ASSESSMENT OF WATER QUALITY OF HAND DUG WELLS IN THE SOUTHERN PART OF BOSSO LOCAL GOVERNMENT AREA, NIGER STATE

BY

OGUNFOLABI, OLAWALE MOSHOOD

2006/24117EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

FEBRUARY, 2012.

ASSESSMENT OF WATER QUALITY OF HAND DUG WELLS IN THE SOUTHERN PART OF BOSSO LOCAL GOVERNMENT AREA, NIGER STATE

BY

OGUNFOLABI, OLAWALE MOSHOOD

2006/24117EA

BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

FEBRUARY, 2012.

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished works were duly referenced in the text.

Ogunfolabi, Olawale Moshood

29/02/2012
Date

CERTIFICATION

This is to certify that the project entitled "Assessment of Water Quality of Hand Dug Wells in Southern Part of Bosso Local Government Area, Niger State" by Ogunfolabi, Olawale Moshood meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

_______________________ 27-02-2012
Dr. N. A. Egharevba — Date
Supervisor

_______________________ 27/02/2012
Dr. P. A. Idah — Date
Head of Department

_______________________ 22-02-2012
External Examiner — Date

DEDICATION

This project is dedicated to the Lord God Almighty, the one who saw me through in the course of my study

ACKNOWLEDGEMENTS

My sincere appreciation goes to the Lord Almighty for his love, care, favour and mercy he showed unto me in the course of my programme in school. Without him by my side, I wonder where I would have been by this moment. To him be the glory for the great things he has done.

My gratitude also goes to my amicable supervisor, Dr. N. A. Egharevba who with his tight schedules still took time to go through this project and also give professional advice which now makes the whole project a success. Your efforts will always be remembered.

I will also be an ingrate if I do not appreciate the following people who have in one way or the other imparted the necessary knowledge on me: The Head of Department in person of Dr. Engr. Peter Idah, My amiable level adviser in person of Engr. Mrs Bosede Orhevba and all my lecturers and the technologists of the department who have contributed to my knowledge in life. Your remembrance will always linger in my heart.

Futhermore, I will like to express my deep appreciation to my ever lovely parents, Mr. and Mrs. Ogunfolabi for their tireless efforts to see me become what I am today and also to my siblings: Samson, Adenike, Funmilola, Esther, Adewale and Daniel. I love you so much. Also extending my hand of appreciation to this wonderful people: Mrs Poluyi, Mr Olusesi, Mrs Igwe, Segun Salisu, Chief N. Ogunfolabi, Rev. & Mrs Adigun, Mr. & Mrs Afolabi and Mrs Coker. God will continue to bless you.

Finally, my gratitude goes to my friends and colleagues Tope, Efomzy, Tosin, Taiwo, Joe, Esther, Tolani, Opeyemi, Tayo and a host of others. Whaooo! See how time flies. I will miss you all. God will surely grant you all your desires and you shall surely succeed in your endeavours. Amen.

ABSTRACT

Hand dug wells is the most prevalent in the rural parts of Niger State. Three water samples from different hand dug wells in southern part of Bosso local Government Area of Niger State were selected and analysed for physical, chemical and microbial parameters. The samples of the water were being collected using sterile containers and were later taken to the Niger State Water Board for the analysis. The mean values of the physical parameters obtained from the analysis were 7.667FTU for turbidity, 40.667PtCo for color, 5mg/l for suspended solids, 430 us/cm for electrical conductivity, 216.667mg/l for total dissolved solids and 24.5°C for temperature. The mean values of the chemical parameters obtained from the analysis were 150mg/l for total hardness with 102.667mg/l for calcium hardness and 47.333mg/l for magnesium hardness, 118.667mg/l for total alkalinity, 0.643mg/l for phosphate, 12.667mg/l for sulphate, 85.16mg/l for nitrate, 0.11mg/l for nitrite, 0.02mg/l for iron, 42.650mg/l for chloride, 0.033mg/l for nitrite as nitrogen and 0.027mg/l for copper. No trace of chromium was found in all the water samples. The mean values of the microbial parameters obtained from the analysis were 206.667 cfu/100ml for the E. Coli and 653.333 cfu/100ml for the total coliform. Most of the parameters were above the limits stipulated by the Nigeria Standard for Drinking Water Quality and the World Health Organization. Therefore the water is unsuitable for drinking and cooking. It is recommended that wells should not be dug near contamination sources and should be properly lined and covered and the government should provide a potable water for the villages as this will assure a better and hazard free water.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

W.H.O	World Health Organization
F.A.O	Food and Agricultural Organization
NSDWQ	Nigerian Standard for Drinking Water Quality
USEPA	United States Environmental Protection Agency

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Water is essential to life which comprises of both animals and plants. It comprises about 70% to 90% of weight of living organism. No life can be sustained on the earth without water. Man live on a planet that is being dominated by water. Scientist estimates that the hydrosphere contains about 1.36 billion cubic kilometres of this substance mostly in the form of liquid (water) that occupies the topographic depression on the earth (Degremont and Mond, 2001)

Water is the dispersion medium for all biochemical reactions, which constitute the living process and takes part in many of these reactions. A purely form of water must be tasteless, colourless, and odourless liquid because water is an almost universal solvent, most naturally as groundwater (i.e. well) as man-made substances are soluble in it to some extent. Consequently water in nature contains dissolved substances which are often identified as the impurities found in water.

Most of the hand-dug wells which are part of groundwater are shallow and often left open that renders the well susceptible to contamination by surface water during heavy rainstorms (precipitation) as well as human activities. This unfortunate situation has led to the prevalence of water borne diseases.

Safe water has been described as water that meets the National Standard for Drinking Water Quality for Nigeria (Federal Ministry of Water Resources, 2004). Access to safe drinking water is a prerequisite to poverty reduction and that access to safe drinking water prevents the spread of water-borne and sanitation-related diseases; however a large proportion of

Nigerians still lack access to safe clean water. In Nigeria, 52% of the population does not have access to safe drinking water. Lack of access to safe water and adequate sanitation services especially in developing countries often results in the death of about two million infants annually (UNICEF, 2005; Cosgrove and Rijsberman, 2000; Gomez and Nakat, 2002). As a result of rapid expansion of cities and subsequent population explosion, the development of groundwater resources for potable use has increased substantially over the last decade especially in developing countries.

One means of establishing and assuring the purity and safety of water is to set a standard for the various contaminants. A standard is a definite rule, principle or measurement which is established by government authority (Shelton, 1995). The fact that it has been established by authority makes a standard rigid, official and also legal.

According to the American Public Health Association (APHA, 1989), good quality water which is portable and of aesthetic attractiveness must be free from;

i. Visible suspended water
ii. Excessive colour and taste
iii. Objectionable dissolved water
iv. Aggressive constituents
v. Bacteria, indication of faecal pollution

1.2 Statement of the Problem

Groundwater which is the source of the hand dug well is of high utility both to the people in the rural areas as well as in the urban areas in Nigeria. The only challenging part of it is that hand dug well is mostly found in the rural areas while pipe borne water is mostly found in the urban areas. Since hand dug well is the most prevalent in the rural areas, it is of great importance to see that the water required for their need must be good, and it should not contain unwanted impurities or harmful chemical compounds or bacteria in it. Supply of safe water to the people for drinking and garden vegetables/fruits will keep diseases away thereby promoting better health.

1.3 Objectives of the Study

The objectives of the study are;

1) To determine the physical, chemical and microbial parameters from selected hand dug wells in southern part of Bosso Local Government Area of Niger State
2) To compare the water analysis results with the international standards and suggest necessary recommendations.

1.4 Justification of the Study

Due to the low awareness of the public especially people in the rural areas on the importance of determining the quality of the water that is being consumed, this project is justified by the need to determine the quality of the well water, analysing the water quality to know its implication on the health of the people and also studying some effects of environmental condition on water quality.

1.5 Scope of the Study

The scope of the study is the assessment of the water quality of some selected hand dug wells in the southern part of Bosso Local Government Area of Niger State in 2011.

1.6 Limitations of the Study

The following are the limitations of the study

1) Not all the water quality test was carried out because of the cost implication and non availability of instruments.
2) Some of the tests were carried out outside the school campus due to lack of instrumentation for the analysis.
3) The duration of study of the wells was for the months of April/May in 2011 due to time constraint.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background

Ground water constitutes the largest source of dug-well water. It is located below the soil surface and largely contained in interstices of bedrocks, sands, gravels, and other interspaces through which precipitation infiltrates and percolates into the underground aquifers due to gravity (Ogedengbe, 2004). The drinking qualities of dug well water are largely dependent on the concentration of biological, chemical and physical contaminants as much as environmental and human activities in such respects (Schewab, et al. 1992).

Groundwater quality and availability is one of the most critical environmental and sustainability issues of the twenty-first century (UNEP, 2006) in which wells also form a larger part of. Groundwater is also widely used, for instance, for drinking water supply and irrigation in food production (Zekster and Everett, 2004). However, groundwater is not only a valuable resource for water supply, but also a vital component of the global water cycle and the environment.

The traditional method of obtaining groundwater in rural areas of the developing world, and still the most common, is by means of hand-dug wells (Watts and Wood, 1985). However, because they are dug by hand their use is restricted to suitable types of ground, such as clays, sands, gravels and mixed soils where only small boulders are encountered. Some communities use the skill and knowledge of local well-diggers, but often the excavation is carried out, under supervision, by the villagers themselves.

Hand dug wells are found in the rural as well as in the urban areas but are more prevalent in the rural area. As environments get urbanized, there is always the influx/increase in population, with increase industrial development, wastes are frequently discharged into water courses, which increases and consequently the water quality becomes seriously endangered (Obasi and Balogun, 2001).

Chemicals pollute water supply through industrial process and agrochemical applications while physical contaminants result from erosion and disposal of solid wastes. These sources contribute to degradation of drinking water quality standards thereby degenerating into prohibitive water pollution situations. Consequently, water borne diseases such as typhoid, cholera, diarrhoea and dysentery become potentially communicable (Musa, 1996). Drinking water quality must be within tolerable use-limits for human consumption. Water taste, colour, odour, SAR, pH and salinity (EC) status must satisfy recommended drinking water standards (Schewab, et al. 1992). Water for irrigation may also become polluted due to the addition of toxic substances which is different from the one present in the water (Egharevba, 2009).

2.2 Analysis of Groundwater

Tekwa et al. (2006) carried out an assessment of dug-well water quality in Mubi, Adamawa state. They examined the quality of 18 drinking dug-well water in six selected wards (Yelwa, Lokuwa, Nassarawo, Wuro-patuji, Kolere and Sabon-layi) within Mubi town. The result indicated that water contamination due to chemical constituents averaged highest in Sabon-layi ward (EC of 8.6×10^{-4}). The mean pH observed in all wards revealed that Yelwa ward dug-wells were more acidic (pH 4.0) in contrast to those noticed in Lokuwa ward (pH 7.2) depicting mild salinity status. The water colour revealed that dug-well water at Nassarawo ward were more physically contaminated (10 hazen) showing a milky coloration in The biological contamination rates were higher (63 coli/100 ml) in Sabon–layi and

Nassarrawo wards. Likewise the SAR amounts were highest (10.70) in Nassarawo ward compared to Kolere ward (7.20) with the least mean value.

