ALUATION OF GROUNDWATER QUALITY FOR 1RRIGATION AND DOMESTIC

ITER SUPPLY IN CHANCHAGA RIVER CATCHMENT: A CASE STUDY OF GURUSU,

NU, RUKU, GORA, KORA AND BUA VILLAGES.

BY

FAGBEMI, FASINA ADEWALE
MATRIC NO. 2007/2/27646EA

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

FEBRUARY, 2012

ALUATION OF GROUNDWATER QUALITY FOR 1RRIGATION AND DOMESTIC

TER SUPPLY IN CHANCHAGA RIVER CATCHMENT: A CASE STUDY OF GURUSU,

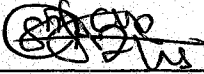NU, RUKU, GORA, KORA AND BUA VILLAGES.

BY

FAGBEMI, FASINA ADEWALE

MATRIC NO. 2007/2/27646EA

ING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF

IE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING, (B.ENG)

GREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING,

DERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

FEBRUARY, 2012

DECLARATION

I hereby declare that this project work is a record of 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 Information derived from personal communications, published and unpublished work were duly referenced in the text.
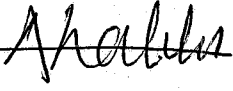
_____   27\02\2012.

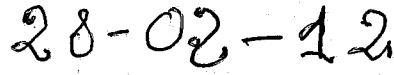Fagbemi, Fasina Adewale   Date

CERTIFICATION

This is to certify that the project entitled "Evaluation of groundwater quality for Irrigation and Domestic Water Supply in Chanchaga River Catchment8A Case Study of Gurusu, Danu, Kora, Gora, Kudu and Bua" by Fagbemi, Fasina Adewale 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.
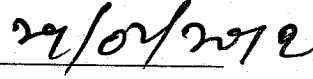
_____   28-02-12
Mr. Adamu Halilu   _____
Supervisor   Date

_____   24/02/2012
Engr. Dr. P. A Idah   _____
Head of Department   Date

_____   22-02-2012
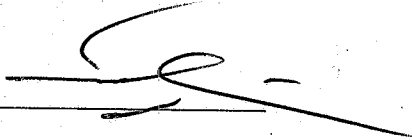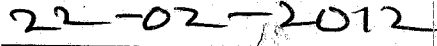External Examiner   _____
                                                                      Date

ACKOWLEDGEMENTS

The completion of this programme is not by my effort but to the Almighty God. Therefore, I give thank, glory, and honour to Him for His mercy, power, wisdom and understanding to attain this level of standard. Great acknowledgement goes to my able supervisor Mr. Adamu Halilu for the assistance rendered to me in the course of the research. Also, I want to use this medium to thank all my wonderhl lecturers. More over, I appreciate the effort of my brother Mr and Mrs Salami, Olaoluwa, Omotoyosi, Ponmile, Oluwasegun, David, Adeola and Miss Elizabeth Anuoluwapo.

ABSTRACT

The Chanchaga river catchment is a part of Minna, Niger state, Nigeria. In order to evaluate the quality of groundwater in the study area (Gurusu, Danu, Ruku, Kora, Gora and Bua villages), six (6) – shallow wells were sampled and analyzed for various parameters. Physical, chemical and bacteriological parameters of groundwater such as electric conductivity, PH, Total dissolved solid, Na, K, Ca, Mg, C1, HC03, C03, S04, N03, Fe, Colour, Turbidity, BOD, COD, Temperature, TDS, PO4, bacteriological were determined. Chemical parameters like percentage of sodium, sodium adsorption ratio and residual sodium carbonated, chloroalkaline indices and Permeability Indices (P1) were calculated. Based on the analytical results groundwater in the study area is not suitable for drinking. Though it has not been treated, but it can be used for agricultural purposes.

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FIVE

CHAPTER ONE

1.0   INTRODUCTION

1.1   Background to the Study

Water is essential for human existence, and its importance for individual health and the well-being of a nation cannot be underestimated. Notwithstanding, many people in developing countries do not have access to safe and clean drinking-water or to adequate amounts of water for basic hygiene. This situation can lead to a variety of health problems. Consumption of water contaminated by disease-causing agents (pathogens) or toxic chemicals can cause health problems such as diarrhoea, cholera, typhoid, dysentery, cancer and skin diseases Ince *et. al.,* (2010) which accounts for 80% of the disease in the tropics Ojo et. al., (2011). Nigeria is the most populous country in Africa. With a population of over 140 million, the country is endowed with generous resources of water bodies. The span of water bodies within the country is estimated at 900 km2. This water provides resources for fishery, transportation, irrigation, recreation and domestic uses (Ekiye *et. al.,*2010)

Surface water is generally composed of dissolved solids from ground water overflows, surface run-off, turbidity, organic matter as well as pathogenic organisms because surface water originates partly from either outflows or rainwater run-offs, which would have flowed over the ground Ojo *et. al.,*(2011). Groundwater is also a valued fresh water resource and constitutes about two-third of the fresh water reserves of the world (Chilton, 1992).

Water quality is determined by the physical and chemical limnology of its source Sidnei *et al.,*(1992) and includes all physical, chemical and biological factors of water that influence the beneficial use of the water. Water quality is important in drinking water supply, irrigation, fish production, recreation and other purposes to which the water must have been impounded (Moshood, 2008).

1

All irrigation waters contain some dissolved salts. Dissolved salts are present because some chemical elements have a strong attraction for water and a relatively weak attraction for other elements. Two such chemical elements, for example, are sodium and chloride.

1.2 Statement of Problem

The demand for water in Chanchaga River Catchment has increase in recent years. The increase is due to the growing demand for water for aquatic wildlife and other uses. These demands are in addition to the traditional use of water for irrigation. Managing existing water supply to fully satisfy all uses have proven difficult particularly in dry years. Part of the solution may be to develop new source of water, groundwater is likely to be one such source. There is broad interest in exploring the use of ground water to alleviate water supply problem. Groundwater use is likely to increase, in addition to this traditional use a number of other groundwater uses are been proposed this include using groundwater to replace surfaces water.

1.3 Objections

The objectives of this project work include:-

(i)   To ascertain the suitability of groundwater of the study area for drinking and irrigation uses

(ii)   To classify groundwater for irrigation on the basis of RSC, SAR and PI values

(iii)   To determine the physicochemical and bacteriological parameters suitable for domestic and irrigation purposes

1.4   Justification

The justification of the work arose from the fact that surface water resources is scares and difficult to treat. Hence the need for exploring ground water for domestic and agricultural purposes.

1.5 Scope of Study

This study cover the following areas Gurusu, Danu, Rudu, Kora, Gora, And Bua Villages. All these area are within Niger State and Chanchaga catchment area.

2

CHAPTER TWO

2.0   LITERATURE REVIEW

2.1   Introduction

A few number of literatures are available regarding the assessment of groundwater quality data based on different irrigation indices in different areas of the world Quddus and Zaman, (1996); Talukderet al., 1998;Shahidullah et al., (2000); Sarkar and Hassan, (2006); (Raihan and Alam, 2008).

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

Shahidullahet 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.

Obiefuna and Orazulike (2010) carried out their work in Yola area of Northeast Nigeria which indicated that the groundwater of the area is largely suitable for irrigation purposes. Similarly, Obiefuna and Sheriff (2011) carried out their work on Assessment of Shallow Ground Water Quality of PindigaGombeArea,Yola Area, NE, Nigeria for Irrigation and Domestic Purposes

3

using fifteen water samples collected from well tapping aquifers. They asserted that major cations and anions, dissolved solids, important constituents were found to be within the safe limits and thus largely suitable for irrigation purposes. The water samples also fall within the recommended limits and are found suitable for domestic purposes.

Fasunwon *et.al.,* (2008) carried out some works on contaminants evaluation as water quality indicator in Ago-Iwoye, South-western, Nigeria. The study evaluates some functional parameters of well water in a densely populated university town, Ago-Iwoye, South-western, Nigeria. Well water samples were collected at ten sites across the town. Analysis of the presence of Coliform count, Salmonella count, standard plate count, physicochemical properties (14 elements and 2 physical parameters) as indicators of water contaminants in the wells were carried out on water samples. 40% of the well samples were contaminated with coli form, whereas 20% were contaminated with salmonella, thus indicating the source of contamination (faecal contaminant). Further analysis revealed that most of the wells have their mineral values within the tolerant level according to WHO standard, however, the two most toxic chemicals from the recommendations of WHO were identified in well 2, 3, 5 and well 10 with values exceeding tolerant level of 0.05 mg/L for lead and 2.56 mg/L value for nitrate in well 2. Results confirm the presence of bacterial growth highly dangerous to life in these samples. Also, wells 2, 4, & 8 were contaminated with excess concentration of Fe mineral which could make the water tasty and have bacteria grow and wells 1, 2, 3, & 7 have excess concentrations of Cu mineral which could cause a stringent taste.

Taekwa *et. al.* (2006) in their worked on an assessment of dug-well water quality and use in Mubi, Nigeria using 18 drinking dug-well water in six selected wards (Yelwa, Lokuwa, Nassarawo, Wuro-patuji, Kolere and Sabon-layi) within Mubi town. From their results, they suggested that well water contamination in the area is largely due to facial (biological)

contaminations. Meanwhile, they recommended that dug-well waters be treated prior to consumption in order to curtail infections.

Moshood (2008) in his work on the assessment of the water quality of Oyun Reservoir, Offa, Nigeria, using selected physico-chemical parameters suggested that Eutrophication which was noticed to be a threat to the water quality should be arrested at the nick of time through denitrification and nutrient control to halt the degradation of the water.

Finally, Arabi et. al. (2010) worked on the investigation of groundwater quality for domestic and irrigation purposes around Gubrunde and Environs, Northeastern Nigeria.In their work, fourteen groundwater samples were collected from boreholes, springs and hand dug wells in and around Gubrunde in Borno State north-eastern Nigeria to investigate its quality for domestic and irrigation uses. The area investigated falls within longitude 11° 35' - 12° 05' and latitude 10° 10' - 10° 31'. The samples were analyzed using Atomic Absorption Spectrometer (AAS), multi-analyte photometer and Flame photometer while interpretation of the results was carried out with RockWareAq•QA software, a spreadsheet for water analysis.Their results showed that Six of the samples investigated are of NaCl water type while fourteen were CaCl water types. Sodium Adsorption Ratio (SAR) values recorded ranges from 0.80 – 2.84, Exchangeable Sodium Ratio (ESR) 0.33 – 1.78, Magnesium hazard (MH) 5.19 – 47.9, Residual Sodium Carbonate (RSC) 0.00, Hardness 0.65 – 221.48 and Total Dissolved Solid (TDS) ranges from 130 – 407308mg/l. Twelve of the samples analyzed had medium Salinity Hazard (SH), and one each for high and low Salinity Hazard (SH), respectively. They asserted that variation in chemical composition of groundwater in the study area may be due to leaching of terrestrial salts, extensive use of chemical fertilizers and ion exchange between water and the host rock. More so, they stated that result of samples analyzed indicates that all the samples are under-saturated in calcite and aragonite, while most of the major anion and cations falls within World Health Organization and Nigeria Industrial Standard for Drinking water Values.

Nine samples had NO3 values ranging from 53 – 106mg/l exceeding the 50mg/l standards. NO3 values exceeding 50mg/l has the tendency of causing asphyxia to infants less than three months old.

A plot of SO4, HCO3 and Cl indicates that the groundwater samples are from intermediate water category (neither fresh nor old). They concluded that the groundwater quality is fairly suitable for agricultural uses and suitable for domestic utilization. (Ogedengbe, 2004).

2.2   Groundwater Resources in Nigeria

Ground water is the part of precipitation that enters the ground and percolates downward through unconsolidated materials and openings in bedrock until it reaches the watertable. The water table is the surface below which all openings in the rock or unconsolidated materials are filled with water. Water entering this zone of saturation is called

Recharge. Ground water, in response to gravity, moves from areas of recharge to areas of discharge. In a general way, the configuration of the water table approximates the overlying topography. In valleys and depressions where the land surface intersects the water table, water is discharged from the ground-water system to become part of the surface-water system (Schewab *et. al.,* 1994).

Ground water perhaps 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). Groundwater resources are limited by the geological structure of the country more than half of which is underlain by the Pre-Cambrian Basement Complex, composed mainly of metamorphic and igneous rocks. However, there are fairly extensive areas of fractured schist, quartzite and metamorphosed derivatives of ancient sediments from which water is often available at great depth. The sedimentary formations such as the Tertiary deposits of the Chad-Sokoto basins, the Cretaceous deposits of the Niger and

6

Benue troughs, and the sedimentary formation of the Niger Delta, yield groundwater in varying quantities (Anukam, 1997)

In Northern Nigeria, where rainfall is scarce and aquifers are shallow, groundwater is usually the only practical source. The geology is such that well yields are unpredictable; often the water can only be accessed using a hand pump. Generally, the quality of groundwater in Nigeria is better than that of surface water in terms of health criteria, but much of the groundwater is corrosive, and some areas have iron, nitrate or fluoride concentrations above WHO guideline values. The corrosive nature of the groundwater necessitates the use of stainless steel and plastic materials for water supply equipment Ince *et. al.,* (2010).If pH is used as an index of corrosive potential, about 20% of the groundwater is highly corrosive (pH <6.5), 40% is moderately corrosive (pH 6.5–6.8), and 40% noncorrosive (pH >6.8)NWSSP, (2000).

From National Water Resources Master Plan completed in 1995, surface water is about 267 billion cubic meters with groundwater resources estimated at 52 billion cubic meters of replenishable yield per year Maduabuchi, (2004). Urbanization, population increase, dewatering of aquifers for irrigation and extensive use of chemical fertilizers are some of the factors that have direct effects on quantity and quality of groundwater resources especially in arid and semi arid region of northern Nigeria. Globally, the quantity and quality of groundwater reserves is diminishing day by day Arabi *et. al.,* (2010).

2.3 Water Quality

Water quality is the physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed Wikipedia, (2011). The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, drinking water, agricultural and irrigation uses. The parameters for water use are determined on the basis of its

intended use Schewab *et. al.,* (1994).In the setting of standards, agencies make political and technical/scientific decisions about how the water will be used.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. Natural water bodies will vary in response to environmental conditions. Soil and Water engineer work to understand how these systems function which in turn helps to identify the sources and fates of contaminants. Environmental lawyers and policy makers work to define legislation that ensures that water is maintained at an appropriate quality for its identified use. The vast majority of surface water on the planet is neither potable nor toxic. This remains true even if sea water in the oceans (which is too salty to drink) is not counted. Another general perception of water quality is that of a simple property that tells whether water is polluted or not (Wikipedia, 2011).

