materials which include both published and unpublished sources such as text books, journals, research thesis, seminar papers, internet, record of water quality standards by FEPA, FME, WHO etc. Information derived from these sources include description of water, global water distribution, water quality parameters, man’s water requirement, quality of water, water quality monitoring and water availability which were derived from text books, some research works and internets. Issues regarding demand and supply of water were sourced from textbooks, research works and journals. Global water quality issues were generated from research works, WHO’s reports and journals. Methods of laboratory analysis were derived from text books. Method of sample collection was sourced from a research journal. Water quality standards used were sourced from FME’s (1997) water quality standards.

**Statistical Techniques/Methods**

For the purpose of this research, t-test was used to analyze the results obtained from laboratory so as to determine whether there is significant difference in the quality of portable water in the
study area between the two seasons. Bar graphs were also used to show comparison of water quality between the seasons.
CHAPTER FIVE

RESULTS AND DISCUSSION

5.1: Introduction

This chapter presents results obtained from field and laboratory analysis of selected water quality parameters which included physicochemical (temperature, pH, odour, colour, taste, turbidity, Hardness, total suspended solids, total dissolved solids, nitrite, nitrate, sulphate, chloride, fluoride phosphates, magnesium, iron, COD, and BOD) and biological (total Coliforms and fecal coliforms). It also entails the general discussion on the results as well as comparison of results obtained with water quality standards set by Federal Ministry of Environment FME (1997), Nigerian Industrial Standards NIS (2007) and World Health Organization WHO (2006). It has been stated in the last chapter that, purposive sampling technique was adopted and samples were drawn purposefully from the four sources of drinking water in the study area (treated tap water, boreholes, hand pumps and open well). Eight water samples were collected from eight sampling points selected, two samples from treated tap water, two samples from hand pumps, two samples from boreholes and two samples from open wells. Sampling collection was carried out thrice in the rainy season and thrice in the dry season respectively. After laboratory processes, six sets of laboratory results were obtained, three results for the rainy season and three results for dry season. The average of the results for both the seasons were taken and presented in tables 4 and 5 below as the main results for the study.
5.2 Results

Table 7: Results of Physiochemical and Biological Analysis of Water Samples collected in Dry Season (Dec, 2015 – April, 2016)

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<td>Unobjectionable</td>
<td>Unobjectionable</td>
<td>Unobjectionable</td>
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<td>5.0</td>
<td>5.0</td>
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<td>5.0</td>
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<td>Tasteless</td>
<td>Tasteless</td>
<td>Tasteless</td>
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<td>16.10</td>
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<td>23</td>
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<td>Nil</td>
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<td>Nil</td>
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Source: Field and Laboratory Analysis (Dec 2015 – May, 2016)
Table 8: Results of Physiochemical and Biological Analysis of Water Samples collected in Rainy Season (June – Sept, 2016)

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<td>6.8</td>
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<td>5.0</td>
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<td>Tasteless</td>
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<td>29.00</td>
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<td>40.00</td>
<td>37.60</td>
<td>54.40</td>
<td>53.6</td>
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<td>2.00</td>
<td>2.00</td>
<td>1.00</td>
<td>2.50</td>
<td>3.25</td>
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<td>Total Coliforms (MPN)</td>
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<td>2</td>
<td>2</td>
<td>18</td>
<td>2</td>
<td>23</td>
<td>9</td>
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<td>Fecal Coliforms / E-Coli (MPN)</td>
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<td>Nil</td>
<td>Nil</td>
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Source: Field and Laboratory Analysis (June – Sept, 2016)
Table 9: Water Quality Standards for Drinking Water

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<td>6.5-8.5</td>
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<td>Odourless</td>
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<td>Tasteless</td>
<td>-</td>
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Table 10: Result of t-test showing seasonal variation in water quality

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<th>STD. Deviat</th>
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<th>T</th>
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<td>Wet season</td>
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<td>408.48</td>
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<td>3.10</td>
<td>8.78</td>
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<td>0.53</td>
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<td>6.66</td>
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<td>7</td>
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<td><strong>COD (Mg/l)</strong></td>
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<td>2.70</td>
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<td><strong>BOD (Mg/l)</strong></td>
<td>Wet season</td>
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<td>0.37</td>
<td>1.06</td>
<td>8</td>
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<td><strong>Total Colifor</strong></td>
<td>Wet season</td>
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<td>3.00</td>
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<td>8</td>
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STD. Error = Standard Error, STD. Deviat = Standard Deviation, d.f.=Degree of Freedom, SIG = Significant, NS = Not Significant. Decision: If P-Value is less than significance level (0.05), then there is significant difference between the two seasons.
5.3 Discussion

**Temperature:** The temperature of water samples analyzed ranged between (25°C to 31°C) in the dry season. Sampling point 1 recorded higher value of temperature (31°C). This was followed by sampling point 6 with (30°C), point 7 and 8 with (29°C), points I and 5 with (28°C), point 3 with (27°C) and point 2 with the lowest value of (25°C). In the rainy season, the temperature readings ranged between (24.3°C to 28.7°C). Sampling point 8 was found to have the highest value (28.7°C), point 6 (28.3°C), point 7 (27°C), point 3 (26.3°C), point 4 and 5 (26°C), point 1 (25°C) and point 2 with lowest temperature of (24.3°C). The values of temperature were found to be higher in the rainy season across all the sampling points. This conformed to the findings of Lawal et-al (2004) and Makwe and Chup (2013). The t-test conducted revealed significant seasonal variation on water temperature. Similar result was observed by Lianthuamluaia et-al (2013).