Efe (2005) investigated on the quality of water from hand dug well in Onitsha metropolitan areas of Nigeria. 15 wells water samples were collected during the month of January, July, and August with the aid of sterilized containers. It was recorded that most of the hand-dug well water qualities are unsafe for human consumption, because they are generally above the WHO maximum acceptable threshold. Since this source of water form one of the major source of water to the inhabitants, there is need for purification proper disposal of waste, public education of the health implication of waste/impure water and other management measures.

Orebiyi, E.O., 2010, assessed the pollution hazards of shallow well water in Abeokuta and environs. Pollution of well water, either from point or non-point sources, has become a thing of health concern both in urban and rural areas. It was also pointed out that the water quality parameters were higher than the world health organization standard and therefore there is need for treatment of the waters prior to consumption by humans and animals.

Quddus and Zaman (1996) studied the irrigation water quality of some selected villages of Meherpur district of Bangladesh and argued that some of the following ions such as calcium, magnesium, sodium, bicarbonate, sulphate, chloride, potassium, boron and silica are more or less beneficial for crop growth and soil properties in little quantities.

Talukder et al. (1998) reported that poor quality irrigation water reduces soil productivity, changes soil physical and chemical properties, creates crop toxicity and ultimately reduces yield.

Shahidullah et al. (2000) assessed the groundwater quality in Mymensigh district of Bangladesh and observed a linear relationship between SAR and SSP. They also discovered that the groundwater can safely be used for long-term irrigation.

Sarkar and Hassan (2006) investigated the water quality of a groundwater basin in Bangladesh for irrigation purposes and observed that standard water quality indices like pH, EC, SAR, RSBC, MAR, PI, KR, and TDS are within the acceptable range for crop production.

Raihan and Alam (2008) presented a pictorial representation of groundwater quality throughout the Sunamganj district that allowed for delineation of groundwater based on its suitability for irrigation purposes.

2.3 Description of Hand Dug Well

If the groundwater is tapped over the first impermeable stratum, it is termed shallow well. If this stratum is near the surface, the water lying upon it has little protection from surface pollution. If deep, the surface water, as it sinks, has the impurities drained out of it by the thick layer of soil. Hand-dug wells are typical examples of shallow wells. A dug well may be 0.9 to 1.8 m in diameter and 4.5 to 10 m deep depending on where the water bearing formation or groundwater is encountered. In order to protect a dug well from contamination, watertight casing of concrete or brick set in cement, or large diameter close jointed piping is installed. The casing is usually carried up to form a platform 0.4 to 1.2 m high around the well mouth. A rounded or rectangular concrete slate is also used as a cover over the well, which is usually made to grower into a slot in the platform.

2.3.1 Prevalence of Hand Dug Wells

Hand dug wells have been used by humanity since before recorded history. Most civilizations that needed them had, and many still have traditional methods for well digging (Watts and Wood, 1985). According to Wikipedia, hand-dug wells are excavations with diameters large enough to accommodate one or more men with shovels digging down to below the water table They can be lined with laid stones or brick; extending this lining upwards above the ground surface into a wall around the well serves to reduce both contamination and injuries by falling into the well. A hand dug well has normally a diameter of 0.8 up to 1.5 metre and varies in depth, depending on how deep water is found (Stephen, 1996)

According to Stephen (1996), between the early 1930's and today, the dug well has evolved in some places from minimal, unlined holes to concrete lined structures with specified depth and yield, and with improved head works and drainage. A brief chronology of hand dug wells includes the following:

- Africa; 1930's; In-situ cast concrete linings to avoid collapse and to exclude contamination. Other lining methods included bricking and stone masonry.

- India; early1950's; Caisson lining methods to meet the need for simpler and lower cost construction technologies. Entire wells were lined by this method.

- India; early1950's; Caisson sinking as a very effective method of deepening wells beyond unstable soils and beyond the water table.

- Africa; 1960's and 70's; Caisson lining methods to deepen wells that were mostly built with in-situ cast linings. Much of the caisson sinking method was lost in the transfer. Not much was done to rediscover it, as the writers of the time, and the users of the recent past did not realize the technology was missing

In modern times some of the methods, equipment, materials, expectations, and standards for well construction have been improved to allow better and more permanent yields, depths suitable for modern pumping, and better protection from contamination (Water Aid's Health and Safety Policy, 2000)

2.3.2 Determining a Well Location

The location of a well is mainly determined by the well's purpose. For drinking and irrigation water-production wells, groundwater quality and long-term groundwater supply are the most important considerations. The hydrogeological assessment to determine whether and where to locate a well should always be done by a knowledgeable driller or professional consultant. The water quality criteria to use for drinking water wells are the applicable local or state drinking water quality standards (Thomas, 1989)

Enough ground water must be available to meet the pumping requirements of the wells. For large municipal and agricultural production wells, pumping rate requirements range from about 120,000 to 960,000 litres per hour (l/hr). Small and medium sized community water systems may depend on water wells that produce from 24000 to 120,000 l/hr. Individual homes' domestic wells may meet their needs with as few as 240 to 1200 l/hr, depending on local regulations. To determine whether the desired amount of ground water is available at a particular location and whether it is of appropriate quality, drillers and groundwater consultants rely on their prior knowledge of the local groundwater system, experience in similar areas, and a diverse array of information such as land surface topography, local vegetation, and rock fracturing (where applicable), local geology, groundwater chemistry, information on thickness, depth, and permeability of local aquifers from existing wells and groundwater levels.

When locating a well, one should also consider the proximity of potential sources of contamination such as fuel or chemical storage areas, nearby streams, sewer lines, and leach fields or septic tanks. The presence of a significant barrier between such potential sources and the well itself is very important for the protection of the well (Thomas, 1989)

2.4 The Occurrence of Groundwater

2.4.1 The Hydrological Cycle

The hydrological cycle, also known as the water cycle, is the constantly-occurring process whereby, in simplified terms, water falls to the ground as rain, or other precipitation, runs along the ground under the force of gravity or percolates down to an impermeable layer of soil or rock, appears again at the surface, eventually reaches the sea or a lake and evaporates to form clouds which produce rain. This process is represented graphically in Figure 2.1. In its use of water for various activities, the world's population intervenes in this cycle at a number of points. For the purpose of this manual, we are interested only in the exploitation of water as it passes through shallow aquifers, when it is referred to as groundwater.

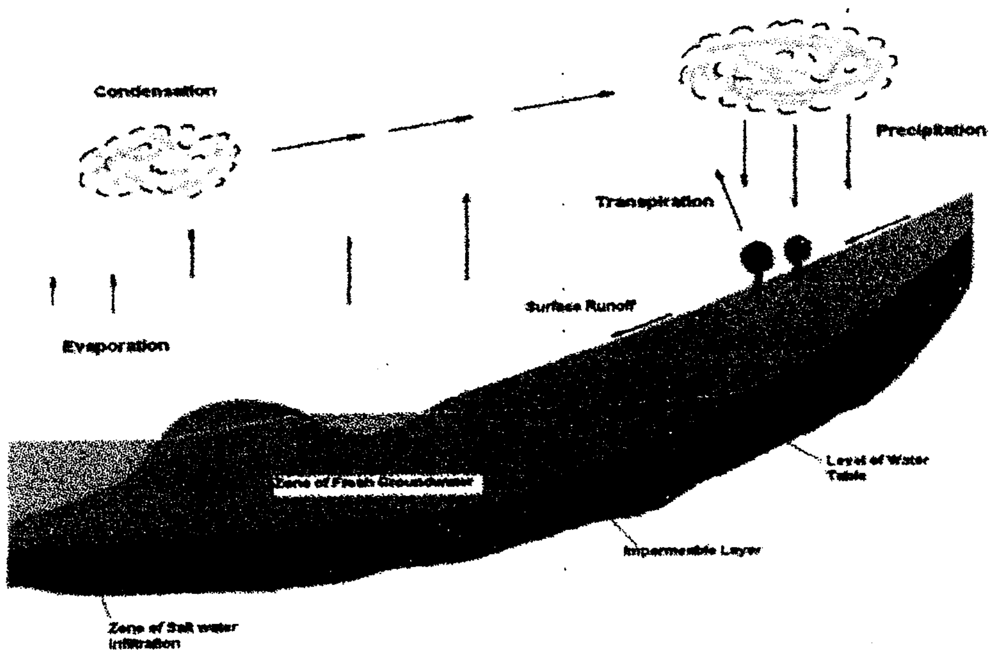

Fig 2.1: Hydrological Cycle

Source: Seamus (2000)

2.4.2 Types of Aquifer

Figure 2.2 illustrates the various types of aquifer which can occur. Aquifers, according to Seamus Collins can be broadly categorized into three, namely,

1. Confined Aquifers are water-bearing strata which lie between two impermeable layers. Water in these aquifers is often under pressure and, if the upper impermeable layer is breached by a borehole, the water from the aquifer will rise to its piezometric level. Where this piezometric level is above ground level, water will emerge from the borehole under pressure and will gush up into the air. This is referred to as an artesian well. In a case where the piezometric level is below ground level, but above the level of the top of the confined aquifer, this is known as a sub-artesian well. Note that the piezometric pressure line refers only to the water in the confined aquifer.

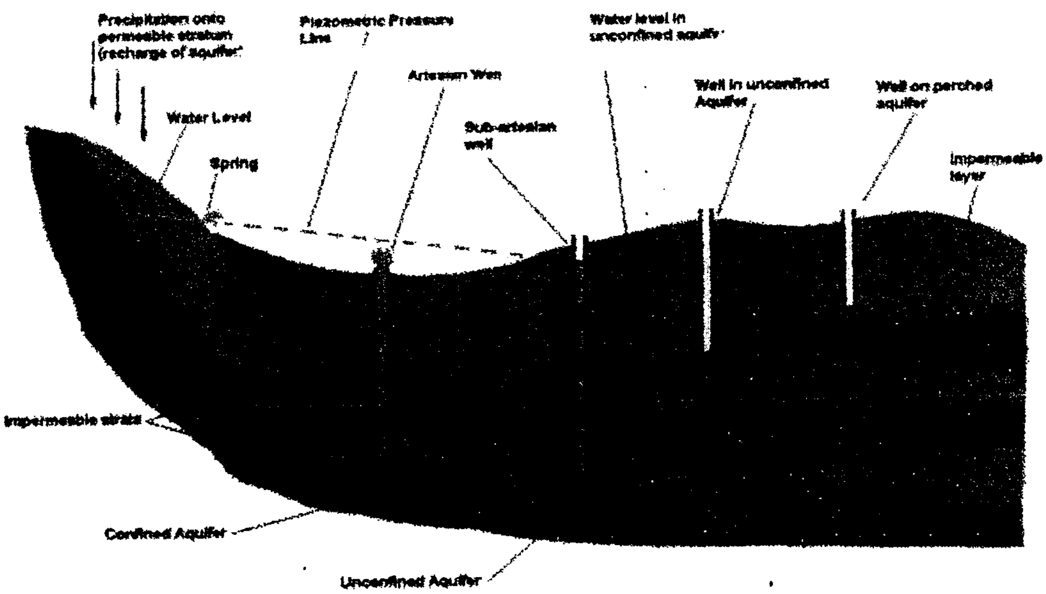

Fig 2.2: Types of aquifers

Source: Seamus (2000)

2. Unconfined Aquifers occur when the water bearing stratum is not covered by an impermeable layer. In this situation, the water in the aquifer is not under pressure, and will not rise in a borehole or well which reaches the level of the aquifer. The level of water in this aquifer will fluctuate with the seasons, and care must be taken when exploiting such an aquifer for water supply purpose.