2.4 Water Quality Deterioration

Water quality deterioration in Nigeria occurs in both rural and urban areas. In rural areas, drinking water from natural sources such as rivers and streams is usually polluted by organic substances from upstream users who use water for agricultural activities. The most common form of stream pollution associated with forestry activities is increased concentrations of soil particles washed into the stream by land disturbance. The large particles sink to the bottom and increase the bed loads while, depending on the stream velocity, smaller particles remain in suspension. In the river Niger, for example, studies have shown that the suspended matter can obstruct the penetration of light and limit the photosynthetic zone to less than 1 m depth. Suspended sediments in watercourses have become a serious concern for the water supply authorities because they lead to increased water treatment costs. Various Industrial and manufacturing companies also contribute to groundwater deterioration but the Oil industry has been known to have the biggest effect on water quality. From time to time accidental oil

spillages occur which endanger local sources of water supply and freshwater living resources, especially in the rural areas (Anukam, 1997).

Urbanization, population increase, dewatering of aquifers for irrigation and extensive use of chemical fertilizers are some of the factors that have direct effects on quantity and quality of groundwater resources especially in arid and semi arid region of northern Nigeria Arabi, (2010). Fasunwon *et. al.,*(2008) stated that improper waste disposal is the biggest source of water quality deterioration. Water quality deterioration in reservoirs usually comes from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution and obnoxious fishing practices. The effects of these "imports" into the reservoir do not only affect the socio-economic functions of the reservoir negatively, but also bring loss of structural biodiversity of the reservoir Moshood, (2008). Ekiye *et. al.,* (2010) stated that indiscriminate dumping of effluents into open water bodies as a source of water quality degradation These effluents range from chlorides, phosphates, oil and grease, nitrates, heavy metals to name a few. The heavy metals present in most Nigerian rivers and found in concentrations well above acceptable and permissible levels are lead, copper, zinc, nickel, chromium, Cadmium and Iron Olayinka and Alo (2004); Esoka and Umaru (2006), Eniola *et al.,* (2010). Degradation of water quality is most severe in the four states that contain 80 percent of the nations industries; Lagos, Rivers, Kano and Kaduna States Ekiye *et. al.,*(2010).

2.5   Irrigation Water Quality

All irrigation waters contain some dissolved salts. Dissolved salts are present because some chemical elements have a strong attraction for water and a relatively weak attraction for other elements. Two such chemical elements, for example, are sodium and chloride. The amounts of these elements contained in water must be very high before sodium will combine with chloride to form the solid material sodium chloride, common table salt. The total amount and kinds of salts determine the suitability of the water for irrigation use. Water from some

sources may contain so much salt that it is unsuitable for irrigation because of potential danger to the soil or crops. Irrigation water quality can best be determined by chemical laboratory analysis. The two most important measures for determining irrigation water quality are: The total amount of dissolved salts in the water, the amount of sodium (Na) in the water compared to calcium (Ca) plus magnesium (Mg).

The total dissolved salt content is estimated by measuring how well the water conducts electricity. Salty water is a good conductor of electricity. Electrical Conductivity (EC) is measured in units of micromhos/cm (μmhoms/cm). The ppm salt concentration of the water is estimated by multiplying 0.65times the EC value. For example, water having an electrical conductivity of 1000 micromhos/cm would contain about 660 ppm salt. Other analytical procedures are used to measure the amounts of individual chemicals, such as sodium, in the water. The list of chemicals (and their symbol or formula) routinely measured to determine irrigation water quality follow: Electrical Conductivity (μmhos/cm), Chloride (Cl), Sodium (Na), Nitrate (NO_3), Calcium (Ca) , Carbonate (CO_3), Magnesium (Mg), Bicarbonate (HCO_3), Sulphate (SO_4) (Gordon and Hailin,(2008).

The measurements of the rates of the exchange, absorption, residualness, adsorption of this element are also important as stated by Arabi (2010), Obiefuna and Sheriff (2011). Moshood (2008) listed Temperature, transparency, pH, conductivity, total dissolved solids, dissolved oxygen, nitrate, phosphate, chemical oxygen demand, total alkalinity, total hardness, calcium, magnesium, silica, sulphate, carbon dioxide as important factors in determining the suitability of water for irrigation purpose.

Table 2.1 Classification of groundwater for irrigation based on EC and SAR

Quality of water	Electrical conductivity	SAR

Excellent	<250	<10
Good	250-750	10-18
Doubthful	750-2250	18-26
Unsuitable	>2250	>26

2.6 Basic Concepts of Groundwater Hydrology

Ground water is water that fills pores and fractures in the ground, much as milk fills the voids within bits of granola in a breakfast bowl. The top of ground water is called the water table. Between the water table and the land surface is the unsaturated zone or vadose zone. In the unsaturated zone, moisture is moving downward to the water table to recharge the ground water. The water table can be very close to the surface (within a few feet), or very deep (up to several hundred feet) (Harter, 2008).

Ground water, in response to gravity, moves from areas of recharge to areas of discharge. In a general way, the configuration of the water table approximates the overlying topography. In valleys and depressions where the land surface intersects the water table, water is discharged from the ground-water system to become part of the surface-water system. The interaction between ground water and surface water can moderate seasonal water-level fluctuations in both systems. During dry periods base flow, or ground-water discharge to streams, can help maintain minimum stream flows.

Conversely, during flood stages surface water can recharge the ground-water system by vertical recharge on the water covered flood plain and bank storage through streambed sediments. The net effect of ground-water recharge is a reduction in flood peaks and replenishment of available ground-water supplies Blake, (2008). The hydrologic characteristics of aquifers and natural chemistry of ground water determine the availability and suitability of ground-water resources for specific uses.

2.6.1 Aquifers

A geologic formation from which significant amounts of ground water can be pumped for domestic, municipal, or agricultural uses is known as an aquifer. In some cases, aquifers are vertically separated from each other by geologic formations that permit little or no water to flow in or out. Aquifers can be of two major types: unconfined or confined. An unconfined aquifer has no overlying aquitard or aquiclude. Where there are multiple levels of aquifers, the uppermost aquifer typically is unconfined. Vertical recharge of an unconfined aquifer by rainwater or irrigation water that filters downward through the soil is not restricted. The water table at the top of the unconfined aquifer can migrate freely up and down within the sediment formation, depending on how much water is stored there. The water level in a borehole drilled into an unconfined aquifer will be at the same depth as the water table in the aquifer.

Confined aquifer, on the other hand, is sandwiched between an aquitard above and an aquiclude or aquitard (e.g., bedrock) below. Because the water table in the recharge area of the confined aquifer is much higher than the top of the confined aquifer itself, water in a confined aquifer is pressurized. This pressurization means that the water level in a borehole drilled into a confined aquifer will rise significantly above the top of the aquifer. A flowing artesian well occurs where the pressure is so high that the water level in a well drilled into the confined aquifer rises above the land surface; in other words, an open well flows freely with no pumping. Sometimes hydrogeologists use the term semi-confined aquifer if an aquifer acts partly like a confined aquifer (particularly if pumping rates are low or if pumping is necessary only over a relatively short period of time) and partly like an unconfined aquifer (for example, after long periods of heavy pumping) (Harter 2008).

2.6.2 Aquitards and Aquicludes

In some cases, aquifers are vertically separated from each other by geologic formations that permit little or no water to flow in or out. A formation that acts as such a water barrier is called acquitard if it is much less permeable than a nearby aquifer but still permits flow (e.g., sandy clay). If the water barrier is almost impermeable (e.g., clay) and forms a formidable flow barrier between aquifers, it is known as an aquiclude Harter, (2008). Aquitards consist of materials with low permeability that restricts ground-water movement. An aquitard overlying an aquifer may limit the recharge to the aquifer but may also protect the aquifer from surface contamination (Blake, 2008).

2.6.3 Springs

Springs form where the water table intersects with the land surface: for example, in a small depression (common on hillsides). Sometimes ground water is forced into a spring because a low permeable layer of rock or fine sediments (clay) keeps the water from percolating deeper. A spring may also occur where subsurface pressure forces water to the surface through a fracture or fault zone that acts as a conduit for water movement from a confined aquifer (Harter, 2008).

2.6.4 Basic Groundwater Hydrology Properties

Groundwater recharge and discharge are has been stated as the two most important properties of groundwater while several others has their usage. These properties affect the ability of an aquifer to store and transmit ground water. Porosity, the ratio of void space to unit volume of rock or soil, is an index of how much ground water the aquifer can store. Permeability, a property largely controlled by size and interconnection of pore spaces within the material, affects the fluid-transmitting capacity of materials.

The water-transmitting characteristics of a groundwater are expressed as hydraulic conductivity and transmissivity. Hydraulic conductivity is a measure of the rate that water will

move through an aquifer; it is usually expressed in gallons per day through a cross section of one square foot under a unit hydraulic gradient. Transmissivity is equal to the hydraulic conductivity multiplied by the saturated thickness of the aquifer. The storage characteristic of an aquifer is expressed as the storage coefficient. Pore spaces in bedrock occur as fractures, solution features, and/or openings between grains composing the rock. In unconsolidated deposits all of the pores are inter granular. However, fine-grained deposits such as clays and silts may also have secondary porosity, commonly in the form of fractures. The size, shape, and sorting of material determine the amount and interconnection of inter-granular pores. Sand and gravel deposits have a high proportion of pore space and high permeability; whereas, fine-grained or clay-rich deposits have a greater proportion of pores, but a lower degree of permeability. Water in confined aquifers exists under hydrostatic pressure that exceeds atmospheric pressure; and wells completed in confined aquifers have water levels that rise above the water bearing formation until the local hydrostatic pressure in the well is equal to the atmospheric pressure. Such wells may or may not be flowing wells. A measure of the pressure of water in a confined aquifer is referred to as the potentiometric level. In contrast, water in an unconfined aquifer exists under atmospheric pressure; and wells that are completed in such aquifers have water levels that correspond to the local water table. An unconfined aquifer is also referred to as a water table aquifer, and the spatial distribution of water levels in wells in unconfined aquifers is shown on a water table map. Water level maps for confined and unconfined aquifers are typically referred to as potentiometric surface maps. As a well discharges water from an aquifer the water level drops in the well. The drop in water level, which is called drawdown, creates a hydraulic gradient and causes ground water around the well to flow toward the well. If an unconfined or confined aquifer is being pumped, an overall lowering of either the water table or the potentiometric surface, respectively, occurs around the well. The zone being influenced by pump age is called the cone of depression. An increase in

14

the pumping rate usually creates a larger cone of depression that may induce more recharge to the aquifer. However, the natural rate of recharge to confined aquifers is limited by the thickness and hydraulic properties of the confining layers (Blake, 2008).

2.6.5 Importance of the Hydrologic Cycle for Groundwater

Infiltration supplies aquifers with a continual source of water to replace that pumped from wells and discharged naturally (such as at springs). During infiltration water can pick up acids in the soil that can subsequently expand the pore space in aquifers, sometimes creating caves. Large areas of impervious cover, such as parking lots, do not allow infiltration. High volumes of rain over a short period of time also reduce the amount of water infiltrating;

Slow rainfall best recharges groundwater. Infiltration and percolation are usually slow processes requiring water to move through a tight maze of sediment which acts as a filter. Together with biological activity, water is cleaned as it moves through the ground. This natural scrubbing is one of the reasons groundwater is so commonly used for drinking (Hopkins, 2005).

Aquifers are recharged from precipitation, seepage from rivers, and seepage from irrigated fields. If no one pumps the ground water, aquifers eventually "overflow;" that is, they discharge water to the surface through springs and seepage along river beds and lakes in the lower parts of Nigerian's valleys and basins. A century of groundwater pumping has lowered water levels in many areas of Nigeria and established a new balance between recharge and groundwater pumping. During a series of wet years less water is pumped from wells, and that allows water levels to rise as a result of surplus recharge. During dry years, however, the amount of recharge water is typically much less than the amount of ground water pumped and groundwater levels drop. If groundwater recharge cannot keep pace with extraction over an extended period of years, despite the absence of a major drought, the groundwater basin is said to be in overdraft.

In Nigeria the regional pattern of groundwater recharge and pumping and its interaction with rivers is dictated by topography and the availability of surface waterfor groundwater recharge. Most of Nigeria has a semi-arid to arid climate. The largest amount of surface water available for recharge is near the mountain fronts where perennial, intermittent, or ephemeral streams draining Nigeria do uplands flow onto the highly permeable, unconsolidated sediments that fill Nigeria's valleys and basins. Thus, most of Nigeria's streams provide significant groundwater recharge.

Rainfall also recharges ground water, but in Nigeria's large groundwater basins direct recharge from precipitation accounts for only a minor fraction of the total recharge. In the agricultural valleys, deep percolation from summer irrigation is a much more important source of recharge than winter precipitation. Recharge from natural precipitation is only significant in some of the coastal valleys, in inland basins in northern Nigeria, and in the small groundwater basins nestled in Nigeria's mountain ranges (Sangodoyin, 2006).

2.7   Groundwater Hydrogeology

Hydrogeology (hydro- meaning water, and -geology meaning the study of the Earth) is the area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crust, (commonly in aquifers). The term geohydrology is often used interchangeably. Some make the minor distinction between a hydrologist or engineer applying themselves to geology (geohydrology), and a geologist applying themselves to hydrology (hydrogeology) (Hopkins, 2005). It's a is a branch of the earth sciences dealing with the flow of water through aquifers and other shallow porous media (typically less than 450 m or 1,500 ft below the land surface.) The very shallow flow of water in the subsurface (the upper 3 m or 10 ft) is pertinent to the fields of soil science, agriculture and civil engineering, as well as to hydrogeology. The general flow of fluids (water, hydrocarbons, geothermal fluids, etc.) in deeper formations is also a concern of geologists, geophysicists and petroleum geologists.

Groundwater is a slow-moving, viscous fluid (with a Reynolds number less than unity); many of the empirically derived laws of groundwater flow can be alternately derived in fluid mechanics from the special case of Stokes flow (viscosity and pressure terms, but no inertial term). (Hopkins, 2005).

The mathematical relationships used to describe the flow of water through porous media are the diffusion and Laplace equations, which have applications in many diverse fields. Steady groundwater flow (Laplace equation) has been simulated using electrical, elastic and heat conduction analogies. Transient groundwater flow is analogous to the diffusion of heat in a solid, therefore some solutions to hydrological problems have been adapted from heat transfer literature. (Hopkins, 2005).

