ENVIRONMENTAL EFFECTS OF URBANISATION ON GROUNDWATER RESOURCES IN PARTS OF MINNA METROPOLIS, NORTH-CENTRAL NIGERIA

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MTech/SPS/2017/6762

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SEPTEMBER, 2021

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THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN GEOLOGY (HYDROGEOLOGY)

SEPTEMBER, 2021

ABSTRACT

A study on the geology and hydrogeology of part of Minna Sheet 164NE was conducted with the aim of establishing the groundwater potential and control mechanism. Minna lies along longitude 6°30′E and 6°32′E and latitude 9°37′36″ N and 9°39′34.5″ N covering a total area of 14 km^2. The area has a high population most of whom depends on groundwater for domestic uses. Geology of the area was studied on a scale of 112,000 using traverse method. Structural disposition of outcrops was established and positions taken. Thin sections of representative rock samples were made and analysed using petrological microscope. Groundwater inventory consisting of well locations, including borehole depth, water level and yield were taken. Samples of the water were obtained and analysed for physical and chemical composition. 90% of the area is underlain by rocks belonging to the older granite suite of the Nigerian Basement complex system while the remaining 10% is underlain by schist. Joint direction is principally in the NNE-SSW. Thickness of the weathered rock is in the range of 5-10m. Wells have a mean depth of 5m and water level of 3.57m. Boreholes have an average depth of 134m and mean yield of 71.28m^3/d(0.83lt/s). Groundwater potential map shows that the north-eastern part of the area has greater potential at shallow level while other areas have slightly lower potential. Regional groundwater flow is in the NE-SW direction. Groundwater has a mean pH of 7.3, Electrical Conductivity 637.5µS/cm, and temperature of 28.6ºC. Parameters with higher concentration include chloride 82.35mg/l, bicarbonate 70.18mg/l, sodium 56.18mg/l and calcium 46.16mg/l, nitrate. Trace elements that occur in fairly high concentration include zinc 1.15mg/l, phosphate 0.81mg/l and fluoride 0.32mg/l. The water primarily plots as mixed calcium-magnesium-chloride water and secondarily as sodium-bicarbonate water. The heavy metals are considered as Potentially Toxic Elements (PTEs)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

According to The Department of Economic and Social Affairs (Vale, 2017), half of the global population already lives in cities, and by 2050 two-thirds of the world's people are expected to live in urban areas. But in cities two of the most pressing problems facing the world today also come together: poverty and environmental degradation. The majority of people move to cities and towns because they view rural areas as places with hardship and backward/primitive lifestyle. Therefore, as populations move to more developed areas (towns and cities) the immediate outcome is urbanization. This normally contributes to the development of land for use in commercial properties; social and economic support institutions, transportation, and residential buildings. Eventually, these activities raise several urbanisation issues.

Poor air and water quality, insufficient water availability, waste-disposal problems, and on density and demands of urban environments. Strong city planning will be essential in managing these and other difficulties as the world's urban areas swell. Urban populations interact with their environment. Urban people change their environment through their consumption of food, energy, water, and land. And in turn, the polluted urban environment affects the health and quality of life of the urban population.

Approximately 97% of the earth’s water is stored in the oceans, and only a fraction of the remaining portion is usable freshwater. When precipitation falls over the land, it follows various routes. Some of it evaporates, returning to the atmosphere, some seeps into the ground, and the remainder becomes surface water, traveling to oceans and lakes by way of rivers and streams.

Impervious surfaces associated with urbanization alter the natural amount of water that takes each route. The consequences of this change are a decrease in the volume of water that percolates into the ground; and a resulting increase in volume and decrease in quality of surface water. These hydrological changes have significant implications for the quantity of fresh; clean water that is available for use by humans, fish and wildlife.

Air pollution often plagues industrialized cities, particularly during their early development. Episodes of high levels of sulphurous smog killed or sickened thousands in Donora in 1948, as well as in London in 1952. Other cities—primarily in the industrialized regions of the United States and Europe—also suffered from notoriously bad air quality. These events were the result of very high emissions of sulphur dioxide, smoke, and other particles during stagnant, foggy weather conditions.

Urbanization has led to reduced physical activity and unhealthy nutrition. The World Health Organization predicts that by 2020, non-communicable diseases such as heart disease will account for 69 percent of all deaths in developing countries. Another urbanization-related threat is infectious diseases. Air travel carries bacteria and viruses from one country to the next. In addition, people relocating from rural areas are not immune to the same diseases as long-time city residents, which puts them at a greater risk of contracting a disease.

The cost of living in urban areas is very high. When this is combined with random and unexpected growth as well as unemployment, there is the spread of unlawful resident settlements represented by slums and squatters. The growth of slums and squatters in urban areas is even further exacerbated by fast-paced industrialization, lack of developed land for housing, large influx of rural immigrants to the cities in search of better life, and the elevated prices of land beyond the reach of the urban poor.

Although urbanization is a necessary condition for modernization, we can mitigate the effect of it. We just need to learn how to save the planet and conserve our natural resources, through recycling water and the use of renewable energy.

Water is essential for the survival of every form of life and the need for water is constantly increasing due to high rates of population growth and urbanization. However, the increased demands in water for drinking, domestic agricultural and industrial purposes are not commensurate with water availability thus, posing significant risks in maintaining acceptable water quality. Therefore, the quality of accessible water is an important index of the living standard (Dara, 2000; Gopinath *et al.*, 2011). Hydrogeochemical study of water sources involves the studying of the chemistry /geochemical elements of water, nature and quality of water in relation to its geology and waste disposal. Mineralogical composition of the underlying rocks and the nature of the surface run off are factors that affect quality of groundwater. Hence, the quality of groundwater is largely controlled by a discharge and recharge pattern, nature of host and associate rocks as well as human activities.

In the study area, there is the challenge of lack of supply of pipe borne water hence many homes have wells sited around the house at unacceptable distances from the septic tanks. It is known that for most communities, the most secure source of safe drinking water is pipe-borne water from municipal water treatment plants. Often, these water treatment facilities do not deliver or fail to meet the water requirements of the served community due mostly to increased population. The scarcity of piped water has made communities to find alternative sources of water where ground water sources are a ready source. Well is a common ground water source that is explored to meet community water requirement or make up the short fall.

These wells serve as major source of water for household uses (drinking, cooking, washing etc.). The most common cause of pollution is attributed to close proximity of septic tanks to wells, unhygienic usage of the wells for example some wells have no cover/lids; they are dirty and unkempt thus, making the water unfit for use, resulting into water borne diseases.

1.2 Statement of the research problem

Ethically, the beauty of any environment lies on its good sanitary condition. This is so because, when an environment is clean the lives of citizenry are not threatened by illnesses and diseases. Proper solid waste disposal is necessary to maintain this status. Also, proper use of available resources is required to ensure sustainability of these resources. Poor environmental management practices and unsustainable demand for natural resources have due to urbanization led to inadequacy in water supply, poor sanitation and environmental degradation issues. This research therefore, seeks to unravel ways in which groundwater has been impacted and recommend ways in which this situation can be remedied.

1.2.1 Some characteristics of the study area

The characteristics of the study area include:

- Densely populated (overcrowded).
- Houses closely packed together and built indiscriminately.
- Poor drainage system.
- Poor sanitation facilities.
- No proper planning.
- Waste disposal system is mostly in open dumps and drainages.
- Inhabitants rely heavily on groundwater for water supplies.

1.3 Justification for the study

It has long been recognised that urbanisation results in important changes to the groundwater balance both by replacing and modifying groundwater mechanisms and by introducing new discharge patterns due to abstraction from wells. In particular, main water and sanitation systems can have a significant impact on shallow aquifers that underlie a city and they may become major components of the urban hydrologic cycle as a result of leakage and/or seepage. The aquifers at such depths have been overwhelmed by population growth and other environmental conditions. Also, aquifers beneath these sites are also prone to contamination.

Further pressure is anticipated as the years go by considering the fact that Minna is experiencing a high population growth rate. Therefore, investigating these activities which are a direct result of urbanisation is important. Furthermore, the results of these investigations will provide information that would be utilised by agencies of the government and public sector to make policies that would regulate these activities.