3. **Perched Aquifers** are a special case of unconfined aquifers. These occur where water, as it percolates down from the surface, is trapped by an isolated impermeable layer, of limited extent, within otherwise permeable strata. Unless the impermeable stratum is very extensive, a perched aquifer is recharged only by locally-occurring rainfall and will provide at best a seasonal supply of water

2.5 Nature of Groundwater

The nature of groundwater can be classified under the following

Composition: The geologic nature of the soil determines the chemical composition of the groundwater. Water is constantly in contact with the ground in which it stagnates or circulates, so equilibrium develops between the composition of the soil and that of the water i.e. water that circulates in a sandy or granitic substratum is acidic and has few minerals. Water that circulates in limestone contains bicarbonates alkalinity. The following table compares the characteristics of surface water and groundwater based on the major analysis parameters (Environmental Protection Agency, (EPA), 2003; Lenntech, 2009).

Table 2.1 Comparison of surface water and groundwater

Characteristics	Surface water	Groundwater
Temperature	Varies with season	Relatively constant
Turbidity, Suspended Solids	Level variable, sometimes high	Low or nil (Except in karst soil
Color	Due to mainly SS (clay, algae) except in very soft or acidic water (humic acids)	Due above all to dissolved solids
Mineral Content	Varies with soil, rainfall, effluents, e.t.c	Largely constant, generally appreciab higher than in surface water from t same area
Divalent Fe and Mn in solution	Usually none, except at the bottom of lakes and pond in the process of eutrophication	Usually present
Dissolved O_2	Often near saturation level, absent in very polluted water	Usually none
Aggressive CO_2	Usually none	Often present
H_2S	Usually none	Often present
NH_4	Found only in polluted water	Often found
Nitrates	Level generally low	Level sometimes high
Silica	Usually moderate proportions	Level often high
Minerals and organic micro pollutants	Can be present but liable to disappear once the source is removed	Usually none but any accident pollution lasts a very long time
Living organisms	Bacteria, viruses, plankton	Iron bacteria frequently found
Chlorinated solvents	Rarely present	Often present
Eutrophic nature	Often increased by high temperatures	None

Source: EPA (2003)

Some of the typical characteristics of groundwater are weak turbidity, a constant temperature and chemical composition and almost overall absence of oxygen. Circulating groundwater can have extreme variation in the composition with the appearance of pollutants and various contaminants. Furthermore, groundwater is often very pure microbiologically (Lenntech, 2009).

Discharges and Velocity: The rate at which groundwater moves through the saturated zones depends on the permeability of the rock and the hydraulic gradient. The hydraulic gradient is defined as the difference in elevation divided by the distance between two points on the water table (Lenntech, 2009). Velocity V, from EPA (2003) is then

$$V = \frac{K\,(h2 - h1)}{L} \qquad 2.1$$

Where K is the coefficient of permeability, h_1 and h_2 are the pressure heads at different levels and L is the length of the pipe.

If the expression is multiplied by the area A (m^2), through which the water is moving, then the discharge Q (Darcy's Law) will be derived

$$Q = \frac{AK\,(h2 - h1)}{L} \qquad 2.2$$

2.6 Physicochemical Properties of Groundwater

Groundwater quality comprises the physical, chemical, and biological qualities of groundwater. Temperature, turbidity, colour, taste, and odour make up list of physical water quality parameters. Since most ground water is colourless, odourless and without specific taste. Most concerned with its physical and chemical qualities. Although, spring water or groundwater products are often sold as "pure," their water quality is different from that of pure water (NRCS, 2003).

Naturally, groundwater contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer (NRCS, 2003). The total mass of dissolved constituents is referred to as the total dissolved solids (TDS) concentration. In water, all of the dissolved solids are either positively charged ions (cations) or negatively charged ions (anions). The total negative charge of the anions always equal the total positive charge of the cations. A higher TDS means that there are more cations and anions in the water. With more ions in the water, the water's electrical conductivity, we can indirectly determine its TDS concentration. At a high TDS concentration, water becomes saline. Water with a TDS above 500 mg/l is not recommended for use as drinking water (Environmental Protection Agency, (EPA), 2003). Water with a TDS above 1,500 to 2,600mg/l (EC greater than 2.25 to 4 mmho/cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance (EPA, 2003).

2.6.1 pH

Groundwater pH is a fundamental property that describes the acidity and alkalinity of groundwater and highly controls the amount and chemical form of many organic and inorganic substances dissolved in groundwater (Lexington, 2003). Many important properties of water are determined by pH. "For example, both the suitability of groundwater for domestic and commercial uses and the ability of water to transport potentially harmful chemicals are controlled by pH (Fisher, 2002). No health-based drinking water standard exists for pH. However, water with a pH that is outside the range 6.5 to 8.5 can lead to high concentration of some dissolved metals, for which there are drinking water standards, as well as potentially harmful health effects (Fisher, 2002).

2.6.2 Electrical Conductivity

Electrical conductivity (EC) is a usefully indicator of dissolved solids (TDS) because the conduction of current in an electrolyte solution is primarily dependent on the concentration of ionic species. EC of water samples is commonly used to examine the mixing of fresh water with seawater (Hiscock et al., 1996), to estimate relative contribution of precipitation and subsurface water in stream hydrograph, and for the dilution of stream discharge

(Dingman, 2002). The reciprocal of EC, electrical resistivity, is used in geophysical investigations to map the extent of contaminant plumes or saline water intrusion.

2.6.3 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand is a chemical procedure for determining how fast biological organisms use up oxygen in a body of water. It is used in water quality management and assessment, ecology and environmental science. BOD is not an accurate quantitative test, although it could be considered as an indication of the quality of a water source (Wikipedia, 2010). When ground water or surface water is polluted severely by infiltration of waste water from industries, the BOD can increase. The BOD of groundwater in developed countries (Europe and U.S.A) is usually high because of high density of industries which release their waste water to the environment (Sawyer et al., 2003).

2.6.4 Turbidity

Turbidity is a measure of suspended solids in water. It is not associated specifically with faecal material, but increases in turbidity are often accompanied with increases in pathogen numbers. Turbidity of water affects treatment processes and especially disinfection with chlorine based chemicals. Turbidity of surface water sources may be heavily influenced by rainfall events or algal growth and treatment processes should be tailored to respond to such changes. Most groundwater have a relatively stable turbidity and any change reflects a major event that needs to be investigated and corrected by tailoring the treatment to the incoming water quality. Even relatively small changes may be important and outbreaks of cryptosporidiosis have been associated with small changes in turbidity of relatively short duration. (Waite, 1997).

2.6.5 Total Dissolved Solids

The total mass of dissolved constituents is referred to as the total dissolved solids (TDS) concentration. In water, all of the dissolved solids are either positively charged ions (cations) or negatively charged ions (anions). The total negative charge of the anions always equals the total positive charge of the cations. A higher TDS means that there are more cations and anions in the water. With more ions in the water, the water's electrical conductivity (EC) increases. By measuring the water's electrical conductivity, we can indirectly determine its TDS concentration. At a high TDS concentration, water becomes saline. Water with a TDS above 500 mg/l is not recommended for use as drinking water (EPA secondary drinking water guidelines). Water with a TDS above 1,500 to 2,600 mg/l (EC greater than 2.25 to 4 mmho/cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance.

2.7 Groundwater Contaminants

Large percentage of Nigeria population depends on groundwater for daily drinking water. Groundwater is also one of our most important sources of irrigation water. Unfortunately, groundwater is susceptible to pollutants. Groundwater is generally a safe source of drinking water, however there are concerns that contamination may increase as toxins dumped on the ground in the past make their way into groundwater supplies.

Naturally, ground water contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer (Davies et al, 2002).

A list of the dissolved solids in any water is long, but it can be divided into four groups which are the major constituents, secondary constituents, minor constituents, and trace elements as shown in Table 2.2

Table 2.2 Classification of important mineral constituents in groundwater

Major constituents [illegible] – 0.01mg/l)	Secondary constituents (0.01 – 10.0 mg/l)	Minor constituent (0.0001 – 0.1 mg/l)	Trace constituents (generally less than 0.001 mg/l)
Sodium	Iron	Antimony	Beryllium
Calcium	Strontium	Aluminium	Bismuth
Magnesium	Potassium	Arsenic	Cerium
Bicarbonate	Carbonate	Barium	Caesium
Sulphate	Nitrate	Bromide	Gallium
Chloride	Fluoride	Cadmium	Gold
Silicate	Boron	Chromium	Indium
		Cobalt	Lanthanum
		Copper	Niobium
		Germanium	Platinum
		Iodide	Radium
		Lead	Ruthenium
		Lithium	Scandium
		Manganese	Silver
		Molybdenum	Thallium
		Nickel	Thorium
		Phosphate	Tin
		Rubidium	Tungsten
		Titanium	Zirconium

Source: EPA (2003)

Except for natural organic matter originating from top soils, all of these naturally occurring dissolved solids are inorganic constituents: minerals, nutrients, and trace elements, including trace metals. In most cases, trace elements occur in such low concentrations that they are not a threat to human health. In fact many of the trace elements are considered essential for the human metabolism. In Europe, water from springs and wells with certain levels of trace elements has long been considered a remedy for ailments. Popular health spas usually are located near such areas. High concentrations of trace metals can also be found in ground water near contaminated sources, however, posing serious health threats. Some trace constituents that are associated with industrial pollution, such as arsenic and chromium, may also occur in completely pristine ground water at concentrations that are high enough to make that water unsuitable as drinking water.

Microbial matter is also a natural constituent of ground water. Just as microbes are ubiquitous in the environment around us, they are very common in the subsurface, including ground water. Hydrogeologists increasingly rely on these, for instance, for subsurface bioremediation of contaminated ground water. Human activities can alter the natural composition of ground water through the disposal or dissemination of chemicals and microbial matter at the land surface and into soils, or through injection of wastes directly into ground water.

2.8 Types of Groundwater Contamination

Groundwater pollution caused by human activities usually falls into one of two categories: point-source pollution and nonpoint-source pollution. Groundwater is exposed to active pollution in both urban and rural areas of Nigeria due to the increase urbanization and indiscriminate waste disposed (Egharevba, 2009). Fertilizers and pesticides applied to crops eventually may reach underlying aquifers, particularly if the aquifer is shallow and not "protected" by an overlying layer of low permeability material, such as clay. Drinking-water wells located close to cropland sometimes are contaminated by these agricultural chemicals (USEPA, 1990).

Point-source pollution refers to contamination originating from a single tank, disposal site, or facility. Industrial waste disposal sites, accidental spills, leaking gasoline storage tanks, and dumps or landfills are examples of point sources. Chemicals used in agriculture, such as fertilizers, pesticides, and herbicides are examples of nonpoint-source pollution because they are spread out across wide areas. Similarly, runoff from urban areas is a nonpoint source of pollution (Boulding and Russell, 1995).