Traditionally, the movement of groundwater has been studied separately from surface water, climatology, and even the chemical and microbiological aspects of hydrogeology (the processes are uncoupled). As the field of hydrogeology matures, the strong interactions between groundwater, surface water, water chemistry, soil moisture and even climate are becoming more clear.Hopkins, (2005).Water can enter the atmosphere by evaporation, transpiration, or sublimation. Evaporation occurs as liquid water becomes a gas; the water can come from anything on the surface, such as plants, soil, rivers, lakes, and oceans. Transpiration is the process by which water is released from green plants into the atmosphere. In many cases it is very difficult to distinguish evaporation from transpiration; evapotranspiration refers to the combination of the two. Sublimation is the process of a solid turning directly into a gas; snow and ice changing into vapor is only a minor part of water entering the atmosphere. Water changes from a gas into a liquid by condensation and returns to the Earth primarily in the form of precipitation (snow and rain). Many different things can happen to precipitation ?in some cases it does not even reach the ground. It can evaporate before hitting anything, or can be

intercepted by vegetation. When water reaches the ground, it can infiltrate into the ground, be stored on the surface, or travel on the surface until it can infiltrate or be stored. Groundwater travels through rock and sediment by percolation. It moves by gravity and pressure until the water table intersects the ground surface. Water can then be discharged at springs or any other body of surface water. Once returned to the surface, this water can be used by plants, stored on the surface, or evaporated (Elliot and R.K. Fresvert , (1992); Hopkins, (2005); (Ogedengbe, 2004)

2.8 The Geology/Hydrogeology of the Study Area

The study area is a vast land on the Minna topographic map sheet SW 164, located at latitudes 9°30'N and longitudes 6°25'E. It covers a total landmass of approximately 1300 km^2 (Adeniyi, 1985).

Geological Map Of The Studied Area

18
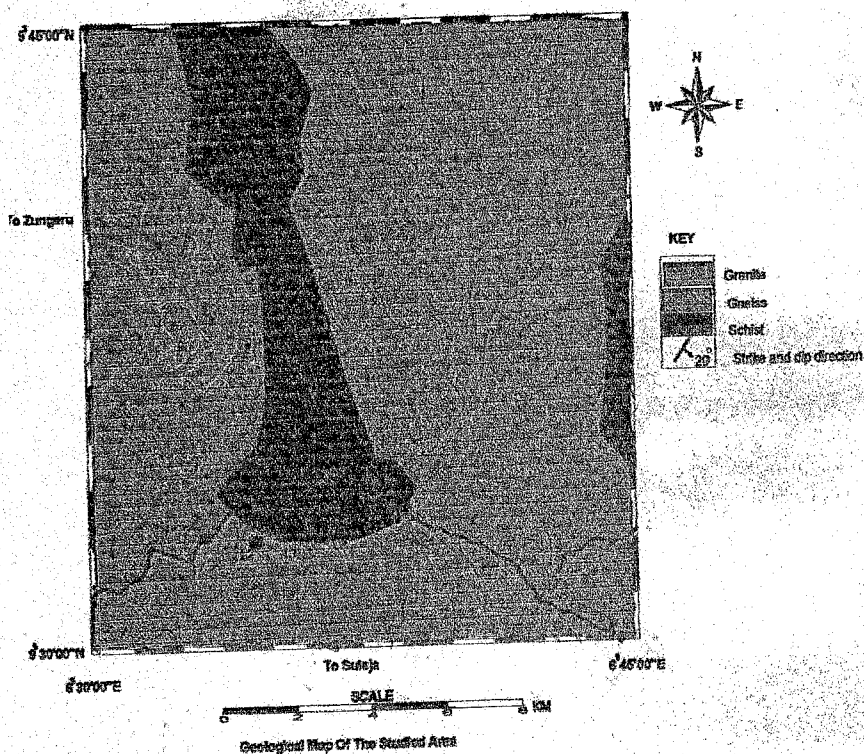
Minna area falls within the larger north-western Nigerian basement complex, which is made up of crystalline rocks consisting of gneisses and migmatatites, and meta sedimentary schists.
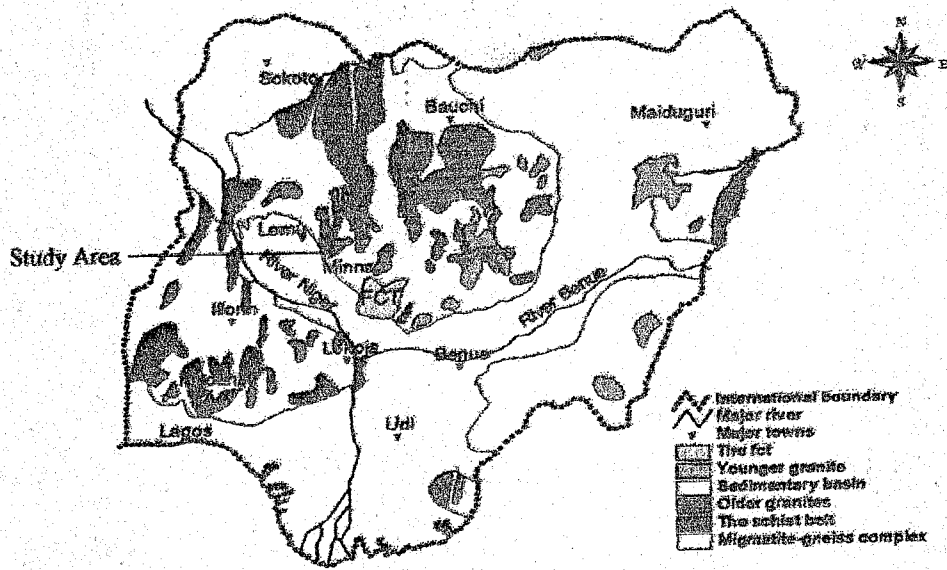
FIG 2.2 *Geological Map of Nigeria showing Study Area (After Ajibade, 1976)*

CHAPTER THREE

3.0.0 Methodology and Techniques for the Study

3.1.0 Materials

The development of new laboratory instrumentations is of great benefit to the water and waste water experts. The new instrument designs have incorporated automatic sample handling, sequential analysis and improved data presentation. The current change to digital output, in contrast to meter readings, has reduced error and increased the speed of the determination. In addition to the expanded variety in the types of laboratory analyses performed, there has been an increase in the number of individual samples to be analyzed. To meet the increased work load, laboratory operations have been redesigned to take advantage of automatic instrumentation wherever possible. The instruments and apparatus that was used in this research work are;

- Atomic Absorption Spectrometer.

- Dissolved oxygen Meter (JENWAY MODEL 9071).

- Conductivity Meter (HACH MODEL CO 150).

- Portable pH/MV/Temperature Meter (Hach Model EC10).

- Turbidity Meter

- Thermometer.

- Conductivity Meter

- pH Meter

- Incubator

- Condenser

- Electric Oven

- Bunsen Burner

- Analytical Balance

- Graduated Cylinders (100ml, 10ml, 1ml)

- Measuring Cylinders (100ml, 10ml, 1ml)

- Pyrex beakers (500ml, 100ml, 10ml)

- Conical Flask

- Burette (50ml)

- Pasteur Pipette (2ml, 5ml, 10ml)

- Crucibles (25ml)

- Desiccators

- Volumetric Flask

- Funnels

- Filter Papers

- Pipette (25cm)

- Sample Bottles of Borosilicate Glass

- Flame Photometer

- Steam Bath

21

- Distillation Apparatus

- Ground Glass Joint

- Horizontal Shaker

- Evaporating Dish.

Procedures for a wide variety of applications. Water Quality, salinity, acids, bases and other samples can be easily analyzed or conductivity with the available conductivity probes. The conductivity meter was pressed to conductivity mode. The probe was rinsed with distilled water and inserted into the sample contained in a beaker, while the display was allowed to stabilize before recording measurements.

3.1.1 Research Methodology

Groundwater sample was collected from 6 shallow and deep wells from the study area during July, 2011. The location of the sampling points is shown in fig 1. The pH and the electrical conductivity was determined using the digital conductivity meter, immediately after sampling. Water samples collected in the field was analyzed in the laboratory for major ions (Ca, Mg, Na, K, HCO_3, CO_3, SO_4, and Cl), Nitrate, Phosphate, ammonia, ion, and fluorine using the standards methods as suggested by American Public Health Association APHA, (1995). Sodium was determined using flames photometer Total Hardness (TH), as $CaCO_3$. Calcium as (Ca^{2+}), Carbonate (CO_3), bicarbonate (HCO_3) and Chloride (Cl) was analyzed by volumetric method. Magnesium (MG) was calculated from TH and Ca contents. Sulphate (SO_4) will be estimated using the colorimetric techniques. Nitrate (NO_3), Iron (Fe), and Fluorine (F) was determined by spectrophotometer. The saturation indexes was determined using the hydro-geochemical equilibrium model Phreeqc for window (1999). Analysis of water samples from 6 monitoring wells for chloro-fuocarbon was used to estimate apparent dates of recharge.

22

3.2.0 List of Reagent Used:

i. Sodium hydroxide pellet

ii. Oxalic acid

iii. Potassium permanganates $KMnO_4$

iv. Sodium nitrate

v. Sodium sulphate

vi. Sodium hydrogen troixocarbonate (IV) $NaHCO_3$

vii. Hydrochloric acid HCL

viii. Chloroform

ix. Manganese sulphate

x. Starch solution

xi. Solid Kl free from iodate

xii. Alkaline iodide

xiii. Sodium thiosulphate solution

xiv. Dipotassium chromate(IV)$K_2Cr_2O_7$

xv. Silver nitrate

xvi. Chloride

xvii. Sodium chloride

xviii. Potassium chloride

xix. Phosphoric acid

xx. Soda lime

xxi. Calcium chloride

xxii. Sulphoric acid

xxiii. Mercury tetraoxosulphate(VI) $HgSO_4$

xxiv. Silver tetraoxosulphate $AgSO_4$

xxv. Iron(II) tetraoxosulphate(VI) Heptahydrate $FeSO_4.7H_2O$

3.3.0 Experimental Procedure

3.3.1 Determination of Physical Parameters

3.3.2 pH Determination

The pH of the effluent sample was determined by HACH model EC10 portable pH/temp digital conductivity meter. The model EC10 features a custom digital LCD display the Ph measurement. This meter has all the features of a simple pH meter plus multi-volt mode, sealed key pad, electrode holder, tilt strand, ergonomic design and battery/line power. The required MODE will be selected using the key pad. The meter electrodes were rinsed with distilled water and the pH electrode probe was immersed into the sample contained in the beaker. The display was allowed to settle and the result will be read.

3.4.0 Electrical Conductivity Determination

The electrical conductivity of the effluent sample was determined with a HACH MODEL CO150 digital conductivity meter. This meter features a micro processor designed which automates complicated and time consuming calibration and inserted into the sample contained in a beaker, while the display was allowed to stabilize before recording measurement.

3.4.1 Turbidity Determination.

Turbidity was determined by Nepheleiometric method. Turbidity meter consist of a Nephelometric with a light source for illuminating the sample and one photoelectric detector, a read out device to indicate intensity of light scattered at 900 to the path of incident light. The sample was thoroughly shaken to allow air bubbles disappear. The shaken sample was poured into turbidity meter tube and immersed into an ultrasonic bath for two seconds, causing

24

complete bubbles release. Turbidity was read directly from the instrument scale as Nepheiometric Turbidity Units (NTU).

3.4.2   Total Dissolved Solid Determination.

A well mixed sample was filtered through a standard glass fiber and the filtrate was evaporates to dryness in an already weighed dish and dried to constant weight at 180c. The increase in dish weight represents the total dissolved solids. The sample was stirred with a stirrer and pipette, 60ml was measured into a glass fiber. Then, wash with three successive 10ml volumes of reagent-grade water allowing complete drainage between washings and continue suction for about three minute after filtration was completed. Total filtrate (with washing) was transferred into a weighed evaporating dish and evaporates to dryness on a steam bath. Dry for about 1 hour in an oven at 180°C cool in desiccators to a balanced temperature and constant weight.

$$total\ dessolved\ solid = \frac{(y-z)}{25ml\ of\ sample\ volume} \times 100 = mg/l$$

Were y= *wieght of dry residue + dish*, Z = *wieght of dish*

3.4.3 Total Suspended Solid

A well mixed sample was filtered through an already weighed standard glass fiber filter and the residue retain on the filter was dried to a constant weight at 105° C. the increase in weight of the filter represents the total suspended solids. The sample was stirred with a stirrer and while stirring 25ml of the sample was pipette into a glass fiber filter. Wash with three successive 10ml volume of reagent-grade water and allow complete drainage between washing and continue suction for about three minute after filtration was completed. The filter will be carefully removed from filtration apparatus and transferred into stainless steel. Dry for about 1 hour at 105oC in an oven, cool in a desiccators to a balanced temperature and constant weight.

Total suspended solids= $\dfrac{(y-z)}{25ml\ of\ sample\ volume} \times 100\ (mg\backslash l)$

Where y= $weight\ of\ filter\ +\ dried\ residue$, z= $wieght\ of\ filter$

3.5.0 Total Hardness

The plastic measuring tube will be filled with water sample to be tested and the content was then poured into a mixing bottle. Three drop of buffer was added into the mixing bottle and was swirled by a drop of Maver hardness indicator solution. EDTA (ethylene-diamine-tetra-acetic acid) titrant was then added to the solution in the mixing bottle drop by drop. The bottle was swirled at each drop and each drop of EDTA titrant added into the mixing bottle was counted. The addition continued until a colour change from pink to blue was seen or noticed. The hardness in mg/l as calcium carbonate ($CaCO_3$) is equal to all number of drops EDTA titrant required to bring about colour change multiply by 20.

3.5.1 Calcium Hardness

The plastic measuring tube was filled with water sample to be tested and contents of the tube was poured into the mixing bottle following by the addition of 8N potassium hydroxide. A clipper was used to open the calver calcium indicator powder pillow which was added in the solution in the mixing bottle. EDTA titrant was then added intohte solution in the mixing bottle drop by drop. The bottle was swirled at each drop and each drop of EDTA titrant added into the mixing bottle was counted. The addition continued until a colour change from pink to blue was seen or noticed. The hardness in mg/l as calcium carbonate ($CaCO_3$) is equal to all number of drops EDTA titrant required to bring about colour change multiply by 20.