![Bar chart showing seasonal variation on temperature](image)

**Bar charts showing seasonal variation on temperature**

**pH:** pH of water is the degree of acidity or alkalinity of water. It measures the concentration of hydrogen ion. The values of pH obtained in this study ranged between (5.44 to 8.16) in the dry season. Higher pH values were recorded from sampling points 7, 8, and 4 (8.16, 8.13 and 8.08),
moderate pH values were obtained from points 5, 3 and 6 (7.7, 7.5 and 7.42). Lower pH values in the dry season (5.51 and 5.44) were found from points 1 and 2 respectively. During rainy season, pH values ranged between (6.15 to 7.5) with sampling points 7 and 8 having the highest values (7.5 and 7.49). Next to them was point 6 (6.9), point 4 (6.85), point 3 (6.80), point 5 (6.6), point 1 (6.2) and point 2 with the lowest value (6.15). pH values were slightly in rainy season than in the dry season. This result agreed with that of Lalparmawii and Mishra (2012) and Makwe and Chup (2013). It however contradicted the findings of Patale et-al (2012) and Efe et-al (2005). The seasonal variation in pH according to t-test was insignificant. All the pH values recorded in both dry and rainy season did not exceed the recommended water quality standards set by WHO (2006), NIS (2007) and FME (1997).

Bar chart showing seasonal variation on pH

Odour, Colour and Taste :- All the water samples analyzed in both the rainy and dry season were found to be odourless, colourless and tasteless. This made all the water sources safe for
human consumption regarding these three physical parameters. The result of these three parameters showed no seasonal variation.

**Turbidity (NTU):** Turbidity values varied between (2.0 to 9.2 NTU) in the dry season. A higher turbidity value of (9.2 NTU) was detected from point 8. This was followed by point 7 (5.25 NTU), point 1 (3.98 NTU), point 2 (3.88 NTU), point 6 (3.5 NTU), point 5 (3.0 NTU), point 4 (2.7 NTU) and point 3 with the lowest value of (2.0 NTU). In the rainy season, the values of turbidity ranged between (6.06 to 9.94 NTU). The values were obtained in this order point 2 (9.94 NTU), point 8 (8.06 NTU), point 7 (7.99 NTU), points 1 and 6 (7.23 NTU), point 3 (6.06 NTU), point 4 (6.41 NTU) and point 5 (6.06 NTU). Contrary to the findings of Efe et-al (2005), turbidity values in this research were found higher in the rainy season than in the dry season across all the sampling points except point 8 with higher value in the dry season, this occurs due to run-off in the rainy. However the result was in conformity with that of Makwe and Chup (2013) and Ibtisam and Abdul (2012). Student’s t-test revealed significant seasonal variation in water quality between the two seasons. Comparison of the turbidity values with the water quality standard showed that, turbidity values for the dry season were within the allowable limit of (5.0 NTU) except for sampling point 8 that had values above the standard (9.2 NTU) because the well is not covered during the research work. However, in the rainy season, the values of all the sampling points were found above the recommended threshold of (5.0 NTU) set by WHO (2006), NIS (2007) and FME (1997).
Bar charts showing seasonal variation on turbidity

**Hardness (Mg/l):** The values of hardness obtained ranged between (43.55 mg/l – 305.00 mg/l) in the dry season with point 7 (305.00 mg/l), point 8 (144.00 mg/l), point 4 (112.00 mg/l), point 6 (96.33 mg/l), point 5 (59.00 mg/l), point 3 (48.00 mg/l), point 1 (47.50 mg/l) and point 2 (43.55 mg/l). In the rainy season, the values of hardness ranged between (56.25 mg/l to 380.00 mg/l). The maximum values (380.00 mg/l) were found in sampling point 7 and minimum value (56.25 mg/l) was found in point 5. Higher values of hardness were obtained in the rainy season except for sampling points 8 (144 mg/L) and 4 (122 mg/L) with higher values in the dry season. This finding was similar to that of Lawal et-al (2014) and Makwe and Chup (2013). The quality of the water according to t-test showed in significant seasonal variation. The values of hardness obtained from all samples were within the recommended standards. All the water samples analyzed had fallen within WHO (2006) standard for hardness of (500 mg/l). In addition to this,
all samples conformed to the NIS (2007) and FME (1997) of (150 mg/l) and (200 mg/l) except sample 7 that was found above NIS (2007) and FME (1997) recommended levels.