Because non point-source substances are used over large areas, they collectively can have a larger impact on the general quality of water in an aquifer than do point sources, particularly when these chemicals are used in areas that overlie aquifers that are vulnerable to pollution. If impacts from individual pollution sources such as septic system drain fields occur over large enough areas, they are often collectively treated as a nonpoint source of pollution.

2.8.1 Natural Substances

Some groundwater pollution occurs naturally. Naturally occurring substances include: minerals such as iron, calcium, magnesium, manganese, copper and selenium while anthropogenic substances are: Synthetic organic chemicals, hydrocarbons, pesticides, Polychlorinated Biphenyl (PCB), landfill leachates (liquids that have dipped through the landfill and carry dissolved substances like heavy metals, organic decomposition products), salts; bacteria and viruses The toxic metal arsenic, for instance, is commonly found in the sediments or rock of the western United States, and can be present in groundwater at concentrations that exceed safe levels for drinking water. (Wiedemeier and Todd, 1999).

Radon gas is a radioactive product of the decay of naturally occurring uranium in the Earth's crust. Groundwater entering a house through a home water-supply system might release radon indoors where it could be breathed.

2.8.2 Petroleum-based Fuels

One of the best known classes of groundwater contaminants includes petroleum-based fuels such as gasoline and diesel. Nationally, the U.S. Environmental Protection Agency (EPA) has recorded that there have been over 400,000 confirmed releases of petroleum-based fuels from leaking underground storage tanks.

Gasoline consists of a mixture of various hydrocarbons (chemicals made up of carbon and hydrogen atoms) that evaporate easily, dissolve to some extent in water, and often are toxic. Benzene, a common component of gasoline, is considered to cause cancer in humans, whereas other gasoline components, such as toluene, ethylbenzene, and xylene, are not believed to cause. Aquifers in industrialized areas are at significant risk of being contaminated by chemicals and petroleum products (Johnson, 2000). In most developed countries, various laws attempt to prevent land and water pollution, and to clean up contaminated areas when they occur. Developing countries and countries in economic distress are less likely than developed nations to assess the risk of groundwater contamination by land-use activities. Cancer in humans may be toxic in other ways. One interesting property of gasoline is that it is less dense than water, and so it tends to float on top of the water table.

2.8.3 Chlorinated Solvents

Another common class of groundwater contaminants includes chemicals known as chlorinated solvents. One example of a chlorinated solvent is dry-cleaning fluid, also known as perchloroethylene. These chemicals are similar to petroleum hydrocarbons in that they are made up of carbon and hydrogen atoms, but the molecules also have chlorine atoms in their structure (Wiedemeier and Todd, 1999).

As a general rule, the chlorine present in chlorinated solvents makes this class of compounds more toxic than fuels. Unlike petroleum-based fuels, solvents are usually heavier than water, and thus tend to sink to the bottoms of aquifers. This makes solvent-contaminated aquifers much more difficult to clean up than those contaminated by fuels.

2.9 Dangers of Contaminated Groundwater

Drinking contaminated groundwater can have serious health effects. Diseases such as hepatitis and dysentery may be caused by contamination from septic tank waste. Poisoning may be caused by toxins that have leached into well water supplies. Wildlife can also be harmed by contaminated groundwater. Other long term effects such as certain types of cancer may also result from exposure to polluted water (Mansfield, 2000; Gupta, 2005)

2.10 Causes of Groundwater Pollutants

A groundwater pollutant is any substance that, when it reaches an aquifer, makes the water unclean or otherwise unsuitable for a particular purpose. Sometimes the substance is a manufactured chemical, but just as often it might be microbial contamination. Contamination also can occur from naturally occurring mineral and metallic deposits in rock and soil.

For many years, people believed that the soil and sediment layers deposited above an aquifer acted as a natural filter that kept many unnatural pollutants from the surface from infiltrating down to groundwater. By the 1970s, however, it became widely understood that those soil layers often did not adequately protect aquifers. Despite this realization, a significant amount of contamination already had been released to the nation's soil and groundwater. Scientists have since realized that once an aquifer becomes polluted, it may become unusable for decades, and is often impossible to clean up quickly and inexpensively.

2.10.1 Pollutants and Groundwater Supplies

Pollutants that contaminate groundwater may be some of the same pollutants that contaminate surface water. Compounds from the surface can move through the soil and end up in the groundwater. For example, pesticides and fertilizers can find their way into groundwater supplies over time. Road salt, toxic substances from mining sites, and used motor oil also may seep into groundwater. In addition, it is possible for untreated waste from septic tanks and toxic chemicals from underground storage tanks to contaminate groundwater. (Groundwater Foundation, 2009).

2.11 Relationship Between Groundwater Quality and Land Use

Close relationship exists between groundwater quality and land use. Various land use activities can result in ground water contamination. Potential sources of groundwater pollution include solid waste landfills, on-site excreta disposal systems, cemetery and animal wastes resulting from human activities among others. In a solid waste landfill (open dumping or sanitary landfill), the organic and inorganic by-products resulting from the decomposition of wastes are leached out by the infiltration of rainfall. If leachate is released to the surrounding soil without proper collection and treatment, it could contaminate groundwater resources (Somjai and Suporn, 1993). Studies have shown that the leachate causes an increase in dissolved inorganic substances such as chloride, sulphate, bicarbonate, sodium and potassium of groundwater (Zanoni and Fungaroli, 1973; Kelly, 1976).

Groundwater contamination can originate on the surface of the ground, above the water table, or below the water table. Where a contamination originates is a factor that can affect its actual impact on groundwater quality. In comparison with rivers, groundwater tends to move very slowly and with very little turbulence. Therefore once the contamination reaches the groundwater, dilution or dispersion normally takes a long time. The contaminants usually form a concentrated plume that flows along the same path as the groundwater. Among the factors that determine the size, form and rate of movement of contaminant plume are the amount and type of contaminant and the velocity of groundwater movement. Groundwater contaminants could be undetected for years until the supply is tapped for use. Substances that can contaminate groundwater can be divided into two basic categories: substances that occur naturally and substances produced by man's activities (USEPA, 1990).

2.12 Landfills and Groundwater

Solid waste landfills are a necessity in modern day society, because the collection and disposal of waste materials into centralized locations helps minimize risks to public health and safety. Solid waste landfills, which are regulated differently than hazardous waste landfills, may accept a variety of solid, semi-solid and small quantities of liquid waste. Landfills generally remain open for decades before undergoing closure and post closure phases, during which steps are taken to minimize the risk of environmental contamination (Lee et al, 1991)

Municipal solid waste (MSW) landfills accept non hazardous wastes from a variety of sources, such as households, businesses, restaurants, medical facilities and schools. Many MSW landfills also can accept contaminated soil from gasoline spills, conditionally exempted hazardous waste from businesses, small quantities of hazardous waste from households, and other toxic wastes. Industrial facilities may utilize their own captive landfill (i.e. a solid waste landfill for their exclusive use) to dispose of nonhazardous waste from their processes, such as sludge from paper mills and wood waste from wood processing facilities (Advameg, 2011).

2.12.1 Impact of Landfills on Groundwater

Although landfills are an indispensable part of everyday living, they may present long-term threats to groundwater and also surface waters that are hydrologically connected. In the United States, Federal standards to protect groundwater quality were implemented in 1991 and required some landfills to use plastic liners, collect and treat leachate. However, many disposal sites were either exempted from these rules or grandfathered (excused from the rules owing to previous usage) (Advameg, 2011; Lee et al, 1991).

2.13 Water Quality Standard

Water required for domestic uses, particularly water required for drinking, must be colourless, odourless, and tasteless. It should be free from turbidity, and excessive or toxic chemical compound. Harmful micro-organisms and radio activity must be absent. The quality of municipal water supplies is generally controlled throughout the world. The World Health Organisation has laid down its standards for portable waters. Different nations also have their standards peculiar to their definitions of water quality.

In the United States of America, the Federal Safe Drinking Water Act (SDWA) sets the minimum standards to be met by all public water systems. In the last two decades, many emerging issues have forced many developed nations to revise their water quality policies resulting in more stringent controls of the maximum contaminant levels of certain pollutants.

In Nigeria, the National Agency for Food and Drug Administration Control (NAFDAC) and other related agencies regulate the national drinking water quality by specifying standards to be met by all water intended for drinking. Such specifications are based on the World Health Organization (WHO) standards for drinking water quality.

In the setting of standards, agencies make political and technical/scientific decisions about how the water will be used (USEPA, 2006). In the case of natural water bodies, they also make some reasonable estimate of pristine conditions. Different uses raise different concerns and therefore different standards are considered.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Description of the Study Area

The study area was the southern part of Bosso Local Government in Niger State. The L.G.A had a mean annual precipitation of 1300mm from an exceptionally long record of 50 years. The highest mean monthly rainfall is September, with almost 300mm. the raining season starts on average between April and lasts between 190 – 200 days (October). Temperature rarely falls below 22^{0}C. The peaks are 40^{0}C (February – March) and 35^{0}C (November – December). This data were obtained from Geography Department, Federal University of Technology, Minna.

The climate of the area is mainly by the rain bearing South West Moonson winds from the oceans and the dry dusty or harmattan North East winds (air masses) from the Sahara Desert. There are mainly the rainy and the dry seasons. The rainy season begins in April and ends in October and the dry season starts in November and end in March. The mean monthly rainfall record from 1998 to 2006 ranges from 0.57mm to 300mm with February/March having the minimum and September having the maximum occurrence.

The area was steep sloppy and the major soil found in the area was sandy loam classified as oxic plaustalf type of soil. It is friable with low water retaining capacity. It is slightly acidic in nature. It has high organic matter level.