It should be noted that magnesium-hardness can be gotten as

magnesium= $total\ hardness - calcium\ hardness$

26

3.5.2 Total Alkalinity

A measure of 40ml of 0.025m Na2CO3 solution sample of the water sample in a conical flask was added to 60ml and 3 drop of methyl orange indicator was used, 0.05m of H2SO4 will be used to titrate until there is a colour change from yellow to orange will be noticed.

3.6.0 Chloride Ion Determination

It was determined by titration with silver nitrate; procedure/reagent

1. The following three reagent were prepared

   a. 48g of silver nitrate was dissolved in 1liter of distilled water and 1mlwas equivalent to 1mg chloride.

   b. 1.6g of sodium chloride standard and 1ml chloride

   c. Potassium chromate indicator, 5g per 100ml was added to silver nitrate solution to produce a slight red precipitation and was filtered.

2. 100ml of water sample was measured into a flask and 1ml of potassium chromate solution was added and titrated with silver nitrate with constant stirring until a slight red colour persists.

$$chloride = \frac{volume\ of\ silver\ nitrate\ for\ sample - blank}{volume\ of\ water\ sample(ml)} 100 = mg/l$$

3.6.1 Phosphate Ion

Phosphate was determined by the turbidity meter method. Colloidal barium sulphate was formed by the reaction of sulphate with barium ion, a barium chloride hydrochloric acid solution in the presence of glycerol land ethyl alcohol. The colour intensity was measured using DR200 spectrophotometer at 42mm wavelength.

27

3.6.2 Sulphate Ion Determination

Sulphate is a minor ion occurring in natural water and waste waters this will be determined by colorimetric technique. Direct anthropogenic sources of sulphate include industrial and municipal waste. To determine sulphate, an excess of barium chloride Bacl2will be added to the water sample. The barium ion react with sulphate to precipitate barium sulphate crystals, the colloidal suspension was measured using a spectrophotometer and the sulphate concentration was determined by comparing with standard.

3.6.3 Nitrate

This is one of the four inorganic nitrogen compound that are sanitary significant. This is measured using spectrophotometer. The stored program for nitrate was entered and a wavelength dial will be rotated. By pressing the entered button on the device, mg/l NO.H was displayed a sample cell was filled with 25ml of the sample to be tested followed by the addition of the contents of one of the five nitrate reagent powder pillow to the cell (prepared sample). The shift time bottom on the devices was pressed and the cell was vigorous until the timer beeped in one minute. The content of the sample was allowed to stand for five minutes. Another sample cell filled with 25ml of distilled water was placed into the cell holder and close until the timer beeped , 0.00mg/l NO_3H^- was displaced. By removing the black and placing the prepared sample in the cell in the holder the value of the nitrate was displayed and removed.

3.7.0   Trace Metals Determination

Prior to metal analyses, each sample of 100ml will be acidified with concentrated HNO_3 (o.5ml). 25ml of each sample was poured into a beaker and diluted with 1.25ml HCl. The mixtures were heated for 15 minute on a steam bath and the final volume was adjusted to 25ml. Graded concentrations of the standard metal solutions were similarly prepared (0.2, 0.4, 0.6,

0.8, 1.0 and 1.2ppm) and aspirated into the flame and the absorbance read in the atomic absorption spectrometer. The absorbance of the standard calibration curve from which the concentrations of the metals present in the sample extrapolated. Metals detected were iron, calcium, magnesium and lead.

3.7.1 Dissolved Oxygen Determination.

The dissolved oxygen (DO) was determined in the field with JEN WAY MODEL 9071, Dissolved oxygen meter. The measurement system consists of a "clark" type photographic oxygen electrode and an oxygen metre. The units give the user readout of dissolved oxygen in mg/I or % and have a temperature measurement range of -30 to 150c. The required mode was selected. The dissolved oxygen probe was immersed in the beaker containing the sample to be measured. The model 9071 dissolved oxygen meter simultaneously display dissolve oxygen and measurement of the results. It is possible to fixed dissolved oxygen by winkers method and subsequently analysis in the laboratory.

3.7.2 Determination of Organic Matter Composition.

Over the years a number of different tests have been developed to determine the number of organic content of water. In general, the test was divided into those used to measure trace concentration in the ranges of 10-13mg/l. The laboratory methods commonly used today to measure gross amount of organic matter (greater than 1mg/l) in water include;

a. Biological Oxygen Demand (BOD)

b. Chemical Oxygen Demand (COD)

c. Total Organic Carbon (TOC)

d. Theoretical Oxygen Demand (ThoD).

Traced organic matters in the range of 10-13mg/l were determined using instrumental methods including gas chromatography and mass spectroscopy. Within the past ten years, the trace organic compound has improved significantly and detection of concentration in the range of 10-13mg/l is now almost routine matter. Metcalf and eddy, (1999)

3.7.3 Bacteriological Analysis

This is the determination of the indicator of organism in a sample of water. This is also referred to as coliform count. The test was carried out using the most Probable Number (MPN). An indicator, bromoresol purple indicator was added into a series of sterilized culture bottles. A change of colour from pink to yellow after 48 hours indicated the presence of coliform. The number of coliform available was estimated by the use of MPN table. The culture media was prepared by dissolving approximately 1g of beef bouillon and 4g of powdered milk in 250ml of distilled water. 15ml of media was then introduced into each 15 screw capped sterilized bottle followed by addition of the drops of bromoresol purple indicator solution. 10ml of water sample was introduced in the first group of culture sterilized bottle which contain the media and indicator solution. The second group of the six sterilized bottle was introduced with 1ml of water sample. And the third group of six sterilized bottles was introduced with 0.1ml of water sample by means of a sterilized syringe. The bottles were then incubated at about 35^{oc} for two days. After two days, the bottles were observed for colour change, possible test bottles that have colour change to pink were obtained. A MPN table was used to estimate the number of coliform present in the water. MPN values per 100ml of sample and the percentage confidence limits for various combinations of positive and negative result when (five 10ml, five 1ml and five 0.1ml) test partition are used.

3.8.1 Site Selection

Selection of site for the installation of monitoring wells was a multiple-step process. Firstly, target areas was defined as the intersection of the alluvial aquifer and areas extend to old and recent area developed residential and local and commercial irrigation land used in the area of study. Secondly, the target area will be defined by excluding areas within 1,000-m of heavy industries such as manufacturing or construction facilities, refinery, raw materials, transportation censers, or airports.

3.8.2 Installation

The installation of the monitoring wells was followed procedures outlined Apham et al., (1995). All monitoring wells was installed between May 24 and June 28, 2011, using 0.11m, inside diameter hollow auger. The casing to be for the 6 monitoring wells was 0.051 m in diameter, fens threaded, equip with scheduled- 40 polyvinyl chloride (PVC) pipe, well screens will be constructed of scheduled 40-PVC and will be 1.5 m in length with mill-slot perforation opening (2.5 E^{-04} wide). The filter pack (packing materials around the well screen) will consist of Silicate sand above which about 0.6 m thick layer of benetonite pellets was installed. Drilling equipments was steam cleaned between monitoring-well installation site. Monitoring well to be installed for irrigation studies was completed at depths (below land surface) of 11.33 m or less. Completion depth was determined by depth of water. One of the purposes of well construction is to ensure suitability for future (10 or more years) sampling for water quality trend analysis. Therefore the placement of well screens relative to possible future water-level declines will be about 1.5m below the current (2011) water levels of about 1.83 m depth. The top of well screens of all 6 wells was installed at a median depth below current (2011) water range from about 1.22 m to 10.67 m with a median depth of about 4.88 m. After installation,water levels in monitoring wells was allowed to "recover" for about 2 weeks before

development. This is a procedure to enhance flow of water to the well, to remove sediments that are artificially of well installation, and to yield water representative of the aquifer being sampled. Well development mitigates at fact association with drilling such as changes in aquifer permeability, sediments distributions, and ground water chemistry Lapham and et al., (1995). For the land use analysis; wells development, consist of pumping the 6 wells with portable low volume submersibles pump at three depths intervals in the water column. These intervals include near the top, middle, and bottom of the water column. Pumping will continue until turbidity reading from discharged water from each interval at less than 10 NTU (Nephelometric turbidity units). Since turbidity is a measure of clarity of the water, the water levels in the monitoring well was allowed to "recover" for 2 weeks before water quality samples was collected.

3.8.3   Samples Collection and Analysis

Sediments samples were collected for determination of pH, organic carbon content, and particles size analysis during the installation of each of the 6 wells. One sample was collected in the unsaturated zone about half-way between the land surface and estimated water level Bevans, (1989), using a spit-spoon sample Wilson, (1995). These samples was used to evaluate potential water quality interactions association with the movement of recharge water through sediments. The 6 monitoring wells was sampled once from July 15 to July28, 2011, for assessment of shallow ground water quality. Ground water samples was collected and sent to laboratories in Niger State Water Board, Upper Niger River Basin and Rural Development Authority Minna, Federal Polytechnic Bida for analysis. Ground water was pumped to the well using a portable, low-volume submersible pumped. All materials in contact with the water samples will consist of either stainless steel of Teflon. Sampling protocol to be used during this study is as described in Eaton (1950). To minimize the risk of samples contamination, all sample collection and preservation took place in dedicated environmental chambers consisting

32

of clear polyethylene bags supported by tubular PVC frames. Sampling items or equipment extending from the permanent sampling point near the well head to the sampling chamber inside the laboratory was decontaminated thoroughly between each sample collection using progression of non-phosphate detergent wash, tap water rinse, methanol rinse, and final ionised water rinse. Polyethylene bags forming the sampling and preservation chambers will be replaced between each sample collection. Sampling wells was first be purged of standing water during initial pumping period. Measurement of special conductance, pH, water temperature, and dissolve Oxygen was monitored after every 5 minutes in a closed-cell, flow through chamber until stable readings were obtained. Turbidity was measured using turbidity meter. Once stable readings of these physical properties were obtained. Water samples will now be immediately collected for analysis, which include the following parameters: dissolve solids, bromide, chloride, iron, manganese, silica, sulphate, bicarbonates, fluoride, potassium, and sodium forming dissolved solids, major irons, and selected trace elements in milligram per litre. Nutrients, and dissolved organic carbon, in milligram per litre include ammonia, Nitrogen as N phosphorus, carbon, organic matter. Trace elements to be analysed include: aluminum arsenic beryllium, chromium copper, manganese, nickel, silver, zinc, antimony, barium, cadmium, lead, molybdenum selenium, uranium natural. While the following pesticides were also to be investigated: 2,6-diethylanline, alachlor, acetochlor, butylatee.t.c. Volatile organic compounds e.g 1,1,1,2- Tetrachloethane, 1,1-dichloroethane e.t.c Samples for analysis of chlorofluorocarbon (CFCS) was collected in triplicate using procedures described by Busenberg and Plummer (1992) that pervert exposure of the samples to air Ca potential of these CFC contamination of potential dates at which the water samples were recharge to the aquifer. Samples to be analyze for major ions nutrients, and trace elements was filtered through 0.45-mm pore-size disposable-capsule filter and collected in pre clean plastic bottles rinsed on-site with filtered groundwater, samples to be analyzed ford concentrations of major cations and

trace elements will be reserve to less than pH 2.0 standard using ultra-pure nitric acid. Filtered unpreserved samples was collected for major anions analysis. Additionally, a filtered sample was collected for on-site titration for carbonate alkalinity, an unfiltered sample for laboratory measurement of specific conductance and pH. To avoid contact between water samples dissolved organic carbon (DOC) and any methanol-rinsed sampling equipment (a possible source of DOC contamination), DOC samples were collected directly from discharge tube close to the well head. The samples were process through a stainless-steel, pressure filtration funnel equipt with 0.45mm pore-size filter silver. Trace concentration of silver imparted by the filter served as a biocidal preservative for the DOC samples. Water samples were force into the chamber using purified Nitrogen gas; the water was collected in clean and baked amber glass bottle and immediately chilled on ice and delivered to the laboratory within 24 hours for analysis. Samples analysis for pesticide was passing through methanol-rinsed, stainless-steel filtered chamber consisting of clear and baked 0.7 mm pore-size glass-filtered. All samples for organic carbon analysis were collected in amber coloured glass bottle and immediately chilled on ice and delivered to the laboratory within 24 hours for analysis. The rate of movement of ground water (flow velocity) is another important property in the study of ground water quality because, when used with the estimated age of the ground water location, the potential recharge can be estimated. The land use characteristics of the recharge areas may help in evaluation of water quality characteristics of the water samples to be collected from the monitoring wells.

3.9.0 Data Analysis

Hydraulics of surface water-groundwater interaction

A flow model was use to determine the hydrologic interaction in the river-aquifer system along the river. Flow line is an imaginary line that traces the path that a particle of groundwater would follow as it flows through an aquifer Fetter, (1994). The flow nets construction was

based on water table and river level measurement. The following assumptions was made in the construction of the flow nets:

1. The soil structure is homogenous.

2. The soil and aquifers are fully saturated

3. The independents strata are isotropic

4. There is a steady state condition (no change in potential field with time)

5. The soil and water are incompressible

6. The boundary conditions are known (depth of water in the river and the water tables in the soil.

4.0 RESULT AND DISCUSSION

4.1 Presentation of Result

Water quality is the physical, chemical and biological characteristics of water. Is a measure of condition of water relative to the requirement of one or more biotic species or to any human needs or purpose. It is most frequently used by reference to a set of standards against which compliance can be accessed. The result of physco-chemical and bacteriological analysis for six(6) water samples are presented below.

4.1.1 Water Quality Assessment for Drinking

RESULT OF PHYSCO-CHEMICAL AND BACTERIOLOGICAL ANALYSIS FOR SIX(6) WATER SAMPLES.

