EVALUATION OF GROUNDWATER QUALITY FOR IRRIGATION AND DOMESTIC WATER SUPPLY IN CHANCHAGA RIVER CATCHMENT A CASE STUDY OF SABON GIDA, SABON GARI, SAHUKA KAHUTA, TAI, KADNA AND SHALUKO VILLAGES

BY

GBENGA MATHEW

MATRIC No. 2007/2/26072EA

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

FEBRUARY, 2012

DECLARATION

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 Information derived from personal communications, published and unpublished work ere duly referenced in the text.

GBENGA, MATHEW

2/3/2012.

DATE

CERTIFICATION

o certify that the project entitled "Evaluation of ground water quality for irrigation and c water supply in chanchaga river catchment . "A case Study of Sabon Gida. Sabon Gari. Kahuta. Tai. Kadna. and Shaluko Villages" by Gbenga Mathew meets the regulations ing the award of the degree of bachelor of engineering (B.ENG) of the Federal University nology . Minna. and it is approved for it contribution to scientific knowledge and y presentation.

alilu

28-02-12

Date

Adamu Halilu

rvisor

02/03/2012

Date

r. Dr. P. A Idah

ad of Department

22-02-2012

Date

xternal Examiner

DEDICATION

to dedicate this project to the almighty God by whose loving kindness I have obtained mercy what I am today. And also to my loving parent elder and late Mrs. Mathew Dare.

ACKNOWLEDGEMENTS .

s God who has been my helper and sustainers from the beginning up to this time. Indeed it was rney of a thousand mile that ended in a day.

nt to thank my supervisor Mr Adamu Halilu for the assistance rendered to me in the course of esearch. I am also grateful to all my lecturers,indeed am very great grateful, My unreserved eciation goes to Mr. and Mrs. Bankole, Mr. Kayode Ajayi, ASP and Mrs Dare, Mr and Mrs i Emmanuel, Pastor Odedoyin, Pastor Odebode, Pastor Alao. I also appreciate my brothers and rs Dorcas, Victoria, Joshua, Tosin Mathews. Sunday, Bunmi, Funmi, Yemisi, Solomon, Victoria of Josephs family.Heritage, Goodness, Bethel all of Bankoles family, Moyin and Paul all of nanuel's family.

at would I eat that I will forget my parent elder and Mrs.Dare infact you are the greatest parents er had. I know that one day I will pay you back for the good you have shown to me. I want to reciate my friends, Kunle, Moses, Shina, Segun, Rotimi and Peter. And to all my friends that I not mention their names. You guys are great I love you all.

ABSTRACT

chaga catchment area is a district in Minna. Shallow groundwater located in this area is ally used for drinking and irrigation purpose by the resident. This research is to evaluate the y of shallow wells collected from the study area in Sabon Gari, Sabon Gida, Shaluko, Sauka ta, Kadna and Tai. In other to achieve this objective physic-chemical parameters (pH, E.C, Ca^{2+} $^{2+}$, Na^{+}, HCO3^{-}, Cl^{-}, SO$_4^{2-}$, NO$_3^{-}$ and PO$_4^{2-}$) were analyzed. Based on the analysis, parameters SAR, %Na, RSC, PI and CAI were calculated. pH, electrical conductivity, calcium, magnesium, um, bicarbonate, chloride, sulphate, nitrate and phosphorus concentration were compared with lard. In addition the calculated values of electrical conductivity shows that 50% of the water les were suitable for irrigation while 33.3% were doubtful and 16.7% are unsuitable for ation. Base on the classification of Sodium Absorbtion Ratio, all the samples were suitable for ation.

TABLE OF CONTENTS

HAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Water Resources

The United Nation Development Programme (UNDP) refers to water to water as the source of life. Water usage forms the backbone of the world's economy because of its importance in all man's activities apart from his physiological functioning, which was estimated to be 6L/head/day Sangodoyin, (1995).

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

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).

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 (Gordon and Hailin, 2008).

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 Objectives

1. To ascertain the suitability of groundwater of the study area for drinking and irrigation uses
2. To classify groundwater for irrigation on the basis of RSC, SAR and PI values

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 Sauka-Kahuta, Sabon Gari, Sabon Gida, shaluko, Tai and Kadna. All these area are within Niger State and Chanchaga River Catchment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Hydrogeology

In any hydrogeological setting, surface water and ground water are main sources or water. Surface water include water from rivers, streams and lakes were as ground constitute water from borehole hand dug wells and springs both source of water are prone to pollution and contamination hence the need for quality assessment. Okagbue (1988) stated that a complete appraisal of available source of water in any area is commonly accomplished where aspect of water quality are included. It has been established that the quality of water is just as important as it s quantity Abinbola *et al.*, 1999, Adelana and Olashininde(2003), Adeyemi *et al.*, (2003). The quality required of ground water required of ground water supply depend on its purpose Todd (1980), Hamill and Dell, (1986), Ezeigebo (1988) Anude *et al.*, (2008). The basic purpose for which water is domestically required include drinking bathing cooking and general sanitation such as laundry, flushing of closet and other house hole chores, were as for agricultural purpose it is especially for irrigation. Therefore and assured supply of water both qualitatively and quantitatively. For this purposes greatly improve the social, economic and agricultural activities of the people.

2.2 Hydrochemistry and Water Quality

Analysing and interpreting the chemistry of water can provide valuable insights into groundwater-surface water interactions. Dissolved constituents can be used as environmental tracers to track the movement of water. For example, a particular characteristic of the groundwater chemistry can be used as an indicator of groundwater discharge when measured in the surface water. Such tracers can be used to determine source areas of water and dissolved chemicals in catchments, calculate hydrologic and chemical fluxes between groundwater and surface water, calculate water ages that indicate the length of time water and dissolved chemicals have been present in the catchment (residence times), and determine average rates of chemical reactions that take place during transport Winter *et al*, (1998). Geochemical mass balance models have been used to estimate mixing ratios of river water and groundwater. Chemicals or materials can be introduced specifically to study groundwater-surface water interactions and are referred to as artificial tracers (Cook *et al*, 2003).

The hydrochemical processes and hydrogeo-chemistry of the groundwater vary spatially and temporally, depending on the geology and chemical characteristics of the aquifer. Apodaca *et al.*, (2002) and Martinez and Bocanegra (2002) have inferred that hydrogeochemical processes such as dissolu-tion, precipitation, ion-exchange processes and the residence time along the flow path control the chemical composition of groundwater. Abimbola *et al.*, (2002) and Olatunji *et al.*, (2001), also established that geology plays a significant role in the chemistry of subsurface water. More so, the importance of mineral diagenesis in the geochemical evolution of ground-water has been elucidated by Wicks *et al.*, (1995), Back *et al.*, (1983), Plummer (1977), Bredehoeft *et al.*, (1983) and Hendry and Schwartz (1990). Studies by Goldenberg et al. (1986), Jones *et al.*, (1969), Drever (1988) and Keller *et al.*, (1991) have shown that, when soluble minerals undergo diagenetic reactions, they provide a medium for cation-exchange reactions, as well as present a significant influence on the geochemistry of an aquifer system. Previous studies carried out in the area have tended to emphasize only the general water supply problems (Etu-Efeotor and Odigi (1983) Amajor (1986). Amadi *et al.*, (1989) assessed the hydrogeo-chemistry of groundwaters in parts of the Niger Delta. Etu-Efeotor (1981), Udom *et al.*, (1999) and Nwankwoala *et al.*, (2007) acknowledged that, the groundwater quality in the area is rapidly deteriorating. Increase in population and rapid urbanization has made groundwater the major source of water supply; hence, it is very essential to understand the hydrogeochemical processes that take place in the aquifer system. In this paper, an attempt is made to evaluate the different water types and hydrogeo-chemistry of the main source of water supply in the area. This study also provides an opportunity to observe a detailed profile of the hydrogeochemicalfacies distribution and processes of groundwater, with a view to predicting their water character.

2.2.1 Drinking and Irrigation Water Quality

Water is one of the most valuable natural resources on earth. In the global water resources about 97.5% is saline water mainly in oceans and only 2.5% is available as freshwater and 70% of it is locked in icecaps and glaciers or lies in deep underground reservoirs. An infinitesimal proportion (0.007%) of all water on earth is readily available fresh water CIMMYT (1999). In this water, the concentrations of toxic chemicals and biologically available nutrients in excess can lead to diverse problems such as toxic algal blooms, loss of oxygen, fish kills, loss of biodiversity and loss of aquatic plant beds and coal reefs Voutsa, Manoli Samara, Sofoniou and Stratis (2001). A study of surface water quality in Macedonia, Greece: Speciation of nitrogen and phosphorus. Water Air Soil Pollut., 129: 13-32. DOI: 10.1023/A). Normally occurring toxic elements in groundwater are B, Na, Cl and Li. Specific water may be suitable for irrigation but may not be suitable for drinking and industrial uses due to presence of some other ions at toxic level. Freeze, A.R. and J.A. Cherry (1979). Groundwater. Prentice Hall, Inc. Englewood Cliffs, New Jersey, ISBN: 0133653129, pp: 604.,Tanninen, J., L. Kamppinen and M. Nyström, (2005). Pre-treatment and hybrid processes. Most toxic elements present in drinking water are As, Cd, Cr, Cl, Pb, Hg, Fe and Zn. The information on concentrations of some important chemical constituents of water is necessary to assess their suitability for irrigation, drinking and industrial uses. Groundwater quality for drinking is a burning issue regarding Arsenic (As) and iron (Fe) toxicity in Bangladesh. Arsenic is a naturally occurring chemical element in rock and soil and it is present in trace amounts in ground water Chen, Fields, Sorg and Wang (2002), Water Works Assoc (1994),Mondal, Samanta,Choudhuri and Dhar *et al.*, (1998). A detailed study report on 'Fakirpara' a very small arsenic affected village of west Bengal-A micro level Study. Proceeding of the International Conference on Arsenic Population of Ground Water in Bangladesh, Sept. 8-12. Arsenic in drinking water is known to cause cancer in human if concentrations are above 300 ppb parts per billion Mondal, Samanta, Choudhuri and Dhar*et al.*, (1998). A detailed study report on 'Fakirpara' a very small arsenic affected village of west Bengal-A micro level Study. Proceeding of the International Conference on Arsenic Population of Ground Water in Bangladesh, (Sept. 8-12). The latest statistics indicate that 80% of Bangladesh or an estimated 40 million people are at risk of arsenic poisoning-related diseases because the ground water in the wells in Bangladesh is contaminated with arsenic Islam,Uddin, Zaman, Mahmood and Rahman. (2003). The problem originates in arsenic-rich bedrock of the Brahmaputra river basin that filters drinking water pumped to the surface through millions of tube wells. Agricultural crops, particularly high yielding varieties of rice, vegetables and cereals are vulnerable to arsenic contamination from contaminated irrigation water. In Bangladesh, 95% of the groundwater is used for irrigation. In view of the importance for the formulation of a base line data, an investigation has been conducted to assess the toxicity of groundwater for irrigation, drinking and industrial usage in Chirirbandar Upazila under Dinajpur District. The total land area of Chirirbandar Upazila is about 31,000 hectares and area under cultivation is above 26,000 hectares. Above 10,000 hectares of arable land is irrigated by groundwater. Keeping all these facts in mind, this area was selected to evaluate the toxicity levels of groundwater.

2.3 Ground Water in Nigeria

Nigeria is situated in West Africa, bordered by Benin in the west, Cameroon in the east and the Gulf of Guinea in the south . It has a large land area of some 911,000 square kilometres. The terrain is very variable, with mountains in the southeast, hills and plateaux including the Jos Plateau in the centre, lowlands in the south and plains in the north. The highest point is Chappal Waddi (2419 m) in eastern Nigeria and the lowest is sea level. Nigeria's climate varies from equatorial in the south to tropical in the centre and arid in the north. Annual rainfall varies from over 4000 mm in the south to less than 250 mm in the north, the national average being 1180 mm. Rainfall is seasonal with a wet season occurring between July to September in the north, extending to between April and November in the delta area. Recent years have seen decreasing rainfall totals in northern Nigeria Carter and Alhassan (1998) and drought is a frequent problem in the region. The mean annual temperature in northern Nigeria is around 25°C Alagbe (2002). Vegetation largely follows the climatic variation, with densely vegetated mangrove swamps in the south, tropical rainforest in the centre, through to savannah in the north and Sahel savannah in the extreme north-east.

2.3.1 Ground water Availability

Groundwater constitutes an important source of water for domestic supply and agriculture in Nigeria. The sedimentary basins generally form the best aquifers. The Sokoto Basin in the north-west is part of the vast Iullemenden Basin of Mali, Niger and Algeria. The depth of the water table in unconfined parts is typically 15–75 m. Artesian conditions occur in confined aquifers at 75–100 m depth at the eastern edge of the basin but with piezometric levels going down to around 50 m below surface further west UN (1988). Significant groundwater ages (in excess of 3000 years) have been found for some confined ground waters from the Sokoto Basin Geyh and Wirth (1980). Artesian conditions also exist in the Chad Basin. Here, three main aquifers have been identified: anupper aquifer at 30–100 m depth, a middle aquifer(eastern part of the basin) some 40–100 m thick occurring from 230 m depth near Maiduguri and a lower aquifer consisting of 100 m of medium to coarse sands and clays occurs at a depth of 425– 530 m. The upper and middle aquifers are exploitedintensively in the Maiduguri area UN (1988). Overexploitation of the aquifers in the Chad Basin has led to a recent decline in groundwater levels and has necessitated drilling to greater depths in order to tap the lower aquifer. Isotopic evidence suggests that groundwaters from the middle and lower aquifers are old (20,000 years or more) and are not being actively replenished by modern recharge Edmunds *et al.,* (1998; 1999). Comparatively little groundwater exploitation has been carried out in the Benue Basin further south. Here, the sediments are more often fine-grained and give relatively low yields. Most of the aquifers in the basin are unconfined, but confined conditions occur locally in the Yola-Numan area UN (1988). The Cretaceous sandstones of the Bida Basin also contain significant groundwater resources. Artesian conditions occur in parts of the aquifer near Pategi UN (1988) and numerous springs also occur. In the Anambra Basin south-east of Lokoja, coarse Cretaceous sandstones form a good aquifer which is largely unconfined in its northern part but becomes artesian further south UN (1988). Groundwater levels are typically 60–150 m deep. Good aquifers are also present in the Tertiary and Quaternary sediments of the southern coastal areas, the best being the Tertiary 'Illaro Formation' composed of sands with occasional beds of clay and shale. An unconfined shallow aquifer also exists at less than 30 m in much of the near-coastal areaUN (1988). Compared to the sedimentary aquifers, groundwater storage in the crystalline basement is small. The failure rate of new boreholes in the basement has in some cases been as high as 80% Edet *et al.*, (1998).Groundwater availability is largely limited to fracture zones and areas of deep weathering. Inplaces, the weathered overburden layer overlying crystalline basement can be thick. Alagbe (2002) reported overburden thicknesses up to 50 m in the River Kan Gimi Basin of north central Nigeria. In large areas of the basement complex, the principal source of groundwater is from dug wells.