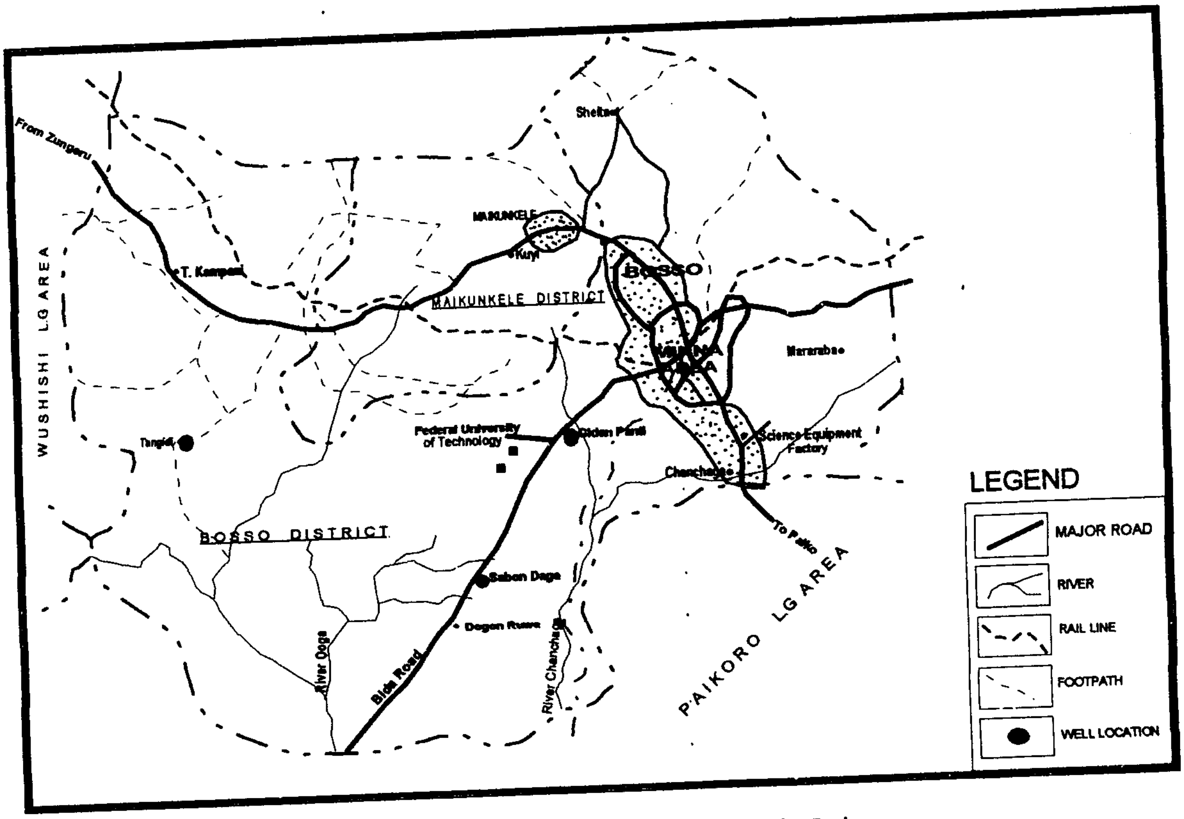

Fig 3.1 Map of Bosso Local Government Area Showing Sample Points

Three locations of wells were chosen from the area which are; Tangidi Village, Sabon Daga Village and Gidan Painti Village. The history and description of each wells are discussed below.

3.1.1 Description of the Well in Tangidi Village

The well was located in a small village at the extreme axis after Beji Market. It was constructed about three years ago by some villagers. The river in the village has been the source of water before the well was being constructed. The main purpose for its construction is to augment the flowing river which sometimes do dry up and which is not always good for drinking. The well has been a better source of water to the villagers. The well is always being covered with some logs of wood when not in use. The well is located between a farm and a grinding mill, both of which are sources of pollution to the well. Dust particles, fumes and effluents from the farm, grinding mill and the surrounding houses can seep into the groundwater thereby contaminating it. Also fertilizers, herbicides and manures used on the farm can also be a major pollution to the well.

Other features of the well and in relation to the well are listed below

Table 3.1 Well Description of Tangidi Village

Features	**Parameter**
Temperature of water	29^0C
Latitude of the well	$006^0$19'183'' east
Longitude of the well	$09^0$31'635'' north
Elevation of the well	182m
Well Diameter	0.73m
Depth of well	6.52m
Depth of water below surface	3.9m
Nearness to grinding mill	3.5m
Nearness to the farm	0.30m
Nearness to residence	50 m away

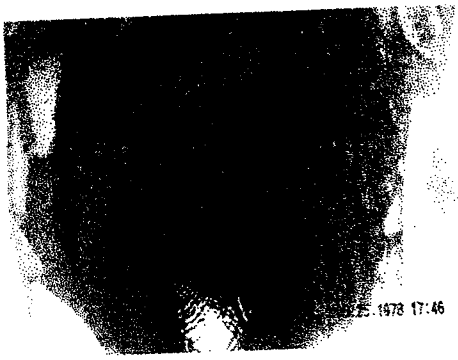

Plate 3.1 Inner view of the well in Tangidi Village

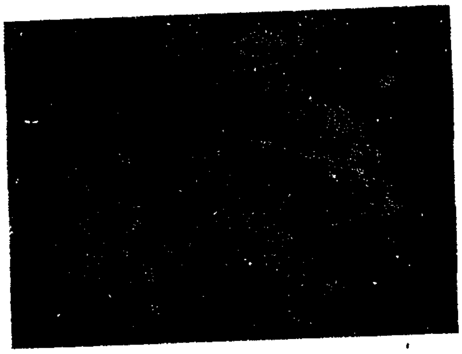

Plate 3.2 Outer view of the well in Tangidi Village

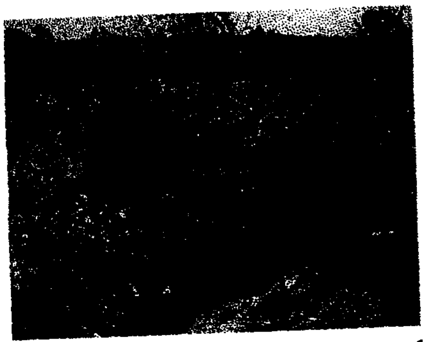

Plate 3.3 The farm beside the well in Tangidi Village

Plate 3.4 The mill beside the well

3.1.2 Description of the Well in Sabon Daga Village

This well is located in the village along Bida-Minna Road which is not too far from Maizube Farm. The well was built about two years ago by Chief Mohammed Tanko (A Former Judge of Bauchi State). The well was located in an open field which helps to augment the supply of water from the borehole. The well is lined inside with a concrete cast outside. It is always covered when not in use. The well location is a bit far away from the surrounding houses but human activities in the area can also be a source of pollution to the water.

Other features of the well and in relation to the well are listed below

Table 3.2 Well Description of Sabon Daga Village

Features	Parameter
Temperature of water	28^0C
Latitude of the well	$006^0$22'980'' east
Longitude of the well	$09^0$25'399'' north
Elevation of the well	184m
Well Diameter	0.68m
Depth of well	7.63m
Depth of water below surface	2.7m
Nearness to the roadway	1.52m
Nearness to residence	100 m away

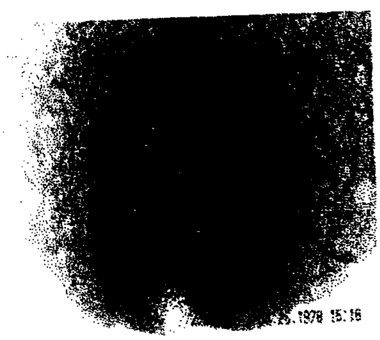

Plate 3.5 Inner view of the well in Sabon Daga Village

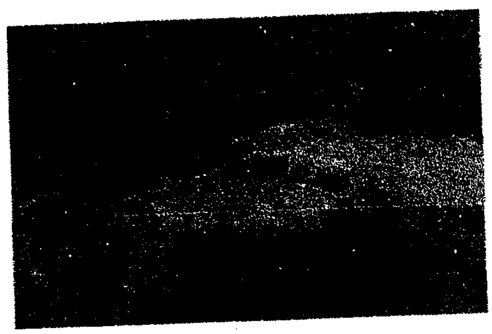

Plate 3.6 Outer view of the well in Sabon Daga Village

Plate 3.7 Open field beside the well in Sabon Daga Village

Plate 3.8 The houses around the well in Sabon Daga Village

3.1.3 Description of the Well in Gidan Painti Village

Gidan Painti is a small village along Minna-Bida road opposite the Gidan Kwano Campus of the Federal University of Technology, Minna. The well in the village was dug about 20 years ago by the Federal Government of Nigeria to supply water to the villagers when they were being relocated from their initial settlement due to the establishment of the Gidan Kwano Campus of the University. The water from the well is also used for irrigation by the farmers in the village. The well is lined inside and bricks are also moulded around it to reduce surface water infiltration into it. It is always covered when not in use. The proximity of the well to the house may also contribute to its contamination as effluents caused by human activities in the house can seep into the water. The use of pesticides, fertilizers and manures on the farm can also be a source of pollution to the well water.

Other features of the well and in relation to the well are listed below

Table 3.3 Well Description of Gidan Painti Village

Features	Parameters
Temperature of water	27⁰C
Latitude of the well	006⁰27'930'' east
Longitude of the well	09⁰31'700'' north
Elevation of the well	232m
Well Diameter	0.75m
Depth of well	7.01m
Depth of water below surface	1.5m
Nearness to the farm	3m
Nearness to residence	30m away

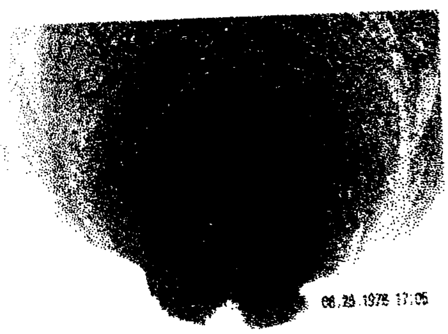

Plate 3.9 Inner view of the well in Gidan Painti Village

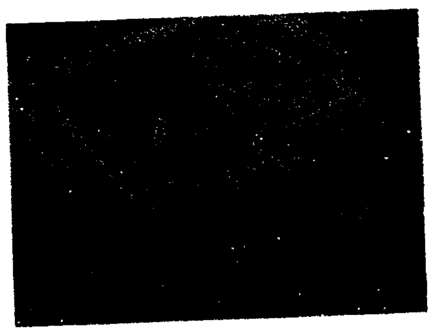

Plate 3.10 Outer view of the well in Gidan Painti Village

Plate 3.11 The farm beside the well in Gidan Painti Village

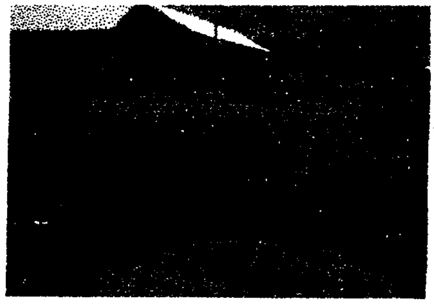

Plate 3.12 The house beside the well in Gidan Painti Village

3.2 Methodology

3.2.1 Brief description of the DR/2000 spectrophotometer

The DR/2000 spectrophotometer is a microprocessor-controlled, single-beam instrument suitable for colorimetric testing in the laboratory or the field. The instrument is pre-calibrated for over 120 different colorimetric measurements and has provisions for user entered calibrations as well as future Hach methods.

Test results can be displayed in percent transmittance, absorbance or concentration in the appropriate units of measure. The instrument offers automatic ranging in the pre-programmed parameters, operated-selected languages, full prompting during testing and error messages for procedural or instrument troubleshooting. A built-in timer helps the operator observe specific reaction times called for in the test procedures by having the appropriate times programmed into the calibration data for that test. The timer can also be used manually by the operator independent of stored methods. RS232 interface capability allows an external printer or computer to interface with the spectrophotometer; and a 0 to 1-volt analog output is provided for a recorder.