UNEP and WHO (1996), argued that it is not significant to merely have access to water in adequate quantities. The water also needs to be of adequate quality to maintain health and it must be potable. Poor sanitation or lack of them, improper municipal and industrial waste disposal system could pose pollution problems to groundwater supplies. For example, influent seepage of urine and leachate from polluted surroundings, a pit latrine or a soak away, sited upstream and near a borehole, could enrich the groundwater with phosphates and ammonia (Okoye and Adeleke, 1991).

1.4 Scope of work and limitations

This research seeks to establish impacts of urbanisation on the environment as it relates to groundwater contamination in shallow aquifers as well as the effects regarding to open dumpsites using information on open dumpsites, hydrogeological and hydrogeochemical data.

The study was limited to Kpakungu, Soje and Barikin Sale areas. It involves a study of the geology, hydrogeological conditions, water quality, wastewater and solid waste disposal as they relate to groundwater contamination. The various results will be used to propose strategies for effective use and sustainability of groundwater resources and suitable methods of solid waste disposal. Acquisition of archived secondary data from relevant agencies may be problematic due to challenges in archiving data by these agencies. However, these limitations will have no negative impact on the outcome of the research.

1.5 Aim and objectives of the study

The research is aimed at evaluating the impact of urbanisation on water resources in parts of Minna metropolis, North Central Nigeria.

Objectives of the study are to:

i. Determine the geology, hydrogeology and the weathering profile of the study area.

ii. Determine the extent of pollution of water due to developmental activities.

iii. Determine the quantities and types of waste generated in the study area

iv. Assess the impacts of activities on the groundwater system and the environment of the study area.

1.6 Study area description

1.6.1 Location, Extent and Accessibility

Minna, the capital city of Niger State is located within the North-Central part of Nigeria. It is located between Latitudes 9°35′24″N and 9°38′24″N and Longitudes 6°31′12″E and 6°34′12″N. It covers Chanchaga Local Government Area and parts of Bosso Local Government Area.

The focus of the study covers Kpakungu, Barikin-Sale and Soje areas of Minna.

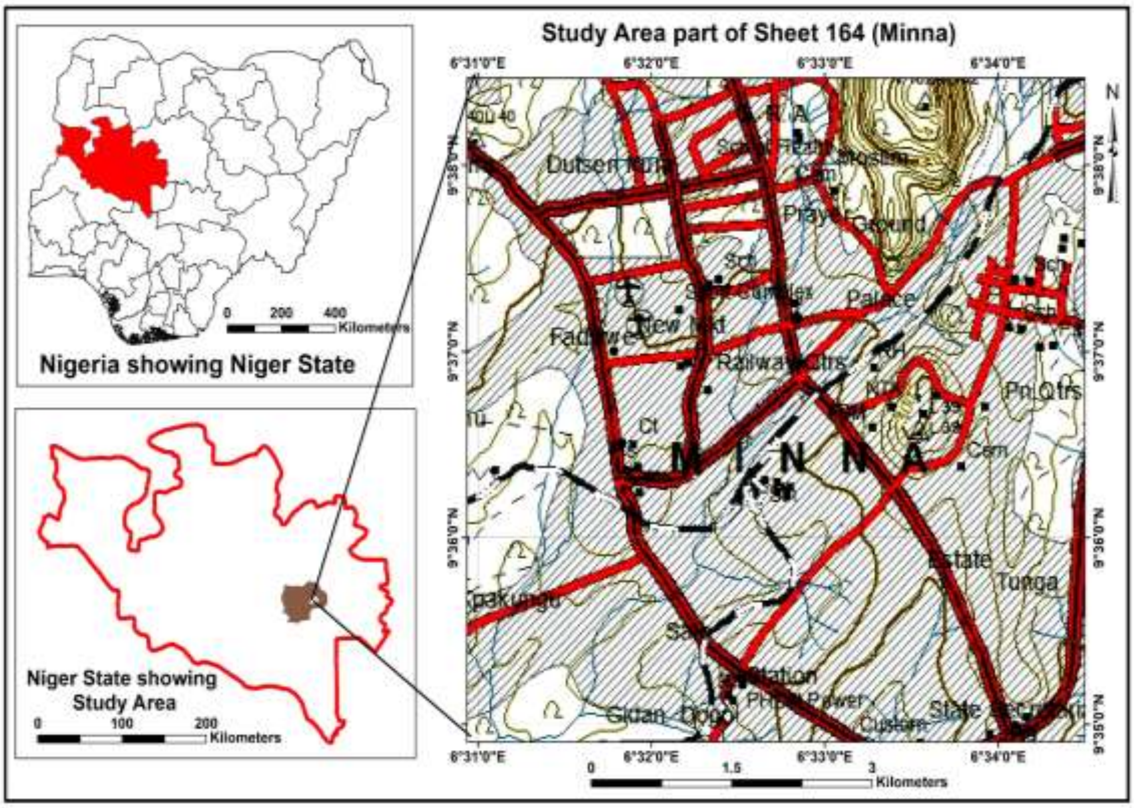

Figure 1.1: Location of Kpakungu, Soje and Barikin-Sale.

Figure 1.2: Satellite Imagery of parts of Minna showing the study areas

1.6.2 Climate and Vegetation

The area falls within the Guinea Savannah vegetation. There are two seasons associated with the climate. These include the rainy and dry seasons. The total annual rainfall in this area is between 1270 mm and 1524 mm, spread over the month of April to October (NIMET, 2019). The maximum daytime temperature is about 35°C in the months of March and April, while a minimum temperature of about 24°C is recorded in the months of December and January. The mean annual temperatures are between 32°C to 33°C. It should however be noted that the above climatic conditions stated are subject to changes. The dry season is marked by influence of harmattan which is a result of North-East trade wind that blows across the Sahara and that is often laden with red dust and lasts from the month of December to the month of February.

1.6.3 Relief and drainage

The area is majorly flat line with contour values ranging from 350 – 400 m also found within the area occurring as a spot height is the geographical point reference referred to as the Minna datum which defines the Universal Traverse Mercator (UTM). This is an elevated spot in the predominant part of the area studied at the top of which the Niger State water and sanitation board placed a 10 million litre capacity concrete reservoir for water distribution by gravity flow to neighbouring areas.

The drainage pattern of the area is the dendritic pattern, seasonal rivers such as river Biyako, Dutsen Kura and Gbaiko drain the area with smaller tributaries joining them. This all eventually drains into River Chanchaga which is a perennial river that occurs in the southern part of the sheet flowing in the SW direction. The seasonal stream within the study area flows from the NE-SW direction. Figure 1.3 is the topographic map of parts of Minna covering the study area, it shows the topographic structure and drainage of the study area.

