ANALYSIS OF GROUNDWATER QUALITY: A CASE STUDY OF BOYS HOSTEL BOREHOLE, FUT, BOSSO CAMPUS, MINNA

BY

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2003/14884EA

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FEBRUARY, 2010

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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, 2010

DECLARATION

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

Salawu K. Mutiu	18/02/10 Date

CERTIFICATION

This is to certify that "Analysis of Groundwater Quality: A Case Study of Boys Hostel Borehole, FUT, Bosso Campus, Minna" 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.

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DEDICATION

; work is dedicated to Almighty Allah for sparing life up till this moment.

ACKNOWLEDGEMENTS

First of all, I thank Almighty Allah for sparing my life to this moment and given the urage and strength to accomplish this noble project.

I also appreciate the effort my supervisor Engr. Mrs H. I. Mustapha for the tremendous ontributions and supervision of my project work in spite of her numerous commitments in her cademic pursuit, she had taken pains to assist and guide me on the work. I will also appreciate he effort our project coordinator Engr. Dr. O. Chukwu for taking to his time to explain how to arrange project and given project format. I say thank you sir. I appreciate the assistance of level adviser Engr. Sadiq, also the effort of Head of Department Engr. Dr. A. A. Balami.

Mt appreciation goes to my wife and children Ameenah, Hassanah, Fatiah for their support during my course of study in school. I say Jazakumllahu Khayran.

I also appreciate my parents Mr and Mrs Salawu, also my brother, Ismail, my sister Wakila Funmilayo, Mutiat, Ganiyat, Kafayat and Saidat for their moral and psychological support. I say a big thank you to you all.

The acknowledgement will not be complete without mentioning my friends Alfa Dauda, Alfa Taofeeq, Akeeb, Alfa Awwal and Abdul Fatai.

ABSTRACT

ɔundwater is one of the major supplies of drinking water in Federal University of Technology, ınna for students. The groundwater quality of borehole besides dining hall, Federal University Technology, Minna (Bosso Campus) was analyzed for physical and chemical parameters. The ılues of the parameters obtained from analyses were pH was 6.53, electrical conductivity was ≀8µS/cm, total dissolved solid was 200mg/l, total hardness of was 200mg/l, hardness was 0.20mg/l, calcium was 7.64mg/l, biochemical oxygen demand was 0.51mg/l and chemical xygen demand was 70pl, potassium was 1.32, sodium was 12.5, Manganese 0.50ppm, Copper vas 0.02, Iron was 0.01ppm and lead 0.01ppm were within the prescribed range recommended ɔy WHO. All values that have no guidelines means that it does not have any serious health implication according to WHO (1993). This showed that this water is safe for drinking and cooking for students.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Water plays a vital role in human life and without water biochemical reaction cannot take place in plants, animals and human beings. Ground water is the source of high – quality water for most communities in developed and developing countries. Groundwater includes wells, boreholes, underground run off, lakes, stream, river etc. Ground water is used to irrigate crops, thus increasing the value of land and crops in many parts of the United States. Water level is pumped from the ground for use, it has to come from somewhere from the soil profile strata. Water levels in wells may go down, there may be less stream flow, less water available for plants, or lower water levels in wetlands or lakes. This means that other users and other resources may be affected when ground water is used (Leete *et al.,* 2004; Pandey and Tiwari, 2009).

The acute shortage of potable water for domestic consumption in developing countries is a reality of the day. It has been reported by WHO that over one and a half billion people across the globe drink contaminated water and about 3.4 million people, majority of them children die annually of water contracted diseases or poisoning from heavy metals such cadmium, lead, arsenic etc (Jones, 2001). The consequence of urbanization, industrialization and improper use of fertilizer leads to contamination of the water. In addition to the problem of industrial and agricultural pollution, the levels of microbiological contaminants especially in natural waters continue to increase (Ayalogu *et al.*, 2001). Most groundwater originates from rainfall that has entered the earth. A typical situation with water saturated soils (overburden aquifer) over a bedrock aquifer. In the over burden aquifer, water fills the void space between grains and soil.'Bedrock quifers underlie the surface soils (overburden) and overburden aquifers. In the bedrock quifers, water occurs in fractures and other voids in the bedrock. Some types of bedrock uch as sandstone may also have additional voids (intergranular voids) that are fill with groundwater. As in the case for surface water, groundwater flows from higher elevations or pressures) toward lower elevations (or lower pressures). Groundwater flow is usually toward groundwater discharge area. Groundwater pressure, rather than elevation, controls the rate and direction of flow in confined (or artesian) aquifers. Those are aquifers that are isolated under impervious or poorly pervious strata (Gleick, 2009).

For agricultural purposes ground water is explored in rural areas especially in those areas where other sources of water like dam and river or a canal is not available. During last decade, it was observed that the underground water get polluted drastically because of increased human activities. Consequently, number of cases of water borne diseases has been seen which a cause of health hazards (Sirkar, 1996; WHO, 1999; Cole and Naik, 2005). So, basic monitoring on water quality has been necessitated to observe the demand and pollution level of ground water. A good number of water analysis experiments are regularly conducted by different groups of chemists and biologists across the country (WHO, 1999).