2.3.2 Groundwater Quality

A number of groundwater quality investigations have been carried out in Nigeria, though these are usually on local scales and consider a limited number of chemical constituents. This account attempts to summarize the salient features from them. The country's shallow aquifers are potentially vulnerable to pollution from agricultural (fertilisers), domestic (waste dumps, latrines) and industrial sources, except where surface layers are of poor permeability and afford some protection of the underlying aquifers. Sangodoyin (1993) found poor bacteriological quality of groundwater close to sites of waste disposal in Abeokuta area, highlighting the potential for impacts from other pollutants. Sangodoyin and Agbawhe (1992) found high concentrations of total dissolved solids, with particular impacts on calcium, chloride and nitrate, in shallow groundwaters affected by leachates from abattoir sites in the Ibadan area. Increased concentrations were notable up to 250 m from the sites of contamination. Oil spillages are also known to have some impact on the environment in the vicinity of oil boreholes and pipelines. Eze, 2002; Akujieze *et al.,* (2003) although their effect on groundwater quality in Nigeria is difficult to quantify. (Aremu *et al.,* 2002)

2.4 Ground Water Pollution

One of the most critical problems of developing countries is improper management of vast amount of wastes generated by various anthropogenic activities. More challenging is the unsafe disposal of these wastes into the ambient environment. Water bodies especially freshwater reservoirs are the most affected. This has often rendered these natural resources unsuitable for both primary and/or secondary usage Fakayode, (2005). Industrial effluent contamination of natural water bodies has emerged as a major challenge in developing and densely populated countries like Nigeria. Estuaries and inland water bodies, which are the major sources of drinking water in Nigeria, are often contaminated by the activities of the adjoining populations and industrial establishments Sangodoyin, (1995). River systems are the primary means for disposal of waste, especially the effluents, from industries that are near them. These effluent from industries have a great deal of influence on the pollution of the water body, these effluent can alter the physical, chemical and biological nature of the receiving water body Sangodoyin, (1991) Increased industrial activities have led to pollution stress on surface waters both from industrial, agricultural and domestic sources . Ajayi and Osibanji (1981) Wastes entering these water bodies are both in solid and liquid forms. These are mostly derived from Industrial, agricultural and domestic activities. As a result, water bodies which are major receptacles of treated and untreated or partially treated industrial wastes have become highly polluted. The resultant effects of this on public health and the environment are usually great in magnitude. Osibanjo, Daso and Gbadebo (2011). Over the last years, in many African countries a considerable population growth has taken place, accompanied by a steep increase in urbanization, industrial and agricultural land use. This has entailed a tremendous increase in discharge of a wide diversity of pollutants to receiving water bodies and has caused undesirable effects on the different components of the aquatic environment and on fisheries. Saad, El-Rayis, and Ahdy (1984) As a result, there is growing appreciation that nationally, regionally, and globally, the management and utilization of natural resources need to be improved and that the amount of waste and pollution generated by human activity need to be reduced on a large scale. Industries are the major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, wash waters and relatively uncontaminated water from heating and cooling operations. Glyn, and Gary (1996). High levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cd, Cr, Ni and Pb and fecal coliform and hence make such water unsuitable for drinking, irrigation and aquatic life. Industrial wastewaters range from high biochemical oxygen demand (BOD) from biodegradable wastes such as those from human sewage, pulp and paper industries, slaughter houses, tanneries and chemical industry. Others include those from plating shops and textiles, which may be toxic and require on-site physiochemical pre-treatment before discharge into municipal sewage system. Emongor, Nkegbe, Kealotswe, Koorapetse,Sankwase and Keikanetswe (2005) Phiri, Mumba, Moyo and Kadewa, (2005). Otokuneforand Obiukwu (2005). Organic pollution of inland water systems in Africa, in contrast to the situation in developed countries of the world, is often the result of extreme poverty and economic and social underdevelopment. According to Tolba. Tolba (1982) it is in these countries that the quality of water, and often the quantity, is lowest, sanitation and nutrition the worst and disease most prevalent. Unfortunately, there are very few water quality studies for most African inland waters. In general, the available data come from scattered investigations, which were carried out by individuals and by very few scientific projects concerned with African waters. Few reviews exist on the state of pollution of African inland waters. Dejoux, Deelstra and Wilkinson(1981). Egborge, and Fagade(1999) Burgisand Symoens (1987). With competing demands on limited water resources, industrial pollution remains one of the major problems facing Nigerian cities. As societies throughout the world become more aware of the issues involved in water pollution, there has been considerable public debate about environmental effects of effluents discharged into aquatic environments. Calamari (1985). Effluent discharge practices in Nigeria are yet too crude and society is in danger, especially in the industrialized part of the cities. The Federal Environmental Protection Agency (FEPA) established to check these environmental abuses has had little or no impact on pollution control in our cities Ezeronye and Amogu (1998). The aim of this review is to assess the impact of industrial wastewater pollution on aquatic environments in Nigeria.

2.5 Mode of Transportation of Contaminant

Saltwater encroachment associated with over drafting of aquifers or natural leaching from natural occurring deposits are natural sources of groundwater pollution. Most concern over groundwater contamination has centered on pollution associated with human activities. Human groundwater contamination can be related to waste disposal (private sewage disposal systems, land disposal of solid waste, municipal wastewater, wastewater impoundments, land spreading of sludge, brine disposal from the petroleum industry, mine wastes, deep-well disposal of liquid wastes, animal feedlot wastes, radioactive wastes) or not directly related to waste disposal (accidents, certain agricultural activities, mining, highway deicing, acid rain, improper well construction and maintenance, road salt)(www.lenntech.com/groungwater).

Large quantities of organic compounds are manufactured and used by industries, agriculture and municipalities. These man-made organic compounds are of most concern. The organic compounds occur in nature and may come from natural sources as well as from human activities. In many locations groundwater has been contaminated by chemicals for many decades, though this form of pollution was not recognized as serious environmental problem until the 1980s (www.lenntech.com/groungwater/pollution).

A brief description of the contamination sources follows

2.5.1 Natural:

Groundwater contains some impurities, even if it is unaffected by human activities. The types and concentrations of natural impurities depend on the nature of the geological material through which the groundwater moves and the quality of the recharge water. Groundwater moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium, and chlorides. Some aquifers have high natural concentration of dissolved constituents such as arsenic, boron, and selenium. The effect of these natural sources of contamination on groundwater quality depends on the type of contaminant and its concentrations. U.S. Environmental Protection Agency. www.epa. waterpollutants.

2.5.2 Agricultural:

Pesticides, fertilizers, herbicides and animal waste are agricultural sources of groundwater contamination. The agricultural contamination sources are varied and numerous: spillage of fertilizers and pesticides during handling, runoff from the loading and washing of pesticide sprayers or other application equipment, using chemicals uphill from or within a few hundred feet of a well. Agricultural land that lacks sufficient drainage is considered by many farmers to be lost income land. So they may install drain tiles or drainage wells to make the land more productive.Storage of agricultural chemicals near conduits to groundwater, such as open and abandoned wells, sink holes, or surface depressions where ponded water is likely to accumulate. Contamination may also occur when chemicals are stored in uncovered areas, unprotected from wind and rain, or are stored in locations where the groundwater flows from the direction of the chemical storage to the well. (www.epa.gov/ebtpages/watewater).

2.5.3 Industrial:

Manufacturing and service industries have high demands for cooling water, processing water and water for cleaning purposes. Groundwater pollution occurs when used water is returned to the hydrological cycle. Modern economic activity requires transportation and storage of material used in manufacturing, processing, and construction. Along the way, some of this material can be lost through spillage, leakage, or improper handling. The disposal of wastes associated with the above activities contributes to another source of groundwater contamination. Some businesses, usually without access to sewer systems, rely on shallow underground disposal. They use cesspools or dry holes, or send the wastewater into septic tanks. Any of these forms of disposal can lead to contamination of underground sources of drinking water. Dry holes and cesspools introduce wastes directly into the ground. Septic systems cannot treat industrial wastes. Wastewater disposal practices of certain types of businesses, such as automobile service stations, dry cleaners, electrical component or machine manufacturers, photo processors, and metal platters or fabricators are of particular concern because the waste they generate is likely to contain toxic chemicals. Other industrial sources of contamination include cleaning off holding tanks or spraying equipment on the open ground, disposing of waste in septic systems or dry wells, and storing hazardous materials in uncovered areas or in areas that do not have pads with drains or catchment basins. Underground and above ground storage tanks holding petroleum products, acids; solvents and chemicals can develop leaks from corrosion, defects, improper installation, or mechanical failure of the pipes and fittings. Mining of fuel and non-fuel minerals can create many opportunities for groundwater contamination. The problems stem from the mining process itself, disposal of wastes, and processing of the ores and the wastes it creates.(" groundwater contamination (U.S. Environmental Protection Agency. http://www.epa. waterpollutants.html).

2.5.4 Residential:

Residential wastewater systems can be a source of many categories of contaminants, including bacteria, viruses, nitrates from human waste, and organic compounds. Injection wells used for domestic wastewater disposal (septic systems, cesspools, drainage wells for storm water runoff, groundwater recharge wells) are of particular concern to groundwater quality if located close to drinking water wells. Improperly storing or disposing of household chemicals such as paints, synthetic detergents, solvents, oils, medicines, disinfectants, pool chemicals, pesticides, batteries, gasoline and diesel fuel can lead to groundwater contamination. When stored in garages or basements with floor drains, spills and flooding may introduce such contaminants into the groundwater. When thrown in the household trash, the products will eventually be carried into the groundwater because community landfills are not equipped to handle hazardous materials. Similarly, wastes dumped or buried in the ground can contaminate the soil and leach into the groundwater.(U.S Environmental Protection Agency www.epa/watewaterpollutants.html.)

2.6 Types of Groundwater Contaminant

There are several ways ground water can be contaminated the most common avenue for groundwater contaminants are: Unplugged abandoned well, well integrity issue, such as poor construction or design age negligence maintenance and faulty location (near septic tank), non-point source (pollution that originate from different sources and cannot be traced to any single point such as pipe) improper use, disposal or release of contaminants (motor oil, cleaner, pesticide etc) joint groundwater monitoring and contamination report Boulding and Russell, 2009).

Groundwater pollution caused by human activities usually falls into one of two categories: point-source pollution and nonpoint-source pollution. Fertilizers and pesticides applied to crops eventually may reach underlying aquifers, particularly if the aquifer is shallow and not "protected" by an overlying layer of lowpermeability material, such as clay. Drinking-water wells located close to cropland sometimes are contaminated by these agricultural chemicals. Point-source pollution refers to contamination originating from a single tank, disposal site, or facility. Industrial waste disposal sites, accidental spills, leaking gasoline storage tanks, and dumps or landfills are examples of point sources. Chemicals used in agriculture, such as fertilizers, pesticides , and herbicides are examples of nonpoint-source pollution because they are spread out across wide areas. Similarly, runoff from urban areas is a nonpoint source of pollution. Because nonpoint-source substances are used over large areas, they collectively can have a larger impact on the general quality of water in an aquifer than do point sources, particularly when these chemicals are used in areas that overlie aquifers that are vulnerable to pollution. If impacts from individual pollution sources such as septic system drain fields occur over large enough areas, they are often collectively treated as a nonpoint source of pollution (Boulding and Russell, 1995).

2.6.1 Natural Substances.

Some groundwater pollution occurs naturally. The toxic metal arsenic, for instance, is commonly found in the sediments or rock of the western United States, and can be present in groundwater at concentrations that exceed safe levels for drinking water. Radon gas is a radioactive product of the decay of naturally occurring uranium in the Earth's crust. Groundwater entering a house through a home water-supply system might release radon indoors where it could be breathed (Boulding and Russell, 1995)

2.6.2 Petroleum-based Fuels.

One of the best known classes of groundwater contaminants includes petroleum-based fuels such as gasoline and diesel. Nationally, the U.S. Environmental Protection Agency (EPA) has recorded that there have been over 400,000 confirmed releases of petroleum-based fuels from leaking underground storage tanks. Gasoline consists of a mixture of various hydrocarbons (chemicals made up of carbon and hydrogen atoms) that evaporate easily, dissolve to some extent in water, and often are toxic. Aquifers in industrialized areas are at significant risk of being contaminated by chemicals and petroleum products. In most developed countries, various laws attempt to prevent land and water pollution, and to clean up contaminated areas when they occur. Developing countries and countries in economic distress are less likely than developed nations to assess the risk of groundwater contamination by land-use activities. Cancer in humans but may be toxic in other ways. One interesting property of gasoline is that it is less dense than water, and so it tends to float on top of the water table. (Boulding and Russell, 1995)

2.6.3 Chlorinated Solvents.

Another common class of groundwater contaminants includes chemicals known as chlorinated solvents. One example of a chlorinated solvent is dry-cleaning fluid, also known as perchloroethylene. These chemicals are similar to petroleum hydrocarbons in that they are made up of carbon and hydrogen atoms, but the molecules also have chlorine atoms in their structure. As a general rule, the chlorine present in chlorinated solvents makes this class of compounds more toxic than fuels. Unlike petroleum-based fuels, solvents are usually heavier than water, and thus tend to sink to the bottoms of aquifers. This makes solvent-contaminated aquifers much more difficult to clean up than those contaminated by fuels. (Boulding and Russell, 1995).

2.7 Ground Water Movement

There is generally little known about the groundwater conditions beneath deep permafrost in crystalline rock environments. In the Kangerlussuaq area there is no information at all about groundwater available in the literature. No groundwater wells seem to have been drilled through the permafrost. A number of deep boreholes have been drilled for diamond exploration purposes, but no data from these have been presented in open literature. A number of hydrogeological studies have been carried out in the area around Sisimiut by the Arctic Technology Centre (ARTEK) at the Technical University of Denmark. Hansen *et al.*, (1998) reported about a project aimed at finding useful groundwater resources in fracture zones in the bedrock. VLF measurements were carried out to identify the fracture zones and a 20 m deep well was drilled in bedrock consisting of gneiss and amphibolites. However, the well yield was much too low for the demands. Matthiesen *et al.*, (2009) carried out investigations at Andenfjorden, north of Sisimiut, where a hydropower plant is under construction. A well, which provides water to the construction site, has been established at a natural spring. Test pumping have been conducted giving an estimate of the transmissivity of the sediment layers. No hydrogeological data from the 4 km long rock tunnel being excavated were presented in this report, but comparisons of the hydrogeochemical composition between well water and tunnel water were made. It can be expected that an overall flow of deep groundwater in the study area of the GAP project occurs from the bedrock underneath the Inland Ice towards the Sea. The dominant fracture orientation in the region appears to be parallel to the regional tectonic foliation, i e ENE-WSW. Other fracture sets are oriented close to N-S and NW-SE. In the area of continuous permafrost, major groundwater discharge is likely to occur only through taliks beneath larger lakes and rivers. If there exist any larger deformation zones with high transmissivity, these zones may stay partly unfrozen and provide pathways for groundwater flow. Although permafrost is not absolutely impermeable, significant groundwater recharge in the continuous permafrost area is not likely. Hence no active groundwater circulation is expected to occur.

2.8 Management of Ground Water

Nigeria is located on the west coast of Africa, between latitudes 4°N and 14°N and between longitudes 2° E and 15°E. The land area is approximately 925,000 km2, with abundant groundwater resources, enough to cater for the needs of her teeming population of about 140 million. Despite the huge groundwater resources, water resources development has not been able to keep pace with the phenomenal population growth Oteze (2006). Water resources represent a major prerequisite and driver of socio-economic development. Economic sectors that water caters for include domestic, agriculture and fisheries, industry, recreation, municipality including waste/effluent disposal, and water transportation. It also plays a prominent role in power and energy generation: hydroelectric power generation's share of total power production has decreased from over 70% in 2004 to the present proportion of about 40% Oyebande (2004). Groundwater is widely used because of its high quality. Groundwater development unfolds rapidly once a minimum level of technology and energy become widely available. Shah (1993). Compared to surface water, groundwater use often brings large economic benefits per unit volume, because of ready local availability, drought reliability and good quality requiring minimal treatment UN/WWAP (2003). The reliable supply of groundwater, uniform quality and temperature, relative turbidity and pollution free, minimal evaporation losses, and low cost of development are attributes making groundwater more attractive when compared to other sources Menon (1998). Yet, at the same time population and economic growth have led to ever more demands on the resources. This papertherefore, attempts to identify the impediments and associated requirements for, and a path towards, long term sustainable groundwater use and management in Nigeria.

2.8.1 Groundwater Resources Potentials Of Nigeria

There is a very large groundwater potential in Nigeria, far greater than the surface water resources, estimated to be 224 trillion L/year.Hanidu (1990).Rijswlk (1981) estimated groundwater resources at 0 to 50 m depth in Nigeria to be 6 × 10 km3 (6 ×1018 m3). However, from the eight aquifers in Nigeria Akujieze *et al.*, (2005), the Ajali Sandstone aquifer yields 7 to 10 L/s, the Benin formation (Coastal Plain Sands) aquifer yields 6 to 9 L/s, the Upper aquifer 2.5 to 30 L/s, the Middle aquifer 24 to 32 L/s, the Lower aquifer with yields of 10 to 35 L/s (of the Chad formation), the Gwandu formation aquifer with yields of 8 to 15 L/s, the Kerrikerri Sandstone aquifer with yields of 1.25 to 9.5 L/s and the crystalline fluvio-volcanic aquifer with a 15 L/s yield in the Jos Plateau region; groundwater occurrence is not limited to only 50 m b.g.l (below ground level). These eight mega regional aquifers have an effective average thickness range of 360 m, with a thickness range of 15 to 3,000 m at a depth range of 0 to 630 m b.g.l with an average depth of 220 m Akujieze *et al.*, (2003). Reserves of groundwater are considerable in large sedimentary basins, which cover some 50% of the country. The potential annual groundwater resources are estimated at 51.93 ×109 m3, out of which the sedimentary basins account for 67% FMWRRD (1995). The occurrence of groundwater is greatly influenced by the local geological conditions which ultimately control yields. Recharge to aquifers, which influences the safe yields of wells, depends on rainfall over the area. Thus, rainfall ultimately controls the amount of groundwater recovered from wells in any given locality Offodile (1979). The amount of groundwater storage is not yet known, but available records indicate that major aquifers in Nigeria are located in the sedimentary deposit basins which cover about 50% of the nation's land area. The remaining 50% is underlain by crystalline rocks of the basement complex. Table 1 shows the static water resources of Nigeria while Table 2.1 shows the summary of the total static water resources in Nigeria Aquifers within the basement are limited, their thickness ranges from 16 to 180 m, but depth of hand dug wells and boreholes are therefore seldom more than 60 m with a variable average of static water level between 1 to 45 m below the surface. This shallow depth coupled with the poor hydraulic conductivity, no doubt account for the general low yield of 1.0 m3/h Nwaogazie (1995). On the sedimentary deposits, groundwater resources usually occur either as confined aquifers with average piezometric level of 75 to 150 m or unconfined aquifers with thickness varying from 15 to 100 m (Nwaogazie, 1995).