The spectrophotometer can operate on battery power, pr AC line power using the battery eliminator/charger unit supplied with accessories. The battery holder supplied holds six D-size dry cells that will power the instrument for approximately 100 tests. An optional rechargeable battery is available, and it can be recharged with the optional battery eliminator/charger. The eliminator/charger cannot be used to charge D-size, rechargeable batteries.(Hach DR/2000 Spectrophotometer Manual)

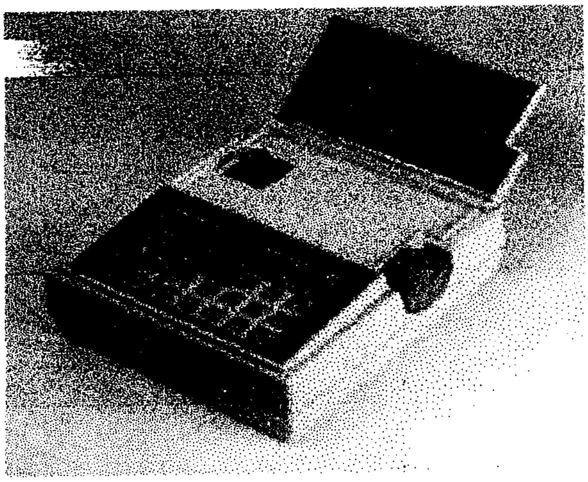

Fig. 3.2 Hach DR/2000 Spectrophotometer

3.2.2 Sample Collection

Six sterile containers of 1 litre each was used to collect the water sample from the locations respectively whereby two sterile containers is being used for a water sample. The sample was collected with the aid of a rope attached to a bucket. The sampling was carried out in the month of May, 2011.

3.3 Physical Analysis of Water

3.3.1 Determination of Electrical Conductivity, Total Dissolved Solids and Temperature

The electrical conductivity, total dissolved solids and temperature were determined using the Hach Conductivity/TDS meter where the electrode probe of the meter was inserted into the water sample to be tested and each of the parameters were gotten by the press of its button on the meter.

3.3.2 Determination of Turbidity

A 25ml sample cell was rinsed and filled with the water sample to be tested. Another 25ml sample cell was filled distilled water which is to serve as the blank. The program number for turbidity test (750) was entered and the wavelength was dialled to 450. The surfaces of the sample cells were wiped using a clean cloth. The sample cell containing the distilled water was inserted into the sample holder and the lid was closed. The reading of the distilled water was taken by pressing ZERO and waiting until Zero appears on the screen before removing the sample cell containing the distilled water. The sample cell containing the water sample to be tested was later inserted and the reading was taken by pressing ENTER.

3.3.3 Determination of Colour

A 25ml sample cell was rinsed and filled with the water sample to be tested. Another 25ml sample cell was filled with distilled water which is to serve as the blank. The program number for the colour test (120) was entered and the wavelength was dialled (455). The surfaces of the sample cells was wiped using a clean cloth. The sample cell containing the distilled water (blank) was inserted into the sample holder and the lid was closed. The reading for the distilled water was taken by pressing the ZERO button on the spectrophotometer, then waiting until Zero appears on the screen and which the sample cell was later removed. The sample cell containing the sample to be tested was later inserted and the reading was taken by pressing ENTER.

3.3.4 Determination of Suspended Solids

A 25ml sample cell was filled with the water sample to be tested. Another 25ml sample cell was filled with distilled water which is to serve as the blank. The program number for total suspended solids test (630) was entered and the wavelength was dialled to 810. The surfaces of the sample cells were wiped using a clean cloth to avoid obstruction of light. The sample cell containing the distilled water was inserted into the sample holder and the lid was closed. The reading of the distilled water was taken by pressing ZERO, and then waiting until Zero appears on the screen before removing the sample cell containing the distilled water. The sample cell containing the water sample to be tested was then inserted and the reading was taken by pressing ENTER.

3.4 Chemical Analysis of Water

3.4.1 Determination of Copper

The program number for copper test (135) was entered and the wavelength was dialled to 560nm. A 25ml sample cell was rinsed and fill with the sample to be tested. One powder pillow of Cu Ver 1 copper reagent was added to the sample and swirled to mix. The sample was kept for a reaction time of 2 minutes, using the spectrophotometer as the timer. After the beep, the second sample cell which is to serve as blank was filled with 25ml of sample. The second sample was placed into the cell holder. The zero button was pressed, and then waiting until zero appears on the screen. Within 30 minutes, after the time beeps, the prepared sample was placed into the cell holder, the light shield was closed and the ENTER key was pressed to take the reading.

3.4.2 Determination of Iron

The program number for iron test (255) was entered and the wavelength was dialled to 510nm. A 25ml sample cell was rinsed and fill with the sample to be tested. One powder pillow of ferrous iron reagent was added to the prepared sample and swirled to mix. The sample was kept for a reaction period of 3 minutes using the spectrophotometer as the timer. After the beep, the second sample cell which is blank was filled with 25ml of sample. The second sample was placed into the cell holder. The zero button was pressed, then waiting until zero appears on the screen. The prepared sample was later placed into the cell holder and the ENTER key was pressed to take the reading.

3.4.3 Determination of Chromium

The program number for chromium hexavalent test (90) was entered and the wavelength was dialled to 540nm. A 25ml sample cell was rinsed and fill with the sample to be tested. One chromaver 3 reagent powder pillow was added to the prepared sample and swirled to mix. The sample was kept for a reaction period of 5 minutes. After the beep, the second sample cell which is blank was filled with 25ml of sample. The second sample was placed into the cell holder. The zero button was pressed, then waiting until zero appears on the screen. The prepared sample was then placed into the cell holder and the ENTER key was pressed to take the reading.

3.4.4 Determination of Sulphate

The program number for sulphate test (680) was entered and the wavelength was dialled to 450nm. A 25ml sample cell was rinsed and fill with the sample to be tested. One powder pillow of sulfa ver 4 reagent was added to the prepared sample and swirled to dissolve. The sample was kept for a reaction period of 5 minutes. After the beep, the second sample cell which is blank was filled with 25ml of sample. The second sample was placed into the cell holder. The zero button was pressed, then waiting until zero displays on the screen. Within 5 minutes after the timer has beeped, the prepared sample was placed into the cell holder and the ENTER key was pressed to take the reading.

3.4.5 Determination of Phosphate

The program number for phosphate test (490) was entered and the wavelength was dialled to 890nm. A 25ml sample cell was rinsed and fill with the sample to be tested. One powder pillow of phos ver 3 phosphate was added to the prepared sample and swirled to dissolve. The sample was kept for a reaction period of 2 minutes. After the beep, the second sample cell which is blank was filled with 25ml of sample. The second sample was placed into the cell holder. The zero button was pressed, then waiting until zero displays on the screen. The prepared sample was then placed into the cell holder and the ENTER key was pressed to take the reading.

3.4.6 Determination of Nitrate

The program number for nitrate test (351) was entered and the wavelength was dialled to 507nm. A 50ml mixing cylinder to the 30ml mark was filled with the sample to be tested. One powder pillow of nitra ver 6 nitrate reagent was added to the cylinder. The sample was kept for a reaction period of 3 minutes, using the spectrophotometer as the timer and the cylinder was continuously shaken during the 3 minutes period. After the beep, another 2 minute period was set to allow the cadmium to settle. After this, 25ml of sample was poured into the sample cell but care was being taken not to transfer any cadmium particles. One powder pillow of nitri ver 3 nitrite reagent was added to the prepared sample and shaken to dissolve. A reaction time of 10 minutes was also set. After the reaction time, another 25ml of sample which is to serve as blank was placed into the cell holder. The zero button was pressed, then waiting until zero displays on the screen. Within 10 minutes after the timer has beeped, the prepared sample was placed into the cell holder and the ENTER key was pressed to take the reading as nitrate nitrogen (NO_3^- -N). The nitrate value was gotten by multiplying the result by 4.4

3.4.7 Determination of Nitrite

The program number for the test (371) was entered and the wavelength was dialled to 507nm. A 25ml sample cell was rinsed and filled with the sample to be tested. One powder pillow of nitri ver 3 nitrite reagent was added to the prepared sample and was shaken to dissolve. The sample was kept for a reaction period of 15 minutes. After the beep, the second sample cell which is blank was filled with 25ml of sample. The second sample was placed into the cell holder. The zero button was pressed, then waiting until zero displays on the screen. The prepared sample was later placed into the cell holder and the ENTER key was pressed to take the reading for nitrite as nitrogen. The nitrite value was gotten by multiplying the result by 3.3

3.4.8 Determination of Chloride

50ml of the water sample was measured and 1ml of K_2CrO_4 was added as an indicator to the water sample. The water sample was titrated with 0.0141 $AgNO_3$ as the titrant until there is a colour change from yellow to reddish end point.

$$\text{Chloride Mg/L} = \frac{\text{A x N x 35,450}}{\text{ml of sample}}$$

Where A = ml of $AgNO_3$ used

N = Molarity of titrant used (0.0141M)

3.4.9 Determination of Total Hardness

50 ml of the water sample was measured into a 125ml flask. 2ml of buffer solution was added to the solution. The buffer solution of pH 10-+0.01 was prepared by dissolving 1.179g EDTA di-sodium salt and 0.780g $MgSO_4.7H_2O$ in distilled water which was later added to 16.9g NH_4Cl and 143 ml concentrated NH_4OH, mixed together and later diluted with distilled water. A small quantity of Erichrome Black T indicator was then added to the mixture of the water sample and the buffer solution. It was then titrated with 0.01M EDTA (ethylene – diamine tetraethanoic acid) slowly while stirring continuously until the last reddish tinge changes to blue.

Total Hardness in mg/l as $CaCO_3 = \frac{A \times D \times 1000}{\text{ml of sample}}$

Where A = ml of titrant used

D = molarity of titrant x molar mass of $CaCO_3$ = 0.01 x 100

Where the molar mass of $CaCO_3$ = 40+12+ (16x3) = 100

3.4.10 Determination of Calcium Hardness

50ml of the water sample was measured into 125ml flask. 25ml of 1M sodium hydroxide buffer solution was added to the sample followed by the addition of 0.1 to 0.2g drops of murexide indicator. The resultant pink colour were titrated with 0.01M EDTA di-sodium salt until the colour changes from pink to purple.

Calcium Hardness in mg/l as $CaCO_3 = \frac{A \times D \times 1000}{\text{ml of sample}}$

Where A = ml of titrant used

D = molarity of titrant x molar mass of $CaCO_3$ = 0.01 x 100

The Magnesium Hardness = Total Hardness – Calcium Hardness

3.4.11 Determination of Alkalinity

50ml of the water sample was measured into 125ml flask. 6 drops of phenolphthalein indicator was added. Since there was no colour change, it means that the hydroxide alkalinity and the carbonate alkalinity are zero while the bicarbonate alkalinity equal to the total alkalinity. The total alkalinity was gotten by using a standard solution of 0.02M H_2SO_4 as the titrant where 6 drops of mixed indicators which are bromocresol and methyl red are added to the unchanged solution of the water sample.

$$\text{Total Alkalinity} = \frac{A \times N \times 50{,}000}{\text{ml of sample}}$$

Where A = ml of H_2SO_4 used

N = molarity of acid used (0.02m)

3.5 Microbial Analysis of water

The membrane lauryl sulphate broth was used for this analysis. It was diluted with distilled water and autoclaved at 21°C for 15 minutes. It was allowed to cool at room temperature before pouring it on an absorbent pad placed into each of the two empty sterile petri dishes. The pads were allowed to get soaked with the membrane lauryl sulphate broth. The excess medium was cleaned off from the dishes with the cotton wool to prevent confluent growth.