1.2 Statement of the problem

Ground water is ultimate, most suitable freshwater resource with nearly balanced concentration of salts for human consumption. Over burden of the population pressure (increase in student intake by school authorities), unplanned location of public toilets in school area (Bosso Campus), unplanned urbanization, unrestricted exploration policies, dumping of polluted water and solid in appropriate place enhance the infiltration of harmful compounds to ground water.

1.3 Aims and objectives

The aim of this project is to analyze ground water (Boys' hostel borehole, Bosso campus, Federal University of Technology, Minna, Niger State). The specific objectives are:

i. To carryout qualitative analysis of the borehole water located near the dining hall (cafeteria).
ii. To identify hazardous chemical contents
iii. To know sources and level of contamination of the borehole, possible way of reducing them.

1.4 Justification of the study

Ground water (borehole) is the only quality water that is available for students in the campus (Bosso). Municipal water supply which is another source of water to the student in Bosso campus is not readily available. It is unsafe for consumption because of its brown colour and odour. Because of the proximity of the borehole to the hostel and cafeteria, students find it easy to fetch water for drinking and cooking. Due to high dependency of students on this borehole, this has necessitated or prompts for this project which would carry out analysis on the borehole water. This project analyzed the water sample collected from the borehole and the findings from the work would serve as recommendations for the appropriate actions by the school authority if necessary.

1.5 Scope of the study

The project will carry out analyses of water samples from the borehole. The water samples would be collected during wet season, (May, 2009) from the borehole near dining hall in Bosso Campus, Federal University of Technology. The water samples collected from the borehole would be analyzed for the physicochemical analysis to know the physical and chemical properties of the borehole. The physical parameters of water sample include the pH (alkalinity and acidity), hardness, total dissolved solids (T.D.S), dissolved oxygen (D.O), Density etc. The chemical parameters of the water will also be determined; the chemical parameters include chlorine (Cl), sodium (Na), potassium (K) and some selected heavy metals. Microbiological safety of the water may also be determined to know if the water source (borehole in near dining hall) contributes to morbidity (sickness of students) in the school environment. The local or map of the study area can be included in the project. The results of the findings could be subjected to statistical analysis to know the level of significant of contamination of the borehole.

CHAPTER TWO

LITERATURE REVIEW

Groundwater is potable water which is stored underground. It can be confined, which means that a deposit of water is surrounded by non-permeable rock, or unconfined, in which case it is surrounded by permeable rock, gravel, soil, and other materials. Around 20% of the worlds freshwater is groundwater, and groundwater makes up a significant portion of the potable water consumed worldwide, with up to 50% of some populations relying on groundwater for drinking, bathing, industrial production, and a variety of other tasks (Smith, 2009).

A number of things can lead to the development of a groundwater formation. Rainfall, for example, drains into the ground and into deposits of groundwater, and runoff from rivers, streams, and lakes also winds up in the world's groundwater. Groundwater levels are also supplemented by snow melt and melting glaciers, and the supply may be seasonal, depending on high rainfall and snow melt to supply groundwater in the spring, with supplies which dwindle in the late summer and fall. When a deposit of groundwater can be used sustainably as a water source by humans, it is known as an aquifer. Many people try to seek out contained aquifers, because the quality of the groundwater tends to be better when it is contained. Contained aquifers are at less risk of pollution, making the water safer to drink. In an unconfined aquifer, water can be tainted with chemicals, biological agents, faeces, and other materials which are not desirable in drinking water (Groundwater Foundation, 2009; Smith, 2009).

One of the most common ways to access a deposit of groundwater is a well. Wells are drilled down into deposits of groundwater and pressurized so that the water bubbles to the surface, allowing people to use it. People can also dip buckets into wells to collect the water, as has been done historically. It is also possible to access groundwater through springs, which periodically bubble up with fresh groundwater. Historically, settlements have often been constructed around springs, to save the cost of sinking a well to supply a community. Sometimes, a water source dries up. This happens when the aquifer is so depleted that it cannot provide water anymore. Sometimes, drilling deeper can solve the problem, by accessing the bottom of the aquifer. In other instances, a well or spring may refill itself at a later juncture, after the aquifer has had a chance to recover. Abandoned wells are viewed as a safety risk in some areas, since the lack of maintenance can result in an uncovered well which people or animals could fall into it (Smith, 2009).

2.1 Properties of groundwater

i. **Composition:** The geological 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 a 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

Characteristic	Surface Water	Ground Water
Temperature	varies with season	relatively constants
Turbidity, SS	Level variable, sometimes high	Low or nil (except in karst soil)
Colour	Due mainly to SS (clays, algae) except in very soft or acidic waters (humic acids)	Due above all to dissolved solids
Mineral content	Varies with soil, rainfall, effluents, etc.	Largely constant, generally appreciably higher than in surface water from the same area
Divalent Fe and Mn in solution	Usually none, except at the bottom of lakes and ponds in the process of eutrophication	Usually present
Aggressive CO_2	Usually none	Often present
Dissolved O_2	Often near saturation level, absent in very polluted water	Usually none
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
Mineral and organic micro-pollutants	Can be present but liable to disappear rapidly once the source is removed	Usually none but any accidental 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 most 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).

ii. **Discharges and velocity:** The rate at which groundwater moves through the saturated zone 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:

$$V = \frac{K(h_2 - h_1)}{L} \quad \text{eqn 2.1}$$

Where,

K is the coefficient of permeability. If we multiply this expression by the area, A (m^2), through which the water is moving, then we get the discharge Q (*Darcy's Law*).