Bar charts showing seasonal variation on total hardness

**Total Suspended Solids TSS. (mg/L):** The values of total suspended solids were found in the range (19.00 mg/l to 52.00 mg/l) in the dry season in the order P3 < p6 < p2 < p4 < p5 < p7 < p8 < p1, that is, point 1 with the maximum value (52.00 mg/l) and point 3 with the minimum value (19.00 mg/l). The values ranged between (15.00 mg/L to 36.00 mg/L) in the rainy season in the order p3 < p7 < p4 < p5 < p6 < p1 < p2 with point 2 having the maximum value (36.00 mg/l) and point 3 having the minimum value (15.00 mg/l). TSS values were found higher in the dry season in all the sampling points except sampling points 6 and 2 with TSS values higher in the rainy season. This contradicted the findings of Efe et-al (2004) and Makwe and Chup (2012). The result of the t-test showed insignificant seasonal variation between the two seasons.
Bar charts showing seasonal variation on total suspended solids

**TDS (mg/L)** :- Total dissolved solids of the water samples were found to be in the range of (102.40 mg/L to 650.00 mg/l) in the dry season in the order p1 < p4 < p5 < p6 < p3 < p2 < p8 < p7 with point 7 having the highest value (650.00 mg/l) and point 1 having the lowest value (102.40 mg/L). The values ranged between (103.50 mg/L to 790.00mg/l) in the rainy season in the order p4 < p5 < p2 < p1 < p3 < p6 < p8 < p7. Maximum values (790.00 mg/L) were found in point 7 and minimum values (103.50) were from point 4. Sampling points 2, 4 and 5 revealed lower values of TDS in the rainy season and higher values in the dry season. While in comparison, points 1, 3, 6, 7 and 8 showed lower TDS values in the dry season and higher values in the rainy season. The seasonal variation in TDS according to t-test was insignificant. With the exception of point 7, all the points revealed TDS values within the allowable limits of NIS (2007) and FME (1997). According to WHO (2006), all the points had fallen within standard.
Bar charts showing seasonal variation on total dissolved solids

**Electrical Conductivity EC us/cm:** The electrical conductivity of the samples was found in the range of (151.00 um/cm to 1100.00 us/cm) in the dry season. Point 7 is having the highest value (1100.00 us/cm). Next to it was point 8 (550.00 us/cm), point 4 (340.00 us/cm), point 6 (185.00 us/cm), point 5 (176.00 us/cm), point 3 (172.00 us/cm), point 1 (156.00 us/cm) and point 2 (151.00 us/cm). The values ranged between (150.00 us/cm) to 1390.00 us/cm) in the rainy season. Higher values (1390.00 us/cm) were detected from point 7. This was followed by point 4 (620.00 us/cm) point 6 (475.00 us/cm), point 8 (360.00 us/cm), point 1 (299.00 us/cm), point 2 (192.00 us/cm), point 5 (189.00 us/cm) and point 3 (150.00 us/cm). Samples 3 and 8 showed lower EC values in the rainy season and higher values in the dry season. Sampling points 1, 2, 4, 5, 6 and 7 revealed higher EC values in the rainy season and lower values in the dry season. The result of t-test showed insignificant seasonal variation. The results of all the samples in the two seasons were within NIS (2007) water quality standard, the exception was
only on sample 7. According to WHO (2006) Standards, samples 1, 2, 3, 5 and 6 were within the allowable limits in the dry season while samples 4 and 8 were above WHO (2006) standard. In the rainy season, samples 1, 2, 3, 5 were within WHO (2006) limit of 300 us/cm, while samples 4, 6, 7 and 8 were above the allowable limit.

Bar charts showing seasonal variation on electrical conductivity

**Nitrate (mg/L):** The results of nitrate ranged from (1.90 to 14.00 mg/l) in the dry season in the order p6 < p2 < p1 < and p3 < p4 < p5 < p8 and p7. Lower values were detected from point 2 (1.90 mg/l) and higher values were detected from point 7 (14.00 mg/l). In the rainy season, the values of nitrate ranged from (1.50 mg/l to 22.00 mg/l). Highest values were detected from point 7 (22.00 mg/l) and lowest values (1.50 mg/l) from point 2. The results of nitrate between the two seasons did not show significant seasonal variation because the p-value (0.118) is greater than the significance level (0.05). Comparison of the results with water quality...
standards revealed that, all the results for both seasons conformed to WHO (2006) and NIS (2007) water quality standards of (50 mg/l) as found by Funtua et-al (2014). This finding however disagreed with that of Yisa et-al 2012), Adejuwon et-al (2011), Ayantobo et-al (2013) and Nwaici et-al (2013). In the case of FME (1997) standard of (10 mg/l), only point 7 deviated from the recommended level in the dry season, while in the rainy season, points 5, 6, 7 and 8 were above the (FME 1997) standards. However the FME (1997) standard on nitrate (10 mg/L) is so strict compared to WHO (2006) and NIS (2007) with nitrate standard of (50 mg/L). This indicated that, most of the water sources are suitable for human computation in terms of nitrate.

Bar charts showing seasonal variation on nitrate

Chloride (mg/l):- The concentration of chloride according to the result varied from (11.40 mg/l to 210.24 mg/l) in the dry season. Point 4 had the lowest value (11.40 mg/l) and point 7 had
the highest value (210.24 mg/l). The concentration ranged from (11.20 mg/l to 202.20 mg/l) in the rainy season. Lower values were observed from point 4 (11.20 mg/l) and higher values were observed from point 7 (202.20 mg/l). The values of chloride were slightly higher in the dry season than in the rainy season. However, the result of t-test revealed that, there is insignificant seasonal variation in the quality of water between the two seasons. Contrary to the findings of Nirmala et-al (2012), Nwaichi et-al (2013) and Mary- Helen et-al (2011), the results of chloride for all the seasons compared well with all the standards of FME (1997), NIS (2007) and WHO (2006). This revealed the suitability of water sources for human consumption in terms of chloride.