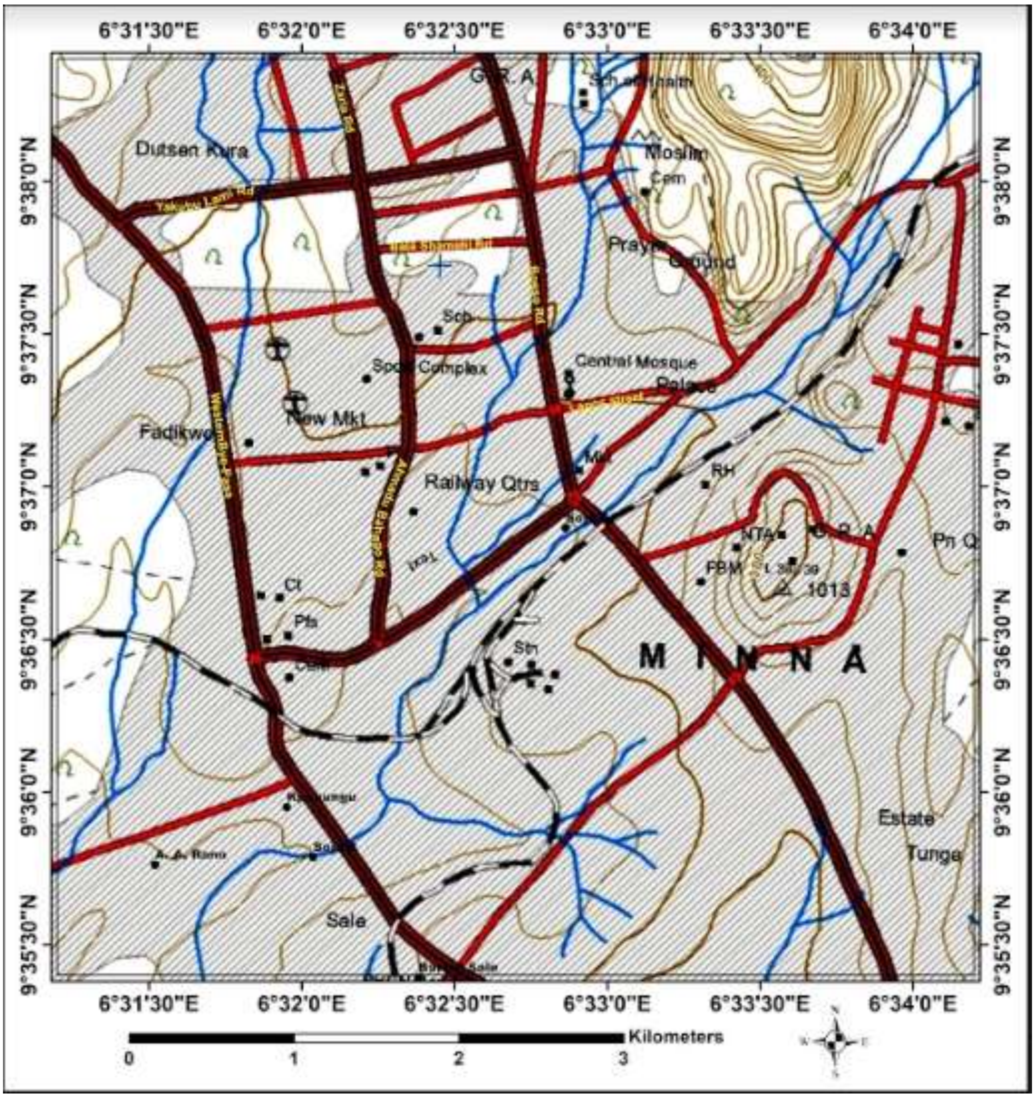

Figure 1.3: Topographical and drainage map of the study area

1.6.4 Local Geology

Minna falls within the North-Central part of Nigeria; the study area is Basement Complex of Nigeria is underlain by Precambrian rocks. This groups of crystalline rocks generally represents; Migmatites, Gneisses, and Meta-Sedimentary Schist (Adeleye, 1976). Two lithological units underlie the area; granites and Gneisses with Pegmatites and quartz veins. About 80% of granitic rock is covered in the areas which are exposed mainly at the western part of the town. The highly jointed, fractured, foliated outcrops are granitic which appears as boulders in some places. The second lithologic unit which is gneiss covers about 20% of the total area. (Adeniyi, 1985). Gneissose banding which are fine grained, characterized by swaying lighter coloured minerals of quartz and feldspar, darker coloured biotite-mica with an intrusion of highly weathered and fractured granitic rocks. A few of the Gneisses contain augen structures, banding and boudinages.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Geology of Nigeria

The geology of Nigeria (Figure 2.1) has been broadly grouped into three main components:

1. The Basement Complex
2. The Sedimentary Basins
3. The Younger Granites or intrusive.

The Nigerian Basement Complex forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons (Figure 2.2) and south of the Tuareg Shield (Black, 1980). It is intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments (Obaje, 2009). The study area is underlain by Precambrian rocks of the Nigerian Basement Complex, which cover about 95% of the land surface. These rocks consist of the Migmatite Gneiss Complex, the Schist Belts and the Older Granite series. The rocks of the sedimentary basin which cover about 15% of the territory in the south-western part consist of the Cretaceous sandstones. The remaining 5% of the area is composed of the Recent Alluvium.

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2.1.1 The Migmatite – Gneiss Complex (MGC)

The Migmatite – Gneiss Complex is generally considered as the Basement Complex *sensustricto* (Rahaman, 1988; Dada, 2006). It has a heterogeneous assemblage comprising migmatites, orthogneisses, paragneisses, and a series of basic and ultrabasic metamorphosed rocks. Petrographic evidence indicates that the Pan-African reworking led to recrystallization of many of the constituent minerals of the Migmatite – Gneiss Complex by partial melting with majority of the rock types displaying medium to upper amphibolite facies metamorphism. The Migmatite – Gneiss Complex has ages ranging from Pan-African to Eburnean.

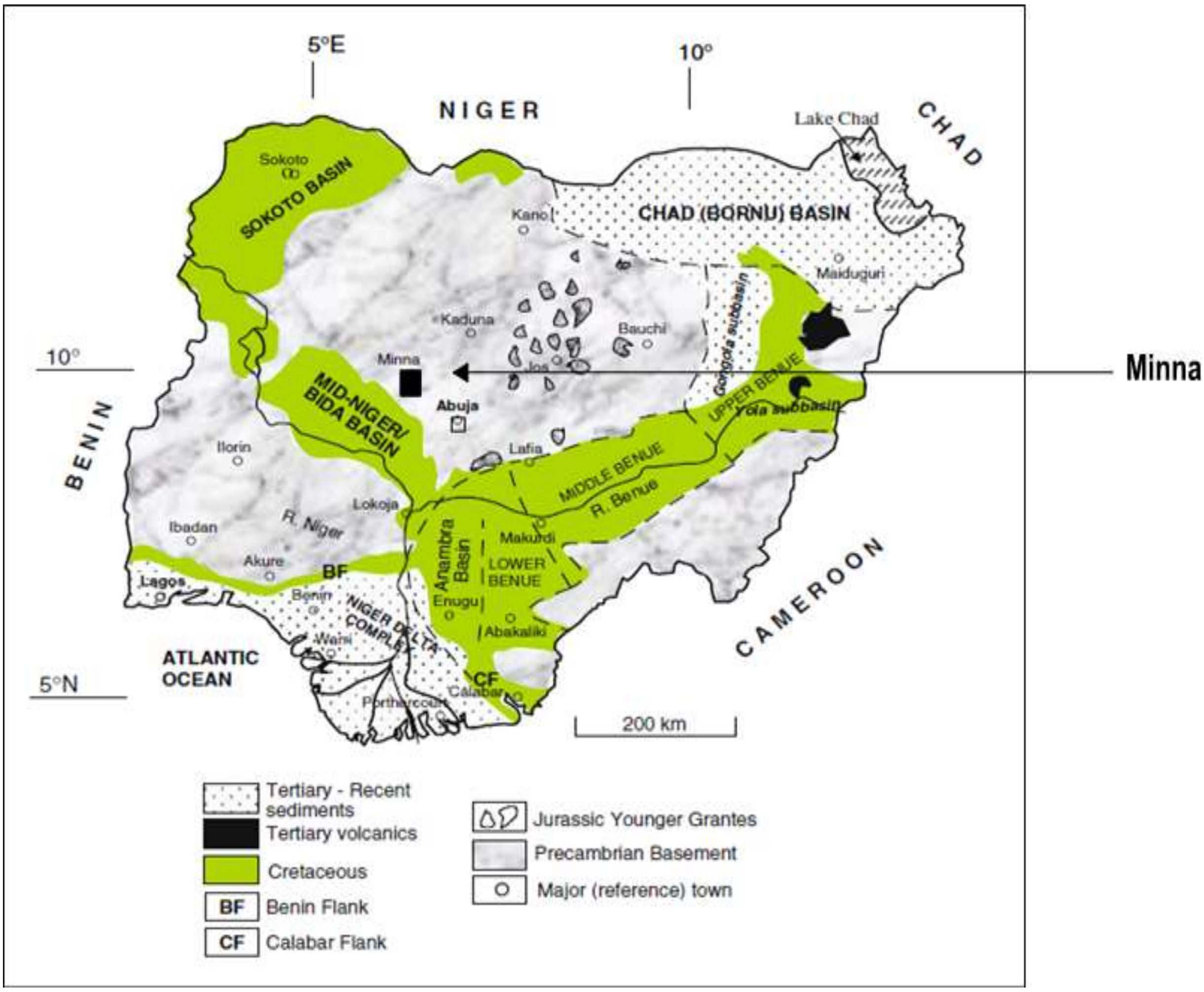

Figure 2.1: Geological map of Nigeria showing Minna (Obaje, 2009).