The sterile filtration apparatus was set up and connected to a source of vacuum with the stop cock turned off. The funnel was carefully removed and a sterile membrane filter was placed onto the porous disc of the filter base. The funnel was later returned and 100 ml of the water sample was poured into the funnel. The stop cock was then opened and the vacuum pump was switched on to filtrate the sample. The vacuum pump was stopped and the stop cock was closed after the sample has been filtered to prevent air from being drawn into the membrane filter.

The funnel was later removed and the membrane filter was carefully transferred to one of the pads saturated with the membrane lauryl sulphate broth. The membrane filter was then covered with the lid of the petri dish. The same process of the filtration was also carried out for the second volume of sample and the membrane filter was also transferred to the other saturated pad and was also covered with the lid of the petri dish.

The two petri dishes were then placed in a sealed container to prevent drying after which they were inverted and placed in an incubator at 30°C for 4 hours. One dish was later transferred to an incubator at 37°C for 14 hours (for the total coliform) and the other dish to an incubator at 44°C for 14 hours (For the E-coli)

After the total incubation period of 18 hours, the membrane filters were examined under the colony counter. The number of yellow colonies counted on the membrane filter incubated at 37°C is the total coliform while the number of yellow colonies counted on the membrane filter incubated at 44°C is the number of E-coli present in the water sample.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

The Table below presents the physico-chemical and bacteriological analysis of the water samples

Table 4.1 Physico-chemical and bacteriological analysis of the water samples

S/N	PARAMETERS	TANGIDI	SABON DAGA	GIDAN PAINTI	NSDWQ
1	Turbidity (FTU)	7.00	12.00	4.00	5.00
2	Color (PtCo)	40.00	62.00	20.00	15.00
3	Suspended Solids (mg/l)	4.00	9.00	2.00	NS
4	Electrical Conductivity (us/cm)	750	320	220	1000
5	Total Dissolved Solids (mg/l)	380	160	110	500
6	pH	6.62	6.58	6.73	6.5-8.5
7	Total Hardness (mg/l)	230.00	145.00	75.00	150.00
8	Calcium Hardness (mg/l)	190.00	77.00	41.00	NS
9	Magnesium Hardness (mg/l)	40.00	68.00	34.00	NS
10	Total Alkalinity (mg/l)	68.00	167.00	121.00	NS
11	Hydroxide Alkalinity (mg/l)	0	0	0	NS
12	Carbonate Alkalinity (mg/l)	0	0	0	NS
13	Bicarbonate Alkalinity (mg/l)	68.00	167.00	121.00	NS
14	Phosphate (mg/l)	0.20	0.52	1.21	NS
15	Sulphate (mg/l)	36.00	1.00	1.00	100
16	Nitrate (mg/l)	238.68	7.96	8.84	50.00
17	Nitrite (mg/l)	0.30	0.02	0.01	0.2
18	Iron, Fe^{2+} (mg/l)	0.04	0.02	0.00	0.30
19	Chloride (mg/l)	92.97	17.49	17.49	250.00
20	Chromium, Cr^{6+} (mg/l)	0.00	0.00	0.00	0.05
21	Temperature (°C)	22.5	25.6	25.4	Ambient
22	Nitrite as N (mg/l)	0.09	0.006	0.003	NS
23	Copper (mg/l)	0.07	0.01	0.00	1.00
24	E. Coli (cfu/100ml)	260	120	240	0
25	Total Coliform (cfu/100ml)	280	1160	520	10

*NB: NSDWQ means Nigerian Standard for Drinking Water Quality

NS means Not Stated

Table 4.2 Range, mean and standard deviation values of the analysis of the water samples of ail the wells

PARAMETERS	RANGE	MEAN	STANDARD DEVIATION	NSDWQ	W.H.O	F.A.O
Turbidity (FTU)	8.00	7.667	4.041	5.00	5.00	5.00
Color (PtCo)	42.00	40.667	21.008	15.00	15.00	15.00
Suspended Solids (mg/l)	7.00	5.000	3.606	NS	NS	NS
Electrical Conductivity (us/cm)	530.00	430.000	281.603	1000	1400	NS
Total Dissolved Solids (mg/l)	270.00	216.667	143.643	500	600	1000
pH	0.15	6.643	0.078	6.5-8.5	6.5-8.5	< 8.0
Total Hardness (mg/l)	155.00	150.000	77.621	150.00	200.00	NS
Calcium Hardness (mg/l)	149.00	102.667	77.745	NS	NS	NS
Magnesium Hardness (mg/l)	34.00	47.333	18.148	NS	NS	NS
Total Alkalinity (mg/l)	99.00	118.667	49.541	NS	200.00	NS
Phosphate (mg/l)	1.01	0.643	0.516	NS	NS	NS
Sulphate (mg/l)	35.00	12.667	20.207	100.00	250.00	250.00
Nitrate (mg/l)	230.72	85.160	132.953	50.00	50.00	NS
Nitrite (mg/l)	0.29	0.110	0.165	0.2	3.00	NS
Iron, Fe^{2+} (mg/l)	0.04	0.020	0.020	0.30	0.30	0.30
Chloride (mg/l)	75.48	42.650	43.578	250.00	250.00	250.00
Temperature (°C)	3.1	24.500	1.735	Ambient		
Nitrite as N (mg/l)	0.087	0.033	0.049	NS	0.9	0.2
Copper (mg/l)	0.07	0.027	0.038	1.00	2.00	1.00
E. Coli (cfu/100ml)	140	206.667	75.719	0	0	0
Total Coliform (cfu/100ml)	880	653.333	454.899	10	0	0

4.2 Discussion of Results

The study investigated the physico-chemical and microbiological qualities of selected hand dug wells in southern part of Bosso Local Government Area in Niger State and will be thus compared with the World Health Organization Standard for drinking water quality and the F.A.O standard.

From the physical analysis of the result, it is seen that the pH of the wells are within the limits of the World Health Organization standard for drinking water quality and also the F.A.O standard. The values for the turbidity of the well samples are out of range except for the well sample from Gidan Painti Village which is 4.00FTU. High turbidity values in these wells are indications of high-suspended materials, algae and aquatic microscopic organisms (Clesceri, 1989). It might also be as a result of inert clay or chalk particles or the precipitation of non soluble reduced iron and other oxides when water is pumped from anaerobic waters (W.H.O, 2011). The colour of the water samples are also out of range. This may be due to the presence of coloured organic matter associated with the humus fraction of the soil or contamination of the water source with industrial effluent. The value of the total dissolved solids (TDS) for all the wells is within the standard value. Thus based on this, the water from the wells has no taste since the total dissolved solids can have an important effect on the taste of drinking water. The electrical conductivity of all the wells are also within the expected value, so therefore may be good to conduct electrical current and it is also related to the total dissolved solids (Harley, 2004).

For the chemical analysis, all the water samples were found to be within the reasonable limit of hardness except for the water sample of Tangidi Village which have the value of 230Mg/l. The mean value of the total hardness is within the standard of the international standard. The hardness is as the result of the dissolution of limestone deposit that underlies most parts of the settlements, which produce calcium trioxocarbonate ($CaCO_3$), and the excess concentration of calcium makes water hard. This means that the water will have the problem of poor lather formation and scale deposition in hot water heaters and low pressure boilers. The mean value of the total alkalinity is also within the range of the threshold value of the World Health Organization. Although total alkalinity of the water does not really have a guideline value which means that it does not have serious health implication on water, it might be dangerous to human body system when in excess.

The international standards does not have a standard value for phosphate however, a save limit of phosphate concentration in uncontaminated water in the range of 0.01-0.03mg/l has been established (Izonfuo and Bariweni, 2001). The sulphate values for all the well samples were also found to be within the range of the standard though it has been found that sulphate is one of the least toxic anions which only in high concentrations can cause catharsis, dehydration and gastrointestinal irritation when consumed. Nitrate values of the wells are also within the required standard except for the well in Tangidi Village (238.68 mg/l) which may be due to agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks (W.H.O, 2011). It is being caused by the movement of the pollutants from the surface water to the groundwater bodies through erosion and sedimentation of soil particles, surface run off, subsurface flow, infiltration, and percolation in the soil (Egharevba, 2009). Its contamination may also be as a consequence of leaching from natural vegetation. This also makes the nitrite value high which makes the water unsafe for drinking because it has been seen that nitrite can cause serious illness and sometimes death in infants less than six months of age.

All the well samples met the acceptable limit of iron. There is no noticeable taste at iron concentration below 0.3mg/l, although turbidity, deposits and colour may develop. At levels above 0.3 mg/l, iron stains laundry and plumbing fixtures. The chloride concentrations of all the well samples were relatively low compared to the standard. However, chloride concentration in excess of 250mg/l can give rise to detectable taste in water and can also cause corrosion. No traces of chromium were found in all the samples. The copper concentration level in all the water samples were also in the acceptable limit of the international standards though excess concentration of copper above 1mg/l can cause staining of laundry and sanitary wares and can also impart a colour and an undesirable bitter taste to water.

For the microbial analysis, the e-coli and the total coliform of all the well samples are extremely too high. This is due to the presence of bacteria organism found in the water that are subject to faecal contamination, whether from humans, agriculture and birds. It is also observed that exposure of the water to natural hazards and lack of treatment causes the presence of the bacteria in the water. Due to this, it was observed that there are prevalence of water borne diseases like cholera, dysentery, e.t.c. in these areas because of the presence of the bacteria in their drinking water. It was also observed that the contamination is not from the water source itself but from the environment in which the well water is being located. Such causes of contamination can results from the proximity of dumpsites to the well, excreta waste from human and animals in the surrounding and the flow and infiltration of waste water which is as a result of human activities in the area which may seep into into the groundwater. Thus, this simply means that all the water samples are unfit for drinking.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the study of the water samples collected, the following can be deduced from the analysis

1. The values of some physico-chemical parameters of the well samples studied are higher than the recommended limits of the World Health Organization standard and the Nigeria Standard for. Drinking Water Quality which is an indication of pollution hazards.
2. The microbiological parameters (bacteria and total coliform) are extremely very high which is as a result of faecal contaminations of the well samples studied.
3. The high values of these parameters may have implications on human health as these wells are the main source of drinking water to the residents. This tends to have serious effect since it can cause water borne diseases like cholera, typhoid, e.t.c which can also lead to increase in mortality.
4. All the water samples are therefore unsuitable for drinking and cooking due to the high values of these parameters.

5.2 Recommendations

Based on the study on the water samples collected, the following recommendations are suggested

1. Wells should not be dug near contamination sources and the wells should always be properly lined and covered.
2. The well water should be treated properly from time to time.

3. The government should provide a portable borehole water for the villages as this will assure a better and hazard-free water supply.
4. The communities or villages should be enlightened on the effects of contaminated water and should be encouraged to keep their environment clean.
5. Further research works should be conducted on the sampled wells for proper monitoring to cover all seasons and over a long period of time.

REFERENCES

Advameg (2011). Landfills: Impact on Groundwater. www.waterencyclopedia.com. Retrieved on 20th April

American Public Health Association (1989). Standard Methods for the Examination of Water and Waste Water. 17th Edition. Pp 3-5

Boulding and Russell, J., (1995). Practical Handbook of Soil, Vadose Zone, and Ground-water Contamination: Assessment, Prevention, and Remediation. Boca Raton, Lewis Publishers, Pp 3-5

Clesceri, L.S. (1989). Standard Methods for the Examination of Water and Wastewater. 17th Edition, American Public Health Association, Washington, DC., USA, Pp 1624

Cosgrove, W.J. and F.R. Rijsberman (2000). World Water Vision: Making Water Everybody's Business. Earthscan Publication Ltd, UK., Pp 108.