Bar charts showing seasonal variation on chloride

Sulphate (Mg/l):- The results of sulphate was found in the ranged of (14.00 mg/l to 74.00 mg/l) in the dry season. Point 6 had the higher value of (74.00 mg/l). This was followed by point 5
(60.00 mg/l), point 4 (50.00 mg/l), point 7 (26.00 mg/l), point 3 (24.00 mg/l), point 1 (21.00 mg/l), point 8 (18.00 mg/l) and point 2 (14.00 mg/l). The result ranged from (12.00 mg/L to 48.00 mg/L) in the rainy season. Point 7 had the highest value of (48.00 mg/l) and points 1 and 8 had the lowest values of (12.00 mg/l). Concentration of sulphate was found to be higher in the dry season than in the rainy season as found by Makwe and Chup (2013). Despite this, seasonal variation between the seasons remained insignificant. All the results of sulphate across the two seasons were accommodated by NIS (2009), FME (1997) and WHO (2006) water quality standards as found by Yisa et-al (2012). This signified the portability of water for human consumption in terms of sulphate.

**Bar charts showing seasonal variation on sulphate**

**Fluoride (mg/l):** Results of Fluoride ranged between (0.90 to 1.70 mg/l) in the dry season and (0.90 to 2.60 mg/l) in the rainy season respectively. Points 1, 2 and 6 revealed higher values of
fluoride in the dry season while point 3, 4, 5, 7 and 8 revealed lower values in the dry season. In comparison with the rainy season, points 3, 4, 5, 7 and 8 had the higher values and points 1, 2 and 6 had the lower values. This implied that, concentration of fluoride is slightly higher in the rainy season. However, the result of t-test showed insignificant seasonal variation between the two seasons. Comparison of fluoride result with the water quality standards revealed that, points 1, 2, 3, 4, 5, 6 were found within NIS (2007) and FME (1997) water quality standards in the dry season. Points 7 and 8 slightly deviated from standard in the rainy season, points 1, 2, 3, 4, and 5 were within the recommended NIS (2007) and FME (1997) standards of (1.50 mg/l). Points 6, 7 and 8 were found above the recommended level.

Bar charts showing seasonal variation on fluoride

Phosphate (mg/l):- The phosphate value of the water sample was found to be in the range of (0.11 to 0.53 mg/l) in the dry season and (0.12 to 0.72 mg/l) in the rainy season. Range of
phosphate values was slightly higher in the rainy season than dry season. The result of t-test showed insignificant seasonal variation between the two seasons. All the results of phosphate had compared well with NIS (2007) and FME (1997) water quality standard of (0.50 mg/l). The exception was only point 7 that was found slightly above the recommended standard with (0.53mg/l) in the dry season and (0.72mg/l) in the rainy season. The comparison of the results of phosphate with water quality standard signified that, most of the water samples analysed were safe for human consumption. This is similar to the finding of yisa et-al (2012).

**Bar charts showing seasonal variation on phosphate**

**Magnesium (Mg/L):** Concentration of magnesium ranged from (20.51 to 50.79 mg/l) in the dry season in the order p8 < p3 < p4 < p5 < p2 < p1 < p6 and p7. Point 8 had the lowest value of (20.50 mg/l) and point 7 had the highest value (50.79 mg/l). During wet season, the concentration of magnesium ranged from (16.60 to 38.09 mg/l) in the order p3 < p5 < p2 < p7 < p4 < p1 < p8 and p6. Point 6 had the highest value of (38.09 mg/l) and point 3 had the lowest
value of (16.60 mg/l). The values of magnesium were slightly higher in the dry season than in the rainy season. This was in accordance with Das et-al (2014). Results of t-test indicated that, there was insignificant seasonal variation in the quality of water between the two seasons. The results from all the points across the two seasons were accommodated by WHO (2006) drinking water standards of (50 mg/l) as against Nwaichi et-al (2013). This indicated that, the water sources are safe for human consumption based on magnesium concentration.

**Bar charts showing seasonal variation on magnesium**

**Iron (mg/l)**: The results of iron ranged from (0.20 to 0.50 mg/l) in the dry season. Points 5 and 6 had the highest values of (0.50 mg/l). Next to them were point 8 (0.40 mg/l), point 4 (0.30 mg/l), points 3 and 7 (0.20 mg/l), point 2 (0.13 mg/l) and point 1 with the lowest value (0.10 mg/l). In the rainy season the values of iron ranged from (0.01 to 0.60 mg/l). Point 6 had the highest value (0.60 mg/l) followed by point 4 (0.40 mg/l), point 1 (0.30 mg/l), point 3 (0.25 mg/l), point 7 (0.20 mg/l) and point 2 (0.13 mg/l).
mg/l), point 2 (0.20 mg/l), points 7 and 8 (0.03 mg/l) and point 5 with the lowest value (0.01 mg/L). Values of iron from points 1, 2, 3, 4 and 5 were higher in the rainy season where as point 6, 7 and 8 were lower and vice-versa. The results of iron between the two seasons did not show significant seasonal variation. All the results of iron across the seasons compared well with FME (1997) standard of (1.0 mg/L). According to NIS (2007) and WHO (2006) standards of (0.03 mg/L), points 1, 2, 3, 4 and 7 were found within standard, sample 5, 6 and 8 were slightly above standard in the dry season. With the exception of point 4 (0.4 mg/l), all the points had fallen within the recommended standard of (0.30 mg/l) in the rainy season.