Table 2.1Static Water Resources of Nigeria

Province	Structural unit	Area (Km^2)	TWRS M1 Million (
Crystalline hydrogeolo province	N. Nigeria Shield	234516	94979
	W. Nigeria Shield	115529	46789
	Mandara Hills	18460	2492
	Biu Plateau	4418	123.54
	Adamawa mountai	60152	8121
	Oban Hills	4276	577
	Total Cryst	437351	166212
Sedimentary hydrogeolo Province	Sokoto Basin	66424	3188352
	Katsina Basin	3564	28512
	Nupe Basin	36704	1468160
	Coastal Monocl.	12365	296760
	Keri-Keri Basin	22593	101669
	Abakaliki + Mamfi	24945	374175
	Benue Synclinr	96216	1443225
	Niger Delta	104234	2084660
	Borno Basin	119377	2148786
	Total Sedum..W.	486422	11134299
	Total Fresh GWtr	923773	11134299
	Total Water Nig.	923773	36201836

Static Water Resources of Nigeria, groundwater and fresh meteoric water,N/B: TWRS = Total static water resources. Source: (Schoeneich, 2003).

Table 2.2 Summary of the total static water resources in NigeriaSource

TWRS			Percentage	Cubic metre
Rain		Atmospheric wa	3.08	1,117 × 10^9
Surface	Fresh water	Fresh surface w	0.03	12 × 10^9
		Fresh groundw	31.23	11,301 × 10^9
Ground wate	Salty groundw		65.66	23,772 × 10^9
Total water Nig			100.00	36.202 ×109

Summary of the total static water resources in NigeriaSource: (Schoeneich, 2003).

2.8.2 Impediments For Sustainable Groundwater Management In Nigeria: Major Issues And Trends

In Nigeria, suitable machinery for the effective and sustainable management of groundwater resources has not yet evolved. This is because the authorities have put up institutions for this purpose, but at the same time set up rival agencies to carry out very overlapping functions. The overall implication is waste of available resources, leading to lack of progress in groundwater development and management. Generally, the Nigerian water problem revolves round two critical issues, namely: Inadequate access/poor distribution of water resources in time and space in relation to the needs of the people, inadequate planning and management of these resources. The above mentioned problems have further manifested themselves in the form of incessant water shortages, poor access to public water supply and water-borne diseases, poor environmental quality causing groundwater pollution, improper or partial distribution of public wells due to lack of water well statistics and favouritism, poor maintenance and often sabotage in the development and operational process of public wells, and proliferation of shallow private/commercial wells of poor standard by individuals who are financially less capable of standard wells drilled with adequate drilling tools. According to Ajayi*et al.*, (2003), Ajayi (2006), Ezeigbo (2003), Goni (2006), Hanidu (2003), Nwankwoala and Mmom (2008), Nwankwoala (2009), Offodile (2003, 2006), Oyebande (2006), Oteze (2006), Tijani (2006), the major obstacles for sound groundwater managementinclude: absence of or ineffective legal/institutional and regulatory framework, poor maintenance culture, poor technical and institutional capacity, lack of coordination, multiple programmes, lack of data and information for planning, shortage of well trained/committed manpower with appropriate local technology, irregular recruitment and limited manpower occasioned by the civil- service structure and the over-bearing bureaucratic control by supervising ministries, lack of professional input on water programmes and projects, absence of professionalism due to politicization, career stagnation and the lure of private practice, lack of community participation and inadequate revenue generation by water agencies, inadequate funding as shown by poor budget allocations, irregular disbursements of subventions, limited sources of aids and grants (particularly from foreign sources), inappropriate infrastructures as well as lack of adequate quality monitoring and evaluation. In Nigeria, data on groundwater levels are not widely published or made available outside government organizations. Extraction and recharge estimates are also unreliable. As a result, discussions on groundwater overexploitation and depletion are always based on unrealistic data. However, it is a fact that falling water tables and depletion of economically accessible groundwater reserves will have serious socio-economic consequences in a country like Nigeria. Therefore, it is needless to point out that there is an urgent need for conservation of this vital resource for sustainable groundwater development and management. In the light of the foregoing, it is highly likely that the future expansion in groundwater will continue to take place in Nigeria. This is primarily due to the relatively high population growth rate, combined with the unprecedented rise in industrialization and welfare, which tends to increase the average per capita water use. The largest single consumer of water is, and will continue to be agriculture with urban and industrial uses on the rise. Though the generalizations made here may not be totally justified, as differences exist in different parts of the country. Current groundwater use is characterized, as earlier noted, by uncoordinated development and supply to all sectors: rural and urban users, small and large scale users, industrial and agricultural users. This, in part, is attributable to the intrinsic properties of the resource. The general prevalence and stability in time and space of groundwater makes it a reliable and widely-accessible resource, easily amenable to private, local, and on – demand exploitation. However, this "common pool" property of groundwater also complicates a more formalized and coordinated control Custodio, (2002). Therefore, options/strategies for significant improvements in groundwater supply are in the areas of formulation of adequate, efficient and effective water policies, funding/appropriate infrastructures as well as monitoring and evaluation.

2.8.3 Approaches To Sustainable Groundwater Management In Nigeria

Groundwater management may be defined as the on-going performance of coordinated actions related to groundwater withdrawal and replenishment to achieve long-term sustainability of the resource without detrimental effects on other resources Kretsinger and Narasimhan (2005). Importantly and preferably, such management programmes are a local responsibility, conducted in coordination with other entities (including cooperative monitoring programmes), and regularly evaluated to ensure consistency with basin-wide management objectives. Globally, the issue of sustainability is on the front burner and has many different meanings; but the most widely espoused view is the continued productivity of commodities to maintain economic growth. The scientific community, however, has defined groundwater resources sustainability in prior publications Sophocleous(1997); Alley *et al.*, (1999); Kretsinger and Narasiham (2005); Alley and Leake (2004). In White paper on groundwater management, sustainability was approached based on the physical laws that govern the behaviour of earth systems and was defined by Kretsinger and Narsimhan (2005): "Sustainability encompasses the beneficial use of groundwater to support present and future generations, while simultaneously ensuring that unacceptable consequences do not result from such use".This view of sustainability entails four premises Kretsinger and Narasimhan (2005): Surface water and groundwater constitute a single resource, groundwater is a finite resource and a component of a larger natural resources system. Actions on one or more system components generally affect the long-term balance of the whole system, groundwater replenishment is strongly influenced by climate variability, as well as natural and enhanced recharge processes. Consequently, groundwater resources development must adapt to the system's varying capacity for renewal, communities need to share and manage groundwater resources so that the natural resources system retains its integrity for the future.

The overall sustainable concept varies primarily in that the overarching sustainability objectives connote greater consideration for balancing the beneficial use of components of the whole systems while avoiding long-term detriment to any part. In fact, rather than sustainability, "sufficiency" is the term presently used in many developed countries. Recent actions now move governments and local entities closer to "full" groundwater management where water agencies bring water supply and use into long-term balance Peters (1982). However, much remains to be done. The issue of groundwater management is multidimensional, related to reliable assessment of available water, its supply and scope for augmentation, distribution, pollution and its protection from overexploitation, depletion and degradation. However, like surface water resource management, not much concerted efforts have been made for management of the hidden complex underground water resources. Understanding the importance of groundwater resources and the growing demand for it makes it pertinent to search for effective strategies for managing the resource. For an effective supply side management, it is very essential to have full knowledge of hydrogeological controls that govern the yield and behaviour of groundwater levels under abstraction stress, the interaction of surface and groundwater in respect of river base flow and changes in flow and recharge rates due to their exploitation Villholth (2006). Because water supply is on the concurrent legislative list in the constitution and that means all tiers of government have responsibilities for the provision of water supply to the people.Realizing the significant role played by potable water supply and clean environment in ensuring good and healthy individual, family and communal lives, government has embarked on certain policies and strategies to improve the coverage level of rural water supply and sanitation facilities. The water supply is to ensure that all Nigerians have access to clean water and sanitation at an affordable price. The viable options/solution to the Nigerian water problem is a unified and integrated approach to water resources planning and the provision of reliable information on the following: The nature and magnitude of available groundwater resources, the future demand for water for domestic, agricultural and industrial purposes, how these demands can be faithfully met within the ambit of available resources. The issues raised above can be adequately addressed through groundwater resources mapping. Not only can the information be obtained at regular intervals but their accurate state, can also be updated. In this context, efficient groundwater policy is imperative if sustainable groundwater utilization is to be realized. Groundwater management policies therefore, will need to address a multitude of issues including, but not restricted to the following: management of supplies to improve water availability in time and space, management of demands including efficiency of water use, sectorial interaction with economic activities etc. Balancing competing demands and preservation of the integrity of water dependent ecosystem. Aside from the above mentioned groundwater management options, there is need for the following: Encourage user participation in the water resources administration, propose and coordinate actions geared towards the protection, defence and knowledge on groundwater use, roper coordination between the different tiers of government and the public, realistic tariff structure to cover cost of services, research into local production of materials required in the water sector, training of professionals and education of the public about water conservation, promote, organize, participate and undertake all kinds of activities, courses and seminars, outreach programmes, training, and specialization on groundwater, and any other relevant collaboration with different public administrations. For an effective management of groundwater resources, there is a need to create awareness among the different user groups and workout area specific plans for sustainable development. Thus, groundwater management not only requires proper assessment of available resources and understanding of theinterconnection between surface and groundwater system, but also actions required for proper resource management and prevention of the adverse effects of uncontrolled development of groundwater resources Velayutham(1999). Generally, according to Nwankwoala and Mmom (2008) the key steps necessary to move towards sustainable use of groundwater include: Improvement of the knowledge of groundwater resource, improvement in reporting and access to groundwater information, improvement in public education and better understanding of the public's attitudinal motivations, use of ecosystem approach to manage groundwater, embracing adaptive management, adoption of a goal of sustainable use. More importantly, one of the important strategies for sustainable management of groundwater is regulation in critical areas. This is because over exploitation / development of groundwater resources is increasingly recognized as a major problem, especially in the Niger Delta region Nwankwoala and Mmom (2006). The tendency towards over exploitation of groundwater resources is rooted in the rapid spread of energized pumping technologies, resource characteristics, demographic shifts and incoherent / inconsistent government policies. There are very little efforts to check over exploitation and regulation of groundwater resource. More specifically, there is an urgent need to check the contamination level of groundwater. The groundwater -protection from contamination/ pollution can be ensured by several ways, as enumerated by Menon (1998) and Nwankwoala and Udom (2008) and summarized as follows: Restricting the disposal of industrial discharges to the ground in vulnerable areas through introduction of discharge permits and appropriate charges to encourage recycling and reduction, inventory of aquifers, their characteristics andclassification, preparation of vulnerability maps, based on distribution of travel times, chemical parameters, types of topsoil, subsoil and land use, control of groundwater withdrawals, delineating and prioritizing areas of high groundwater vulnerability for main sewerage extension and effective enforcement provisions for groundwater protection regulations.

If the Millennium Development Goals (MDGs) formulated by the United Nations, designed to halve the number of people without access to safe drinking water by the year 2015, is to be attained, then all stakeholders – government, scientists, water managers, community leaders, Corporate Organizations, NGOs, CBOs, and others should begin to recognize that there is a distinct need for better data and better utilization of that data.

These needs, though, generally exceed, most times the financial capacity to effectively address them, efforts must be intensified for improvement. Additionally, federal, states and local governments support must be garnered to address wide – reaching technological and research needs vital to developing the best possible science and groundwater management strategies that keep pace with the resource. This is very imperative because, with business as usual, Millennium Development Goals will not be met. Therefore, the challenge is to communicate to decision makers and legislators that presently available information must be significantly enhanced to accomplish sustainability goals. Particularly, fundamental data, ongoing programmes, data standards, data coordination and sharing and regional aquifer characterization are core requirements for more effective management.

2.9 Ground Water Exploration

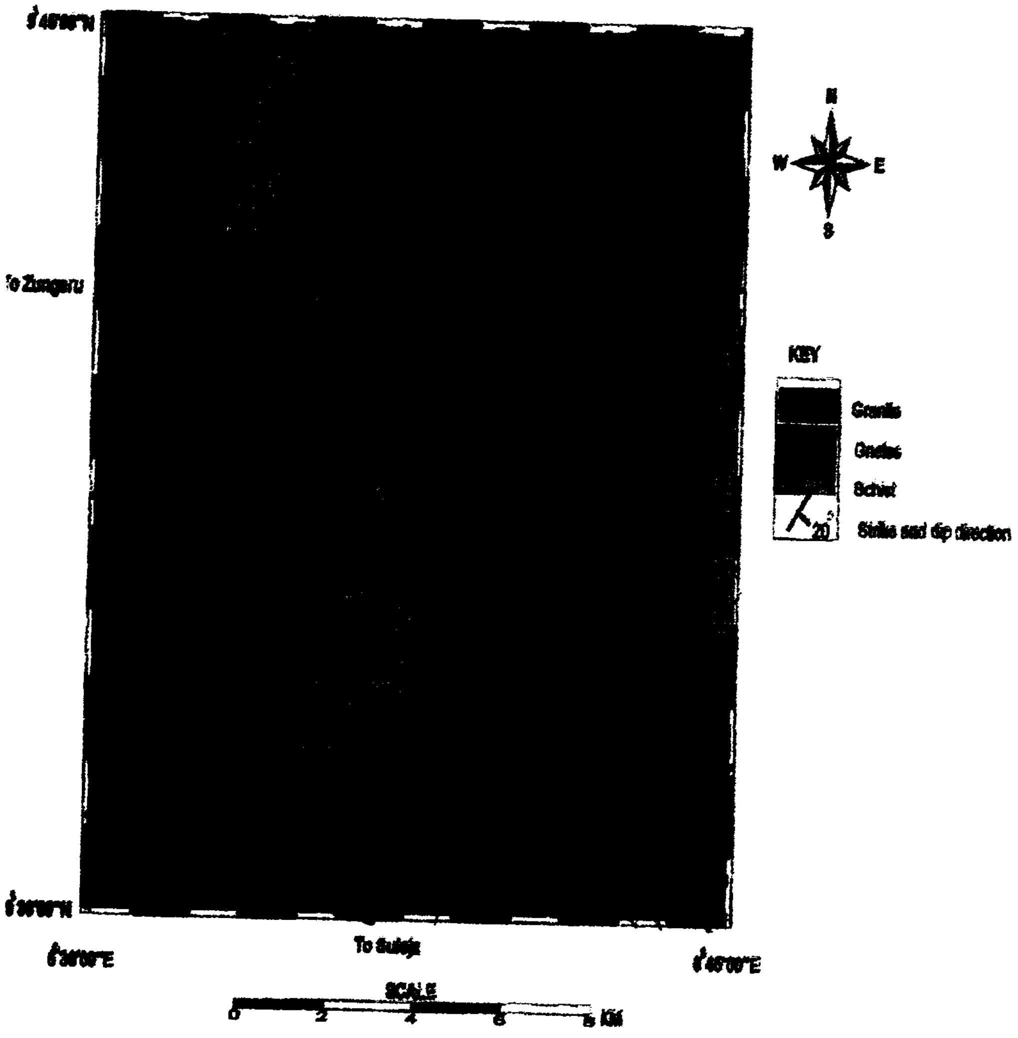
As part of its rural development mandate, PFRA assists rural residents in obtaining reliable supplies of groundwater for domestic, agricultural and industrial use. Securing an adequate supply of good quality water is often a constraint in the development and growth of value-added businesses in rural communities. This is particularly apparent in low rainfall, drought prone areas on the Prairies. Over the years, PFRA has successfully used traditional groundwater exploration methods to meet client needs. In an attempt to build on this success, for the past two years PFRA has been experimenting with geophysical techniques such as ground penetrating radar (GPR) and electromagnetic methods to assist in groundwater exploration. This technology is most effectively employed where there is insufficient subsurface data and surface expressions of underlying features are poor. While geophysics is used to assist in targeting drilling locations, test hole drilling is always required to confirm potential well yields and water quality.