PARAMETERS	GURUSU VILLAGE	DANU VILLAGE	RUKU VILLAGE	KORA VILLAGE	GORA VILLAGE	BUA VILLAGE
Turbidity(NTU)	24.00	12.00	12.00	20.00	10.00	6.00
Colour	5.00	10.00	20.00	10.00	5.00	15.00
Suspended Solid(mg/l)	180.00	380.00	540.00	580.00	310.00	160.00
E. Conductivity(μm has)	8000.00	10000.00	2300.00	21300.00	14000.00	1600.00
TDS	500.00	410.00	445.00	170.00	196.00	200.00
Total solid (mg/l)	180.00	380.00	540.00	580.00	310.00	160.00
Temperature (^{0}C)	24.00	24.00	24.00	24.00	24.00	24.00
pH	6.70	7.00	6.50	6.90	6.70	7.00
Nitrite (mg/l)	0.01	0.02	0.26	0.18	0.07	0.30
Nitrate (mg/l	25.00	32.00	35.00	28.00	4.00	27.00
Phosphate (mg/l	0.40	0.60	1.30	0.80	1.90	1.60
Sulphate (mg/l	5.00	10.00	5.00	35.00	30.00	10.00
Nitrate as N	5.20	6.70	5.70	5.60	2.90	3.90

(mg/l)						
Iron (mg/l)	0.40	0.60	0.00	0.30	0.01	0.01
Chloride (mg/l)	18.99	33.48	10.49	97.96	47.98	26.99
Dissolved Oxygen (mg/l)	2.60	2.20	3.80	2.30	2.20	2.10
Total Hardness (mg/l)	202.00	585.80	222.20	646.40	434.30	636.30
Calcium Hardness (mg/l)	141.60	133.50	80.90	157.80	141.60	210.50
Magnesium Hardness(mg/l)	60.40	452.20	141.20	488.50	292.70	425.80
Total Alkalinity (mg/l)	40.00	38.00	80.00	70.00	101.00	50.00
HCO_3 (mg/l)	250.00	186.00	106.00	87.00	99.00	270.00
CO_3 (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00
PO_4(mg/l)	0.70	0.50	0.50	0.06	0.06	0.70
COD(mg/l)	30.00	34.00	28.00	19.00	23.00	16.00
BOD(mg/l)	18.00	16.00	13.26	20.21	10.32	12.22
E-coli	150.00	200.00	180.00	190.00	210.00	220.00
Total Coliform	200.00	300.00	275.00	410.00	110.00	300.00

NSDQW- NIGERIA STANDARD FOR DRINKING WATER QUALITY

Correlation matrix (water quality parameters):

	turb	col	SS	E.cond	TDS	TS	pH	Nitrite	Nitrate	phos	sulp	Nitrate as N	iron	Cl	DO	TH	Ca	Mg	Total alka	HCO3	po4	K	Na	COD	bod	ecoli	totalcoliform
turb	1																										
col	-0.523	1																									
SS	0.156	0.379	1																								
E.cond	0.565	-0.626	0.447	1																							
TDS	0.546	-0.079	-0.084	-0.140	1																						
TS	0.156	0.379	10.000*	0.447	-0.140	1																					
pH	0.149	0.510	0.175	-0.341	0.098	0.335	1																				
Nitrite	-0.518	0.227	-0.255	0.447	-0.608	-0.255	-0.395	1																			
Nitrate	0.156	0.229	0.847*	0.175	0.098	0.960*	0.117	0.172	0.317																		
phos	0.149	0.667	0.335	-0.205	0.469	0.391	0.940*	-0.169	-0.229	1																	
sulp	0.142	0.231	-0.297	-0.351	-0.103	0.823*	0.109	0.209	0.338	-0.058	1																
Nitrate as N	-0.776	-0.474	-0.205	0.036	0.421	0.832*	-0.876*	-0.421	0.446	-0.208	-0.021	1															
iron	-0.378	0.275	0.391	0.336	0.573	0.391	-0.801	0.209	0.338	-0.876*	-0.120	-0.348	1														
Cl	0.529	-0.419	-0.103	0.026	0.478	-0.613	0.281	-0.553	-0.559	0.281	0.974*	0.720	0.149	1													
DO	0.392	0.163	0.335	0.478	0.026	-0.697	0.439	-0.179	-0.208	-0.058	-0.451	0.310	-0.308	0.288	1												
TH	0.102	0.629	0.036	-0.103	0.480	0.117	0.329	-0.226	-0.004	0.136	0.160	-0.023	0.144	0.541	-0.802	1											
Ca	-0.378	0.478	0.391	0.336	0.573	0.391	0.823*	0.745	0.446	-0.021	-0.451	0.310	-0.055	0.288	-0.723	0.636	1										
Mg	0.529	-0.053	0.026	0.307	0.073	-0.677	0.648	-0.620	-0.209	0.174	0.505	-0.427	-0.055	0.288	-0.802	0.886*	0.273	1									
Total alka	-0.408	-0.053	0.478	-0.157	-0.577	-0.715	0.940*	-0.620	-0.209	0.174	-0.281	0.074	0.178	-0.125	-0.639	0.886*	0.273	1									
HCO3	-0.137	-0.060	-0.103	0.504	0.073	-0.376	-0.125	-0.003	0.045	0.115	-0.281	0.074	0.178	-0.125	0.245	-0.060	0.021	-0.241	1								
po4	-0.451	0.181	0.406	0.002	-0.609	0.406	0.376	0.329	-0.591	0.728	0.584	-0.565	-0.700	0.567	0.245	-0.060	0.021	-0.241	0.631	1							
K	-0.208	0.037	-0.846*	-0.081	0.043	-0.846*	0.445	0.756*	0.207	-0.245	0.269	-0.022	0.214	0.168	-0.313	0.038	0.626	-0.233	-0.442	0.631	1						
Na	0.200	-0.383	-0.734	-0.235	0.043	-0.734	0.224	-0.525	-0.305	0.038	0.000	-0.538	-0.168	0.014	-0.451	0.033	0.737	-0.135	-0.251	0.163	0.365	1					
COD	-0.025	-0.419	-0.081	0.552	-0.682	-0.164	0.889*	-0.475	-0.201	-0.068	0.571	-0.122	0.314	0.698	-0.915*	0.880*	0.805	0.818*	-0.247	0.296	0.451	0.365	1				
bod	0.226	-0.264	-0.734	-0.130	0.853*	-0.106	0.838*	-0.361	0.136	-0.349	0.372	0.125	0.412	0.644	-0.724	0.755	0.765	0.683	-0.481	0.033	0.304	-0.521	0.905*	1			
ecoli	-0.304	-0.149	-0.106	0.455	0.066	-0.106	-0.262	-0.137	0.262	-0.574	-0.507	0.614	0.632	-0.462	0.321	-0.506	-0.678	-0.420	-0.339	0.271	-0.521	0.451	0.789	-0.441	1		
(COD/OD)	0.630	-0.070	0.115	0.035	0.066	0.115	0.462	-0.069	0.548	-0.750	0.036	0.542	0.566	0.431	-0.479	0.747	0.495	0.738	-0.642	0.033	0.304	0.470	0.188	-0.101	1		
coli	0.866*	0.195	-0.063	0.316	0.115	-0.063	0.524	0.462	0.548	-0.750	0.361	0.542	-0.373	0.217	-0.479	0.747	0.331	0.264	0.281	-0.078	-0.090	0.480	0.188	-0.528	-0.376	1	
ilifior	0.138	0.461	0.521	0.206	-0.187	0.521	0.467	0.355	0.734	-0.397	0.115	0.613	0.281	0.472	-0.002	0.543	0.181	0.579	-0.358	-0.068	-0.165	0.380	0.624	-0.244	0.753	0.063	

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed). a Cannot be computed because at least one of the variables is constant0.

4.3 Minimum, maximum and average values of physical and chemical parameters of six (6) groundwater samples

Parameters	Unit	Minimum	Maximum
Turbidity	NTU	6.00	24.00
Colour		5.00	20.00
Suspended Solid	mg/l	160.00	580.00
E-Conductivity	Umhas	1600.00	21300.00
TDS		170.00	500.00
Total Solid	mg/l	160.00	580.00
Temperature	°C	24.00	24.00
pH		6.50	7.00
Nitrite	mg/l	0.01	0.30
Nitrate	mg/l	4.00	35.00
Phosphate	mg/l	0.40	1.90
Sulphate	mg/l	5.00	35.00
Nitrate as N	mg/l	2.90	6.70
Iron	mg/l	0.00	0.60
Chloride	mg/l	10.49	97.96
DO	mg/l	2.10	3.80
Total Hardness	mg/l	202.00	646.40
Calcium Hardness	mg/l	80.90	210.50
Magnesium Hardness	mg/l	60.40	488.50
Total Alkalinity	mg/l	38.00	101.00
HCO_3	mg/l	87.00	270.00

CO_3	mg/l	0.00	0.00
PO_4	mg/l	0.06	0.70
COD	mg/l	16.00	34.00
BOD	mg/l	10.32	20.21
Na	mg/l	1.10	15.00
K	mg/l	1.32	12.00

4.2 Analysis of Result

4.2.1 Alkalinity

The Nigeria standard for total alkalinity is given as 150mg/l (NSDQW, 2008) while that of WHO is 100mg/l of which all samples are below the standard. Alkalinity is defined to be a measure of the capacity of water to neutralize acids. Water may have a low alkalinity rating but a high pH or vice versa, so alkalinity alone is not of major importance as a measure of water quality.
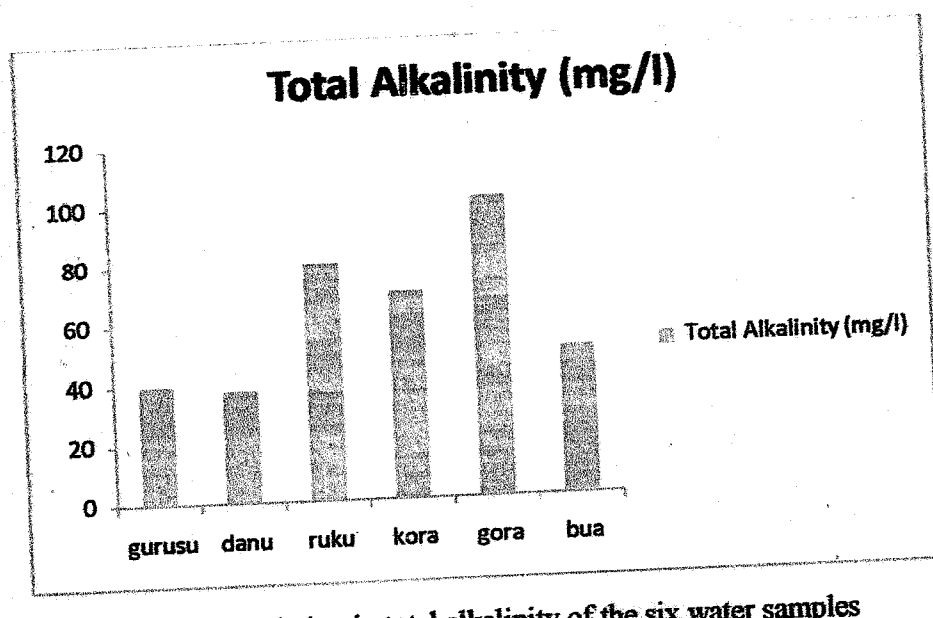
Fig. 4.1 showing variation in total alkalinity of the six water samples

4.2.2 Calcium Hardness (mg/l)

The Nigeria standard for total hardness is given as 200 (NSDQW, 2008) which indicate that four of the samples were above the standard limit while two were below the standard limit The minimum and maximum values are 80.90mg/l and 210.50mg/l respectively. The presence of calcium contributes to the general water hardness which makes it unsuitable for some domestic and industrial use.
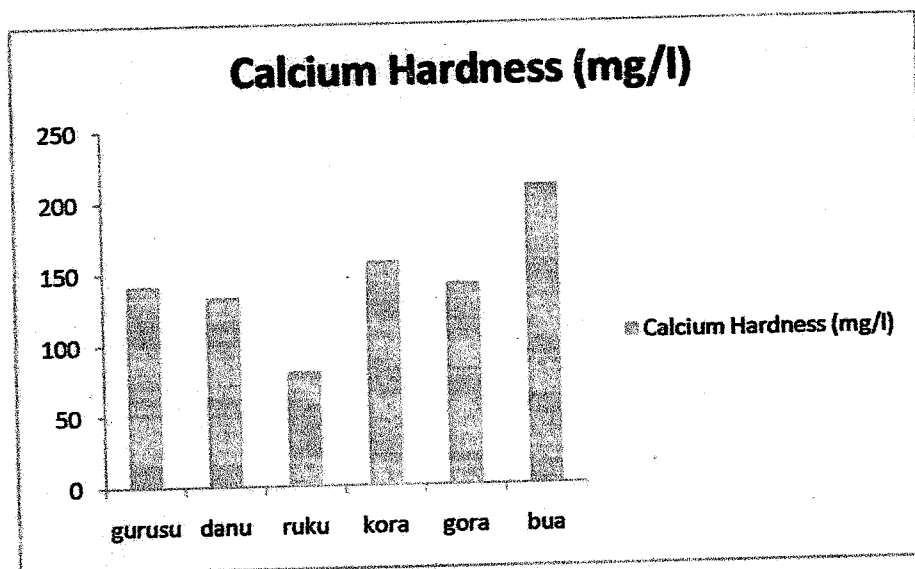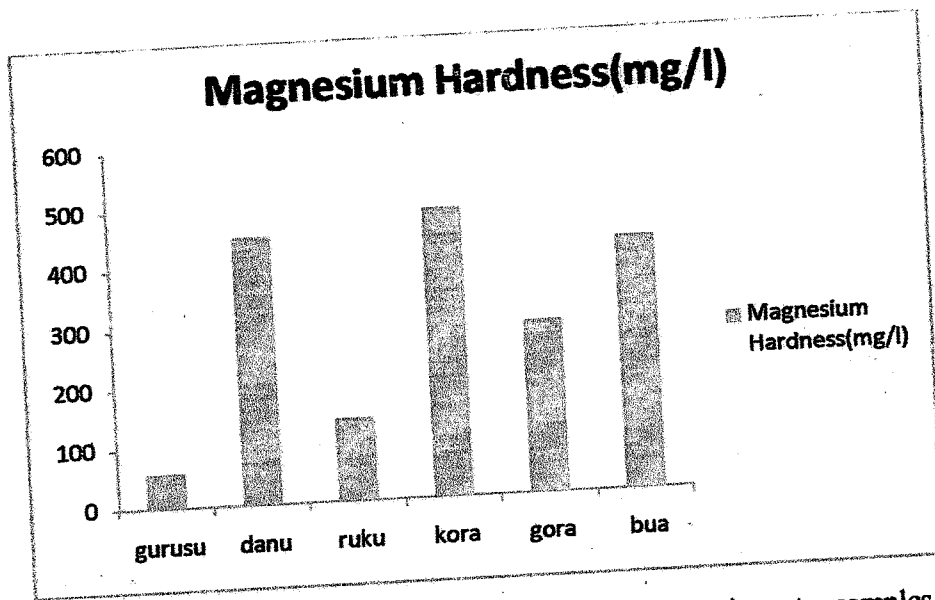

Fig. 4.2 showing variation in calcium hardness of the six water samples

4.2.3 Iron (mg/l)

The Nigeria Standard for Drinking Water Quality (2008) and WHO (2004) is 0.30mg/l. From the result, the minimum and maximum obtained were 0.00 mg/l and 0.60 mg/l respectively. From Fig 4.15 below, five values were above while only one was below the maximum permitted level.