$$Q = \frac{AK(h_2 - h_1)}{L} \quad \text{eqn 2.2}$$

h = Height (m), K is still the coefficient of permeability, Length (m)

iii. **Springs and wells:** A *spring* is an area on the surface of the Earth where the water table intersects the surface and water flows out of the ground. Springs occur when an impermeable rock (called an aquiclude) intersects a permeable rock that contains groundwater (an aquifer) Fig 1(Lenntech, 2009). The occurrence of springs is closely related to the geology of an area. If an impervious layer of rock, such as a clay deposit, underlies a layer of saturated soil or rock, then a line of springs will tend to appear on a slope where the clay layer outcrops (The part of a rock formation that appears above the surface of the surrounding land) (Lenntech, 2009). Igneous rocks are also impervious to water, yet they are often extensively fractured, and springs commonly appear where these fractures come to the surface. Fractures in limestone are often enlarged by the dissolving action of groundwater, forming small underground channels and caves. A *well* is human-made hole that is dug or drilled deep enough to intersect the water table. If the well is dug beneath the water table, water will fill the open space to the level of the water table, and can be drawn out by a bucket or by pumping. An *artesian well* is a deep drilled well through which water is forced upward under pressure Fig 2. The geologic conditions necessary for an artesian well are an inclined aquifer sandwiched between impervious rock layers above and below that trap water in it. Water enters the exposed edge of the aquifer at a high elevation and percolates downward through interconnected pore spaces. The water held in these spaces is under pressure because of the weight of water in the portion of the aquifer above it. If a well is drilled from the land surface through the overlying impervious layer into the aquifer, this pressure will cause the water to rise in the well. In areas where the slope of the aquifer is great enough, pressure will drive the water above ground level in a spectacular, permanent fountain (Lenntech, 2009).

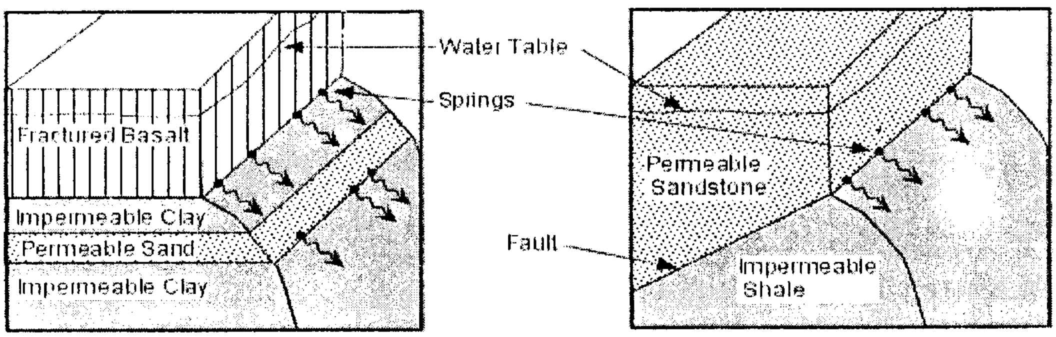

Fig 1: Spring

Source: Lenntech (2009)

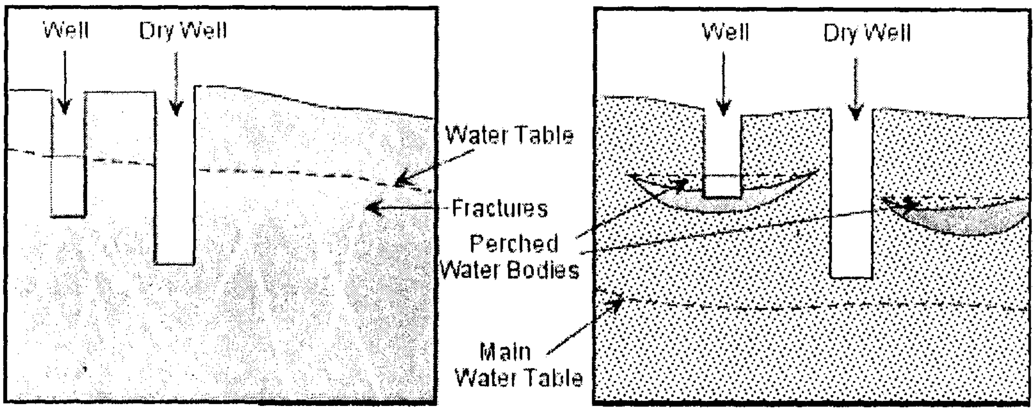

Fig 2: Well

Source: Lenntech, (2009)

2.2 Physicochemical Properties of Groundwater

Groundwater quality comprises the physical, chemical, and biological qualities of ground water. Temperature, turbidity, colour, taste, and odor make up the 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 (Natural Resources Centre Services, (NRCS), 2003).

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 (Natural Resources Centre Services, (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 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 (Environmental Protection Agency, (EPA), 2003). 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 (EPA, 2003).

2.2.1 pH

Groundwater pH is a fundamental property that describes the acidity and alkalinity of groundwater and largely 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 standards exist for pH. However, water with a pH that is outside the range 6.5 to 8.5 can lead to high concentrations of some dissolved metals, for which there are drinking water standards, as well as potentially harmful health effects (Fisher, 2002).