Typically, a groundwater exploration program starts with a detailed review of all available geological groundwater data. Potential aquifer sources are identified and decisions made on possible field-exploration options. If judged to be desirable, a geophysical survey may be conducted to assist in identifying potential aquifers. A number of small diameter test holes are then drilled and flow tested. If sufficient yields and suitable water quality are obtained, a production well and pump may be installed. One geophysical technique being evaluated by PFRA is ground penetrating radar, or GPR. It is a shallow depth investigation tool that can provide results to approximately 25 metres depth in fine grained material, with penetration depth increasing in coarse grained sediments. The radar component is a high frequency electromagnetic pulse which is transmitted into the ground. Receivers then detect the radar signals reflected back to the surface of the ground.

Electrical properties of sediments are primarily controlled by their composition. The manner in which an electromagnetic pulse responds to sediments reflects their electrical and thus physical properties. Advanced computer technology, developed by the petroleum industry, is used to process and interpret the data. With the assistance of geophysical consultants, PFRA has applied GPR technology to confirm or assist in locating groundwater sources in several areas in Alberta. Examples of potential aquifers which have been investigated with the support of GPR are the Calgary Buried Valley near Empress and a shallow buried channel located near the Village of Jenner. These communities are both in drought prone areas of southeastern Alberta. Evaluation of GPR as an exploration tool is continuing. A study is being conducted by the University of Calgary to assess geophysical results obtained from PFRA projects using GPR, electromagnetic and seismic methods. In addition, several water sourcing projects applying geophysical techniques are in progress in Alberta. (Agriculture and Agri-Food Canada, 832 - 220 Fourth Avenue S.E., Calgary, AB).

2.9.1 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

FIG 2.1

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.

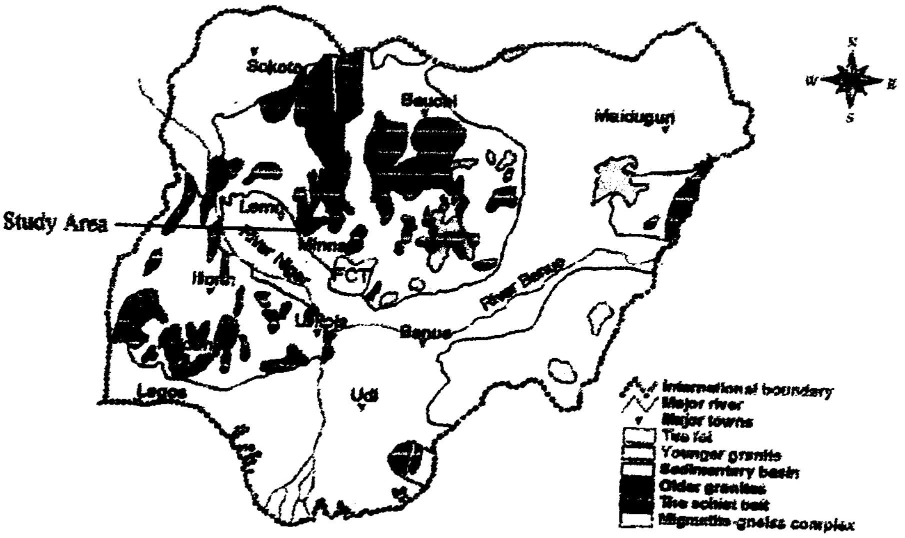


FIG 2.2 *Geological Map of Nigeria showing Study Area (After Ajibade, 1976)*

Table2.3 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

Source: (WHO 2004)

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 will be 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
- 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 will be 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 will be determined using the digital conductivity meter, immediately after sampling. Water samples collected in the field will be 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 will be determined using flames photometer Total Hardness (TH), as $CaCO_3$. Calcium as (Ca^{2+}), Carbonate (CO_3), bicarbonate (HCO_3) and Chloride (Cl) will be analysed by volumetric method. Magnesium (MG) will be calculated from TH and Ca contents. Sulphate (SO_4) will be estimated using the colorimetric techniques. Nitrate (NO_3), Iron (Fe), and Fluorine (F) will be determined by spectrophotometer. The saturation indexes will be determined using the hydro-geochemical equilibrium model Phreeqc for window (1999). Analysis ofg water samples from 31 monitoring wells for chloro-fuocarbon will be used to estimate apparent dates of recharge.

List of Reagent Used:

Sodium hydroxide pellet

Oxalic acid

ii. Potassium permanganates $KMnO_4$

iv. Sodium nitrate

v. Sodium sulphate

vi. Sodium hydrogen trioxocarbonate (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 will be 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 will be 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 will be 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 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 will be 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 will be 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 will be 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 will be 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= $\frac{(y-z)}{25ml\ of\ sample\ volume} \times 100\ (mg\backslash l)$

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 will be 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 will be filled with water sample to be tested and contents of the tube will the poured into the mixing bottle following by the addition of 8N potassium hydroxide. A clipper will be 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 will be swirled at each drop and each drop of EDTA titrant added into the mixing bottle will be counted. The addition continued until a colour change from pink to blue will be 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= $total\ hardness - calcium\ hardness$

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 will be 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 will be determined by the turbidity meter method. Colloidal barium sulphate will be 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 will be measured using DR200 spectrophotometer at 42mm wavelength.

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 may be 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. ChemicalOxygen Demand (COD)

c. Total Organic Carbon (TOC)

d. Theoretical Oxygen Demand (ThoD).

Traced organic matters in the range of 10-13mg/l are 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 will be 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 will be 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 will be a multiple-step process. Firstly, target areas will be 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 will follow procedures outlined Apham et al., (1995). All monitoring wells will be installed between May 24 and June 28, 2011, using 0.11m, inside diameter hollow auger. The casing to be for the 6 monitoring wells will be 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 will be installed. Drilling equipments will be steam cleaned between monitoring-well installation site. Monitoring well to be installed for irrigation studies will be completed at depths (below land surface) of 11.33 m or less. Completion depth will be 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 31 wells will be 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 will be 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 will be allowed to "recover" for 2 weeks before water quality samples will be collected.

3.8.3 Samples Collection and Analysis

Sediments samples will be collected for determination of pH, organic carbon content, and particles size analysis during the installation of each of the 6 wells. One sample will be 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 will be used to evaluate potential water quality interactions association with the movement of recharge water through sediments. The 6 monitoring wells will be sampled once fromJuly15 to July28, 2011, for assessment of shallow ground water quality. Ground water samples will be 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 will be pump 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 shall take place in dedicated environmental chambers consisting 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 will be decontaminated thoroughly between each sample collection using progression of non-phosphate detergent wash, tap water rinse, methanol rinse, and final deionised water rinse. Polyethylene bags forming the sampling and preservation chambers will be replaced between each sample collection. Sampling wells will first be purged of standing water during initial pumping period. Measurement of special conductance, pH, water temperature, and dissolve Oxygen will be monitored after every 5 minutes in a closed-cell, flow through chamber until stable readings were obtained. Turbidity will be 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) will be 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 will be 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 will be collected for major anions analysis. Additionally, a filtered sample will be 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 will be collected directly from discharge tube close to the well head. The samples will be 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 will be force into the chamber using purified Nitrogen gas; the water will be 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 will be 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 will be 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 will be 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 will be based on water table and river level measurement. The following assumptions will be 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.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

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.

S/N	PARAMETERS	SABON GARI VILLAGE	SHALUKO VILLAGE	SAUKA KAHUTA VILLAGE	SABON GIDA VILLAGE	KADNA VILLAGE	TAI VILLAGE
1	**Turbidity(NTU)**	1.00	4.00	5.00	16.00	1.00	5.00
2	**Colour**	5.00	5.00	5.00	15.00	10.00	5.00
3	**Suspended Solid(mg/l)**	1890.00	170.00	3340.00	1760.00	4480.00	5610.00
4	**E.Conductivity(µmhas)**	10.40	160.00	40.00	3700.00	5200.00	20200.00
5	**TDS**	210.00	201.00	150.00	330.00	230.00	156.00
6	**Total solid (mg/l)**	9300.00	3950.00	9370.00	8000.00	10070.00	10050.00
7	**Temperature (^{o}C)**	24.00	24.00	24.00	24.00	24.00	24.00
8	**pH**	7.00	7.60	7.70	7.00	7.00	6.60
9	**Nitrite (mg/l)**	0.04	0.20	0.30	0.20	0.27	0.11
10	**Nitrate (mg/l**	5.00	16.00	16.00	32.00	10.00	20.00
11	**Phosphate (mg/l**	4.30	1.10	1.50	0.70	1.20	0.60
12	**Sulphate (mg/l**	95.00	90.00	15.00	50.00	5.00	50.00
13	**Nitrate as N (mg/l)**	3.20	5.60	3.10	4.30	4.40	2.60
14	**Iron (mg/l)**	0.02	0.01	0.01	0.01	0.01	0.50
15	**Chloride (mg/l)**	7.99	12.49	8.49	9.99	8.49	599.8
16	**Dissolved Oxygen**	2.60	2.20	3.80	2.30	2.20	2.10

	(mg/l)						
17	**Total Hardness (mg/l)**	1181.70	1252.40	848.40	292.90	363.60	646.40
18	**Calcium Hardness (mg/l)**	392.70	360.30	275.30	68.82	121.40	222.60
19	**Magnesium Hardness (mg/l)**	789.00	892.10	573.10	224.00	242.20	423.80
20	**Total Alkalinity (mg/l)**	40.00	48.00	38.00	112.00	125.00	32.00
21	**HCO_3 (mg/l)**	0.04	0.20	0.30	0.20	0.27	0.11
22	**CO_3 (mg/l)**	0.00	0.00	0.00	0.00	0.00	0.00
23	**PO_4(mg/l)**	0.01	0.01	0.20	0.01	0.60	0.20
24	**COD(mg/l)**	21.00	18.00	30.00	22.00	23.00	20.00
25	**BOD(mg/l)**	10.26	10.81	10.44	16.60	20.68	16.22
26	**E-coli**	170.00	110.00	120.00	90.00	140.00	120.00
27	**Total Coliform**	270.00	210.00	400.00	150.00	460.00	315.00

Table 4.1 Result Of Physco-Chemical And Bacteriological Analysis For Six(6) Under Groundwater Samples

NSDQW- NIGERIA STANDARD FOR DRINKING WATER QUALITY

	turb	colour	SS	E.cond	TDS	TS	pH	nitrite	nitrate	Phos	Sul	Nitrate as N	Iron	Cl	DO	TH	Ca	Mg	Total alkality	Hco3	po4	K	Ma	COD	BOD	ecoli	talcolif rm
turb	1																										
colour	0.574	1																									
SS	-0.175	-0.356	1																								
e0.cond	0.050	-0.170	0.742	1																							
TDS	0.435	-0.028	0.204	0.014	1																						
TS	-0.160	0.072	0.829*	0.419	-0.161	1																					
pH	-0.066	0.353	-0.704	-0.605	-0.713	-0.554	1																				
Nitrite	-0.024	0.597	-0.510	-0.203	-0.796*	-0.065	0.802*	1																			
Nitrate	0.781*	0.059	0.258	0.325	0.724	-0.184	-0.523	-0.589	1																		
Phos	-0.027	0.595	-0.511	-0.203	-0.797*	0.162	0.801*	10.000**	-0.591	1																	
Sul	-0.039	0.443	-0.696	-0.254	-0.709	-0.571	0.726	0.911**	-0.582	0.913**	1																
Nitrate as N	-0.018	0.609	-0.543	-0.229	-0.779*	-0.809	0.814*	0.998**	-0.583	0.998**	0.915**	1															
Iron	-0.037	0.020	0.330	0.783*	-0.552	0.335	-0.037	0.394	-0.096	0.395	0.357	0.366	1														
Chloride	-0.033	-0.087	0.438	0.865*	-0.439	0.328	-0.184	0.235	0.008	0.236	0.213	0.206	0.986**	1													
DO	-0.065	-0.297	-0.005	-0.451	-0.401	0.212	0.638	0.419	-0.141	0.224	-0.332	-0.372	-0.330	-0.332	1												
TH	-0.368	-0.582	-0.214	-0.039	0.236	-0.547	-0.319	-0.388	-0.100	-0.384	-0.011	-0.368	-0.145	-0.081	-0.447	1											
Ca hardness	-0.570	-0.828*	-0.185	-0.240	-0.126	-0.348	-0.001	-0.281	-0.328	-0.277	0.006	-0.281	-0.169	-0.128	0.246	0.760*	1										
Mg hardness	-0.396	-0.821*	-0.193	-0.259	0.140	-0.575	-0.124	-0.488	-0.066	-0.485	-0.182	-0.476	-0.334	-0.263	0.184	0.814*	0.946**	1									
Total alkalinity	0.316	0.859*	-0.142	-0.185	0.182	0.111	0.150	0.326	0.022	0.323	0.115	0.348	-0.220	-0.292	-0.352	-0.493	-0.822*	-0.760*	1								
HCO3	0.143	0.270	0.072	-0.278	0.015	-0.065	0.579	10.000**	0.226	-0.569	-0.763	0.336	-0.385	-0.385	0.419	-0.687	-0.441	-0.355	0.424	1							
PO4	-0.422	0.109	0.681	0.242	-0.168	0.533	-0.184	0.502	-0.308	-0.261	-0.799	-0.056	0.060	0.058	-0.052	-0.476	-0.452	-0.551	0.489	0.502	1						
K	-0.033	0.601	-0.525	-0.215	-0.785*	-0.215	0.795*	0.999**	-0.601	0.999**	0.920**	0.998**	0.381	0.222	-0.538	-0.362	-0.271	-0.478	0.335	-0.521	-0.146	1					
Na	-0.053	0.593	-0.525	-0.223	-0.793*	-0.411	0.807*	0.999**	-0.612	0.999**	0.914**	0.999**	0.372	0.212	-0.353	-0.362	-0.268	-0.472	0.340	0.124	0.326	0.999**	1				
COD	0.029	0.000	0.284	-0.281	-0.238	0.476	0.428	0.614	-0.021	0.006	-0.694	-0.409	-0.277	-0.281	0.897*	-0.770	-0.164	-0.248	0.002	0.614	0.297	-0.603	-0.371	1			
BOD	0.165	0.631	0.572	0.496	0.401	0.419	-0.604	0.249	0.256	-0.516	-0.591	0.066	0.233	0.232	-0.540	-0.455	-0.850*	-0.870*	0.778	0.249	0.712	0.035	0.109	-0.113	1		
E coli	-0.354	-0.707	0.515	0.112	0.603	0.417	-0.759*	-0.885**	0.173	-0.883**	-0.771*	-0.892**	-0.388	-0.252	0.079	0.509	0.481	0.568	-0.389	-0.464	0.221	-0.874*	-0.874*	0.000	-0.177	1	
Total coliform	-0.431	-0.593	0.773*	0.227	0.343	0.608	-0.561	-0.719	0.114	-0.720	-0.864*	-0.732	-0.247	-0.133	0.348	0.007	0.152	0.208	-0.189	0.437	0.867*	-0.728	-0.713	0.550	0.302	0.781*	

* Correlation is significant at the 00.05 level (2-tailed). ** Correlation is significant at the 00.01 level (2-tailed)0. a Cannot be computed because at least one of the variables is constant0.