Most iron is absorbed in the duodenum. Absorption depends on the individual's iron status and is regulated so that excessive amounts of iron are not stored in the body.

41
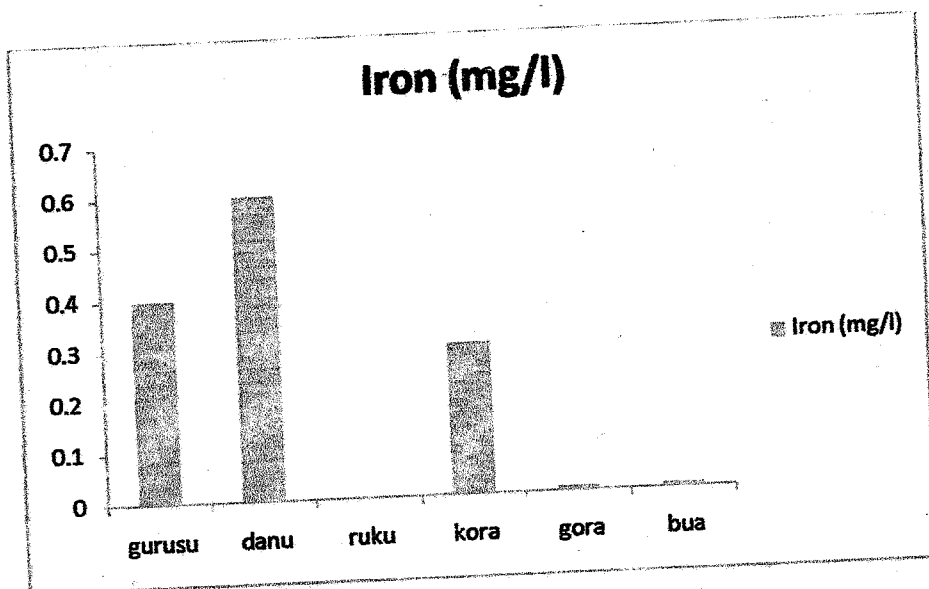
Fig 4.3 showing variation in Iron of the six water samples with the standard

4.2.4 Magnesium Hardness (mg/l)

The standard for magnesium hardness is given as 150mg/l (NSDQW, 2008) while that of WHO (2004) standard is 50mg/l. The minimum and maximum values recorded from the analyses were 60.00 mg/l and 488.50 mg/l respectively. The presence of magnesium in particular water contributes to the total hardness in such water. It may also contribute to undesirable taste of such water. According to the analysis, all the samples are above the standard have high tendency of being interfering with almost every cleaning task from laundering and dishwashing to bathing and personal grooming.

42

Fig 4.4 showing variation in Magnesium hardness of the six water samples

4.2.5 Nitrate (mg/l)

The Nigeria Standard for Drinking Water Quality (2008) for nitrate (NO_3) is 50mg/l. The minimum and maximum values obtained from the analyses were 4.00 mg/l and 35.00 mg/l respectively, which implies that all the samples were within the permitted level. The nitrate represents there is fully oxidized organic matter, and such waters may not be harmful. However, the presence of too much of nitrate in water may adversely affect the health of infants.
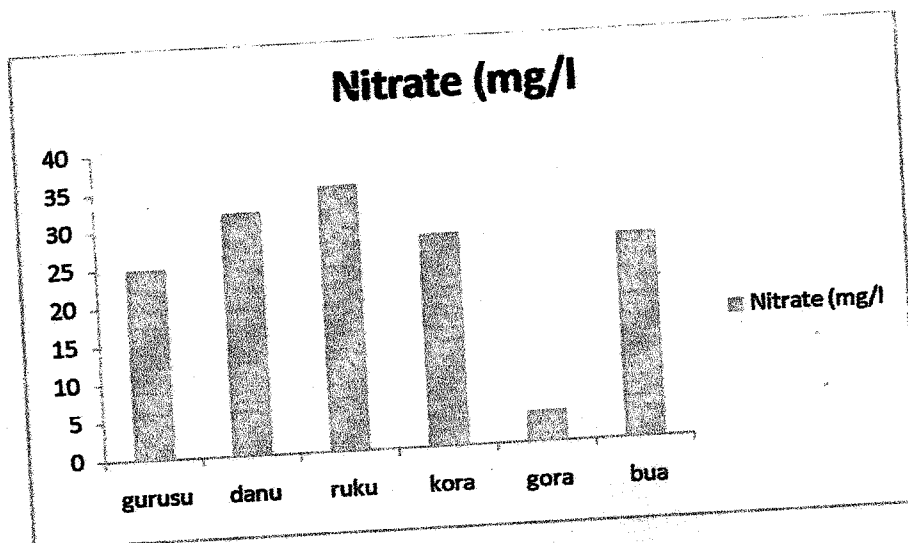
Fig 4.5 showing variation in Nitrate of the six water samples

4.2.6 Nitrite (mg/l)

Nigeria Standard for Drinking Water Quality (2008) stated that nitrite in drinking water should not exceed 0.30mg/l. The minimum and the maximum values are 0.01 mg/l and 0.30mg/l. Among the six samples, all were below the standard.

Excessive concentrations of nitrate can be harmful to humans and wildlife.
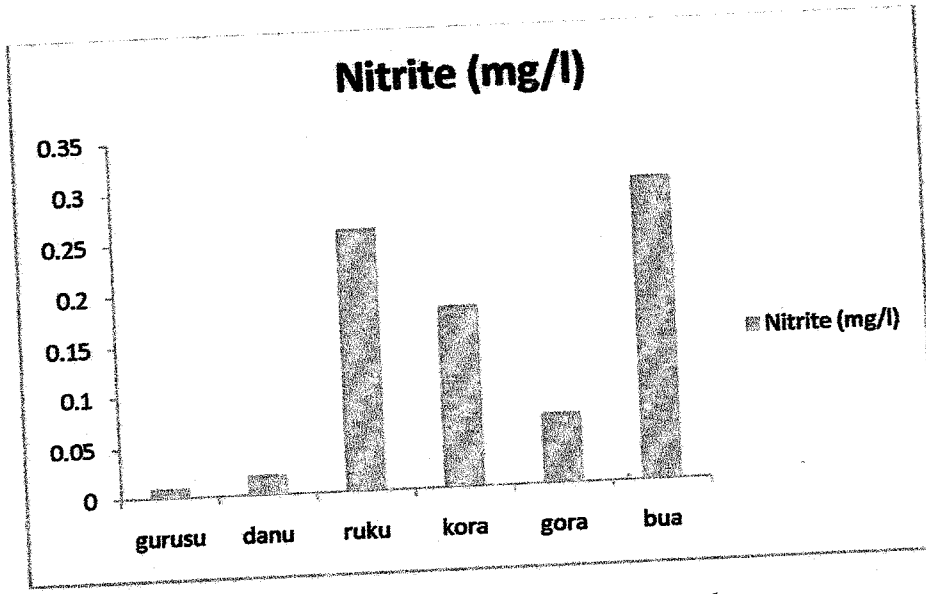

Fig 4.6 showing variation in Nitrite of the six water samples

4.2.7 pH

The standard for pH is given as 6.5 – 8.5 based on the standard set by NSWQ (2008). While that of WHO (2004) standard is 7.0-8.5. The minimum value and maximum values are 6.50 and 7.00. pH is a measure of the acidity or the alkalinity of a substance. Water with a low pH (< 6.5) could be acidic, soft, and corrosive while water with a pH > 8.5 could indicate that the water is hard.
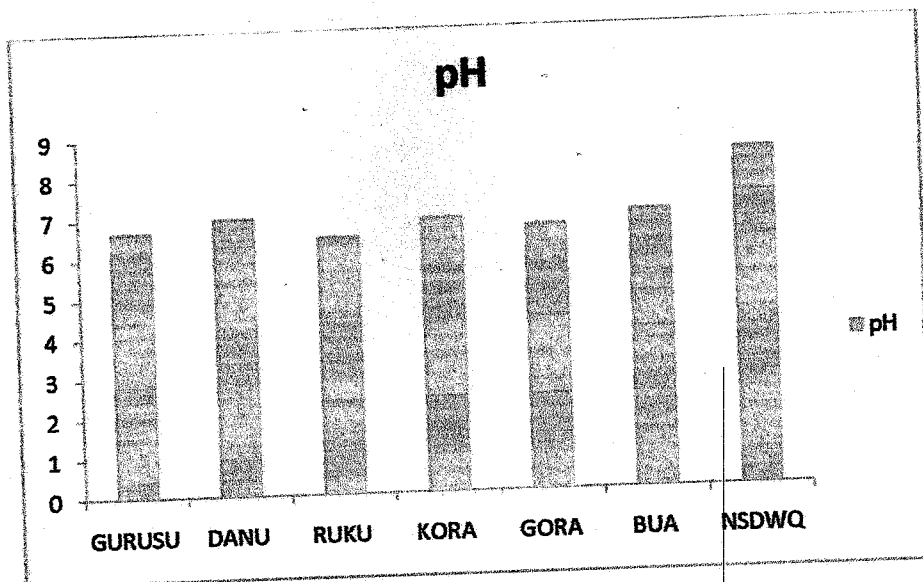
Fig. 4.7 showing variation in pH of the six water samples with the standard

4.2.8 Sulphate (mg/l)

The Nigeria Standard for Drinking Water Quality for sulphate (SO_4) is 250 mg/l. The minimum and maximum values obtained were 5.00 mg/l and 35.00 mg/l respectively, thus, shows that they were all within the permitted level of the standard.

Sulphate is a substance that occurs naturally in drinking water at various concentrations. Health concerns regarding high sulphate concentrations in drinking water have been raised because of reports that link it with an increased occurrence of diarrhea.
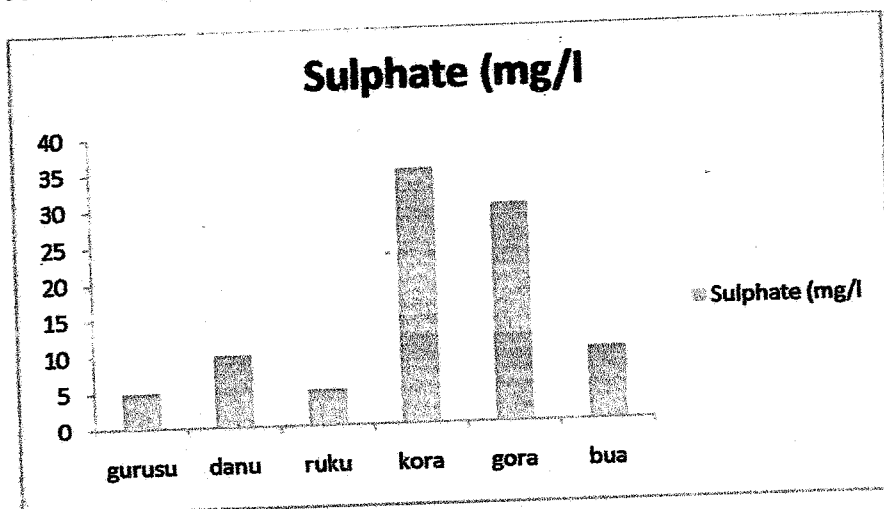

Fig. 4.8 showing variation in sulphate of the six water samples

45

4.2.9 Total Dissolved Solids (mg/l)

The Nigeria Standard for Drinking Water Quality (NSDWQ 2008) is given to be 500mg/l while WHO standard is 1000mg/l. The minimum and maximum total dissolved solids were 170.00 mg/l and 500.00 mg/l respectively, comparing these values with that of the standard, it can be seen that the values are above the standard value. The effects of total dissolved solids on drinking water depend on the level of individual elements, compounds, and components.
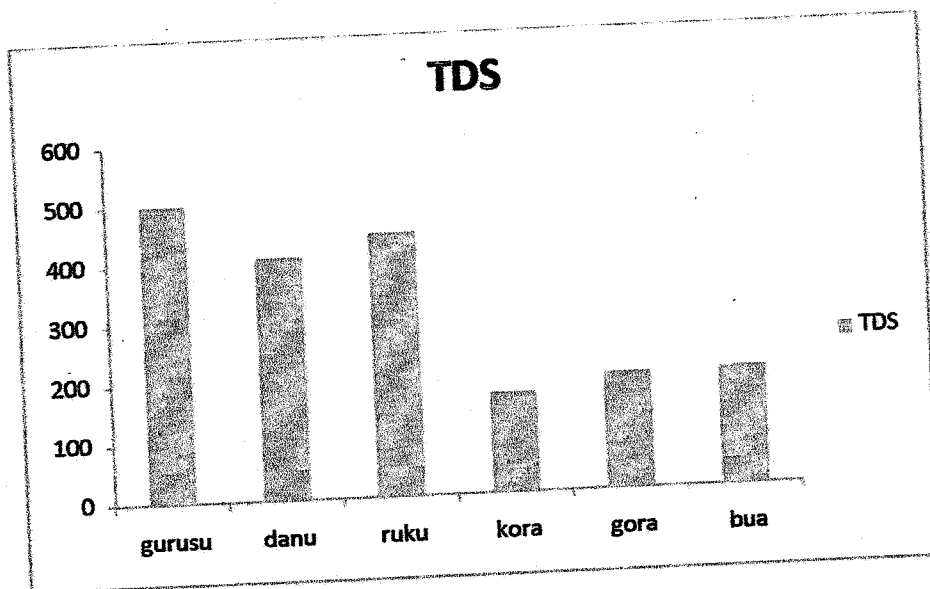

Fig 4.9 showing variation in TDS of the six water samples

Total Bacterial Count (cfu/ml) and Escherichia Coli

The maximum Nigeria Standard for Drinking Water Quality (2008) for Total Coliform Count and Escherichia Coli (E. Coli) are 10cfu/ml and 0cfu/ml respectively. From the analyses, the minimum and maximum obtained for Total Coliform Count were 150cfu/ml and 460cfu/ml respectively while that of the Escherichia Coli were 90cfu/ml and 170cfu/ml. From Figures 4.16 and 4.17 below, it can be simply seen that all the values are beyond the maximum permitted level.