2.2.2 Electrical conductivity

Electrical conductivity (EC) is a useful indicator of total 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 contributions of precipitation and subsurface water in stream hydrograph (Kobayashi, 1986), and for the dilution gauging 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 (Yechieli *et al.*, 2001).

2.2.3 Biochemical Oxygen Demand (BOD) or Chemical Oxygen Demand

Biochemical oxygen demand or biological oxygen demand (BOD) 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, 2009). When ground water or surface water is polluted severely by infiltration of wastewater from industries, the BOD can increase. The BOD of ground water in developed countries (Europe and U.S.A) are usually because of high density of industries which release their wastewater to the environment (Sawyer *et al.*, 2003).

2.3 Sources of Groundwater Contamination

Groundwater contaminants can be divided between micro-organisms (biological contaminants) and inorganic contaminants (Davies *et al.*, 2002). Groundwater contamination occurs when man-made products such as gasoline, oil, road salts and chemicals get into the groundwater and cause it to become unsafe and unfit for human use. Some of the major sources of these products, called contaminants, are storage tanks, septic systems, hazardous waste sites, landfills, and the widespread use of road salts, fertilizers, pesticides and other chemicals (Fig 2.1) (Groundwater Foundation, 2009).

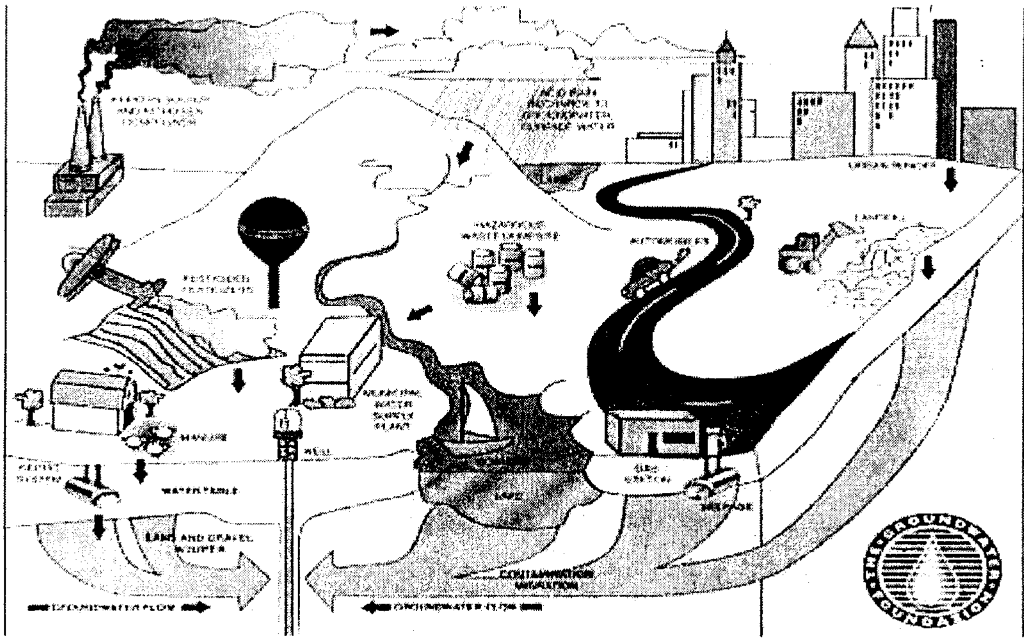

Fig 2.1: Sources of groundwater contamination.
Source: Mansfield (2000)

Storage tanks may contain gasoline, oil, chemicals, or other types of liquids and they can either be above or below ground. There are estimated to be over 10 million storage tanks buried in the United States and over time the tanks can corrode, crack and develop leaks. If the contaminants leak out and get into the groundwater, serious contamination can occur. Septic systems can be another serious contamination source (Masaki, 2009). Septic systems are used by homes, offices or other buildings that are not connected to a city sewer system. Septic systems are designed to slowly drain away human waste underground at a slow, harmless rate. An improperly designed, located, constructed, or maintained septic system can leak bacteria, viruses, household chemicals, and other contaminants into the groundwater causing serious problems (Ben, 2006; Masaki, 2009). In the United States today, there are thought to be over 20,000 known abandoned and uncontrolled hazardous waste sites and the numbers grow every year. Hazardous waste sites can lead to groundwater contamination if there are barrels or other containers laying around that are full of hazardous materials. If there is a leak, these contaminants can eventually make their way down through the soil and into the groundwater (Mansfield, 2000; Gupta, 2005; Ben, 2006).

Landfills are another major source of contamination. Landfills are the places that our garbage is taken to be buried. Landfills are supposed to have a protective bottom layer to prevent contaminants from getting into the water. However, if there is no layer or it is cracked, contaminants from the landfill (car battery acid, paint, household cleaners, etc.) can make their way down into the groundwater (Mansfield, 2000; Gupta, 2005). The widespread use of road salts and chemicals is another source of potential groundwater contamination. Road salts are used in the wintertime to put melt ice on roads to keep cars from sliding around. When the ice melts, the salt gets washed off the roads and eventually ends up in the water. Chemicals include products used on lawns and farm fields to kill weeds and insects and to fertilize the plants. When the rain comes, these chemicals get washed into the ground and eventually into the water (Waikato Regional Council, (WRC), 2007). Since groundwater is part of the hydrologic cycle, contaminants in other parts of the cycle, such as the atmosphere or bodies of surface water, can eventually be transferred into our groundwater supplies (WRC, 2007).