Bar charts showing seasonal variation on total iron

COD (mg/l):- COD values were found in the range of (39.00 to 86.00 mg/l) in the dry season with point 8 having the highest value (86.00 mg/l) and point 4 having the lowest value (39.00 mg/l). In the rainy season, the value of COD ranged from (36.0 mg/l to 54.40 mg/l). Lowest
value (36.0 mg/l) was observed from point 2 and highest value (54.40 mg/l) was observed from point 7. Values of chemical oxygen demand (COD) were found higher in the dry season than in the rainy season. The result of t-test indicated significant seasonal variation in the quality of water between the two seasons.

Bar charts showing seasonal variation on chemical oxygen demand

**BOD (mg/l):** Concentration of BOD ranged from (1.50 to 3.00 mg/l) in the dry season in the order p1 and p2 < p4 < p5 < p3 < p6 < p8 < p7. Lower value was detected from point 1 and 2 (1.50 mg/l) and higher value was detected from point 7 (3.00 mg/l). The values ranged from (1.00 to 4.00 mg/l) in the rainy season in the order p1 and p5 < p2 < p4 & p5 < p6< p7< p8 with point 1 and 2 having lowest value (1.00 mg/L) and point 8 having highest value (4.00 mg/L). BOD values were slightly higher in the dry season in points 1, 3, 5 and 6 and lower values in
points 2, 4, 7 and 8 and vice versa. The result of t-test showed insignificant seasonal variation between the two seasons.

Bar charts showing seasonal variation on biochemical oxygen demand

**Total Coliforms (MPN)**: The MPN of total coliforms varied from (2 to 350) in the dry season, point 7 recorded higher number of coliforms (350), points 8 and 5 recorded (23) and points 1, 2, 3, 4 and 6 recorded (2). In the rainy season the number of coliforms observed ranged from (2 to 23) with point 7 having the highest number (23), point 5 (18), point 8 (9) and points 1, 2, 3, 4, and 6 with minimum number (2). Coliforms counts were higher in the dry seasons as found by Krishnaraj et-al (2013). However, t-test result showed insignificant seasonal variation between the two seasons as p value (0.322) is greater than significance level (0.05). The result of coliforms from points 1, 2, 3, 4, 6 and 8 in the rainy season conformed to the NIS (2007) and WHO (2006) standards of (10), points 5 and 7 were above the standard. In the case of dry
season, points 1, 2, 3, 4 and 6 were found within recommended levels while points 5, 7 and 8 were found above the standards.

Bar charts showing seasonal variation on total coliforms

**E-coli (MPN):** E-coli were not detected from all the points. This signified that, the water sources were free from fecal contamination.
Plate 1: Some parts of Ajiwa Water Treatment Plant Central laboratory where water analysis was conducted
Plate 2: Some of the sampling points in the study area where water samples were collected.
CHAPTER SIX

RESULT’S SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter presents summary of the result presented and discussed in chapter five as well as general conclusion and recommendations.

6.2 Result’s Summary:

The selected water parameters were analysed using standard laboratory techniques. All the parameters were detected except fecal coliform (E- coli) that was completely absent in all the water samples. The results revealed that,

- The temperature of water was found slightly higher in the dry season and the seasonal variation was insignificant. pH values were higher in the rainy season with insignificant seasonal variation. The values of pH across all the sampling points and Seasons were found within recommended levels of NIS (2007) WHO (2006) and FME (1997). All the water samples were colourless, Tasteless and odorless.

- The level of turbidity was found higher in the rainy season with significant seasonal variation. Turbidity values obtained in the dry season conformed to the NIS (2007), WHO (2006) and FME (1997) water quality standards. Turbidity results in the rainy season were found above the recommended standard. The levels of Hardness obtained were higher in the rainy season except for point 4 and 8. The seasonal variation was insignificant and all the samples were within the recommended WHO (2006), FME, (1997) and NIS (2007) water quality standard, except point 7 that was found above FME (1997) and NIS (2007) standard.
Total suspended solids values were found higher in the dry season in all the points except point 2 and 6. The values of TSS did not show significant seasonal variation. Total Dissolved solids values were higher in the rainy season except points 2, 4 and 5. Results of TDS showed insignificant seasonal variation. All the results of TDS from all sampling points were accommodated by WHO (2006) NIS (2007) and FME (1997) water quality standards, the only exception was point 7 which was found slightly above FME (1997) and NIS (2007) standards.

Electrical conductivity values were higher in the rainy season in all the points except points 3 and 8. The values of EC showed insignificant seasonal variation. The result of EC from all the points had fallen within NIS (2007) standard except point 7. Points 1, 2, 3, 4, and 6 were within WHO (2006) standards in dry season and points 1, 2, 3, and 4 were found within WHO (2006) standard in the rainy season. Nitrate results across all the points were found higher in the rainy season with insignificant seasonal variation. All the values of nitrate compared well with WHO (2006) and NIS (2007) water quality standards.

chloride and sulphate, were at their maximum during dry season with insignificant seasonal variation. All results for chloride and sulphate were found within the recommended water quality standards set by WHO (2006), FME (1997) and NIS (2007). Fluoride’s results were found slightly higher in the rainy season with insignificant seasonal variation. The values of fluoride were found within NIS (2007) & FME (1997) standard in the rainy season except points 7 and 8. In the dry season, points 1, 2, 3, 4, & 5 were found within NIS (2007) & FME (1997) standard while point 6, 7 & 8 were above recommended threshold.
Phosphate values were slightly higher in the rainy season with insignificant seasonal variation. With the exception of point 7 all the values of phosphate from all the points matched well with the recommended NIS (2007) and FME (1997) standards. The results of magnesium were slightly higher in the dry season with insignificant seasonal variation. Values of magnesium across all the points were found within the recommended WHO (2006) standard of (50 mg/L). In the case of iron, higher values were obtained from points 1, 2, 3, 4, and 5 in the rainy season and points 6, 7 and 8 in the dry season.