Coliform bacteria occur in high quantity in human faeces, and detected occurrence is as low as one bacterium per 100ml. Hence, they are sensitive indicators of faecal pollution. The total coliform bacteria count in the samples show that the wells are exposed to serious and complex pollution. Coliform count indicates the likelihood of sewage pollution, and faecal coliform count confirms the pollution source as that of human or animal origin. Also, the result obtained through the observed coliform bacteria count indicate that the bacteria content is above the recommended value by the World Health Organization (W.H.O) of less them 10 coliform bacteria per 100ml of water..
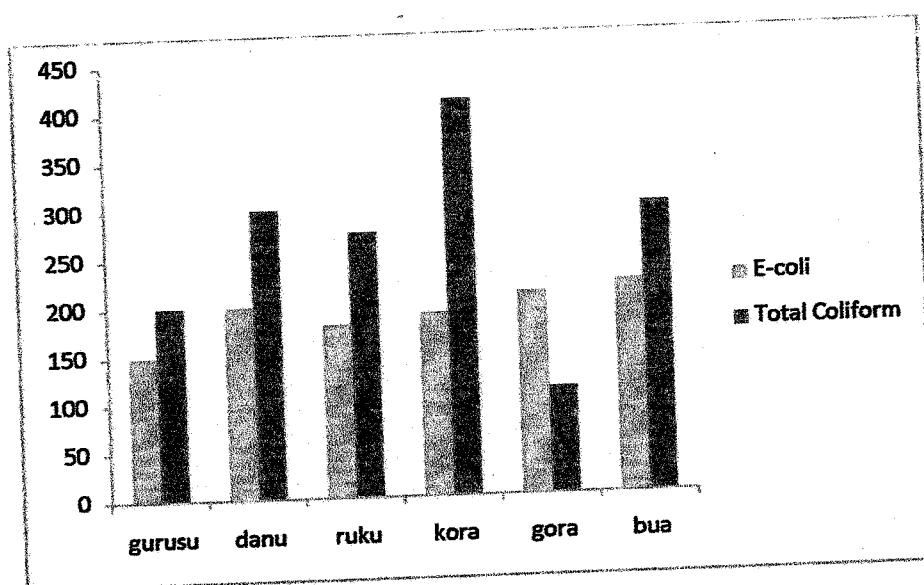

Fig. 4.10 showing variation in total coliform and E coliof the six water samples

4.2.11 Total Suspended Solids (mg/l)

No standard was set by the NSDWQ while that of WHO (2004) is 25mg/l for total suspended solids, but the minimum and maximum values obtained during the analyses were 160.00mg/l and 580.00mg/l respectively.

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial

wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.
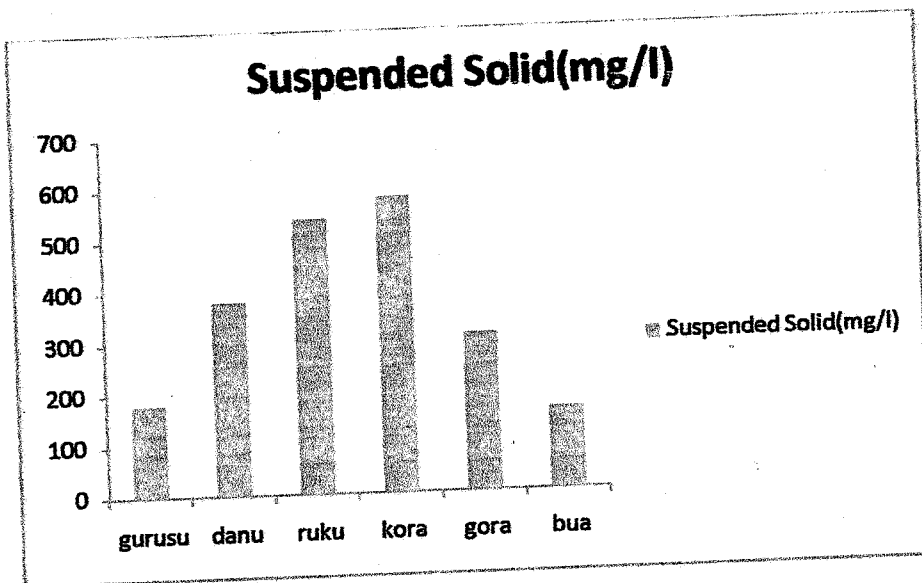
Suspended Solid(mg/l)

Fig 4.11 showing variation in suspended solid of the six water samples

4.2.12 Turbidity (NTU)

The Nigeria standard for drinking water quality (2008) and WHO (2004) stated that the maximum turbidity level for drinking water to be 5ntu. Based on the analysis of the samples from the six villages, samples from five villages were below the maximum permissible limit while one was above the maximum permissible limit.Turbidity is suspended biological,

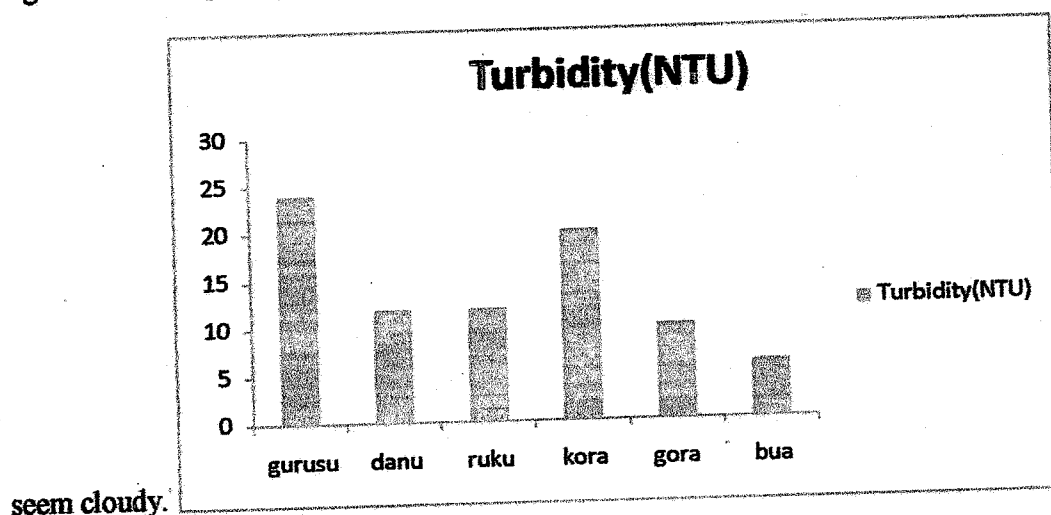organic and inorganic particles in water which may be in high quantity to make the water

Turbidity(NTU)

seem cloudy.

Fig 4.12 showing variation in Turbidity of the six water samples

4.3 Correlation Analyses

The correlation matrix for the physicochemical and bacteriological properties of water samples from the study site are presented in Table 4.2

There was significant correlation observed between suspended solid and Nitrite which exhibit positive correlation ($r = 0.847$ at $P < 0.01 respectively$) meaning that there is increase in the Nitrite of the sample there was increase suspended solid.

There was a significant correlation between TDS and COD, which exhibit positive correlation ($r = 0.853$ at $p < 0.01$ $respectively$). which indicate that the increasing values of TDS led to the increasing values of COD.

There was significant correlation observed between Total Solid and Nitrite which exhibit positive correlation ($r = 0.847 at$ $p < 0.01$) which indicate that there was increase in Nitrite when the TDS increased.

There was significant correlation observed between pH and potassium and sodium which exhibit positive correlation ($r = 0.889$, and 0.838 at $p < 0.01$ $respectively$) which means that there was increasing in the values of potassium and sodium when the value of pH increases.

There was significant correlation observed between Nitrate and Nitrate as N ($r = 0.832$ at $p < 0.01 respectively$). which mean that when Nitrate increase, Nitrate as N also increases.

There was significant correlation observed between Total hardness and Potassium which exhibit positive correlation($r = 0.818$ at $p < 0.01$). This implies that if there is an increase in Total hardness, there must be an increase in Potassium.

There was significant correlation observed between potassium and sodium which exhibit positive correlation ($r = 0.905$ at $p < 0.01$). which implies that if there is an increase in potassium there must be an increase in sodium.

There was significant correlation observed between Turbidity and E.coli which exhibit a negative correlation ($r = -0.866$ at $p < 0.01$). which implies that if there is an increasing Turbidity there must be a decrease in E.coli.

There was significant correlation observed between suspended solid and HCO₃ which exhibit a negative correlation ($r = -0.846$ at $p < 0.01$). which implies the if there is an increasing suspended solid there must be a decrease in HCO_3.

There was significant correlation observed between Total solid and HCO₃ which exhibit a negative correlation ($r = -0.846$ at $p < 0.01$). which implies the if there is an increasing Total solid there must be a decrease in HCO_3.

There was significant correlation observed between pH and Dissolved Oxygen which exhibit a negative correlation ($r = -0.823$ at $p < 0.01$). which implies that if there is an increasing pH there must be a decrease in Dissolved Oxygen.

There was significant correlation observed between Nitrite and HCO_3 which exhibit a negative correlation ($r = -0.756$ at $p < 0.01$). which implies that if there is an increasing Nitrite there must be a decrease in HCO_3.

There was significant correlation observed between phosphate and Fe which exhibit a negative correlation ($r = -0.876$ at $p < 0.01$). which implies that if there is an increasing phosphate there must be a decrease in Fe.

There was significant correlation observed between Dissolved oxygen and potassium which exhibit a negative correlation ($r = -0.915$ at $p < 0.01$). which implies that if there is an increasing Dissolved oxygen there must be a decrease in potassium.

4.1.2 Suitability for Irrigation Use

The water quality evaluation in the area of study is carried out to determine their suitability for agricultural purposes. The suitability of groundwater for irrigation is contingent on the effects on the mineral constituents of the water on both the plant and the soil. In fact, salts can be highly harmful. They can limit growth of plants physically, by restricting the taking up of water through modification of osmotic processes. Also salts may damage plant growth chemically by the effects of toxic substances upon metabolic processes. Salinity, sodicity and toxicity generally need to be considered for evaluation of the suitable quality of groundwater for irrigation Todd 1980; (Shainberg and Oster 1976).

From table 4.1 it was observed that the value for the electrical conductivity is is doubtful when those values are compare to with the standard given below (table 4.2).

Salinity and indices such as sodium absorption ratio (SAR), sodium percentage (%Na), residual sodium carbonate (RSC) and permeability index (PI) are important parameters for determining the suitability groundwater for agricultural uses. Sirnivasa (2005); Raju (2006).

Electrical conductivity is a good measure for salinity hazard to crops as it reflects the TDS in

51

groundwater. Sodium absorption ratio (SAR) is an important parameters for determining the suitability groundwater for irrigation because it measure of alkali/sodium hazard to crop Subramani, Elango and Damodarasamy (2005). SAR is defined by Karanth (1987).

$$SAR = Na/[(Ca + Mg) /2]^{1/2} \qquad 1$$

The SAR values ranges from 0.543 to 1.06 and according to Richard (1954) classification base on SAR values (table 4.2). All the samples belong to excellent category SAR can indicate the degree to which irrigation water tend to enter into cation-exchange reactions in soil.Sirnivasa (2005).

The sodium percentage (Na %) indicate that all samples falls in the excellent category of the table given below. That is the groundwater samples are excellent for irrigation.

$$\%Na = [Na + K] \times 100/[Ca + Mg + Na + K] \qquad 2$$

Residual sodium carbonate (RSC) has being calculated to determine the hazardous effect of carbonate and bi-carbonate on the quality of water for agricultural purposes. Where all ionic concentration are expresses in mg/L Eaton (1950) the classification of irrigation water according to the RSC values in waters containing more than 2.5 meq/l of RSC are not suitable for irrigation while those having – 2.93 to 2.3meq/l are doubtful and those with less than .25meq/l are good for irrigation. This indicate that all the samples from the six villages are doubtful. (table 4.1)

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \qquad 3$$

The permeability index (PI) values also indicate that the groundwater is suitable for irrigation since it is within the permissible limit set by WHO (2004).

$$PI = 100 \times [([Na] + [HCO3]^{1/2})/[Na] + [Ca] + [Mg] \qquad 4$$

52

Chloro-Alkaline Indices (CAI) is essential to know the changes in chemical composition of groundwater during its travel in the subsurface Aastri (1994). The Chloro-alkaline indices CAI 1, 2 are suggested by Schoeller (1977), which indicate the ion exchange between the groundwater and the host environment. The Chloro-alkaline indices used in the evaluation of Base Exchange are calculated using the equation (5 and 6)

1. Chloro-Alkaline Indices

$$1 = [Cl - (Na + K)]/Cl \qquad 5$$

2. Chloro-Alkaline Indices

$$2 = [Cl-(Na+K)] \quad / \quad (SO_4+HCO_3+CO_3+NO_3) \qquad 6$$

If there is ion exchange of Na and K from water with magnesium and calcium in the rock, the exchange is known as direct when the indices are positive .if the exchange is reverse than the exchange is indirect and the indeces are found to be negative. From the calculation of the six samples 77.8% of the ground water are positive samples and the remaining 22.2% are negative.

4.3 Results of Parameters for Irrigation

PARAMETERS	gurusu	danu	Ruku	Kora	Gora	Bua
K	4.40	6.40	1.11	7.96	5.5	7.10
Na	10.7	11.1	7.71	13.2	9.2	12.1
SAR	1.065	0.649	0.732	0.734	0.624	0.678
%Na	9.26	142.75	5.23.823	3.17	3.274	2.929
RSC	-48.00	-399	-115.9	-558.5	-335.3	-366.3
PI	12.46	4.15	7.84	3.42	4.32	4.41
CAI	-4.87	0.48	0.16	0.78	0.69	0.29
CAII	-0.355	0.09	0.01	0.60	0.25	0.03

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The following conclusions were made based on the project work:

The three new wells and the existing ones are not good for drinking because they have not been treated.

Considering the location of the well which may be close to dumping site, septic tank and surface runoff which has contributed to the high value of the E. Coli and the total coliform, which was higher when compared to the recommended value of E. Coli and total coliform given by WHO standard which means that the water is not suitable for drinking.

Based on the electrical conductivity, the water samples from the following villages are not suitable for irrigation purposes (i.e Gurusu, Ruku and Bua), while the water samples from Danu, Gora and Kora are not suitable for irrigation because they have higher values greater the recommended by WHO.

Based on the Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC), all the water samples from the six villages are suitable for irrigation purposes because they have values less than the value recommended by the WHO (SAR and RSC < 10).

5.1 RECOMMENDATIONS

The following recommendation were made base on the result obtained:

i.   Effective treatment must be done to make water free of any coliform organism.

ii. Waste must be disposed properly to increase water quality and reduce the water borne disease.

iii. Groundwater must be cited away from soak away and septic tank to prevent contamination.