2.4 Groundwater Contamination Concerns

Fifty (50%) percent of the United States population depends on groundwater for daily drinking water (Contamination Foundation, 2009). In Nigeria, between 70 - 80percent depend ground water for different uses. Most of the ground water are wells and stagnant water (WHO, 2008). 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 (Mansfield, 2000).

2.5 Pollutants Can Seep into 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. To read about other ways groundwater can become contaminated (Contaminated Foundation, 2009).

2.6 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).

2.7 Landfills and ground water

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 wastes. 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 (Cater, 2008). Municipal solid waste (MSW) landfills accept nonhazardous 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, 2007).

2.7.1 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 and 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, 2007; Cater, 2008).

2.8 Groundwater Movement

The water table (or the potentiometric surface of a confined aquifer) is not a flat surface: rather, there are high areas and low areas just like the hills and valleys found on land. Just as surface water tends to flow downhill, groundwater tends to move downgradient from water-table areas (or potentiometric regions) of higher elevation to water-table areas (or potentiometric regions) of lower elevation (Advameg, 2007). Normally, but not exclusively, the higher water-table areas of unconfined aquifers coincide with higher elevation at the land surface, and the lower water-table areas coincide with low areas. As a result, groundwater in unconfined aquifers tends to flow towards, and discharge to, streams, lakes, and wetlands, because these water bodies often occur in low points of the watershed. Even groundwater from confined aquifers tends to discharge to larger area-wide rivers (Advameg, 2007).

Two other common discharge areas for groundwater are springs and wells. A spring is an area where groundwater has access to the land surface. In some cases, precipitation infiltrating downward from the ground surface encounters a relatively impermeable rock or sediment layer as it moves down toward the underlying aquifer. The groundwater, which cannot pass through the low-permeability layer, moves along the top of the layer until the layer is exposed at the ground surface and the water can emerge as a spring. In this typical "gravity spring," the most common form of spring, gravity is the driving force for water movement. Such springs commonly occur at the side of a hill, or at an outcrop such as a bluff or canyon wall. In other cases, fractures allow groundwater to move from the aquifer to the surface. Groundwater from a spring can issue onto the land surface, or directly into a stream, lake, or ocean (Heath, 2003). A well also provides a connection between groundwater and the land surface (Heath, 2003). In general, a pump is used to draw the groundwater up to the land surface where it can then be used.

2.8.1 Flow Rate

When referring to how fast surface water moves, experts (hydrologists) generally talk in terms of either meters or feet per second. Groundwater moves much more slowly than water in streams, often at rates of only a few centimeters (inches) per day. Groundwater velocity is controlled by the permeability of the aquifer and steepness of the water table (or potentiometric surface). The more permeable the aquifer and the steeper the slope of the water table or potentiometric surface (i.e., the pressure gradient), the faster groundwater moves. In highly permeable gravels or in fractures, groundwater may move 10 meters (33 feet) per day or more (Advameg, 2007).

2.9 The Hydrologic Cycle

From the time the earth was formed, water has been endlessly circulating. This circulation is known as the hydrologic cycle. Groundwater is part of this continuous cycle as water evaporates, forms clouds, and returns to earth as precipitation (Groundwater Foundation, 2009).

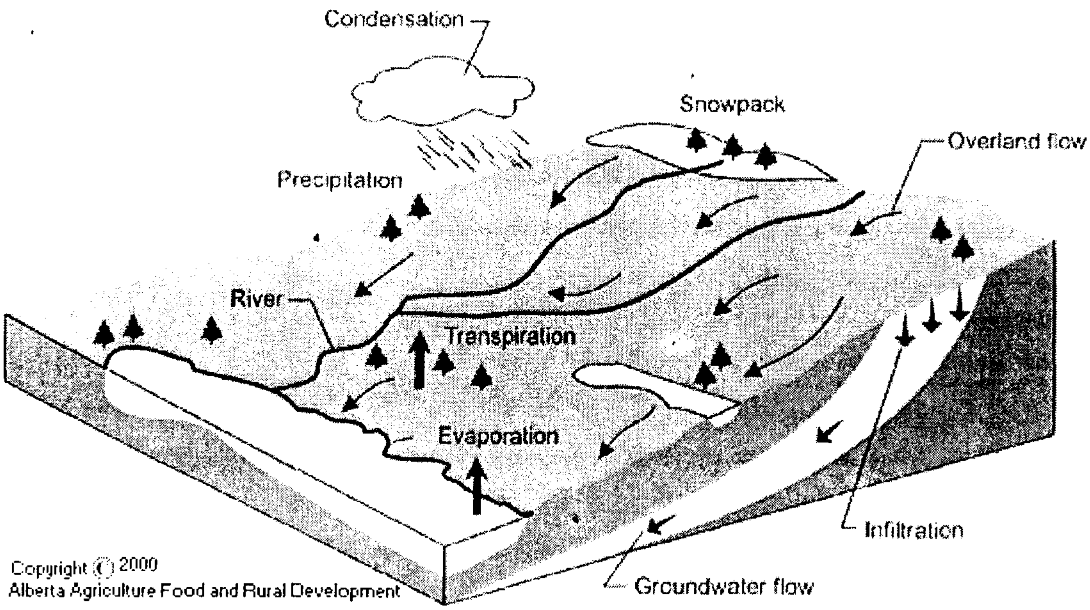

Fig 2.2: Hydrologic Cycle

Source: Alberta Agriculture Food and Rural Development (2000)

2.9.1 The Process of Hydrologic Cycle

Surface water is evaporated from the earth by the energy of the sun. The water vapor forms clouds in the sky. Depending on the temperature and weather conditions, the water vapor condenses and falls to the earth as different types of precipitation. Some precipitation runs from high areas to low areas on the earth's surface. This is known as surface runoff. Other precipitation seeps into the ground and is stored as groundwater (Groundwater Foundation, 2009).