Table 4.3 WHO and NSDWQ Standard for Drinking Purpose

PARAMETERS	WHO (2004)	NSDWQ (2008)
Turbidity(NTU)	5.00	5.00
Colour	15.00	15.00
Suspended Solid(mg/l)	25.00	NS
E. Conductivity(μmhas	1000.00	1000
TDS	1000.00	500
Total solid (mg/l)	-	NS
Temperature (°C)	-	Ambient
pH	7.0-8.50	6.5-8.5
Nitrite (mg/l)	0.20	50.00
Nitrate (mg/l	-	0.20
Phosphate (mg/l	0.30	100.00
Sulphate (mg/l	250.00	NS
Nitrate as N (mg/l)	50.00	NS
Iron (mg/l)	0.30	0.30
Chloride (mg/l)	200.00	250.00
Dissolved Oxygen (mg/l)	-	NS
Total Hardness (mg/l)	100.00	150.00
Calcium Hardness (mg/l)	50.00	NS
Magnesium Hardness (mg/l)	50.00	150
Total Alkalinity (mg/l)	100.00	NS
Sodium (mg/l)	200.00	NS
Potassium (mg/l)	-	NS

HCO_3 (mg/l)	-	NS
CO_3 (mg/l)	-	NS
PO_4(mg/l)	-	NS
COD(mg/l)	-	0.00
BOD(mg/l)	-	10.00
E-coli	-	-
Total Coliform	-	-

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

Parameters	Unit	Minimum	Maximum	Average
Turbidity	NTU	1.00	16.00	8.50
Colour		5.00	15.00	10.00
Suspended Solid	mg/l	170.00	5610.00	2890.00
E-Conductivity	Umhas	10.40	20200.00	10105.2
TDS		150.00	330.00	240
Total Solid	mg/l	3950.00	10070.00	7010.00
Temperature		24.00	24.00	24.00
pH		6.60	7.70	7.15
Nitrite	mg/l	0.04	0.30	0.17
Nitrate	mg/l	5.00	32.00	18.5
Phosphate	mg/l	0.60	4.30	2.45
Sulphate	mg/l	5.00	95.00	50.00
Nitrate as N	mg/l	2.60	5.60	4.10
Iron	mg/l	0.01	0.50	0.255

Chloride	mg/l	7.99	599.80	303.90
DO	mg/l	2.10	3.80	2.95
Total Hardness	mg/l	292.90	1252.40	772.65
Calcium Hardness	mg/l	68.82	392.70	230.76
Magnesium Hardne	mg/l	224.00	892.10	558.35
Total Alkalinity	mg/l	32.00	125.00	78.5
HCO3	mg/l	0.04	0.30	0.17
CO3	mg/l	0.00	0.00	0.00
PO4	mg/l	0.01	0.60	0.305
COD	mg/l	18.00	30.00	24.00
BOD	mg/l	10.26	20.68	15.47
Na	mg/l	2.10	11.32	6.71
K	mg/l	1.32	10.00	5.66

4.2 Analysis of Result

4.2.1 Electrical Conductivity (µs/cm)

The Nigeria standard for drinking water quality (2008) and WHO (2004) for electrical conductivity drinking water is 1000µmhas. The values obtain for the minimum and maximum values are 10.40 and 20200µmhas respectively. From figure 4.1 three of the values are below the permissible limit while three were above the limit. The effect of E.C is that when the concentration is too high or too low it may limit the survival, growth or reproduction aquatic organisms

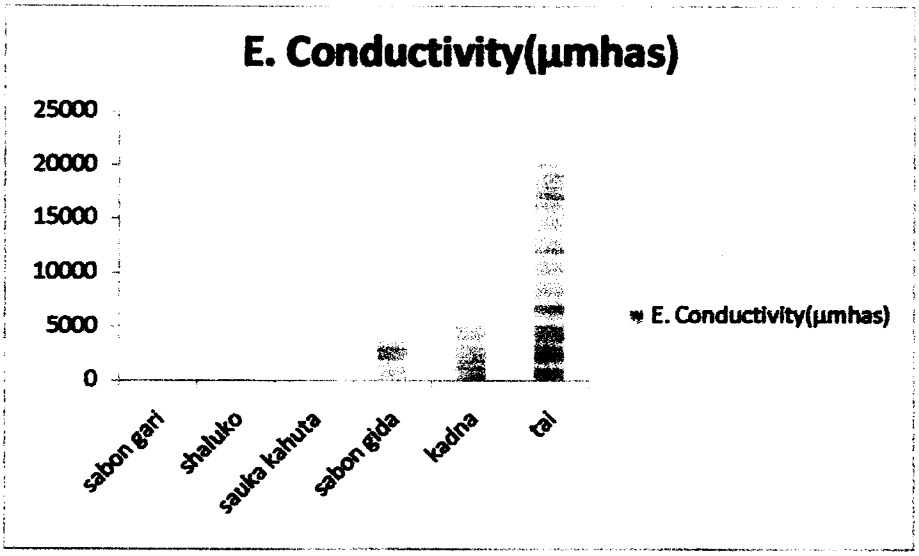


Fig 4.1 showing variation in E.conductivity of the six water samples

4.2.2 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 3950.00 mg/l and 1070.00 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 which causes cancer, coronary heart disease and cardiovascular disease. Treatment for household use is reverse osmosis.

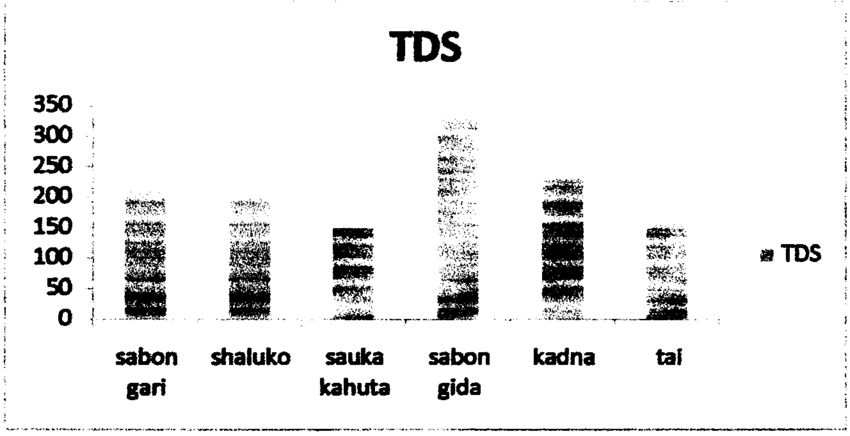


Fig 4.2 showing variation in TDS of the six water samples

4.2.3 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 170.00mg/l and 5610.00mg/l respectively.

Total Suspended Solids (TSS) is 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.

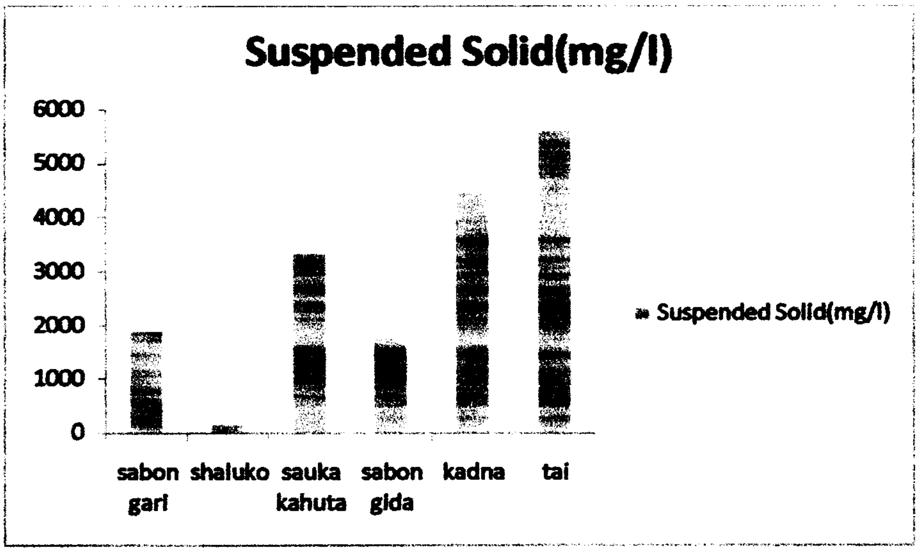


Fig 4.3 showing variation in suspended solid of the six water samples

4.2.4 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 0.01 mg/l and 0.50 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.

Autopsies have shown haemorrhagic necrosis and sloughing of areas of mucosa in the stomach with extension into the sub-mucosa. Chronic iron overload result primarily from a genetic disorder (Haemochromatosis) characterised by increased iron absorption and from diseases that require frequent transfusion.

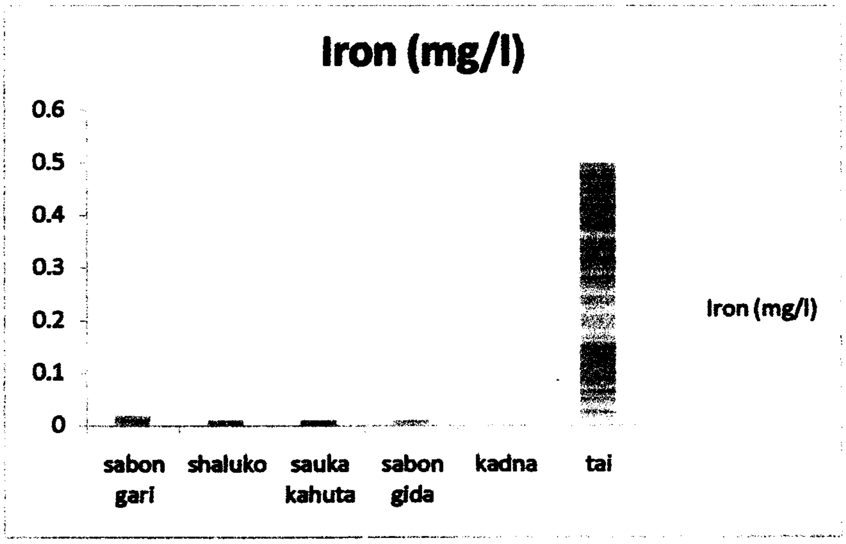


Fig 4.4 showing variation in Iron of the six water samples

4.2.5 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 sabon gari, shaluko, sauka kahuta, kadna and tai village (1.00, 4.00, 5.00, 16.00, 1.00 and 5.00 respectively) were below the maximum permissible limit while that of Sabon Gida (16.00) is 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 seem cloudy. Treatment includes mixing with a substance such as alum that causes the coagulation of the suspended materials followed by sand filter filtration.

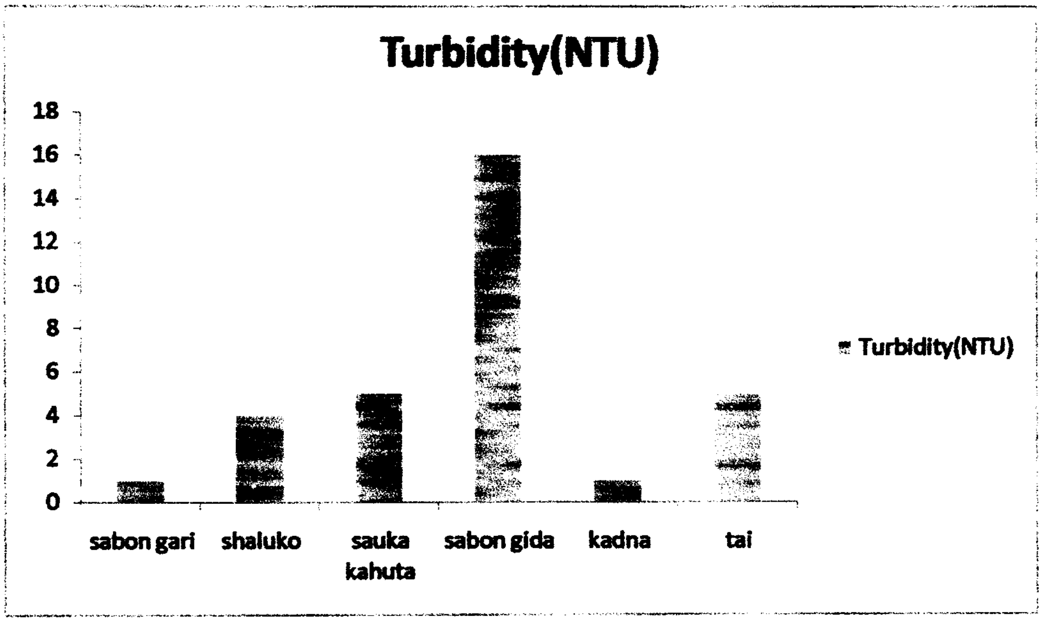


Fig 4.5 showing variation in Turbidity of the six water samples

4.2.6 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 224.00 mg/l and 892.10 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. Clothes laundered in such hard water may look dingy and feel harsh and scratchy. Dishes and glasses may be spotted when dry. Hard water may cause a film on glass shower doors, shower walls, bathtubs, sinks, faucets, etc. Hair washed in magnesium contained water may feel sticky and look dull. Water flow may be reduced by deposits in pipes. Magnesium hardness can be managed with packaged water softeners or with a mechanical ion exchange softening unit.

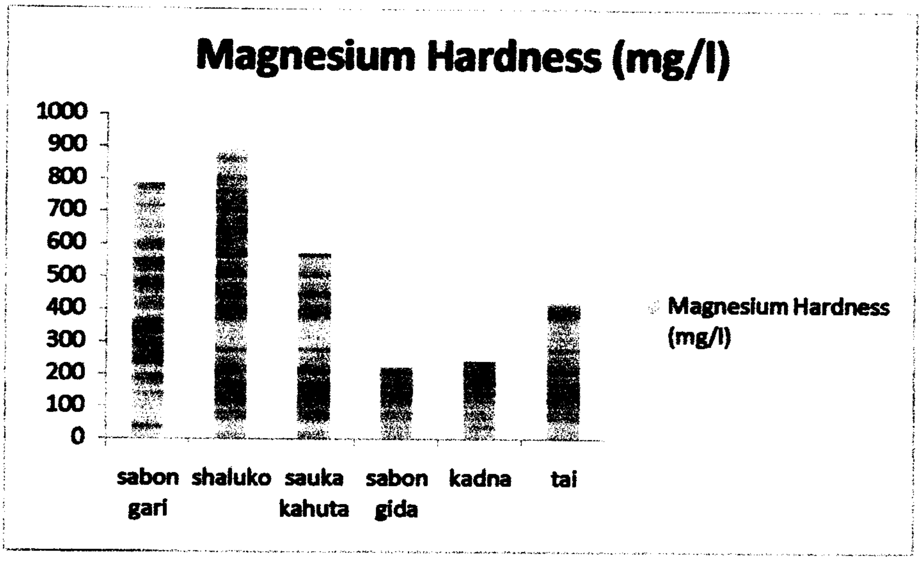


Fig 4.6 showing variation in Magnesium hardness of the six water samples

4.2.7 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 5.00 mg/l and 32.00 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 causing a disease commonly called blue baby disease. Children suffering from this disease may be vomiting; their skin colour may become dark, and may lead to death in extreme cases.

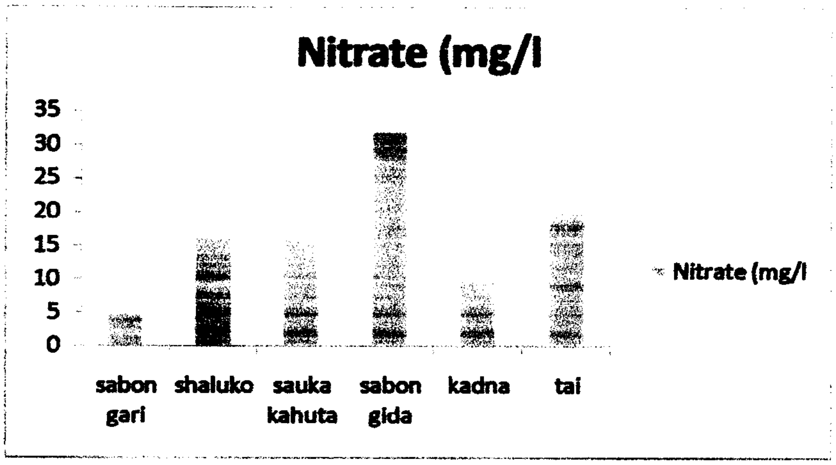


Fig 4.7 showing variation in Nitrate of the six water samples

4.2.8 Nitrite (mg/l)

Nigeria Standard for Drinking Water Quality (2008) stated that nitrite in drinking water should not exceed 0.30mg/l. While that of WHO (2004) standard is 0.2mg/l. The minimum and the maximum values are 0.04 mg/l and 0.11mg/l. Among the six samples, all were below the standard.