Results of iron showed insignificant seasonal variation. All the points compared well with FME (1997) standard in both rainy and dry season. Points 1, 2, 3, 4, and 7 were found within WHO (2006) & NIS (2007) standards in dry season where as in the rainy season, only point 4 deviated from WHO (2006) and NIS (2007) standards. COD values were found higher in dry season with significant seasonal variation. BOD values were also slightly higher in the dry season with insignificant seasonal variation. Total coliforms counted higher in the dry season with insignificant seasonal variation. With the exception of points 5 and 7, coliforms count from all the points conformed to NIS (2007) and WHO (2006) standards. In the dry season, points 1, 2, 3, 4 and 6 were found within recommended levels while points 5, 7 and 8 were found above standards.

According to the results of T-test and comparison of results with water quality standards, the null hypothesis is rejected while the alternative hypothesis is accepted because the quality of water varies with two different seasons and most of water sources were suitable for human consumption.
6.3 Conclusion

The quality of water varies slightly with the season. Some parameters recorded maximum levels in the dry season and others were at their maximum in rainy season. The average values of $pH$ (6.8), Turbidity (7.5 NTU), Hardness (124.1mg/l), total Dissolved solids (259mg/l), Electrical conductivity (459), Nitrate (9.83mg/l), Fluoride 1.48mg/l, Phosphate (0.3mg/l) and Iron (0.23mg/l) were found slightly higher in the rainy season than in the dry season. Those of temperature (28.5), total suspended solids (33.5mg/l), chloride (46.64mg/l), sulphate 35.88mg/l), magnesium (30.97mg/l), COD (62.5mg/l) and BOD (2.2mg/l) were found slightly higher in the dry season than in the rainy season. However in both the two seasons, most of the parameters did not deviate from recommended water quality standards for drinking. According to the t-test conducted, all the parameters with the exception of temperature, turbidity and COD showed insignificant seasonal variation. Temperature, turbidity and COD showed significant seasonal variation. The results of parameters from eight sampling points were accurately compared with water quality standards recommended by WHO (2006), NIS (2007) and FME (1997). The comparison revealed that, most of the water quality parameters studied were found within the recommend levels. Thus, most of the water sources were safe for human consumption.

Based on the result analyzed and discussed, it may be concluded that, water quality in the study area varies slightly with the season as most of the parameters showed insignificant seasonal variation and most of the water sources studied were found suitable for human consumption. Exception was on point 7 with some parameters above the recommended threshold.
6.4 Recommendations

- There is the need for regular monitoring and evaluation of water quality parameters to ascertain their eligibility for human consumption and other uses.

- More treatment should be given to the water sources especially during rainy season to meet the required standard.

- Well water should be properly covered, as some of the wells in the study area are open throughout the year.

- Well water was found to have some casualties compared to other sources, so it should be properly treated before consumption.

- Boreholes should be maintained regularly, because many boreholes were not functioning during the research work.

- This research covered some drinking water quality parameters, many parameters were not touched. There is the need to carry out more researches so as to cover more parameters.

- Demand for water is increasing at an alarming rate due to rapid population growth in the city. More boreholes and reservoirs should be drilled or constructed across the study area in order to boost water supply to meet the current demand for water.

- Water users in the city are still using outdated methods of harvesting water. Modern methods and strategies of harvesting water should be made available.
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William, L. (2014). Assessment of Borehole Water Quality and Consumption in Yei County, South Sudan. MSc Thesis, Department of Geography, Makerere University, South Sudan.

WHO (1992) guidelines for drinking water quality, vol 1: Recommendation and Vol.2 health criteria and other supporting information In Nancy project office ECEH, PP.31-32, ANN E.F 54500 Vandoeurre N France.)


## APPENDIX I

Results of Physiochemical and Biological Analysis of Water Samples collected in Dry Season (January, 2016)

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<td>Tasteless</td>
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Source: Field and Laboratory Analysis (January, 2016)
APPENDIX II

Results of Physiochemical and Biological Analysis of Water Samples collected in Dry Season (February, 2016)

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Source: Field and Laboratory Analysis (February, 2016)
# APPENDIX III