2.9.2 Defining Groundwater

Think of groundwater as water that fills the spaces between rocks and soil particles underground, in much the same way as water fills a sponge. Groundwater begins as precipitation and soaks into the ground where it is stored in underground geological water systems called aquifers. Sometimes groundwater feeds springs, lakes, and other surface waters, or is drawn out of the ground by humans through wells. The water then can evaporate, form clouds, and return to the earth to begin the cycle over again (Groundwater Foundation, 2009).

2.10 Hydraulic conductivity

Hydraulic conductivity, symbolically represented as K, is a property of vascular plants, soil or rock, that describes the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity, K_{sat}, describes water movement through saturated media. One application of it is the Starling equation, which calculates flow across walls of capillaries (Wikipedia, 2009).

2.11 Factors Affecting Groundwater Quality

An understanding of the factors that affect groundwater quality can help you make decisions on well depth and the best water quality for a particular application. There are several factors that affect groundwater quality:

- Depth from surface
- Permeability and chemical makeup of the sediments through which groundwater moves
- Climatic variations.

2.11.1 Depth from surface

Water is the world's greatest and most abundant solvent. It attempts to dissolve everything it comes in contact with. As a result, the longer groundwater takes to move through the sediments, the more mineralized it becomes. Thus, shallow groundwater aquifers have a lower level of mineralization, or total dissolved solids (TDS), than deeper aquifers. Water from deeper groundwater aquifers typically has a much longer trip to its destination and thus it is usually more mineralized (Carter, 2008; Alberta Agriculture and Rural Development, 2008). While shallow wells have lower levels of TDS, they do have higher levels of calcium, magnesium and iron than deeper wells. High levels of these minerals make the water "hard." Deeper wells have higher levels of sodium and lower levels of hardness, making the water "soft." The reason is that deeper sediments and rock formations contain higher levels of sodium and as water moves downward through the sediment and rock formation, a natural ion exchange process occurs. Calcium, magnesium and iron in the groundwater are exchanged for sodium in the sediment and rock formations. The result is groundwater with higher levels of sodium and little or no hardness. The process is identical to what occurs in an automatic water softener, except in this case, it is a natural phenomenon (Alberta Agriculture and Rural Development, 2008).

2.11.2 Permeability of sediments

Groundwater moves very slowly through sediments with low permeability, such as clay. This allows more time for minerals to dissolve. In contrast, sediments with high permeability, such as sand, allow groundwater to move more quickly. There is less time for minerals to dissolve and thus the groundwater usually contains lower levels of dissolved minerals. There is also a difference in dissolved solids between groundwater in recharge zones and water in discharge zones. Recharge zones are uplands areas where precipitation readily enters the ground through permeable, sandier sediments. Generally, water in recharge zones has a low level of mineralization. Discharge areas are low areas where groundwater flow eventually makes its way back to (or near) the ground surface. Groundwater found in such areas can be extremely high in minerals such as sodium, sulphates and chlorides. Examples are saline seeps, sloughs and lakes (Alberta Agriculture and Rural Development, 2008).

2.11.3 Chemical makeup of sediments

Another factor affecting groundwater quality is the chemical makeup of minerals. Some chemicals are more soluble than others, making them more likely to become dissolved in the water. For example, groundwater in contact with sediments containing large concentrations of sodium, sulfate and chloride will become mineralized at a faster rate than if other chemicals were present.

2.11.4 Climatic variations

Climatic variations such as annual rainfall and evaporation rates also play an important role in groundwater quality. In semi-arid regions, discharging groundwater often evaporates as it approaches the surface. The minerals from the water are deposited in the soil, creating a salt buildup. Precipitation infiltrating through the soil can redissolve the salts, carrying them back into the groundwater. For example, in east central and southern Alberta where annual precipitation is from 25-40 cm (10-16 in.) and the evaporation rate is high, TDS are about 2500 parts per million (ppm). In areas with higher precipitation and lower evaporation rates, precipitation that reaches groundwater is less mineralized. For example, in western Alberta where annual precipitation is more than 45 cm (18 in.) groundwater in surficial deposits contains less than 800 ppm of TDS (Alberta Agriculture and Rural Development, 2008).