These rocks record three major geological events (Rahaman and Lancelot, 1984); the earliest, at 2,500 Mya, involved initiation of crust forming processes (for example the banded Ibadan grey gneiss of mantle origin) and of crustal growth by sedimentation and orogeny; next came the Eburnean, 2,000 ± 200 Ma, marked by the Ibadan type granite gneisses; this was followed by ages in the range from 900 to 450 Ma which represent the imprint of the Pan-African event which not only structurally overprinted and re-set many geochronological clocks in the older rocks, but also gave rise to granite gneisses, migmatites and other similar lithological units.

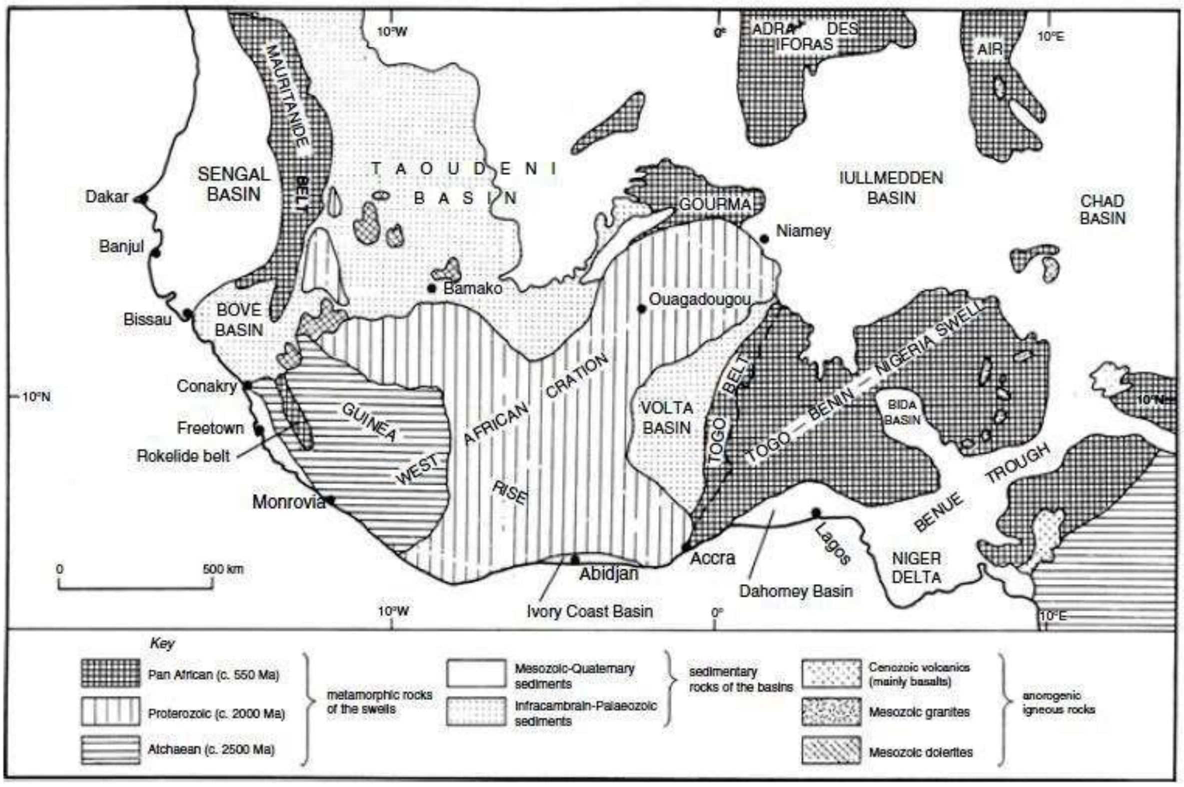

Figure 2.2: Generalized geological map of Nigeria within the framework of the geology of West-Africa (Adapted from Wright *et al.*, 1985).

The close analogy in line with the development of the Birrimian of the West African Craton is striking. However, although gold, manganese and iron mineral deposits are associated with Birrimian rocks, the same age rocks in Nigeria are very sparsely, if at all, mineralized. The extent of Eburnean and older rocks in Nigeria is not known. Definite geochemical evidence for the existence of these rocks exists for the area south of latitude 9◦N (Rahaman and Lancelot, 1984). Lithologically similar rocks in other parts of Nigeria, especially in the northeast and southeast, have given only Pan-African ages (Tubosun, 1983).

2.1.2 The Schist belt

Low to medium grade metamorphosed sedimentary and volcanic rocks occupy three belts of the larger Minna sheet. Following Truswell and Cope (1963), each of the belts is given a formational name, viz: the Kushaka, the Birnin Gwari and the Ushama Schist Formations. Truswell and Cope (1963), defined a formation as a basic mapping unit with a distinctive lithology or combinations of lithologies.

However, they mapped the Ushama belt as part of the Kushaka schist belt on account of similar lithologies, even though separated from the main outcrops of the Kushaka schist belt by the rocks of the gneiss complex, the Birnin Gwari Schist formation and by granites. Although the schist belts form prominent strike ridges, the rocks are very poorly exposed and are deeply weathered, with few exceptions where there are extensive exposures.

The Kushaka Schist belt, to which the study area belongs, have been intruded by large bodies of granitic rocks and the present outcrops of the belt represent remnants of previously more extensive assemblages. This formation has been extensively migmatised during the emplacement of the older granites to form the Pan-African Migmatites.

The rocks of the Schist Belt occur in isolation in the north-eastern and the south-eastern part of the study area. The Schists in the study area consist predominantly of phyllite, mica Schist, talc Schist and quartz Schist interlayered with amphibolites.

2.1.3 The Older Granite suite (Pan – African granitoids)

Rocks of the older granite suite account for over 50% of the geology of the Minna Sheet. The Older Granites in the study area are underlain by granitic rocks and show evidences of ancient tectonic activity in the form of major and minor faults, joints, fracture etc. most especially around the rock exposure at the Lupma settlement. The trends of the linear structures are approximately N-S, NE-SW and NW-SE of which the NE-SW trend are predominant.

The Older Granites series crop out as isolated hills, inselbergs and low whalebacks. They are foliated and variable contact relationships within the country rocks. These include sharp, cross-cutting and gradational contacts. Abundant xenoliths of the country rocks are included in the granitic rocks and contact metamorphic minerals are developed in the country rocks. Some of the bodies are elongated parallel to the regional structures. They range in size from plutons to batholiths. They include rocks of a wide range of compositions: granites, granodiorites, ademellites, quartz monzonite, syenites and pegmatites (Rahaman, 1988).

Age determination on the older granites, by various methods from all parts of the Nigerian Basement lie between 750 My and 450 My and show that the older granites were emplaced during the late Precambrian to Early Palaeozoic. It is generally agreed that they are products of the last orogenic event to affect the Nigerian basement about 600 My Pan-African Orogeny. A major granitic body, Minna Batholith dominates the geology of the Minna Sheet.

2.2 Effects of urbanisation

Urbanisation refers to the population shift from rural areas to urban areas, the decrease in the proportion of people living in rural areas, and the ways in which each society adapts to this change. It is predominantly the process by which towns and cities are formed and become larger as more people begin living and working in central areas. Although the two concepts are sometimes used interchangeably, urbanization should be distinguished from urban growth: urbanization is "the proportion of the total national population living in areas classed as urban", while urban growth refers to "the absolute number of people living in areas classed as urban" (Pateman, 2011). The United Nations projected that half of the world's population would live in urban areas at the end of 2020 (UN, 2014). It is predicted that by 2050 about 64% of the developing world and 86% of the developed world will be urbanized (UN, 2017). That is equivalent to approximately 3 billion urbanites by 2050, much of which will occur in Africa and Asia. Notably, the United Nations has also recently projected that nearly all global population growth from 2017 to 2030 will be by cities, about 1.1 billion new urbanites over the next 10 years.

Poor air and water quality, insufficient water availability, waste-disposal problems, and high energy consumption are exacerbated by the increasing population density and demands of urban environments. Strong city planning will be essential in managing these and other difficulties as the world's urban areas swell.

2.2.1 Threats

- Intensive urban growth can lead to greater poverty, with local governments unable to provide services for all people.
- Concentrated energy use leads to greater air pollution with significant impact on human health.
- Automobile exhaust produces elevated lead levels in urban air.
- Large volumes of uncollected waste create multiple health hazards.
- Urban development can magnify the risk of environmental hazards such as flash flooding.
- Pollution and physical barriers to root growth promote loss of urban tree cover.