## Results of Physiochemical and Biological Analysis of Water Samples collected in Dry Season (April, 2016)

| Sampling Points | Temp. (°C) | pH | Odour | Colour (Hazen) | Taste | Turbidity (NTU) | Hardness (Mg/l) | TSS (Mg/l) | TDS (Mg/l) | EC | Nitrate (Mg/l) | Chloride (Mg/l) | Sulphate (Mg/l) | Fluoride (Mg/l) | Magnesium (Mg/l) | Iron (Mg/l) | COD (Mg/l) | BOD (Mg/l) | Total Coliforms (MPN) | Fecal Coliforms / E-Coli (MPN) |
|-----------------|-----------|----|-------|---------------|-------|----------------|----------------|------------|------------|----|--------------|----------------|----------------|----------------|----------------|----------------|----------|------------|----------|----------------------|------------------------|
| 1. Water Treatment Plant | 28 | 5.23 | Unobjectionable | 5.0 | Tasteless | 46.00 | 56.00 | 101.00 | 165.00 | 3.00 | 16.65 | 20.00 | 1.45 | 0.43 | 39.20 | 0.10 | 70.50 | 1.45 | 2 | Nil |
| 2. Bayan Area Treated Tap | 24 | 5.50 | Unobjectionable | 5.0 | Tasteless | 4.00 | 25.00 | 164.00 | 144.00 | 2.50 | 19.45 | 14.00 | 1.21 | 0.48 | 34.13 | 0.14 | 39.00 | 1.50 | 2 | Nil |
| 3. I.K.C.O.E Dutsinma Borehole | 27 | 8.00 | Unobjectionable | 5.0 | Tasteless | 1.80 | 19.00 | 170.31 | 177.00 | 2.95 | 24.50 | 24.50 | 0.91 | 0.12 | 22.55 | 0.20 | 45.00 | 2.30 | 2 | Nil |
| 4. Sokoto Rima Borehole | 29 | 8.10 | Unobjectionable | 5.0 | Tasteless | 2.70 | 29.00 | 105.50 | 355.00 | 4.60 | 55.00 | 55.00 | 0.87 | 0.43 | 22.20 | 0.30 | 43.00 | 1.53 | 2 | Nil |
| 5. Lowcoast Hand Pump | 30 | 7.20 | Unobjectionable | 5.0 | Tasteless | 3.0 | 29.00 | 122.80 | 184.00 | 5.31 | 18.33 | 18.33 | 0.96 | 0.35 | 25.21 | 0.48 | 62.00 | 1.60 | 2 | Nil |
| 6. Unguwar Kudu Hand Pump | 29 | 8.10 | Unobjectionable | 5.0 | Tasteless | 4.00 | 22.00 | 130.00 | 191.00 | 2.0 | 16.20 | 16.20 | 1.03 | 0.22 | 35.30 | 0.48 | 82.50 | 2.60 | 2 | Nil |
| 7. Police Station Mosque Open Well | 29 | 8.20 | Unobjectionable | 5.0 | Tasteless | 5.20 | 22.00 | 666.00 | 1090.00 | 9.60 | 209.67 | 209.67 | 1.82 | 0.51 | 287.50 | 5.00 | 610.00 | 2.95 | 2 | Nil |
| 8. Zubairu Primary School Open Well | 28 | 9.60 | Unobjectionable | 5.0 | Tasteless | 9.60 | 41.00 | 222.00 | 666.00 | 666.00 | 209.67 | 209.67 | 1.66 | 0.29 | 135.00 | 52.00 | 610.00 | 3.00 | 2 | Nil |

*Source: Field and Laboratory Analysis (April, 2016)*
# APPENDIX IV

## Results of Physiochemical and Biological Analysis of Water Samples collected in Rainy Season (July, 2016)

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<td>24.00</td>
</tr>
<tr>
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<td>200.07</td>
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<td><strong>EC</strong></td>
<td>196.10</td>
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<td>194.20</td>
<td>475.00</td>
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<td>1.50</td>
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<td>22.00</td>
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<td>15.20</td>
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<td>32.00</td>
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<td>29.00</td>
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<td>0.30</td>
<td>0.68</td>
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<td>19.20</td>
<td>20.14</td>
<td>38.41</td>
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<td>0.01</td>
<td>0.80</td>
<td>0.02</td>
<td>0.03</td>
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<td>40.00</td>
<td>52.50</td>
<td>36.20</td>
<td>39.50</td>
<td>41.30</td>
<td>50.18</td>
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<td>2</td>
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<td>2</td>
<td>23</td>
<td>9</td>
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<td><strong>Fecal Coliforms / E-Coli (MPN)</strong></td>
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<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
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Source: Field and Laboratory Analysis (July, 2016)
## APPENDIX V

Results of Physiochemical and Biological Analysis of Water Samples collected in Rainy Season (August, 2016)