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

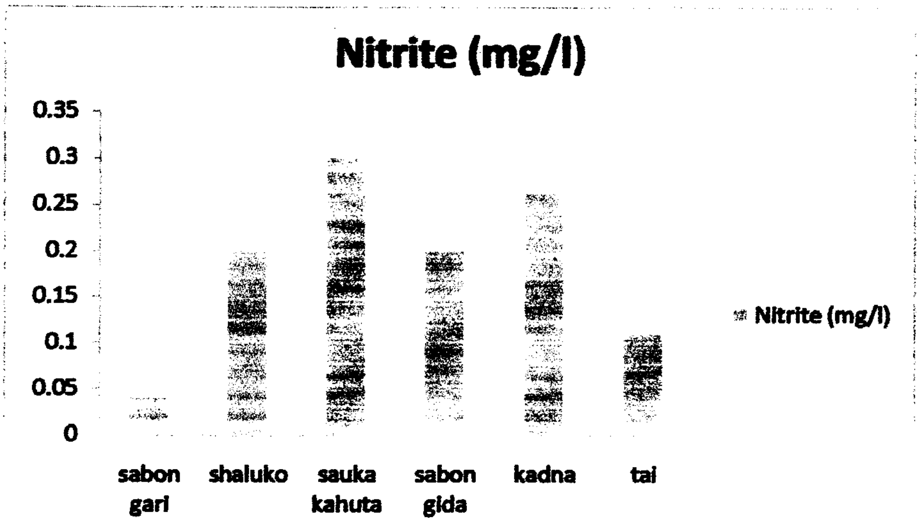


Fig 4.8 showing variation in Nitrite of the six water samples

4.2.9 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 6.60 and 7.70. 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. Water can be softened through the use of ion-exchange or the addition of a lime-soda ash mixture, but both processes increase the sodium content of the water.

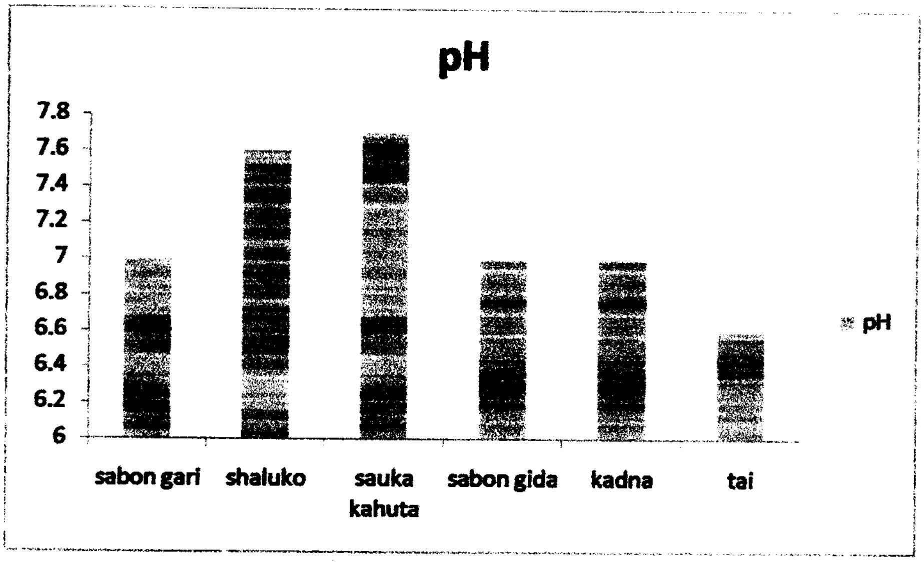


Fig. 4.9 showing variation in pH of the six water samples

4.2.10 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 were 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.

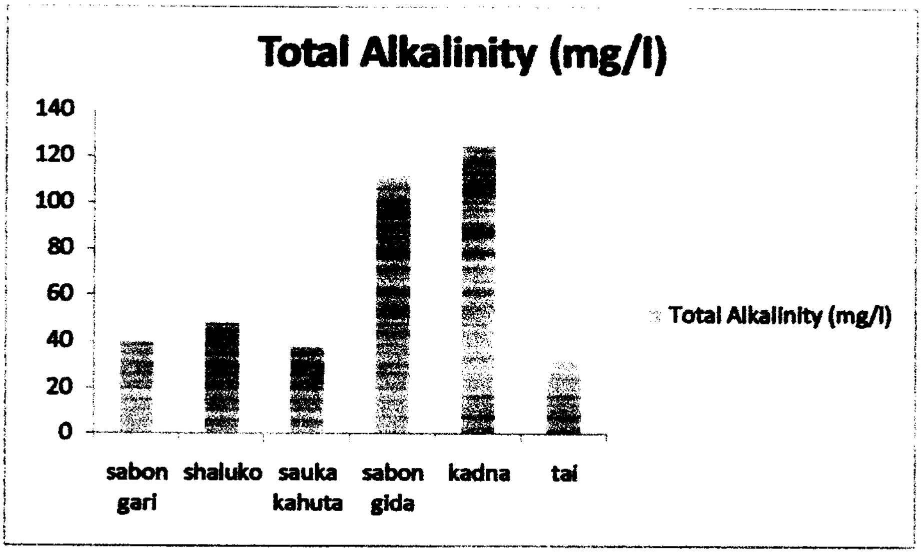


Fig. 4.10 showing variation in total alkalinity of the six water samples

4.2.11 Calcium Hardness (mg/l)

The Nigeria standard for total hardness is given as 200mg/l (NSDQW, 2008) while that of WHO (2004) standard is 50mg/l which indicate that all the samples were above the standard limit for WHO while two were below the standard limit for NSDQW. The minimum and maximum values are 68.82mg/l and 392.7mg/l respectively. The presence of calcium contributes to the general water hardness which makes it unsuitable for some domestic and industrial use. Calcium hardness can be managed with packaged water softeners or with a mechanical ion exchange softening unit.

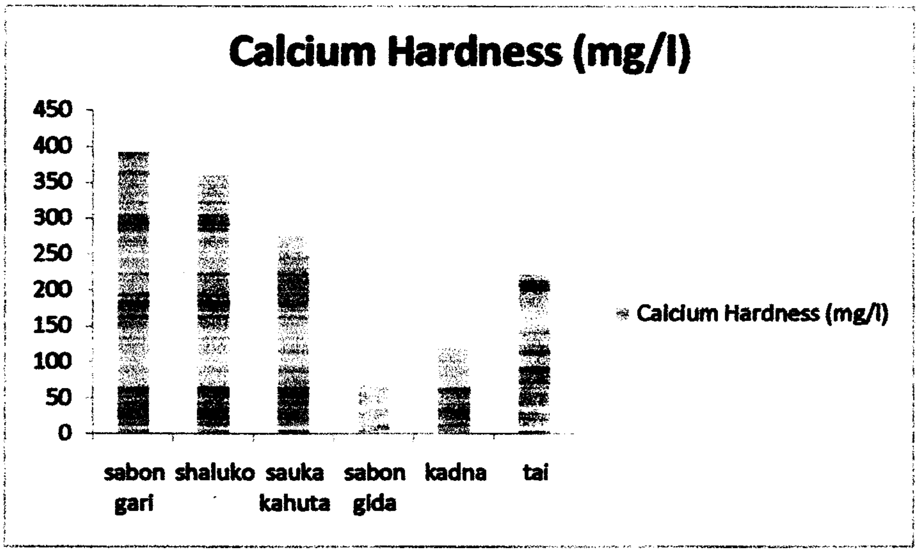


Fig. 4.11 showing variation in calcium hardness of the six water samples

4.2.12 Sulphate (mg/l)

The Nigeria Standard for Drinking Water Quality for sulphate (SO_4) and WHO (2004) standard is 250 mg/l. The minimum and maximum values obtained were 5.00 mg/l and 95.00 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.

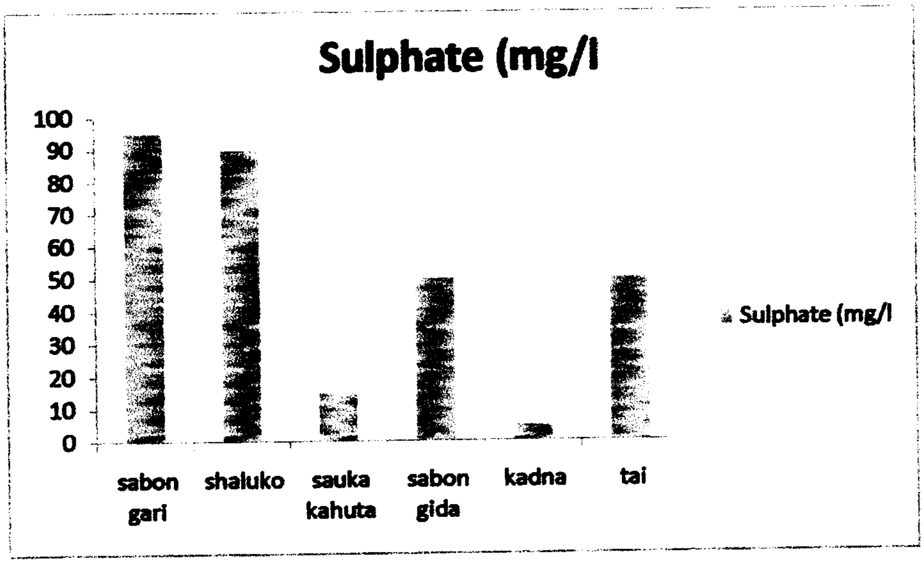


Fig. 4.12 showing variation in sulphate of the six water samples

4.2.13 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..

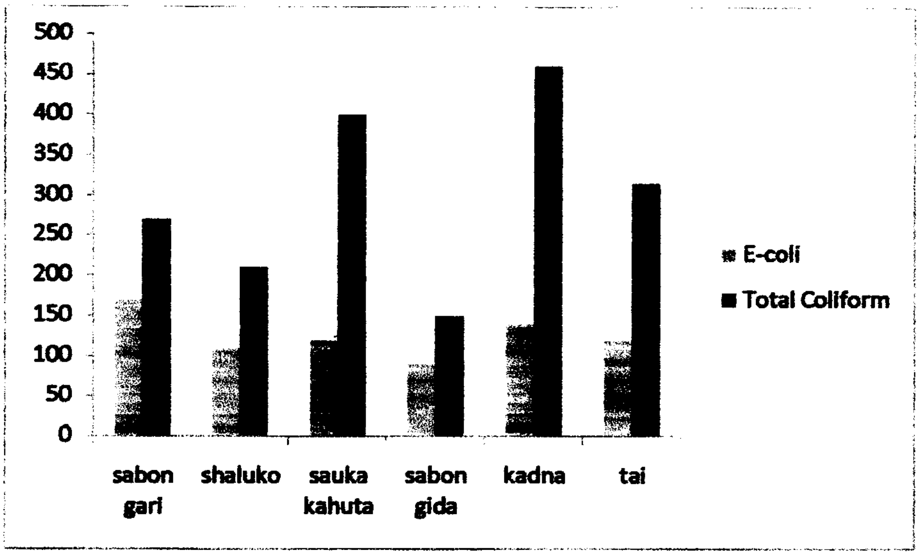


Fig. 4.13 showing variation in total coliform and E coli of the six water samples

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 significanc correlation observed between Nitirite and suphate, Nitrate as N, K and Na which exhibit positive correlation ($r = 0.911, 0.998, 0.999$ *and* 0.999 *at* $P < 0.01$ *respectively*) meaning that there is increase in the Nitrite of the sample there was increase Suphate, Nitrate as N, K and Na.

There was a significant correlation between phosphate and sulphate, Nitrate as N, potassium and Sodium which exhibit positive correlation ($r = 0.913, 0.998, 0.999$ *and* 0.999 *at* $p < 0.01$ *respectively*). which indicate that the increasing values of Phosphate led to the increasing values of sulphate, nitrate as N, potassium and sodium.

There was significant correlation observed between Sulphate and Nitrate as N, potassium and sodium which exhibit positive correlation ($r = 0.915$, 0.920 *and* 0.914 *at* $p < 0.01$) which indicate that there was increase in Nitrate as N, potassium and sodium when the Sulphate increased.

There was significant correlation observed between Nitrate as N and potassium and sodium which exhibit positive correlation ($r = 0.998,\ and\ 0.999\ at\ p < 0.01\ respectively$) which means that there was increasing in the values of potassium and sodium when the value of Nitrate as N increases.

There was significant correlation observed between Iron and Chloride ($r = 0.986\ at\ p < 0.01 respectively$). which mean that when Iron increase, Chloride also increases.

There was significant correlation observed between calcium hardness and Magnesium hardness which exhibit positive correlation($r = 0.946\ at\ p < 0.01$). This implies that if there is an increase in calcium hardness, there must be an increase in Magnesium hardness.

There was significant correlation observed between potassium and sodium which exhibit positive correlation ($r = 0.999\ at\ p < 0.01$). which implies that if there is an increase in potassium there must be an increase in sodium.

There was significant correlation observed between Nitrite and E.coli which exhibit a negative correlation ($r = -0.885\ at\ p < 0.01$). which implies that if there is an increasing Nitrite there must be a decrease in E.coli.

There was significant correlation observed between Phosphate and E.coli which exhibit a negative correlation ($r = -0.883\ at\ p < 0.01$). which implies the if there is an increasing Phosphate there must be a decrease in E.coli.

There was significant correlation observed between Nitrate as N and E.coli which exhibit a negative correlation ($r = -0.892\ at\ p < 0.01$). which implies the if there is an increasing Nitrate as N there must be a decrease in E.coli.

4.1.2 Assessment of Water Quality for Irrigation

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

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

Where all the ions are expressed in meq/l WHO (2004). WHO Aastri (1994) uses a criterion for assessing the suitability of water for irrigation base on permeability index.

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 groundwater. Sodium absorption ratio (SAR) is 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).

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

Where the ionic concentrations are expressed in mg/L. The SAR values ranges from 0.04 to 0.27 and according to Richard (1954) classification base on SAR values (table4.3). 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. Sodium replacing adsorbed calcium and magnesium is as hazard as it causes damage to the soil structure and become compact and impervious Sirnivasa (2005). The sodium percentage (Na %) is obtain from equation (3) it indicate that all samples falls in the excellent category of the table 2.1. That is the groundwater samples are excellent for irrigation.

$$\%Na = [Na + K] \times 100/[Ca + Mg + Na + K] \qquad 3$$

Were all ionic concentrations are expressed in mg/L.

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 and has being determined by the equation (4)

$$RSC = (CO_3+HCO_3)-(Ca+Mg) \qquad 4$$

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 1.25meq/l are good for irrigation. This implies that all samples form the six villages are doubtful because their values ranges between -10.923 to -130.44.

1. Chloro-Alkaline Indices

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

2. Chloro-Alkaline Indices

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

Table 4.4 Results of calculated values of K, Na, SAR, %Na, RSC, PI, CAI and CAII

Parameters	Sabon gari village	Shaluko village	Sauka kahuta village	Sabon gida Village	Kadna village	Tai Village
K	10.00	7.00	1.32	6.37	7.30	3.32
Na	7.33	10.80	3.10	3.32	11.32	2.10
Sar	0.04	0.10	0.035	0.062	0.193	0.27
%na	0.44	2.53	0.53	2.27	4.72	0.76
Rsc	-130.44	-45.68	-30.435	-10.923	-12.984	-22.985

Pi	0.264	1.15	0.670	1.818	4.16	0.97
Cai	-1.56	-0.84	0.293	-0.084	-1.84	0.98
Caii	-0.336	-0.287	0.333	-0.039	-3.54	29.78

CHAPTER FIVE

5.0. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The following conclusions were made based on the research work

The three existing wells and the three new dugged well 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.

Base on the classification in Table 2.3, for electrical conductivity the water samples from the following villages Sabon Gari, Shaluko and sahuka kahuta are excellent for irrigation purpose while the remaining water samples from Sabon Gida, Kadna and Tai are not suitable for irrigation because they have values greater than the recommended value by WHO (2004)

Base on the Sodium Absorption Ratio (SAR) from Table 4.4, all the water samples from the six villages are excellent for irrigation purposes because they have values less than the <10 as recommended by WHO (2004)

5.2 Recommendation

The following recommendation were made base on the result obtained:

1. Groundwater must be properly sited away from soak away and septic tank to prevent contamination.

2. Proper disposal of waste must be carried out so as to minimize the spread of water borne deseas thereby promoting better health.