- Animal populations are inhibited by toxic substances, vehicles, and the loss of habitat and food sources.

2.2.2 Solutions

- Combat poverty by promoting economic development and job creation.
- Involve local community in local government.
- Reduce air pollution by upgrading energy use and alternative transport systems.
- Create private-public partnerships to provide services such as waste disposal and housing.
- Plant trees and incorporate the care of city green spaces as a key element in urban planning.

2.3 Review of previous literature

African cities have a long history of water supply from surface and groundwater sources. However, due to deteriorating quality and quantity of surface water through increased urbanization and industrialization and high cost of developing new dams, urban groundwater is viewed as a better option (Adelana *et al.*, 2008). This advantage notwithstanding, urbanization

has important overall implications for freshwater use and waste management and specifically for the development, protection and management of sub-surface water in an urban environment (Eni *et al.*, 2011). In a comprehensive study by Adelana *et al.*, (2003, 2004, 2005) of groundwater quality of the south-eastern parts of Lagos from 1999-2001 on the impact of urbanization, found that of the water samples analysed, concentrations of sulphate, nitrate and chloride at objectionable proportion were noted in all the wells. Nitrate particularly was noted to be very high and is linked with anthropogenic activities. Groundwater in Lagos is particularly vulnerable to contamination due to shallow depth and the unconsolidated permeable sand and gravel aquifer. In a similar study, Eni *et al.*, (2011) assessed the impact of urbanization on the sub-surface water of Calabar town noted water to be acidic, nitrate and faecal coliform to have very high concentration in the wells. Results of multiple regression show faecal coliform, pH, and chlorine have positive relationship with urbanization. Amadi *et al.*, (2010) examined the effect of urbanization on groundwater quality of Makurdi metropolis. Results of analyses show water samples collected within the vicinity of dumpsite have low pH, higher concentration of iron, manganese, calcium and total dissolved solids and total coliform when compared to those far away from the dumpsite suggesting leachate influence. In a related study, Tse and Adamu (2012) in the chemical and bacteriological analyses of hand dug wells in Makurdi town noted water to be slightly acidic, moderately hard, low total dissolved solids. Heavy metal such as iron, zinc, copper, lead and cadmium occur in traces, while high concentration of coliform is noted in all the wells. Most recent in the same study area, Ezeabasili *et al.*, (2014), reported the dangers of Arsenic pollution in boreholes sampled as a result of urbanization through refuse dumps, effluents from industries and sewage amongst other sources. Water and sanitation problems are a major concern globally. According to Balint, (1999) there are over one billion people worldwide without water sources and three billion lack minimally acceptable sanitation facilities. A lack of adequate water and sanitation services is particularly apparent in developing countries. The problem people experience with water supply and sanitation in developing countries are numerous and complex. There are various explanations to the causes of water and sanitation problems.

The main objective of this review is to assess water and sanitation problems internationally, continentally and nationally. To achieve this research main objective, the review provided some historical background regarding water supply and sanitation development throughout the world in order to understand the emergence of water and sanitation resources. The review critically examines the funds allocation for water and sanitation sector and human access to water and sanitation. The review assessed the underlying causes of water and sanitation problems which include: infrastructure failure, low water availability, poverty, low coverage for water supply and sanitation, population growth, privatization of water services and unplanned rural settlements.

Palamuleni, (2002) conducted research on the effect of sanitation facilities, domestic solid waste disposal and hygiene practices on water quality in Blantyre, Malawi. The study revealed that the major form of sewerage disposal is the on-site sanitation system where about 58.8% of the respondents use traditional pit latrine while indiscriminate solid waste disposal is rampant in the area. Water samples collected from the major sources of domestic water supply showed that there are variations in the levels of water pollution between the groundwater and surface water sources and between the wet and dry season. Groundwater turbidity levels were in the range of 2–12 mg/l during the dry season but increased to a maximum of 114 mg/l during the wet season while for surface water the turbidity increased from 4 to 408 mg/l over the seasons compared to the WHO standard set at 5 mg/l and the Water Department standard set at 25 mg/l. Chemical pollution for surface water sources show seasonal variations with an increase in the concentration during the wet season, for instance, iron levels ranged from 2.3 to 4.03 mg/l. This is above the WHO and Water Department drinking standards which are 1 and 3 mg/l, respectively. However, bacteriologically, both the groundwater and the surface water sources are grossly polluted. Groundwater spring coliform count ranged from 190/100 ml to 9500/100 ml, and the well 3500/100 ml to 11,000/100 ml having the maximum during the wet season. Surface water results also indicated the coliform count ranging from 2900/100 ml to 4600/100 ml way higher than the WHO, MBS standard for drinking water which is 0 and the Water Department standard for untreated water of which range from 10–50 coliforms/100 ml. The results indicate that water resources have been polluted by lack of sanitation facilities, indiscriminate disposal of waste and the institutional set-up governing the provision of services in the area.

Dzwairo *et al.*, (2006) conducted research on the assessment of the impacts of pit latrines on groundwater quality in rural areas, using a case study from Marondera district, Zimbabwe. This study assessed impacts of pit latrines on groundwater quality in the area. Groundwater samples from 14 monitoring boreholes and 3 shallow wells were analysed during 6 sampling campaigns. Parameters analysed were total and faecal coliforms, NH_4^+–N, NO_3^--N, conductivity, turbidity and pH, both for boreholes and shallow wells. Depth from the ground surface to the water table for the period of February 2005 to May 2005 was determined for all sampling points. The soil infiltration layer was taken as the layer between the pit latrine bottom and the water table. A questionnaire was also administered to study prevalence of diseases and structural failure of the latrines. Total and faecal coliforms both ranged 0-TNTC (too-numerous-to-count), 78% of results meeting the 0 CFU/100 ml WHO guidelines value. NH_4^+ –N range was 0–2.0 mg/l, with 99% of results falling below the 1.5 mg/l WHO recommended value. NO_3 –N range was 0.0–6.7 mg/l, within 10 mg/l WHO guidelines value. The range for conductivity values was 46–370 lS/cm while the pH range was 6.8–7.9. There are no WHO guideline values for these two parameters. Turbidity ranged from 1 NTU to 45 NTU, 59% of results meeting the 5 NTU WHO guidelines limit.

Results indicated that pit latrines were microbiologically impacting on groundwater quality up to 25 m lateral distance. Nitrogen values were of no immediate threat to health. Soil from the monitoring boreholes was classified as sandy. It averaged from 1.3 m to 1.7 m above the water table for two latrines and 2 – 3.2 m below it for one pit latrine. The drop-in water table averaged from 1.1m to 1.9m. The shallow water table increased pollution potential from pit latrines. The questionnaire survey revealed the prevalence of diarrhoea and structural failure of latrines. Raised and lined pit latrines and other low-cost technologies were recommended to minimize the potential of groundwater pollution.

Pit latrines are one of the most common forms of onsite sanitation facilities in many developing countries. These latrines are suitable as a means of isolating human waste, however, conditions within pits often lead to nitrification of the contained waste. In areas with a near-surface aquifer, the potential for nitrate pollution arising from pit latrines cannot be ignored. Templeton *et al.*, (2015) conducted a research on nitrate pollution of groundwater by pit latrines in developing countries. The research was conducted on three densely populated, peri-urban areas near three West African cities (Dakar, Abidjan, Abomey-Calavi) to gather relevant information about the latrines in use and the soil and groundwater underneath the sites. Modelling was then conducted to demonstrate the potential for nitrate pollution of the groundwater from the latrines in such settings. The depth from the bottom of the pits to the water table was considered as 5, 10 or 30 m, to represent the range of aquifer depths at the study sites. Nitrate half-lives ranging from 500 to 1500 days were considered, and time scales from 6 months to several years were modelled. The results highlighted the high likelihood of nitrate pollution of groundwater reaching levels exceeding the World Health Organization guideline value for nitrate in drinking water of 50 mg/L after as short a period as two years for the aquifer situated 5 m below the pits, when considering moderate to long nitrate half-lives in the subsurface. Careful siting of latrines away from high water table areas, more frequent pit emptying, or switching to urine diversion toilets may be effective solutions to reduce nitrate passage from pit latrines into groundwater, although these solutions may not always be applicable, because of social, technical and economic constraints. The study highlights the need for more reliable data on the typical nitrate concentrations in pit latrines and the nitrate half-life in different subsurface conditions.