Davies, F., David, T., Nester, T. and O'neil, K. (2002). Environmental Impacts of Groundwater Overdraft. *Environmental Geology*. 47:396-404

Degremont G. and Mond J. (2001). Water Treatment Handbook. Vol. 1. 4th Edition. Pp 76-81

Dingman, C. (2002). Assessment of Drinking Water in Gzaipat, India. *Journal of Water Resources.* 12(4):11-15

Efe, S. I. (2005). Quality of Water From Hand Dug Wells in Onitsha Metropolitan Area of Nigeria. *The Journal of Earth and Environmental Science.* Vol 25, 1: 5 - 12

Egharevba, N. A. (2009). Irrigation and Drainage Engineering: Principles, Design, and Practices. *Jos University Press*. Pp 54-55, 62

Environmental Protection Agency, (2003). Groundwater Contamination in the United States, Philadelphia: University of Pennsylvania Press. Pp 200-208

Federal Ministry of Water Resources (2004). National Rural Water Supply and Sanitation: *A Strategic Framework. Department of Water Supply and Quality Control, Abuja*, Pp 48.

Fischer, A. (2002). Physiochemical Properties of Drinking Water in Selected Area of Darul-el-salam. *African Journal of Technology*. Pp 12

Gomez, J.D. and A.C. Nakat (2002). Community Participation in Water and Sanitation. Water Int., 27: 343-353.

Groundwater Foundation (2009). Groundwater Contamination Concerns, http://www.groundwater.org/gi/gcc.html

Gupta, B. K (2005). Physicochemical and Biological Study of Drinking Water in Satna, Madhya Pradesh. Poll. Res. 18:523-525

Hach DR/2000 Spectrophotometer Instrument Manual. Pp3

Harley, C. (2004). Water Quality in South Darkota. www.darkota.com

Hiscock, Lee, Z., Gan, C. and Yakoma, T. (1996). A Temperature Analysis of Groundwater Flow System in the Upper Part of the Ashigara Plain. *Tracers in Hydrology* 9(1):23-28

Izonfuo, L.W.A. and Bariweni, P.A. (2001). The Effect of Urban Run-off Water and Human Activities on Some Physico-chemical Parameters of the Epie Creek in the Niger Delta. *Journal of Applied Science Environment Management*,5: 47-55

Johnson, R. (2000)."MTBE: To What Extent Will Past Releases Contaminate Community Supply Wells?" *Environmental Science & Technology Journal*. Vol 34, Pp 9

Kelly, W. (1976). Groundwater Pollution Near a Landfill. J. Environ. Eng. Division. America Society, 102: 1189-1199.

Lee, G. Fred, and A. R. Jones. (1991). Landfills and Groundwater Quality. *Groundwater* 29:482–486.

Lenntech, B. V. (2009). Properties of Groundwater. http://www.lenntech.com/properties.html

Lexington, T. (2003).Importance of Groundwater pH. *Journal of American Sciences* 12:3-7

Mansfield, L. (2000). Different Sources of Groundwater Contamination

http://www.groundwater.org/index.html

Musa, S. M. (1996). Groundwater Hydrology and Wells. Unpublished Seminar Paper Presented to the Department of Agricultural Engineering, University of Maiduguri, Nigeria, Pp 2-10

Natural Resources Centre Services (2003). Physiochemical Properties of Groundwater in Minnesota. http://www.nrcs.org/groundwater/groundwater.html

Obasi, R. A. and Balogun, O. (2001). Water Quality and Environmental Impact Assessment of Water Resources in Nigeria. *African Journal of Environmental Studies*. 2(2): 232-235

Obiefuna G.I. and Sheriff A. (2011). Assessment of Shallow Ground Water Quality of Pindiga Gombe Area, Yola Area, NE, Nigeria for Irrigation and Domestic Purposes, *Research Journal of Environmental and Earth Sciences* 3(2): 131-141

Ogedengbe, K. (2004). Introduction to Agricultural Engineering. 1st Edition. Stirling Hoden Publishers, Ibadan, Nigeria. Pp 24-25

Orebiyi, E. O. (2010). Assessment of Pollution Hazards of Shallow Well Water in Abeokuta, *American Journal of Environmental Sciences* 6 (1): 50-56

Quddus, K.G. and Zaman, M. W. (1996). Irrigation Water Quality in Some Selected Villages of Meherpur in Bangladesh. J. Agric. Sci., 23(1): 51-57

Raihan, F. and Alam, J. B. (2008). Assessment of Groundwater Quality in Sunamganj of Bangladesh. *Iran. J. Environ. Health. Sci. Eng.*, Vol. 5, No. 3, pp. 155-166

Sarkar, A. A. and Hassan, A. A. (2006). Water Quality Assessment of a Groundwater Basin in Bangladesh for Irrigation Use. *Pakistan Journal of Biological Sciences*, (9):1677-1684.

Sawyer, C., Shan, H. and Cole, H. (2003). Interactions Between Groundwater and Surface Water: The State of the Science, *Hydrogeology Journal*, 10:52-67

Schewab, G. O., D. D., Fangmeier, W. J. Elliot and R. K. Fresuert (1992). Soil and Water Conservation Engineering. 4th Edition. New York. Pp 256-265

Seamus, C. (2000). Hand Dug Shallow Wells; Series of Manual on Drinking Water Quality. Vol. 5, Pp 15-17

Shahidullah, S.M., M.A. Hakim, M.S. Alam and A.T.M. Shansuddoha, (2000). Assessment of Groundwater Quality in a Selected Area of Bangladesh. Pak. J. Biol. Sci., 3(2): 246-249

Shelton, T. B. (1995). Interpreting Drinking Water Quality Analysis: What do the numbers mean? *Rutgers Co-operative Extension. Pp 2*

Somjai, K. and K.T.I. Suporn, (1993). Monitoring and Evaluation of Shallow Well Water Quality Near a Waste Disposal Site. Environ. Int., 19: 579-587.

Stephen P. Abott (1996). A Manual of Hand Dug Well Construction and Organization

Talukder, M.S.U., S.M. Shirazi and U.K. Paul, (1998). Suitability of Groundwater for Irrigation at Kirimganj Upazila Kishoreganj. Progress Agric., 9: 107-112.

Tekwa, I. J. Abbal, M. U. and Ray, H. H., (2006). An Assessment of Dug-well Water Quality and Use in Mubi, Nigeria, *Journal of Sustainable Development in Agriculture and Environment* 2(1). Pp 1-5

Thomas, H. (1989). Water Well Design and Construction, University Of California Division of Agriculture and Natural Resources, Publication 8086

United Nations Environmental Programme (UNEP) (2002). Global Environmental Outlook (GEO-3), Pp 416

UNICEF, (2005). National Rural Water Supply and Sanitation Investment Programme. Final draft, Pp 1

USEPA, (1990). Citizen's Guide to Groundwater Protection. United States Environmental Protection Agency, 440/6-90-004.

United States Environmental Protection Agency (2006). Washington, DC. "Water Quality Standards Review and Revision."

Waite, W. M (1997). Assessment of Water Supply and Associated Matters in Relation to the Incidence of Cryptosporidiosis in Torbay in August and September 1995. *Drinking Water Inspectorate*, London, pp 15-17

WaterAid's Health and Safety Policy (2000). Publication of Hand Dug Wells. www.wateraid.com. Retrieved on 24th July

Watts, S. B. and Wood, W. E., (1985). Hand Dug Wells and Their Construction. Intermediate Technology Publications, Southampton Road, London. Pp 21-25

Wiedemeier and Todd H. (1999). Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface. John Wiley & Sons Ltd, New York. Pp 26-29

Wikipedia (2010). Groundwater. http://en.wikipedia.org/wiki/groundwater

World Health Organization, (2011). Guidelines for Drinking Water Quality. Fourth Edition

Zanoni, A.E. and A. A. Fungaroli, (1973). Potential for Ground Water Pollution from the Land Disposal of Solid Wastes. Crit. Rev. Environ. Sci. Technol., 3: 225-260.

Zekster, I. S. and Everett, L. G. (2004). Groundwater Resources of the World and Their Uses: Series on Groundwater. No 6 UNESCO (United Nations Educational Scientific and Cultural Organization). Pp 342

APPENDIX

NIGER STATE WATER BOARD

Western By-Pass, P.M.B. 70, Minna, Niger State, Nigeria.
☎:066-221526 Fax: 224590 E-mail:nigerstatewaterboard@yahoo.co.uk

Ref.

Date:

OGUNFOLOBI OLAWALE MOSHOOD (2006/24117EA)
DEPARTMENT OF AGRIC & BIORESOURCES ENGNR'G
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

25TH MAY, 2011

PHYSICO-CHEMICAL AND BACTERIOLOGICAL ANALYSIS OF WATER SAMPLES

S/N	PARAMETER	TANGIDI	SABON DAGA	GIDAN PAINTI	NSDWQ
1	Turbidity (FTU)	7.00	12.00	4.00	5.00
2	Colour (PtCo)	40.00	62.00	20.00	15.00
3	Suspended Solids (mg/L)	4.00	9.00	2.00	NS
4	Electrical Conductivity (us/cm)	750	320	220	1000
5	Total Dissolved Solids (mg/L)	380	160	110	500
6	pH	6.62	6.58	6.73	6.5-8.5
7	Total Hardness (mg/L)	230.00	145.00	75.00	150.00
8	Calcium Hardness (mg/L)	190.00	77.00	41.00	NS
9	Magnesium Hardness (mg/L)	40.00	68.00	34.00	NS
10	Total Alkalinity (mg/L)	68.00	167.00	121.00	NS
11	Hydroxide Alkalinity (mg/L)	0	0	0	NS
12	Carbonate Alkalinity (mg/L)	0	0	0	NS
13	Bicarbonate Alkalinity (mg/L)	68.00	167.00	121.80	NS
14	Phosphate (mg/L)	0.20	0.52	1.21	NS
15	Sulphate (mg/L)	36.00	1.00	1.00	100.00
16	Nitrate (mg/L)	[illegible]	[illegible]	8.84	50.00
17	Nitrite (mg/L)	0.30	[illegible]	0.01	0.2
18	Iron, Fe^{2+} (mg/L)	0.04	0.02	0.60	0.30
19	Chloride (mg/L)	92.97	17.49	17.49	250.00
20	Chromium, Cr^{6+} (mg/L)	0.00	0.00	0.00	0.05
21	Temperature (°C)	22.5	25.6	25.4	Ambient
22	Nitrite as N (mg/L)	0.09	0.006	0.003	NS
23	Copper (mg/L)	0.07	0.01	0.00	1.00
24	E. Coli (cfu/100mL)	260	120	240	0
25	Total Coliform (cfu/100mL)	280	1,160	520	10

NSDWQ- Nigerian Standard for Drinking Water Quality
NS- Not Stated

Mr. Daniel S. Nisa
O/C Quality Control Laboratory,

25 MAY 2011