3. Effective treatment including disnfection must be done to make water free of any coliform organism

REFERENCES

Amadi P.A., Ofoegbu C.O. and Morrison T., Hydrogeochemical Assessment of Groundwater Quality in parts of the Niger Delta, Nigeria, *Environmental Geol. Water Science*, **14(3),** 195 – 202 **(1989)**

Alley WM, Reilly TE, Frank OL (1999). Sustainability of groundwater resources. USGS Circ 1186.http://water.usgs.gov/pubs/circ/circ1186/pdf/circ1186.pdf Cited2 Aug2005

Apodaca L.E, Jeffrey B.B. and Michelle C.S.,Water quality in shallow alluvial aquifers, Upper Colarado River Basin, Colorado, Journal of American Water Research Association, **38(1),**133-143**(2002)**

Ajayi S.O. and Osibanji O.1981 Pollution studies on Nigeria Rivers 11; Water quality of Some Nigerian Rivers. Environ. Pollut. Series 2: 87-95

Alagbe, S.A. 2002. Groundwater resources of river Kan Gimi Basin, north-central, Nigeria

Environmental Geology, 42, 404-413.

Ajayi S.O. and Osibanji O.1981 Pollution studies on Nigeria Rivers 11; Water quality of some Nigerian Rivers. Environ. Pollut. Series 2: 87-95

Akujieze, C.N., Coker, S.J.L. and Oteze, G.E. 2003.Groundwater in Nigeria – a millennium experience – distribution, practice, problems and solutions. *Hydrogeology Journal*, 11, 259-274.

Akujieze CN, Coker SJL, Oteze GE (2003). Groundwater in Nigeria – a millennium experience – distribution, practice, problems and solutions. Hydrogeol. J., 11: 259-274.

Ajayi JO, Sonuga FA, Aliboh OP, Oloke DA (2003). Sustainable potable water supply to Nigerians through conjunctive development of surface and groundwater resources, In: A. A. Elueze (ed.) Contributions of Geoscienes and Mining to National Development, (NMGS) pp. 9 – 17.

BOULDING, J. R. (1995). *Practical Handbook of Soil, Vadose Zone, and Ground-Water Contamination; Assessment, Prevention and Remediation.* Lewis Publishers, Boca Raton, FL, USA, 948 pp.

Burgis, M.J. and J.J. Symoens, 1987 African wetlands and shallow water bodies/Zones humides et lacs peu profonds d'Afrique. Directory/Repertoire. Trav.Doc.Inst. Fr.Rech. Sci. Dév. Coop., (211):650 p.

Back W., Hydro chemical facies and groundwater flow patterns in northern part of Atlantic Coastal Plain: US Geological Survey Professional Paper 498 – A, 42 **(1966)**

Burgis, M.J. and J.J. Symoens, 1987 African wetlands and shallow water bodies/Zones humides etlacs peu profonds d'Afrique. Directory/Repertoire. Trav.Doc.Inst. Fr.Rech. Sci. Dév. Coop.,(211):650 p.

Calamari, D., 1985 Review of the state of aquatic pollution of West and Central African inland waters. CIFA Occas.Pap., (12):26 p.

Calamari, D., 1985 Review of the state of aquatic pollution of West and Central African inland water.c.Pap., (12):269

Carter, R C. and Alhassan, A.B. 1998. Groundwater, soils, and development in the oases of the Manga grasslands, northeast Nigeria. In: *Hydrology in a Changing Environment*, eds: Wheater

Custodio E (2002). Aquifer overexploitation: what does it mean? Hydrogeol. J., 10: 254–277.

Dejoux, C., H. Deelstra and R. Wilkinson, 1981 Pollution. In The ecology and utilization of African inland waters, edited by J. Symoens, M. Burgis and J. Gaudet. UNEP Rep.Proc.Ser., (1):149–161

David Henley Q:\Personal\WORD\Nigeria Water Sector\Nigeria WSS Strategy 6-21-2000.doc 06/26/00 10:47 AM

Egborge, A.B.M. and Fagade, S. O. 1999 Notes on the hydrobiology of the Wikki warm spring, Yankari Game Reserve, Nigeria. Pol. Arch Hydrobiol. 23:313-3225.

Eze, R.A.M. 2002. Oil pollution in the riverine areas– a case study of Akwa-Ibom State. *Global Journalof Environmental Sciences*, 1,

Ekiye, et al, Water quality monitoring 2010 Journal of American Science :6(4)

Edmunds, W.M., Fellman, E., Goni, I.B., McNeill,G. and Harkness, D.D. 1998.

Ezeronye, O.U and Amogu, N.1998 Microbiological Studies of Effluents from the Nigerian Fertilizer and Paper Mill Plants. International Journal of Environmental Studies,54: 213-221.

Emongor,.V. Nkegbe, E. Kealotswe, B. Koorapetse, I. Sankwase, S. and Keikanetswe, S 2005 Pollution indicators in Gaborone industrial effluent. Journal of Appl Sci. 5: 147-150

Ezeigbo HI (2003). Towards sustainable potable water supply to Nigerians in the New Millennium. In: A.A Elueze (ed.) Contributions of Geosciences and Mining to National Development, (NMGS), pp. 19– 21.

Etu- Effeotor, J.O., Preliminary hydrogeochemical investigations of subsurface waters in parts of the Niger Delta, *Journ. Min.Geol.*, **18(1)**, 103 – 107 **(1981)**

Egborge, A.B.M. and Fagade, S. O. 1999 Notes on the hydrobiology of the Wikki warm spring,Yankari Game Reserve, Nigeria. Pol. Arch Hydrobiol. 23:313-322

Fakayode, S. O. 2005 Impact assessment of industrial effluent on water quality of the receiving Alaro river in Ibadan Nigeria AJEAM-RAGEE 10: 1-13. (good style)

Fakayode, S. O. 2005 Impact assessment of industrial effluent on water quality of the receiving Alaroriver in Ibadan Nigeria AJEAM-RAGEE 10: 1-13. (good style)

Edmunds, W.M., Fellman, E., Goni, I.B., 1999.Lakes, groundwater and palaeohydrology in the Sahel of NE Nigeria: evidence fromhydrogeochemistry. *Journal of the Geological Societyof London*, 156, 345-355.

Edet, A.E., Okereke, C.S., Teme, S.C. and Esu,E.O. 1998. Application of remote-sensing data.to groundwater exploration: a case study of theCross River State, southeastern Nigeria. *Hydrogeology Journal*, 6, 394-404.

Freeze R.A. and Cherry J.A., Groundwater, Prentice-Hall Inc. Englewood Cliffs, N.J **(1979)**
Samanta, B.B. and van Wijk, C.A. (1 998). Criteria for successful sanitation
Pr programmes in low income country s. *Health Policy and Planning* **13**(1), 78 - 86.

FMWRRD (1995). The study on the National Water Resources Master Plan. Japan International Cooperation (JICA) and Federal Ministry of Water Resources and Rural Development, Federal Republic of Nigeria, Abuja

Food and Agriculture Organization of the United Nations (FAO): Water Resources, Development and Management Service. 2002. *AQUASTAT Information System on Water in Agriculture: Review of Water Resource Statistics by Country.* Rome: FAO. Available on-line at

Geyh, M.A. and Wirth, K. 1980. 14C ages of confined groundwater from the Gwandu aquifer, Sokoto Basin, northern Nigeria. *Journal of Hydrology*, 48, 281-288.

Groundwater, palaeoclimate and recharge in the southwestChad Basin, Borno State, Nigeria. In: *Isoto,Techniques in the Study of Environmental Change*`.Proceedings of an International Symposium,IAEA, Vienna, 1997.

Glyn, H. J. and Gary, W. H. 1996 Environmental Sciences and Engineering Prentice Hall International Inc. pp778

Glyn, H. J. and Gary, W. H. 1996 Environmental Sciences and Engineering Prentice Hall International Inc. pp778

Goni IB (2006). The challenges of meeting domestic water supply in Nigeria. J. Min. Geol., 42(1): 51–55.

Hanidu JA (1990). National growth, water resources and supply strategies in Nigeria in the 1990's. Water Resources J. Nig. Assoc. Hydrogeol., 1: 1-6.

Hanidu JA (2003). Provision of potable water supplies to rural communities in Nigeria. Contributions of Geosciences and Mining to National Development, In: A.A Elueze (ed.), pp 23–25.

Kretsinger VG, Narasimhan TN (2005). Sustaining groundwater resources: California's shift toward more effective groundwater management. Southwest Hydrol., 4: 18-19

Nwankwoala H.O., Okeke E.V. and Okereke S.C., Groundwater quality in parts of Port Harcourt, Nigeria: An overview, trends and concerns, *International Journal of Biotechnology and Allied Sciences*, **2(3),** 282 – 289 **(2007)**

Nwaogazie IL (1995). Water resources development in Nigeria. Global outlook? Proceedings of the 8th Annual Conference on Environmental Considerations in Water Resources Development, Nigerian Association of Hydrogeologists held in Port Harcourt, Nigeria, Nov.19-23, 1995.

Nwankwoala HO, Mmom PC (2008). Groundwater utilization versus millennium development goals: Implications for sustainable development. J. Nig. Environ. Soc. (JNES), 4(3): 34 – 42

Martinez D.E. and Bocanegra E.M., Hydro geochemistry and Cation Exchange Processes in the Coastal Aquifers of Mar Del Plata, Argentina, *Hydrogeology Journal,* **(10),** 393 - 408 **(2002)**

Menon S (1998). Groundwater management: need for sustainable approach. Proceedings of the seminar on Artificial Recharge of Groundwater, December, 1998, Central Groundwater Board, Ministry of Water Resources, New Delhi, www.wikipedia.org

Otokunefor, T. V. and Obiukwu, C.2005 Impact of refinery effluent on the physicochemical properties of a water body in the Niger Delta. Appl. Ecology Env. Res. 3: 61-72

Phiri, O. Mumba, P. Moyo,B.H.Z. and Kadewa, W.2005 Assessment of the impact of industrial effluents on water quality of receiving rivers in urban areas of Malawi Int. J. Environ. Sci. Tech. 2:237-244.

Oteze GE (2006). Management approaches for Nigeria's water resources J. Min. Geol., 42(1): 15–20.

Oyebande L (2004). Power generation and development in the Nigeria's power sector. Int. J. Hydropower Dams, (6): 213-219

Osibanjo,O. Daso A P. and Gbadebo A M. 2011 The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria Afr. J. Biotechno. 10 (4): 696-702,

Offodile ME (1979). Water resources policy. Working paper on policy on Nigeria's water resources development, unpublished paper from the Chairman of the Nigerian Mining and Geosciences Society Committee on water resources policy.

Offodile ME (2003). The development and management of groundwater in Nigeria. In: A.A Elueze (ed.) Contributions of Geosciences and Mining to National Development, (NMGS), pp. 1-7.

Offodile ME (2006). Overview on sustainable development and management of water resources in Nigeria. J. Min. Geol., 42(1): 57– 61.

Oyebande L (2006). Appropriate administrative structures in harnessing water resources for sustainable growth in Nigeria. J. Min. Geol., 42(1): 21 – 30.

Otokunefor, T. V. and Obiukwu, C.2005 Impact of refinery effluent on the physicochemical propertiesof a water body in the Niger Delta. Appl. Ecology Env. Res. 3: 61-72

Okagbue, C.O. 1988. Hydrology and chemical characteristics of surface and groundwater resources of the Okigwi area and environs, Imo State, Nigeria. In: *Groundwater and Mineral Resources of Nigeria*, ed: Ofoegbu, C.O. Vieweg & Sohn, Braunschweig, pp 3-16.

Saad, M. A, H. El-Rayis, O. and Ahdy, H.1984 Status of nutrientsin Lake Mariut, a delta lake in Egypt suffering from intensive pollution. Mar Pollut Bull 15 (1): 408-411

Sangodoyin, A.Y.1991 Groundwater and Surface Water Pollution by Open Refuse Dump in Ibadan, Nigeria. Journal of Discovery and Innovations, 3 (1): 24-31.

Sangodoyin, A.Y. 1995 Characteristics of control of industrial effluents-generated pollution Env. Mgt. & Health 6: 15-18

Sangodoyin AY. Characteristics and control of industrial effluent generated pollution. Environmental management and Health. 1995. 6 (4): 15 – 18

Shah T (1993). Groundwater markets and irrigation development:political economy and practical policy. Oxford University Press, Bombay

Sophocleous M (1997). Managing water resources systems: Why "safe yield" is not sustainable. Groundwater 35: 561-569

Rijswlk K (1981). Small community water supplies. IRC Technical Paper Series, No.18. The Netherlands.

Tolba, M.K., 1982 Development without destruction. Evolving environmental perceptions. Dublin, Tycooly, Nat.Resour.Environ.Ser., (12):197 p.

Tijani MN (2006). The need for action- driven vision and sustainable management of water resources in Nigeria. J. Min. Geol., 42(1): 31 – 40.

Peters HJ (1982). Groundwater management in California. Proc. ASCE Convention and Exposition. Preprint 82 035, ASCE, Reston, VA, p.15.

UN/WWAP (United Nations/ World Water Assessment Programme) (2003). UN World Water Development Report: Water for people, water for life. UNESCO (United Nations Educational, Scientific and Cultural Organization) and Berghahn Books, Paris, New York and Oxford.

Udom G.J., Etu- Efeotor J.O. and Esu,E.O., Hydrochemical evaluation of groundwater in parts of Port Harcourt and Tai-Eleme Local Government Area, Rivers State., *Global Journal of Pure and Applied Sciences*, **(5),** 546 – 552 **(1999)**

UN, 1988. Ground Water in North and WestAfrica. Natural Resources/Water Series No. 18, United Nations, New York.

Villholth KG (2006). Groundwater assessment and management: implications and opportunities of globalization. Hydrogeol. J., 14(3): 330 – 339

Velayutham M (1999). 50 years of natural resource management research. In: G.B Singh and B.R. Sharma (eds). The citizen's fifth report: state of India's environment, Part -11 Statistical Database, Centre for Science and Environment, New Delhi.

H and Kirby, C. Proceedings of the British Hydrological Society, Exeter, July 1998, pp 205- 211

Sangodoyin, A.Y 1993. Considerations oncontamination of groundwater by waste-disposal systems in Nigeria. *Environmental Technology*, 14,957-964.

Sangodoyin, A.Y. and Agbawhe, O.M. 1992.Environmental study on surface andgroundwater pollutants from abattoir effluents.*Bioresource Technology*, 41, 193-200.

Sangodoyin, A.Y. 1995 Characteristics of control of industrial effluents-generated pollution Env. Mgt.& Health 6: 15-18

Sangodoyin, A.Y.1991 Groundwater and Surface Water Pollution by Open Refuse Dump in Ibadan, Nigeria. Journal of Discovery and Innovations, 3 (1): 24-31.

Osibanjo,O. Daso A P. and Gbadebo A M. 2011 The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria Afr. J. Biotechno. 10(4): 696-702,

Phiri, O. Mumba, P. Moyo,B.H.Z. and Kadewa, W.2005 Assessment of the impact of industrialeffluents on water quality of receiving rivers in urban areas of Malawi Int. J. Environ. Sci.Tech. 2:237-244.

Saad, M. A, H. El-Rayis, O. and Ahdy, H.1984 Status of nutrientsin Lake Mariut, a delta lake in Egypt suffering from intensive pollution. Mar Pollut Bull 15 (1): 408-411

Tollba, M.K., 1982 Development without destruction. Evolving environmental perceptions. Dublin,Tycooly, Nat.Resour.Environ.Ser., (12):197 p.