In many peri-urban areas of most developing countries, potable piped water does not exist and where it does, it is rarely reliable. Thus, in such areas, residents heavily rely on groundwater sources for their daily survival. Therefore, it is common to find individual wells in each plot within such a peri-urban dwelling. Furthermore, in most cases, such dwellings lack municipal sewers, hence forcing residents to construct pit latrines at close proximity to their wells. Indeed, it is not uncommon to find a well located just a few metres from an un-lined pit latrine. A study was carried out by Kiptum and Ndambuki, (2012) on the well water contamination by pit latrines in Langas which is peri-urban settlement of Eldoret town, Kenya. The study sought to establish the quality of water in wells located near pit latrines on individual plots of the settlement. The results show that most wells were contaminated and posed a health risk to the dwellers of the settlement. From the results, it is recommended that a safe well-pit latrine separation distance of 48m be maintained which will avoid contamination of well water from pit latrines.

Ibemenuga and Avoaja, (2014) conducted a research on the assessment of groundwater quality in wells within Bombali district, Sierra Leone. This study assessed the quality of 60 groundwater wells within the area. Water samples from the wells were analysed for physical parameters (temperature, turbidity, conductivity, total dissolved solids and salinity), chemical (pH, nitrate-nitrogen, sulphate, calcium, ammonia, fluoride, aluminium, iron, copper and manganese) using potable water testing kit and bacteriological (faecal and non-faecal coliforms) qualities. Results show that 73% of the samples had turbidity values below the WHO, ICMR and United USPHS standards of 5 NTU. The electrical conductivity (mS/cm) of 5% of the whole samples exceeded the WHO guideline value, 8% of the entire samples had values higher than the WHO, ICMR and USPHS recommended concentration. In terms of iron, 25% of all the samples had values in excess of WHO, ICMR and USPHS recommended value of 0.3mg/l. For manganese, 12% of the entire samples had values more than the WHO and ICMR standards. On the other hand, more water samples (22%) had manganese values above USPHS guideline value. For bacteriological quality, 28% of the wells were polluted by faecal and non-faecal coliforms. 60% and 40% of the entire samples had faecal and non-faecal coliforms respectively above the WHO standard. Remedial measures recommended include regular monitoring of the physico-chemical and bacteriological quality of water yield from these wells as well as teaching of the communities' basic sanitation and hygiene practices.

Lutterodt *et al.*, (2018) studied the microbial groundwater quality status of hand-dug wells and boreholes in the Dodowa area of Ghana, West Africa. The aim of the study was to assess the suitability of groundwater for drinking purposes. The samples were taken from boreholes and hand-dug wells and were analysed for the presence of faecal indicator bacteria (Escherichia coli) and viruses (Adenovirus and Rotavirus), using membrane filtration with plating and glass wool filtration with quantitative polymerase chain reaction (PCR), respectively. In addition, sanitary inspection of surroundings of the sources was conducted to identify their vulnerability to pollution. The presence of viruses was also assessed in water samples from the Dodowa River. More than 70% of the hand-dug wells were sited within 10m of nearby sources of contamination. All sources contained E. coli bacteria, and their numbers in samples of water between dug wells and boreholes showed no significant difference ($p = 0.48$). Quantitative PCR results for Adenovirus indicated 27% and 55% were positive for the boreholes and hand-dug wells, respectively. Samples from all boreholes tested negative for the presence of Rotavirus while 27% of the dug wells were positive for Rotavirus. PCR tests of 20% of groundwater samples were inhibited. Based on these results we concluded that there is systemic microbial and faecal contamination of groundwater in the area. On-site sanitation facilities of pit latrines and unlined wastewater drains, are likely the most common sources of faecal contamination of groundwater in the area. Recommendation prescribed treatment of abstracted water from groundwater sources needs before use for consumption purposes. In addition, efforts should be made to delineate protected areas around groundwater abstraction points to minimize contamination from point sources of pollution.

The groundwater of forty wells in Agbowo community was assessed for Total Aerobic Bacteria Counts (TABC) and Total Coliform Counts (TCC) by Adetunji and Odetokun, (2011). The location and distances of wells from septic tanks were determined using the Global Positioning System (GPS) device and a tape rule respectively. All the wells sampled, had high TABC (4.76±1.41 log CFU/mL) and TCC (2.29±0.67 log CFU/mL) counts which exceeded the international standard of 0 per 100 mL of potable water. There were no significant differences in the bacterial counts between covered and uncovered wells ($p>0.05$). The mean distance (8.93±3.61m) of wells from the septic tanks was below the limit (15.24 m or 50 ft) set by United State Environmental Protection Agency (USEPA). TABC increased with a decrease in distance between the wells and septic tanks though not significant ($p<0.05$). A very weak positive correlation

(r^2 =0.021) ensued between the distance from septic tank and CC, while a weak negative correlation (r^2 = –0.261) was obtained between the TCC and TABC. The study accentuated the need to set standards for the siting of wells from septic tanks while considering all possible sources of well contamination as well as treatment of groundwater before use.

A study by Ahaneku and Adeoye, (2013) to determine the impact of pit latrines on groundwater quality in Foko slum, Southwestern Nigeria was conducted. Water quality of shallow wells was assessed within the slum with respect to their distance from five pit latrines. Water samples were collected from the shallow wells and analysed for determination of total and faecal coliforms (FC), alkalinity, total dissolved solids (TDS), total suspended solids (TSS), nitrates, electrical conductivity, turbidity and pH. The faecal coliform values were regressed with distance between the pit latrines and the wells. The resulting equation was evaluated to obtain a minimum lateral distance between a pit latrine and shallow well for zero value of microbiological parameters in the wells. Results showed that the physico-chemical parameters of the water samples were within the World Health Organization (WHO) guidelines for drinking water quality. Nevertheless, biological contaminants exceeded the recommendation of WHO drinking water quality guidelines. Maximum coliform counts enumerated were 9300cfu/100ml of water. This study shows that there is an indicator gradient in faecal bacteria with distance from pit latrines, and that pit latrines which impact on shallow well water at lateral distances of 19.75m.

The main objective of the study by Idris-Nda *et al.*, (2013) was to examine the challenges and risk of domestic wastewater management. The methodology adopted involved the use of questionnaire, field survey, government documents, Global Positioning System (GPS) and sampling of the wastewater for laboratory analysis. The result showed that the wastewater generated is mostly from bathing and laundry. The daily amount of wastewater generated is 36,493,920 litres (36,494 m^3). The physico-chemical composition of the domestic wastewater shows that pH has a range of 7.5 and 8.7, Temperature 29^oC and 30.1^oC, Salinity 1051mg/l and 1329mg/l, Chloride 240mg/l and 280mg/l, Sodium 152mg/l and 178.7mg/l, Potassium 84.35mg/l and 99.34mg/l, Calcium 24.01mg/l and 48.1mg/l, Magnesium 24.4mg/l and 39.04mg/l, sulphate 10mg/l and 19mg/l, Carbonate 370.5mg/l and 525mg/l and Bicarbonate 945.75mg/l and 1462.5mg/l. Environmental implications of domestic wastewater include medium growth for pathogens like mosquito parasite. The public are exposed to these pathogens via contaminated drinking water, water bodies or eating contaminated food. Common ailments that afflict the inhabitants include malaria, typhoid and cholera. Wastewater treatment and re-use was recommended as a complement for water use and also as a disaster risk reduction strategy. The wastewater can be reused for fire protection, irrigation/fish farming and for aquifer recharge.

Musa and Ahanonu, (2013) conducted a research to determine the biological, chemical and physical drinking water quality from shallow wells in agrarian communities. An *insitu* membrane filtration test kit was used to determine the microbiological quality of water and a photometer was used for the chemical analyses. Water samples were collected from protected shallow wells during wet and dry seasons of the year 2012 to determine the change in quality with different seasons. The results of the analysis show that Gapkan had the least value of pH of 6.7 while Lade had the highest value of 8.4. ANOVA ($P<0.05$) showed pH to be statistically higher during the wet season than in the dry season. The conductivity during the wet season was observed to range between 1210 μS/cm and 1678 μS/cm for Kpada and Gakpan communities respectively. Turbidity values during the wet season ranged between 4 and 7 NTU while dry season analysis ranged between 2 and 3 NTU. Sulphate concentration was the lowest at 431 mg/L in Fey and highest of 532 mg/L at Duro and Rifun Woro during the wet season. Chloride content within the wet season varied between 260 and 269 mg/L while that of the dry season varied between 124 and 130 mg/L. Highest and lowest concentrations of nitrate recorded during wet season was 0.42 and 0.23 mg/L for Kusogi and Fey respectively. The colour observed during the wet season ranged between 17 TCU and 19 TCU while that of the dry season ranged between 10 and 13 TCU. Current status of the water in the study areas are fit as source of drinking water for the community, though plans should be put in place for mini treatment plants that can serve these communities to enhance good drinking water delivery.