REFERENCE

Anukam, C. (1997): Water Pollution Control - A Guide to the Use of Water Quality

Management Principles, Case study IV of Nigeria, A publication of the United Nations

Environment Programme, the Water Supply & Sanitation Collaborative Council and

the World Health Organization.

Arabi,S.; Funtua, I.; Alagbe, S.; Zabosrki, P.; and Dewu, B. (2010): Investigation of

Groundwater quality for Domestic and Irrigation purposes around Gubrunde and

Environs, northeastern Nigeria..Journal of American Science, 2010;6(12)

Blake, J. (2008): Introduction to Irrigation Engineering, Prentihill Publishers.

Chilton C (1992). Women and Water. Waterlines, 2(110): 2–4.

Ekiye, E., Luo, Z., Olubi, K. (2010): Water quality monitoring in Nigeria; Case Study of

Nigeria's industrial cities. *Journal of American Science, 2010:6(4)*.

Elliot and R.K. Fresvert (1992):*Soil and Water Conservation Engineering. (*4th Eds). New

York.pp. 256-65.

Eniola, E., Chukwu, L.; and Olaide B. (2010):Hydro-Chemistry, Macro-Invertebrate Fauna

and Fish Production of Acdja Fishing Sites in A Tropical Lagoonal Ecosystem. *Journal*

of American Science. 2010:6(1)

Essoka, P., and Umaru, J. (2006): Industrial effluent and water pollution in Kakuri area,

Kaduna South,Nigeria. *Journal of Industrial pollution and control 22 (1)*.

Fasunwon, J.; Olowofela, O., Akinyemi, J., Fasunwon, B. and, Akintokun, O (2008):

Contaminants Evaluation as Water Quality Indicator in Ago-Iwoye, South-western,

Nigeria, African Physical Review **2**:0012

Gordon, J.; and Hailin, Z. (2008) : Classification of Irrigation Water Quality, a publication of

the Oklahoma State University.

Harter, T. (2008): Basic Concepts of groundwater hydrology, Publication 8083, University of California.

Hopkins, J. (2005): Hydrogeology and its concept, available on internet on http://www.esi.utexas.edu/outreach/groundwater/hydrogeology.php?sec=hydr&pag=cycl

Ince, M., Bashir ,D., Oni, O. , Awe, O.; Ogbechie,V. , Korve,K; Adeyinka, M., Olufolabo, A., Ofordu, J., Kehinde, M. (2010):Rapid Assessment of drinking water quality of the Federal Republic of Nigeria, Country Report of the World Health Organization.

Maduabuchi, C. (2004): Surface and Groundwater resources Management Monitoring in Nigeria. A paper presented at the United Nations,EPA and Federal Government Project in Graz, Austria.

Moshood, K. (2008): Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria, UsingSelected Physico-Chemical Parameters.*Turkish Journal of Fisheries and Aquatic Sciences 8: 309-319*

NTA (2011): Inside the National Assembly, a live broadcast of the Nigerian Television Authority on June 26th.

Obiefuna, G. and Orazulike, M. (2010): Assessment of groundwater quality of Yola area for irrigation purposes water resources. *J. Nigerian Assoc. Hydrogeol., 20(1): 32-52*

Obiefuna, G. and Sheriff, A. (2011):Assessment of Shallow Ground Water Quality of PindigaGombe 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 Eds). Stirling, Horden Publishers.Ibadan.Nigeria. pp. 24-25.

Ojo O., Ogedengbe K., Ochieng, M.(2011):Efficacy of solar water disinfection for well waters:

Case study of Ibadan slums, Nigeria.*International Journal of the Physical Sciences Vol. 6(5),* pp. 1059-1067, SN 1992 – 1950.

Olayinka, K.; and Alo, B (2004): Studies on industrial pollution in Nigeria: the effects of textile effluents on the quality of groundwater in some parts of Lagos. *Nigeria Journal of Health and Biomedical Sciences. 3(1): 44-50*

Quddus, K. and Zaman, M. (1996):Irrigation water quality in some selected villages of Meherpur in Bangladesh. *J. Agric. Sci., 23(1): 51-57.*

Raihan, F. and Alam, J.(2008) Assessment of groundwater quality in sunamganj Bangladesh Iranian.*J. Environ. Health Sci. Eng., 6(3): 155-166.*

Sangodoyin AY (1987). Considerations on Contamination of Groundwater by Waste Disposal System in Nigeria Environmental Technology. 14: 957–964.

Sangodoyin, A. Y(2006):Water Source Pollution and Disease Diagnosis in a Nigerian Rural Community, water Source Pollution and Disease Diagnosis in a Nigerian Rural Community.Sarkar, A., and Hassan, A. (2006). Water quality assessment of a groundwater basin in Bangladesh for irrigation use. Pak. *J. Biol. Sci., 9(9): 1677-1684.*

Schewab, G.O., D.D. Fangmeier, W.J. Elliot and R.K. Fresvert (1992): *Soiland Water ConservationEngineering.* (4th Eds). New York. pp. 256-65.

Shahidullah, S., Hakim, M, Alam, A. and Shansuddoha, S (2000): Assessment of groundwater quality in a selected area of Bangladesh. Pak. *J. Biol. Sci., 3(2): 246-249.*

Sidnei, M.T., Fakio, A.L.T., Maria, C.R., Francises, A.E. and Adaunto, F. (1992): Seasonal variation of some limnological factors of Lagoa does Guarana, a Varzea lake of the Rio Paranana State of MatoGroso do Sul,Brazil. *Rev. Hydrobiol., 25(4): 269-276.*

Tekwa, I. J. and B. H. Usman (2006): Estimation of soil loss by gully erosion in Mubi, Adamawa State. *Journal of the Environment.Vol. 1No. 1*.Paraclete Publishers, Yola.Nigeria.

Talukder, M., Shirazi, M. and Paul, K.(1998):Suitability of groundwater for irrigation at KirimganjUpazilaKishoreganj. *Progress Agric., 9: 107-112.*

ThisDay Newspaper (2011): Cholera Epidemic in Niger State, pg 17 of January 14 Edition.

Water Quality Policy, Water Aid Nigeria, Oct. 2004

Wikipedia Online Encyclopedia (2011):Water Quality available on www.wikipedia.org/wiki/water_quality, Accessed on 7th of June, 2011.

APPENDIX 1

Conversion of Units from mg/L to meq/L

$$meq/l = \frac{mg/l}{molar\ mass}$$

	GURUSU meq/l	DANU meq/l	RUKU meq/l	KORA meq/l	GORA meq/l	BUA meq/l
Na	$= \frac{10.7}{23}$ $= 0.465$	$= \frac{11.1}{23}$ $= 0.483$	$= \frac{7.71}{23}$ $= 0.335$	$= \frac{13.2}{23}$ $= 0.574$	$= \frac{9.2}{23}$ $= 0.400$	$= \frac{12.1}{23}$ $= 0.526$
k	$= \frac{4.40}{39.1}$ $= 0.113$	$= \frac{6.40}{39.1}$ $= 0.164$	$= \frac{1.11}{39.1}$ $= 0.028$	$= \frac{7.96}{39.1}$ $= 0.204$	$= \frac{5.50}{39.1}$ $= 0.14$	$= \frac{7.10}{39.1}$ $= 0.309$
NO$_3$	$= \frac{5.20}{39.1}$ $= 0.403$	$= \frac{6.70}{39.1}$ $= 0.516$	$= \frac{5.70}{39.1}$ $= 0.564$	$= \frac{5.60}{39.1}$ $= 0.451$	$= \frac{2.90}{39.1}$ $= 0.065$	$= \frac{3.90}{39.1}$ $= 0.436$
Ca	$= \frac{141.60}{40.08}$ $= 3.54$	$= \frac{133.50}{40.08}$ $= 3.34$	$\Box\Box = \frac{80.90}{40.08}$ $= 2.02$	$= \frac{157.80}{40.08}$ $= 3.95$	$= \frac{141.60}{40.08}$ $= 3.54$	$= \frac{210.50}{40.08}$ $= 5.26$
HCO$_3$	$= \frac{250.00}{61.0168}$ $= 4.$	$\frac{186.00}{61.0168} = 3.05$	$= \frac{106.00}{61.0168}$ $= 1.24$	$= \frac{87.00}{61.0168}$ $= 1.43$	$= \frac{99.00}{61.0168}$ $= 1.62$	$= \frac{270}{61.0168}$ $= 4.43$
Cl	$= \frac{18.99}{35.45}$ $= 0.54$	$= \frac{33.48}{35.45}$ $= 0.94$	$= \frac{10.49}{35.45}$ $= 0.30$	$= \frac{97.96}{35.45} = 2.7$	$= \frac{47.98}{35.45}$ $= 1.35$	$= \frac{26.99}{35.45}$ $= 0.76$

61

CO_3 $\qquad = \dfrac{0}{60} = 0 \qquad = \dfrac{0}{60} = 0 \qquad = \dfrac{0}{60} = 0 \qquad = \dfrac{0}{60} = 0 \qquad = \dfrac{0}{60} = 0 \qquad = \dfrac{0}{60} = 0$

SO_2 $\qquad = \dfrac{5.00}{55} = \qquad = \dfrac{10.00}{55} = \qquad = \dfrac{5.00}{55} = \qquad = \dfrac{35.00}{55} = \qquad = \dfrac{30.00}{55} = \qquad = \dfrac{10.00}{55} =$

$$\%Na = [Na + K] \times 100/[Ca + Mg + Na + K]$$

$$\%Na = \frac{(0.465 + 0.133)}{(3.54 + 2.86 + 0.465 + 0.133)} \times 100$$

$$= 8.54 meq/l$$

$$\%Na = \frac{(0.483 + 0.164)}{(3.34 + 18.601 + 0.483 + 0.164)} \times 100$$

$$\frac{2.86 meq}{l}$$

$$\%Na = \frac{(0.335 + 0.028)}{2.02 + 5.8 + 0.335 + 0.028} \times 100$$

$$= 4.43 meq/l$$

$$\%Na = \frac{(0.574 + 0.204)}{(3.945 + 20.095 + 0.574 + 0.204)} \times 100$$

$$= \frac{3.13 meq}{l}$$

$$\%Na = \frac{(0.4 + 0.14)}{(3.54 + 12.04 + 0.4 + 0.14)} \times 100$$

$$= \frac{3.34 meq}{l}$$

$$\%Na = \frac{(0.526 + 0.182)}{(5.26 + 17.151 + 0.526 + 0.182)} \times 100$$

$$= 3.01 meq/l$$

1

$$SAR = Na/[(Ca + Mg) \ /2]^{1/2}$$

$$\frac{0.465}{[(3.54 + 2.86) \ /2]^{1/2}} = 0.260 meq/l$$

$$\frac{0.483}{[(3.34 + 18.601)/_2]^{1/_2}} = 0.145 meq/l$$

$$\frac{0.335}{[(2.02 + 5.8)/_2]^{1/_2}} = 0.169 meq/l$$

$$\frac{0.574}{[(3.945 + 20.095)/_2]^{1/_2}} = 0.165 meq/l$$

$$\frac{0.4}{[(3.54 + 12.04)/_2]^{1/_2}} = 0.143 meq/l$$

$$\frac{0.526}{[(5.26 + 17.15)/_2]^{1/_2}} = 0.155 meq/l$$

$RSC = (CO_3 + HCO_3) - (Ca + Mg)$

$$(0 + 4.10) - (3.54 + 2.86) = -2.3 q/l$$

$$(0 + 3.05) - (3.34 + 18.601) = -18.89 l$$

$$(0 + 1.24) - (2.08 + 5.80) = -6.58 meq/$$

64

$$(0 + 143) - (3.945 + 20.095) = -22.61 meq/l$$

$$(0 + 1.62) - (3.54 + 1204) = -13.96 meq/l$$

$$(0 + 4.43) - (5.26 + 17.515) = -18.33 meq/l$$

$$PI = 100 \times [([Na] + [HCO3]^{1/2})/[Na] + [Ca] + [Mg]$$

4

$$100 \times [\frac{[0.113) + [4.10]^{1/2}}{[0.113] + [3.54] + [2.86]}] = 32.86 meq/l$$

$$100 \times [\frac{[0.483) + [3.05]^{1/2}}{[0.483] + [3.34] + [18.601]}] = 9.94 meq/l$$

$$100 \times [\frac{[0.335) + [1.24]^{1/2}}{[0.335] + [2.02] + [5.80]}] = 17.8 meq/l$$

$$100 \times [\frac{[0.574) + [1.43]^{1/2}}{[0.574] + [3.945] + [20.095]}] = 7.19 meq/l$$

$$100 \times [\frac{[0.40] + [1.62]^{1/2}}{[0.40] + [3.54] + [12.40]}] = 10.22 meq/l$$

$$100 \times [\frac{[0.526] + [4.43]^{1/2}}{[0.526] + [5.26] + [17.515]}] = 11.29 meq/l$$

1. Chloro-Alkaline Indices

$$1 = [Cl - (Na + K)]/Cl$$

5

$$[0.54 - (0.465 + 0.113)]/0.54 = -0.11 meq/l$$

$$[0.94 - (0.483 + 0.164)]/0.94 = 0.31 meq/l$$

$$[0.30 - (0.335 + 0.028)]/0.30 = -1.21 meq/l$$

$$[2.76 - (0.574 + 0.204)]/2.76 = 0.72 meq/l$$

$$[1.35 - (0.4 + 0.14)]/1.35 = 0.81 meq/l$$

$$[0.76 - (0.526 + 0.182)]/0.76 = -0.052 meq/l$$

1. Chloro-Alkaline Indices

$$2 = [Cl-(Na+K)] \quad / \quad (SO_4+HCO_3+CO_3+NO_3)$$

6

$$\frac{[113.96 - (4.5 + 6.3)]}{(75 + 245 + 0 + 35)} = 2.9 meq/l$$

$$\frac{[45.48 - (4.32 + 10.1)]}{(36 + 93 + 0 + 12.2)} = 2.2 meq/l$$

$$\frac{[36.99 - (8.4 + 2.1)]}{(8 + 256 + 0 + 4.7)} = 0.99 meq/l$$

$$\frac{[53.96 - (6.33 + 7.3)]}{(30 + 168 + +0 + 11)} = 1.95 meq/l$$

$$\frac{[20.49 - (10 + 9.3)]}{(26 + 127 + 0 + 5.3)} = 0.075 meq/l$$

$$\frac{[43.99 - (5.4 + 1.1)]}{(8 + 113 + 0 + 10.2)} = 2.9 meq/l$$