| Sampling Points | Temp. (°C) | pH | Odour | Colour (Haz.) | Taste | Turbidity (NTU) | Hardness (Mg/l) | TSS (Mg/l) | TDS (Mg/l) | EC | Nitrate (Mg/l) | Chloride (Mg/l) | Sulphate (Mg/l) | Fluoride (Mg/l) | Phosphate (Mg/l) | Magnesium (Mg/l) | Iron (Mg/l) | COD (Mg/l) | BOD (Mg/l) | Total Coliforms (MPN) | Fecal Coliforms / E-Coli (MPN) |
|-----------------|-----------|----|-------|--------------|-------|----------------|---------------|------------|------------|----|--------------|---------------|----------------|---------------|----------------|----------------|--------------|--------|----------|-----------|---------------------|----------------------|
| 1. Water Treatment Plant | 26 | 6.3 | Unobjecionable | 5.0 | Tasteless | 7.00 | 57.35 | 33.00 | 120.10 | 196.40 | 2.30 | 15.44 | 14.00 | 0.90 | 0.16 | 22.00 | 0.30 | 38.30 | 1.00 | 2 | Nil |
| 2. Bayan Area Treated Tap | 25 | 6.4 | Unobjecionable | 3.0 | Tasteless | 10.22 | 75.10 | 31.50 | 115.00 | 193.00 | 1.50 | 19.00 | 30.00 | 1.00 | 0.22 | 21.00 | 0.15 | 32.50 | 1.46 | 2 | Nil |
| 3. I.K.C.O.E Dutsimma Borehole | 26 | 6.5 | Unobjecionable | 5.0 | Tasteless | 6.50 | 107.10 | 15.00 | 203.00 | 163.50 | 2.11 | 13.40 | 32.00 | 1.50 | 0.15 | 16.50 | 0.20 | 40.50 | 2.00 | 2 | Nil |
| 4. Sokoto Rima Borehole | 26 | 6.5 | Unobjecionable | 5.0 | Tasteless | 6.50 | 87.25 | 11.00 | 110.00 | 135.50 | 2.50 | 11.00 | 32.00 | 1.00 | 0.22 | 20.15 | 0.30 | 42.50 | 0.75 | 2 | Nil |
| 5. Lowcoast Hand Pump | 26 | 6.8 | Unobjecionable | 5.0 | Tasteless | 6.80 | 96.50 | 17.30 | 116.00 | 127.30 | 12.50 | 17.30 | 42.50 | 1.00 | 0.22 | 32.20 | 0.30 | 40.50 | 1.75 | 2 | Nil |
| 6. Unguwar Kudu Hand Pump | 28 | 8.0 | Unobjecionable | 5.0 | Tasteless | 8.00 | 75.00 | 28.50 | 288.00 | 480.00 | 21.00 | 28.50 | 201.00 | 1.00 | 0.15 | 28.00 | 0.50 | 115.00 | 1.01 | 2 | Nil |
| 7. Police Station Mosque Open Well | 29 | 8.0 | Unobjecionable | 5.0 | Tasteless | 8.00 | 352.00 | 20.00 | 765.00 | 1228.00 | 21.00 | 192.60 | 28.00 | 1.00 | 0.22 | 32.00 | 0.50 | 117.3 | 4.00 | 2 | Nil |
| 8. Zubairu Primary School Open Well | 29 | 7.5 | Unobjecionable | 5.0 | Tasteless | 7.50 | 117.3 | 19.50 | 310.10 | 360.00 | 22.00 | 192.60 | 115.00 | 1.00 | 0.15 | 20.15 | 0.20 | 53.00 | 1.95 | 2 | Nil |

Source: Field and Laboratory Analysis (August, 2016)
# APPENDIX VI

Results of Physiochemical and Biological Analysis of Water Samples collected in Rainy Season (September, 2016)

<table>
<thead>
<tr>
<th>Sampling Points</th>
<th>Temp. (°C)</th>
<th>pH</th>
<th>Odour</th>
<th>Colour (Hazen)</th>
<th>Taste</th>
<th>Turbidity (NTU)</th>
<th>Hardness (Mg/l)</th>
<th>TSS (Mg/l)</th>
<th>TDS (Mg/l)</th>
<th>EC</th>
<th>Nitrate (Mg/l)</th>
<th>Chloride (Mg/l)</th>
<th>Sulphate (Mg/l)</th>
<th>Fluoride (Mg/l)</th>
<th>Phosphate (Mg/l)</th>
<th>Magnesium (Mg/l)</th>
<th>Iron (Mg/l)</th>
<th>COD (Mg/l)</th>
<th>BOD (Mg/l)</th>
<th>Total Coliforms (MPN)</th>
<th>Fecal Coliforms / E-Coli (MPN)</th>
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<tbody>
<tr>
<td>1. Water Treatment Plant</td>
<td>24</td>
<td>6.2</td>
<td>Unobjectiable</td>
<td>5.0</td>
<td>Tasteless</td>
<td>7.29</td>
<td>55.90</td>
<td>30.50</td>
<td>120.50</td>
<td>204.50</td>
<td>2.15</td>
<td>19.12</td>
<td>10.00</td>
<td>1.10</td>
<td>0.13</td>
<td>26.22</td>
<td>0.30</td>
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<td>1.00</td>
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<td>Nil</td>
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<td>2. Bayan Area Treated Tap</td>
<td>24</td>
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<td>Unobjectiable</td>
<td>3.0</td>
<td>Tasteless</td>
<td>10.10</td>
<td>76.22</td>
<td>36.00</td>
<td>120.40</td>
<td>191.00</td>
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<td>21.25</td>
<td>39.00</td>
<td>1.00</td>
<td>0.21</td>
<td>17.33</td>
<td>0.25</td>
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<td>6.90</td>
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<td>Tasteless</td>
<td>6.0</td>
<td>87.50</td>
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<td>174.50</td>
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<td>92.50</td>
<td>18.00</td>
<td>115.40</td>
<td>475.00</td>
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<td>27.00</td>
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<td>88.60</td>
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Source: Field and Laboratory Analysis (September, 2016)
APPENDIX VII


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<th>Standards</th>
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<td>Odour</td>
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<tr>
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<td>Taste</td>
<td>Unobjectionable</td>
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Source: NIS (2007).
APPENDIX VIII


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<td>Odour</td>
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Source: FME (1997).
APPENDIX IX

Water Quality Standards for Drinking Water set by World Health Organization

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</tr>
<tr>
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<td>Ph</td>
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<td>Odour</td>
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</tr>
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</tr>
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<td>6</td>
<td>Turbidity (NTU)</td>
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<td>7</td>
<td>Hardness (Mg/l)</td>
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<td>TSS (Mg/l)</td>
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