Bacteriological contamination of drinking water is responsible for the occurrence of waterborne diseases such as typhoid fever, dysentery, cholera, meningitis and diarrhoea. Little is known about the microbiology of well water in Nigeria as most analyses focuses on physical and chemical parameters. Faecal contamination of the wells comes from the presence of human and animal faeces. Groundwater has been recognized as playing a very important role in the development of our rural populace as most dwellers depend solely on water from hand dug wells and boreholes for their daily needs. With this in mind, Tukur and Amadi (2014) studied the bacteriological quality of groundwater from hand-dug wells were analysed in Zango Local Government Area of Katsina State with the aim of evaluating their suitability for domestic purposes. A total of 87 groundwater samples from the wells were collected for both dry and rainy season and analysed. The results indicate faecal contamination of the hand dug wells. The poor sanitary condition in the area and the closeness of some hand dug wells to pit-latrines, soakaways and dumpsites were identified as the factors responsible for the microbial contamination of the groundwater from the shallow aquifers. Boiling of water was recommended and subsequent hand dug wells should be cited far away from pit-toilet and soakaways to avoid contamination by leachates.

The study by Muhammed and Demirici (2015), pursued a recommendation to search for the sources of water pollution in the hand dug wells (HDW) from Hardo ward a high-density residential area in the ancient traditional city of Bauchi metropolis, Nigeria. Secondary data on pollution by coliform concentration in water from HDW in Hardo ward was used as the dependent variable (Y) while primary data was collected on four parameters as potential sources of water pollution: the depth of the well; type of well; setback distances between HDW and pit latrines, setback distances between HDW and unlined water drainage channels served as independent variables (IV) = X1, X2, X3 and X4 respectively. The data were subjected to both standard and hierarchical/sequential multiple regression analysis (MRA) using the SPSS 20.0 software to determine the significant sources of water pollution in the study area. The results were presented in coefficients tables and figures. The standard multiple regression showed a highly significant positive correlation at R2 = 0.758 (adjusted R2 0.693) implying that the level of pollution in the HWD is directly affected by the combined effect of the four independent variables. However, when each independent variable was controlled, in the hierarchical multiple regressions, the model indicated that only distance from pit latrine (X2) had a significant impact on water pollution by Coliform and with the highest correlation. The study recommended the use of community boreholes for water supply in the area and educating the residents on the need for proper treatment of water before drinking, as well as measures to achieve standards of construction and the setback standards of locations of HDWs from all the pollution sources in general.

Idris-Nda *et al.*, (2016a) carried out a study on the water quality of shallow unconfined sedimentary aquifers in Bida, Nigeria with the aim of assessing physicochemical and bacteriological contamination of groundwater as a result of poor design of water and sanitation facilities in Bida, Nigeria. The study was conducted using a grid-based approach on wells, boreholes, surface water and households. The water has a high Total Dissolved Solids. Slightly acidic pH and mean distance of wells to waste disposal facilities is 12 m. Chemical parameters that occur in high concentrations are sulphates, chlorides, nitrates and sodium and total coliform is very high. Contamination of deeper sources of water from the dug wells are both lateral and vertical with contamination plume spreading to better planned areas. Surface water has the least contamination and is proposed for water supply. They recommended that sanitation facilities should be upgraded from pit to ventilated improved pit latrines.

Idris – Nda *et al.*, (2016b) conducted research on the effects of pit latrines and poor design of sanitary facilities on groundwater quality using Minna and Bida, North-Central Nigeria as case studies. This was with the aim of assessing physicochemical and bacteriological contamination of groundwater as a result of poor design of water and sanitation facilities. The research employed a grid-based approach on wells and boreholes in households. The water has a high Total Dissolved Solids and Electrical Conductivity indicating high concentration of dissolved and suspended materials. The pH is slightly acidic to basic and the mean distance of wells to pit latrines, septic tanks and other waste disposal facilities is 12m. Chemical parameters that occur in high concentrations are sulphates, chlorides, nitrates and sodium. Nitrate and chloride are pollution indicators from sewage in groundwater. Total Coliform count, Faecal Coliforms and Faecal Streptococci are very high and far above the maximum permissible limit. Contamination of deeper sources of water from the dug wells is both lateral and vertical with contamination plume spreading to better planned areas. Sanitation facilities in unplanned areas should be upgraded from pit to Ventilated

Improved Pit latrines and with adequate provision of water to pour-flush and septic tank system. It was recommended that septic tanks and soakaways should be designed to protect groundwater from contamination.

2.4 Water resources

Water is one of the essentials that supports all forms of plant and animal life (Vanloon and Duffy, 2005) and it is generally obtained from two principal natural sources; Surface water such as freshwater lakes, rivers, streams and Ground water such as borehole water and well water (McMurray and Fay, 2004; Mendie, 2005). Water has unique chemical properties due to its polarity and hydrogen bonds which means it is able to dissolve, absorb, adsorb or suspend many different compounds (WHO, 2007), thus, in nature, water is not pure as it acquires contaminants from its surrounding and those arising from humans and animals as well as other biological activities (Mendie, 2005, Momodu and Anyakora, 2010).

2.4.1 Surface water resources

Surface waters include the lakes (as well as ponds), reservoirs, rivers and streams and wetlands our societies have depended upon and benefited from throughout history. Rivers are the most important freshwater resource for man (WHO, 2004). Municipal areas draw heavily on surface water for their drinking water supplies. Precipitation that does not evaporate or infiltrate into the ground runs as surface water, which may accumulate to form streams, and streams join to form rivers. Lakes are inland depressions that hold standing freshwater. Ponds are generally considered to be small temporary or permanent bodies of water shallow enough for rooted plants to grow over and at the bottom. While lakes contain nearly one hundred times as much water as all rivers and streams combined, they are still a major component of total world water supply (Carr *et al.,* 2012).

Because of the interconnectedness of groundwater and surface water, these contaminants may be shared between the two sources. Neither water source can ever be entirely free from water contaminants. Due to the hydrological cycle, the two sources of drinking water feed each other, sharing contaminants.

2.4.2 Groundwater resources

Groundwater is underground or subsurface water. Groundwater comes from surface water percolating through overlying soils and it resides in the pore spaces between particles of soil and other geologic materials. Formations that have all the pore spaces saturated with water are called saturated zones or aquifers. The top of the aquifer is called the water table. Aquifers typically consist of gravel, sand, sandstone, or fractured rock, like limestone. These materials are permeable because they have large connected spaces that allow water to flow through. The amount of ground water and the speed at which groundwater flows depends on the size of the spaces in the soil or rock and how well the spaces are connected (USGS, 2008).

Groundwater is located in an underground, saturated zone but can intercept surface water. Water wells extend into aquifers to allow water to be collected and pumped to the surface. Groundwater does not (generally) exist as underground rivers or pools – instead it is captured between particles above an impermeable layer that restricts water movement further downward. The quality of ground water is the resultant of all the processes and reactions that act on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring and varies from place to place and with the depth of the water table (Jain *et al.*,2006) With sufficient water infiltration, soil contaminants such as heavy metals can leach to underlying groundwater. Unconfined aquifers are especially vulnerable to various contaminants (Nouri *et al.,* 2006) and sediment loads (including microscopic bacteria, viruses and protozoa).