2.12 Analyzing Groundwater in Nigeria

Shekwolo and Brisbe (1999) investigated the Bacteriological properties of groundwater in parts of Niger State, Nigeria. He suggested that buried faeces or damaged sewers could be potential sources of contamination to the groundwater system, if wells are inadvertently sited in such areas. It is suggested that in developing countries, microbiological analysis of soil deposits be included in the exploration program for selection of a suitable drilling site, and in the general quality assessment for potability of water, particularly in urban areas that may be suspected to host potential contaminant sources. Olobaniyi and Owoyemi (2006) analyzed the chemical facies of groundwater in the Deltaic plain sands aquifer of Warri, Western Niger Delta, Nigeria. He collected 60 samples of water and analyzed for various parameters including pH, total dissolved solids (TDS), K, Na, Ca, Mg, Cl, HCO3 and SO4 after standard procedures. He found out that decrease in the concentration of ions(K, Na, Cl, Mg, Ca and HCO_3) that are predominantly responsible for the salinity of groundwater away from the banks. The implication of this is that groundwater quality improves away from the banks of River Warri. Also, Yerima *et al.* (2008) assess Groundwater Quality of Bama Town, Borno State, Nigeria. The results from their laboratory analysis revealed evidences of pollution from both chemical and biological sources. These were evident from high levels of nitrite (16 mg/l), manganese (0.9 mg/l) and *E. coli.* (4.0 n/100 mg). He concluded that boreholes and wells were more polluted in areas nearer to farms and sanitation units than the areas further away from them. Improper sanitation management and improper education for farmers on farming skills could be the major problem for groundwater quality of the study areas. Omofonmwan and Eseigbe (2009) Effects of Solid Waste on the Quality of Underground Water in Benin Metropolis, Nigeria. They found out that most of the water parameters tested fall within WHO recommendations while some are not. And recommendations are made to remedy the situations which include encouraging analysis of raw water, the need for enlightenment campaign, ground water exploration in Benin metropolis should be deep and the principle of resource management should be adhered to.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Description of the study area

The study area is located on latitude 9^0 37' north and 6^0 33'east, beside school dining hall, Bosso Campus, Federal University of Technology, Minna (Bosso Campus). The town (Minna) had a mean annual precipitation of 1300mm from an exceptionally long record of 50years. The highest mean monthly rainfall is September with almost 300mm. The raining season starts on average between April and lasts between 190 – 200days (October). Temperature rarely falls below 22^0C falls below 22^0C. The peaks are 40^0C (February – March) and 35^0C (November –December). This data were obtained from Geography Department, Federal University of Technology, Minna.

3.1.1 Climate

The climate of Minna 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 ends 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.

3.1.2 Topography

The area was steep sloppy, the soil found in this area was sandy loam classified as the oxic plaustalf type of soil. It is friable with low water retaining capacity it is slightly acidic in nature 4.9 – 5.6. It has high organic matter level. This data were obtained from Soil Science department of Federal university of Technology Minna

.2 Methodology

.2.1 Samplé collection

A sterile container of 1 litre was used to collect the water sample. The water was umped by using manual pumping machine. The sampling was carried out in the month f June, 2009. The borehole is 50m away from soak away and the soil sample is sandy oam.

.2.2 Physical parameters of water

Air and water temperatures were determined with a common mercury – in – bulb hermometer (-10 – 110^{0}C range). Air temperature is measured by holding the ermometer above the water surface for about 5minutes until it stabilizes before taking he reading. Water temperature was determined by lowering the thermometer into the vater in an inclined position for about 5 minutes to allow for equilibrium before taking eading.

.2.2.1 Total Hardness

This was determined by adding 1ml of ammonium chloride buffer solution to 0mls of water sample and followed by addition of 3 drops of Eriochrome black T ndicator. The resultant wine colour were titrated with 0.01N EDTA (ethylene – diamine tetraethanoic acid) titrant until a blue end point was observed.

$$\text{'otal hardness in mg/l as } CaCO_3 = \frac{\text{vol. of EDTA}}{\text{vol. of samples}} \qquad 3.1$$

2.2.2 Alkalinity

The alkalinity of the samples were determined by taking a known volume of ater sample in a clean conical flask, 2 drops of methyl orange indicator was added and aked. This was titrated with 0.2N sulphuric acid until colour of the solution changed from yellow to orange which marked the end point. The total alkalinity was calculated using the equation below:

$$\text{Total alkalinity mg/l} = \frac{\text{Vol.}(H_2SO_4) \text{ x molarity}(H_2SO_4) \text{ x } (100{,}000)}{\text{vol. of sample}} \qquad 3.2$$

3.2.2.3 Determination of dissolved gases

3.2.2.3.1 Dissolved Oxygen

This was determined by using Winkler – azide method. Water samples were collected in 250mls BOD stopper bottles and fixed them right on the field with 2ml of reagent (I) (Managanons sulphate) and 2ml of reagent (II) alkaline – iodide – solution) KOH + KI). 2mls of sulphuric acid was then be added to each sample in the laboratory and mixed gently. 10mls of the sample was titrated with 0.025N sodium thiosulphate in starch indicator and it turns colourless. Calcium of DO was done based on the formula below

$$\text{Dissolved Oxygen (mg/l)} = \frac{\text{Volume}(Na_2SO_3) \times \text{Normality(acid)} \times 8 \text{ x} 1000}{\text{volume of sample}} \qquad 3.3$$