APPENDIX 1

Conversion of Units from mg/L to meq/L

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

SABON GARI

$$Na = \frac{7.33}{23}$$

$$= 0.319 meq/l$$

SHALUKO

$$Na = \frac{10.80}{23}$$

$$= 0.469 meq/l$$

SAUKA KAHUTA

$$Na = \frac{3.10}{23}$$

$$= 0.135 meq/l$$

SABON GIDA

$$Na = \frac{3.32}{23}$$

$$= 0.144 meq/l$$

KADNA

$$Na = \frac{11.32}{23}$$

$$= 0.49 meq/l$$

TAI

$$Na = \frac{2.10}{23}$$

$$= 4.09 meq/l$$

SABON GARI

$$K = \frac{10.00}{39.1}$$

$$= 0.256 meq/l$$

SHALUKO

$$K = \frac{7.00}{39.1}$$

$$= 0.179 meq/l$$

SAUKA KAHUTA

$$K = \frac{1.32}{39.1}$$

$$= 0.134 meq/l$$

SABON GIDA

$$K = \frac{6.30}{39.1}$$

$$= 0.161 meq/l$$

KADNA

$$K = \frac{7.30}{39.1}$$

$$= 0.187 meq/l$$

TAI

$$K = \frac{3.32}{39.1}$$

$$= 0.085 meq/l$$

SABON GARI

$NO_3 = \frac{3.20}{39.1} =$

$0.052 meq/l$

SHALUKO

$NO_3 = \frac{5.60}{39.1} = 0.09 meq/l$

SAUKA KAHUTA

$NO_3 = \frac{3.10}{39.1} = 0.49 meq/l$

SABON GIDA

KADNA

TAI

NO$_3$= $\frac{4.30}{39.1} = 0.07 meq/l$	NO$_3$= $\frac{4.40}{39.1} = 0.07 meq/l$	NO$_3$= $\frac{2.60}{39.1} = 0.042 meq/l$
SABON GARI	*SHALUKO*	*SAUKA KAHUTA*
$Ca = \frac{392.70}{40.08} = 9.7979 meq/l$	$Ca = \frac{360.30}{40.08} = 8.989 meq/l$	$Ca = \frac{275.30}{40.08} = 6.87 meq/l$
SABON GIDA	*KADNA*	*TAI*
$Ca = \frac{68.82}{40.08} = 1.72 meq/l$	$Ca = \frac{121.4}{40.08} = 3.03 meq/l$	$Ca = \frac{222.6}{40.08} = 5.55 meq/l$
SABON GARI	*SHALUKO*	*SAUKA KAHUTA*
HCO$_3$= $\frac{0.04}{61.0168} = 0.00065 meq/l$	HCO$_3$= $\frac{0.20}{61.0168} = 0.00328 meq/l$	HCO$_3$= $\frac{0.30}{61.0168} = 0.0049 meq/l$
SABON GIDA	*KADNA*	*TAI*
HCO$_3$= $\frac{0.20}{61.0168} = 0.0028 meq/l$	HCO$_3$= $\frac{0.27}{61.0168} = 0.00442 meq/l$	HCO$_3$= $\frac{0.11}{61.0168} = 0.001803 meq/l$
SABON GARI	*SHALUKO*	*SAUKA KAHUTA*
$Cl = \frac{7.99}{35.45} = 0.225 meq/l$	$Cl = \frac{12.49}{35.45} = 0.352 meq/l$	$Cl = \frac{8.49}{35.45} = 0.239 meq/l$
SABON GIDA	*KADNA*	*TAI*
$Cl = \frac{9.99}{35.45} = 0.2813 meq/l$	$Cl = \frac{8.49}{35.45} = 0.239 meq/l$	$Cl = \frac{599.}{35.45} = 16.92 meq/l$
SABON GARI	*SHALUKO*	*SAUKA KAHUTA*
CO$_3$= $\frac{0}{60} = 0 meq/l$	CO$_3$= $\frac{0}{60} = 0 meq/l$	CO$_3$= $\frac{0}{60} = 0 meq/l$
SABON GIDA	*KADNA*	*TAI*

$CO_3 = \frac{0}{60} = 0 meq/l$ $CO_3 = \frac{0}{60} = 0 meq/l$ $CO_3 = \frac{0}{60} = 0 meq/l$

SABON GARI *SHALUKO* *SAUKA KAHUTA*

$SO_2 = \frac{95.00}{55} = meq/l$ $SO_2 = \frac{90.00}{55} = meq/l$ $SO_2 = \frac{15.00}{55} = meq/l$

SABON GIDA *KADNA* *TAI*

$SO_2 = \frac{50.00}{55} = meq/l$ $SO_2 = \frac{5.00}{55} = meq/l$ $SO_2 = \frac{50.00}{55} = meq/l$

APPENDIX 2

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

SABON GARI

$$\frac{0.319}{[(97.98+32.46)/2]^{\ 1/2}} = 0.040meq/l$$

SHALUKO

$$\frac{0.469}{[(8.99+36.69)/2]^{\ 1/2}} = 0.10meq/l$$

SAUKA KAHUTA

$$\frac{0.135}{[(6.89+23.57)/2]^{\ 1/2}} = 0.035meq/l$$

SABON GIDA

$$\frac{0.144}{[(1.717+9.21)/2]^{\ 1/2}} = 0.062meq/l$$

KADNA

$$\frac{0.492}{[(3.029+9.953)/2]^{\ 1/2}} = 0.193meq/l$$

TAI

$$\frac{0.09}{[(5.554+17.433)/2]^{\ 1/2}} = 0.027meq/l$$

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

SABON GARI

$$\frac{[0.319 + 0.256]}{[97.98 + 32.46 + 0.319 + 0.256]} \times 100 = 0.44\%$$

SHALUKO

$$\frac{[0.469 + 0.179]}{[8.99 + 36.69 + 0.469 + 0.179]} \times 100 = 2.53\%$$

SAUKA KAHUTA

$$\frac{[0.135 + 0.034]}{[6.89 + 23.57 + 0.135 + 0.034]} \times 100 = 0.55\%$$

SABON GIDA

$$\frac{[0.144 + 0.161]}{[1.717 + 9.21 + 0.144 + 0.161]} \times 100 = 2.72\%$$

KADNA

$$\frac{[0.492 + 0.187]}{[3.029 + 9.953 + 0.492 + 0.187]} \times 100 = 4.97\%$$

TAI

$$\frac{[0.09 + 0.085]}{[5.554 + 17.433 + 0.09 + 0.085]} \times 100 = 0.76\%$$

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

SABON GARI

$$(0 + 0.00065) - (97.98 + 32.46) = -130.44 meq/l$$

SHALUKO

$$(0 + 0.0033) - (8.989 + 36.69) = -45.68meq/l$$

SAUKA KAHUTA

$$(0 + 0.0049) - (6.87 + 23.57) = -30.435meq/l$$

SABON GIDA

$$(0 + 0.0033) - (1.717 + 9.21) = -10.923meq/l$$

KADNA

$$(0 + 0.00442) - (3.029 + 9.96) = -12.984meq/l$$

TAI

$$(0 + 0.0018) - (5.556 + 17.433) = -22.985meq/l$$

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

SABON GARI

$$100 \times \frac{[([0.319] + [0.00065] \quad ^{1}/_{2})}{[0.319] + [97.98] + [32.46]} = 0.264meq/l$$

SHALUKO

$$100 \times \frac{[([0.469] + [0.00328] \quad ^{1}/_{2})}{[0.469] + [8.99] + [36.69]} = 1.15meq/l$$

SAUKA KAHUTA

$$100 \times \frac{[([0.135] + [0.0049] \quad {}^{1}/_{2})}{[0.135] + [6.87] + [23.57]} = 0.670 meq/l$$

SABON GIDA

$$100 \times \frac{[([0.144] + [0.00328] \quad {}^{1}/_{2})}{[0.144] + [1.717] + [9.21]} = 1.818 meq/l$$

KADNA

$$100 \times \frac{[([0.492] + [0.00442] \quad {}^{1}/_{2})}{[0.492] + [3.029] + [9.955]} = 4.16 meq/l$$

TAI

$$100 \times \frac{[([0.09] + [0.001803] \quad {}^{1}/_{2})}{[0.09] + [5.554] + [17.433]} = 0.97 meq/l$$

1. Chloro-Alkaline Indices

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

SABON GARI

$$\frac{[0.225 - (0.319 + 0.256)]}{0.225} = -1.56 meq/l$$

SHALUKO

$$\frac{[0.352 - (0.469 + 0.179)]}{0.352} = -0.84 meq/l$$

SAUKA KAHUTA

$$\frac{[0.239 - (0.135 + 0.034)]}{0.239} = 0.293 meq/l$$

SABON GIDA

$$\frac{[0.2813-(0.144+0.161)]}{0.2813}=-0.084meq/l$$

KADNA

$$\frac{[0.239-(0.492+0.187)]}{0.239}=-1.84meq/l$$

TAI

$$\frac{[16.919-(0.09+0.085)]}{16.919}=0.98meq/l$$

1. Chloro-Alkaline Indices

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

SABON GARI

$$\frac{[0.225-(0.319+0.256)}{(0.989+0.00065+0+0.052)}=-0.3$$

SHALUKO

$$\frac{[0.352-(0.469+0.179)]}{(0.937+0.00328+0+0.09)}=-0.$$

SAUKA KAHUTA

$$\frac{[0.239-(0.135+0.034)]}{(0.156+0.0049+0+0.049)}=0.$$

SABON GIDA

$$\frac{[0.2813-(0.144+0.161)]}{(0.52+0.00328+0+0.07)}=-0.039 meq/l$$

$$KADNA$$

$$\frac{[0.239-(0.492+0.187)]}{(0.05+0.00442+0+0.07)}=-3.54 meq/l$$

$$TAI$$

$$\frac{[16.919-(0.09+0.085)]}{(0.52+0.001803+0+0.042)}=29.7.8 meq/l$$

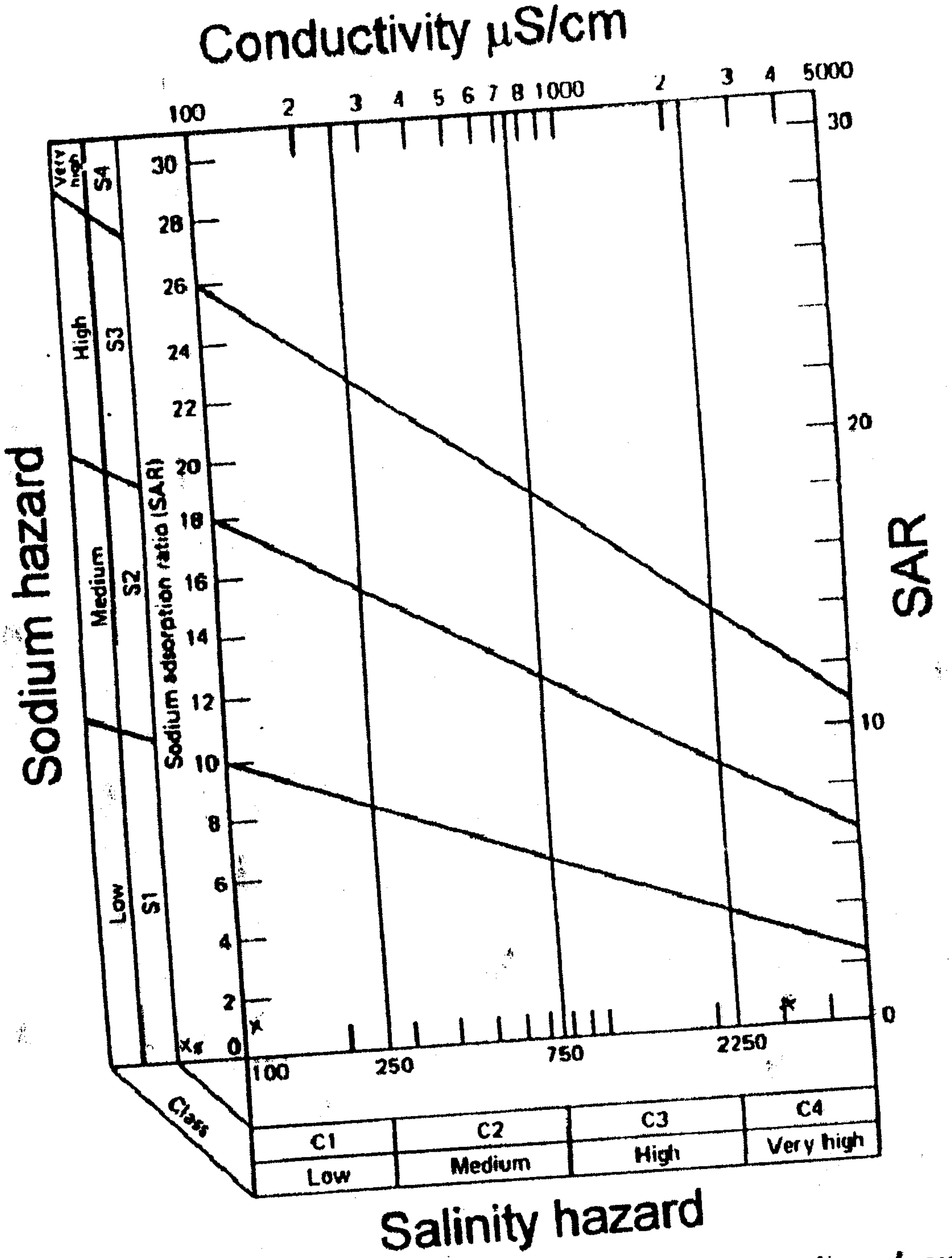
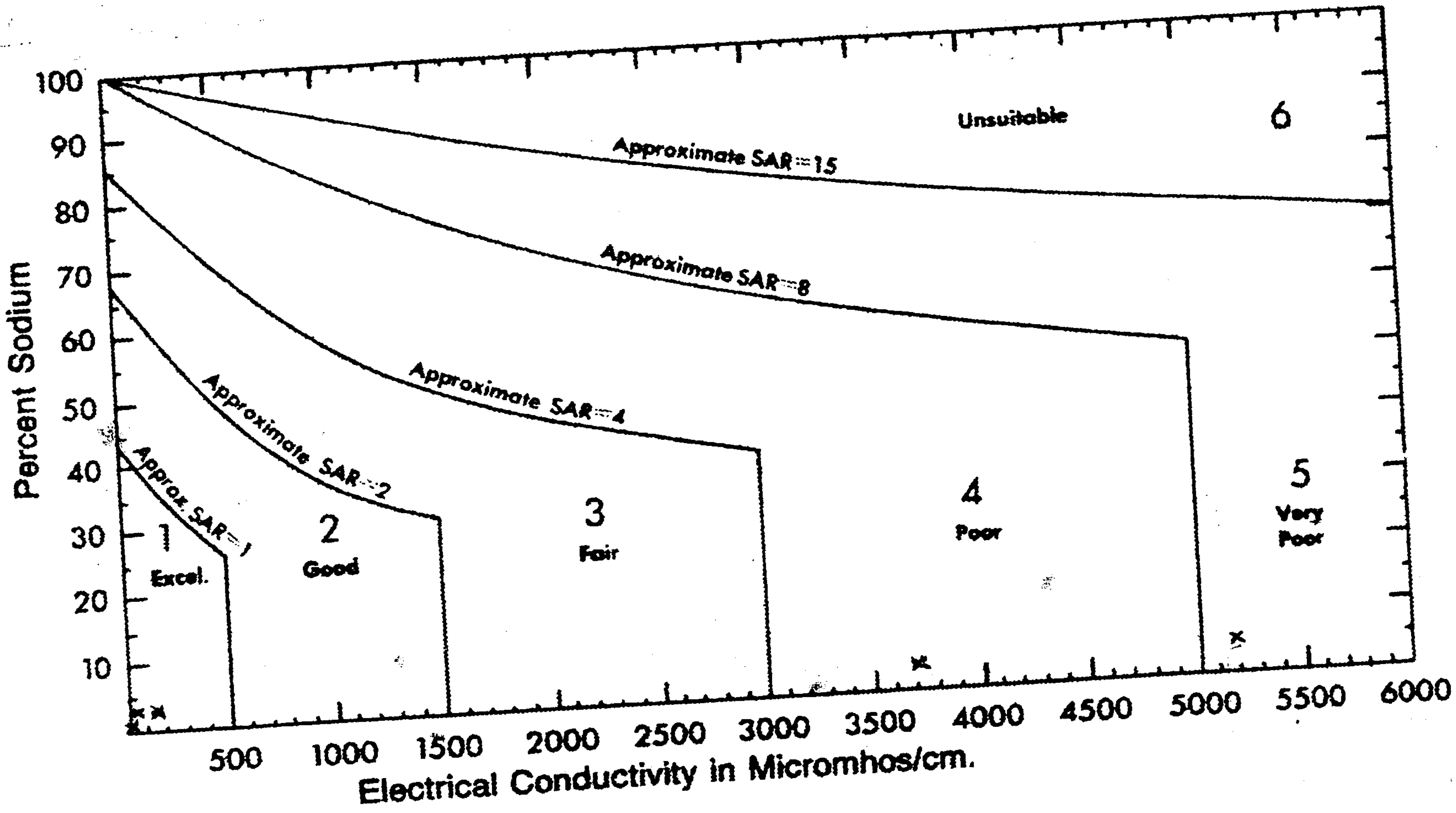


Figure 4 USDA classification for agricultural waters



Percent Sodium
100
90
80
70
60
50
40
30
20
10
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Electrical Conductivity in Micromhos/cm.
Approx. SAR=1
Approximate SAR=2
Approximate SAR=4
Approximate SAR=8
Approximate SAR=15
1
Excel.
2
Good
3
Fair
4
Poor
5
Very Poor
6
Unsuitable