3.2.2.3.2 Chemical Oxygen Demand (COD)

The sample was refluxed with excess potassium dichromate in concentrated sulphuric acid for 2hrs. This oxidizes most of the organic matter in the sample. Silver sulphate was included as a catalyst to speed up to the oxidation process. After digestion the unreacted dichromate remaining in the solution is filtrated with ferrous ammonium sulphate. 50ml of the water sample was refluxed in 500ml flask. 25ml of the of the standard potassium dichromate solution was added to the refluxing flask.

$$COD = (MgO_2) = \frac{8000 \times M \times (V_1 - V_2)}{\text{volume of sample}} \qquad 3.4$$

3.2.3 Chemical parameters

3.2.3.1 Calcium Determination

Twenty five (25ml) millimeter of the sample was pippeted into a conical flask and 100ml of distilled water was added to the sample 25ml of 20% KOH was added, a pinch of mure oxide indicator was also added. The sample was titrated with 0.02 normal EDTA. From pinkish red to pinkish purple end point. This titration is a measure of (Ca) alone in the sample.

3.2.3.2 Sulphate Determination

Mix 50ml of filtered sample containing not more than 10ml SO_4^2 or an aliquot diluted to 50ml with 10ml each of (NaCl HCl) and glyce – vol – alcohol solution) measure the absorbance against a water blank in calorimeter at any wavelength between 380nm and 420nm or in a turbidometre.

3.2.3.3 Chloride determination

Mix 100ml of sample containing not more than 10ml of an aliquots dilute to 100ml, with 10 drops (0.5ml) of indicator solution add 0.2m HNO_3 drop wise until the solution become yellow. Add 5 drops (0.25ml) more of 0.2m HNO_3. Titrate with $Hg(NO_3)_2$ to the point where the 1st thin of blue purple appears which does not disappear on shaking prior warning that the end point is near. Change in colour to orange indicate the end point.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

The Table below presents the physicochemical parameters of groundwater.

Table 4.1: Physical Parameters of groundwater sample

Parameters	Samples Value	Standard Value *
pH	6.53	7.0 – 8.5
Electrical Conductivity	128μS/cm	300μS/cm
Total dissolved Solid	200mg/l	500mg/l
Hardness	60.20mg/l	65.20mg/l
Alkalinity	60mg/l	200mg/l
Biochemical Oxygen Demand	0.51mg/l	1mg/l
Chemical Oxygen Demand	70pl	<10mg/l

**NB Standard value are values gotten from WHO (1993)*

4.2 Chemical Parameters of groundwater sample

Table 4.2: Chemical parameters of groundwater sample

Parameters	Samples Value	Standard Value*
Potassium	1.32	75mg/l
Sodium	12.5	20mg/l
Magnesium	14.4	No guidelines
Chloride	21.48	250mg/l
HCO_3^-	43.13	No guideline
NO_3^-	2.44	50mg/l
PO_4^{2-}	40.08	No guideline

**NB Standard value are values gotten from WHO (1993)*

Table 4.3: Heavy metals present in groundwater sample

Parameters	Samples Value	Standard Value*
Manganese	0.50ppm	0.5mg/l
Copper	0.02ppm	2mg/l
Iron	0.01ppm	No guidelines
Calcium	7.64	No guidelines
Lead	0.01	0.01mg/l

** NB Standard value are values gotten from WHO (1993)*

4.3 Discussion of results

4.3.1 Physicochemical

The value of pH was 6.53. It is in prescribed limit of WHO. A little bit increase in pH level may depress the effectiveness of the disinfectants like chlorinations thereby requiring the additional chlorines. The value of total dissolved solid is 200mg/l, this value is within the prescribed limit of WHO. Total hardness of is 200mg/l, the total hardness is within the prescribed limit of WHO. Calcium hardness is 7.64mg/l. Biochemical oxygen demand and chemical oxygen demand is within the prescribed range of WHO. Chloride, Conductivity, Alkalinity, potassium, sodium, Manganese, Copper, Iron and lead are within the prescribed range recommended by WHO. All values that have no guidelines means that it does have any serious health implication according to WHO (1993). The Quality of groundwater under study is fit for drinking water purpose, but it is recommended that groundwater analysis should be carried out from time to time to monitor the rate and kind of contamination along with analysis of microbiological analysis. Physical parameters such as pH, conductivity and total dissolved solid have a major influence on bacterial population growth. pH values ranging from 3 to 10.5 could favor both indicator and pathogenic microorganism growth (Zamxaka, 2004). Previously indicated pH levels seem to support bacterial growth. Conductivity measures the ability of water to conduct in electrical current, and is directly related to the TDS (Harley, 2004). TDS represents the amount of inorganic substances (salts and minerals). High TDS is commonly objectional or offensive to taste. A higher concentration of TDS usually serves as no health threat to humans until the values exceed 10,000 mg/l (Adelaide, 1997). Individual wells and localized aquifer zones yielding lower TDS and conductivity values as well as elevated turbidity, correlated with wells and aquifer zones with elevated bacterial contamination

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The borehole water is fit to drink because the physicochemical analysis was within the range prescribed by World Health Organization (WHO). The standard values comply with health based guideline by WHO. This shows that it does not have any serious health effect physicochemically. Hence, it suitable for drinking and cooking.

5.2 Recommendation

The following are the recommendations:

1. Constant Monitoring of the borehole should be carried out from time to time.
2. Microbiological analysis of the water should also be done to know the safety level of the water.
3. The water sample should be sample throughout the season because this only available source water to students in FUT Minna, Bosso Campus

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