Groundwater is the primary source of drinking water for half of the world's population (IAEA, 2014). Worldwide, about 1.5 billion people depend upon groundwater for their drinking water supply (Foster and Chilton, 2003; WRI, 1996; UNDP, 2008; UNEP, 2008). The amount of groundwater withdrawn annually is roughly estimated at 600 – 700 km^3, representing about 20 % of global water withdrawals (WMO, 1997). Groundwater is a globally important and valuable renewable resource for human life and economic development (lal *et al.,* 2016). Groundwater is generally a very good source of drinking water because of the self-purifying properties of soil (Coe, 1970). Even where surface water is abundant, rivers and lakes may be contaminated with disease-causing organisms such as guinea worm or bilharzias. In such cases, groundwater may be an alternative (IAEA, 2014). The dominant role of groundwater resources is clear and their use and protection is, therefore, of fundamental importance to human life and economic activity (Chapman and Malone, 2002).

Groundwater is the most important source of water supply in arid and semi-arid regions due to its large volumes and its low vulnerability to pollution when compared to surface waters (USEPA, 1985). Water use in Africa is set to increase markedly over the next few decades as a result of population growth (Vörösmarty *et al.*, 2005).

Rijswljk (1981) estimated groundwater resources at 0–50m depth in Nigeria to be $6*10^6$ km^3 ($6*10^{18}$ m^3).However, from the eight great aquifers in Nigeria, the Ajali Sandstone aquifer with yields of 7–10 l/s, the Benin Formation (coastal plain sands) aquifer with yields of 6–9 l/s, the Upper aquifer with 2.5–30 l/s, the Middle aquifer with yields of 24–32 l/s, the Lower aquifer with yields of 10–35 l/s (of the Chad Formation), the Gwandu Formation aquifer with yields of 8–15 l/s, the Kerri-Kerri Sandstone aquifer with yields of 1.25–9.5 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 of 360 m, with a thickness range of 15–3,000 m at a depth range of 0–630 m b.g.l, with an average depth of 220m. Thus, additional ground water resources of 7.2 times Rijswljk's figure is estimated at a total of 50million trillion l/year). Hence, there is a very large groundwater potential in Nigeria, far greater than the surface water resources estimated to be 224trillion l/year by Hanidu (1990).

2.5 Water quality

The term 'water quality' is a widely used expression which has an extremely broad spectrum of meanings. Each individual has vested interest in water for his particular use, which may include commercial and industrial uses or recreational pursuits. Since the desired characteristics of water vary with its intended use, there is frequently unsatisfactory communication among the users of water where quality is concerned. Thus, in discussing a public water supply, a housewife may declare the water to be of good quality, while a brewer considers the water quality to be poor. All other water uses must be subordinated to man's need for a helpful fluid for his consumption.

Water for drinking and food preparation must be free from minerals and organic substances that can produce adverse physiological effects. To encourage man to drink this health-promoting liquid, the water must be aesthetically acceptable. For example, it should be free from apparent turbidity, colour and odour and any objectionable taste. Drinking water should also have a reasonable temperature. Such water is termed "potable," meaning that it could be consumed in any desired amount without concern for adverse health effects. Potable water is thus defined as water that is free from disease producing microorganisms and chemical substances detrimental to health (Tebutt, 1983). The provision of potable water to the rural and urban population is necessary to prevent health hazards. Before water can be described as potable, it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is palatable and safe for drinking (Tebutt, 1983).

2.5.1 Factors that affect water quality

A number of factors influence water chemistry. Gibbs, (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallisation control the chemistry of surface water. The influence of geology on chemical water quality is widely recognised (Gibbs, 1970; Jasper *et al.*, 2004; Muchuweti *et al.*, 2006). The influence of soils on water quality is very complex and can be credited to the processes controlling the exchange of chemicals between the soil and water (Shafer *et al.*, 1998). Apart from natural factors influencing water quality, human activities such as domestic and agricultural practices impact negatively on river water quality. It is therefore, important to carry out water quality assessments for sustainable management of water bodies.

The WHO (2004) reported that water quality problems intensified through the ages in response to the increased growth and concentration of populations and industrial centres. Polluted water is an important vehicle for the spread of diseases. In developing countries 1.8 million people, mostly children, die every year as a result of water-related diseases (WHO, 2004).

Nigeria's water resources have been under increasing threat of pollution in recent years due to rapid demographic changes, which have coincided with the establishment of human settlements lacking appropriate sanitary infrastructure. Many such settlements have developed with no proper water supply and sanitation services. People living in these areas, as well as downstream users, often utilise the contaminated surface water for drinking, recreation and irrigation, which creates a situation that poses a serious health risk to the people (Verma and Srivastava, 1990).

2.6 Water quality monitoring standards

2.6.1 Nigerian Standard for Drinking Water Quality

Nigerian Standard for Drinking Water Quality contains mandatory limits concerning constituents and contaminants of water that are known to be hazardous to health and give rise to complaints from consumers. The standard includes a set of procedures and good practices required to meet the mandatory limits.

In 2005, the National Council on Water Resources (NCWR) recognized the need to urgently establish acceptable Nigerian Standard for Drinking Water Quality because it was observed that the "Nigerian Industrial Standard for Potable Water" developed by Standards Organisation of Nigeria and the "National Guidelines and Standards for Water Quality in Nigeria" developed by Federal Ministry of Environment did not receive a wide acceptance by all stakeholders in the country. Since water quality issues are health related issues, the Federal Ministry of Health, collaborating with the Standards Organisation of Nigeria (the only body responsible for developing National

Standards in Nigeria) and working through a technical committee of key stakeholders developed this Standard.

It is in the principle of the NSDWQ to effectively protect public health against water related diseases through a preventive integrated management approach. These include:

a) The protection of drinking water from catchments and source to its use by consumers.

b) A collaborative multi-agency approach that involve all agencies with responsibilities in the management of water quality.

c) Water quality standard that is comprehensive, realistic and implementable within the resources of the implementing agencies.

d) The development of procedures and requirements that ensure good water quality management in order to meet the maximum allowable limits. These procedures also protect the environment

e) An independent surveillance agency with strong enforcement authority and functions decentralized to local government level.

f) An effective drinking water quality data management system to enable generation of data for the development of coherent public health-centred policies and practices.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Data types and sources

The data for this study was collected from both Primary and Secondary sources. Primary sources involve generation of data using direct data acquisition methods like questionnaires, fieldwork, and sampling. While secondary data obtained from both published and unpublished information and data from Government agencies were utilized and include relevant data from Niger Geographic and Information System (NGIS), Niger State Water Board and Hospital within the study area was explored in order to broaden the scope of the research work.

3.2 Data Collection Instruments

Both primary and secondary sources collection techniques were used in sourcing for relevant data for the research. In this view, the following data collection instrument was used.

3.2.1 Questionnaire

Closed ended questionnaire were formulated and used as a vital instrument for data collection. The questionnaire was standardized, so that every respondent answered exactly the same questions which made it a reliable data collection instrument. The questionnaire was divided into sections relating to population information in each household, water generation and usage, public health and potential reuse of wastewater. Possible answers were provided in which the respondent was required to choose the one that best suits them.

3.2.2 Research materials

The research materials used in this study is basically water, consisting of groundwater, surface water and wastewater from open drains and septic tanks.

Equipment and tools used for geological and hydrogeological mapping include the following;

3.2.3 Geologic mapping:

1. Topographic map of Minna Sheet 164 SW on a scale of 1:12,500
2. Compass/clinometer
3. Geological hammer
4. Global Positioning System (GPS)
5. Digital camera
6. Weighted tape (100m)
7. Handbook
8. Marker/pen
9. Coloured pencils

3.2.4 Hydrogeologic mapping:

1. Weighted Tape
2. Field notebook
3. Bucket
4. Stopwatch
5. Topographic map of Minna Sheet 164 SW on a scale of 1:12,500
6. Sample containers
7. Digital camera
8. Portable water testing kit

3.3 Preliminary studies

Preliminary studies involved literature reviews, compilation of maps, background studies, acquisition of materials needed for fieldwork and carrying out reconnaissance studies in the area.

3.4 Fieldwork

Field work was conducted after the reconnaissance studies, the exercise involved collection of information from the study area through conducting geological and hydrogeological studies, administration of questionnaires, conducting oral interviews of residents and collection of water samples for analysis.

3.4.1 Geological mapping

Geological mapping was conducted using a topographical map of the area derived from the original map of Minna Sheet 164 in order to map various lithologies in the area with the use of GPS device in locating different lithologies, lithologic boundaries and outcrop locations. The traverse method of mapping was adopted for this phase of the research. Surface fracture orientations were mapped in order to determine the principal joint directions.

Plate I: Taking water inventory

Plate II: Taking of well inventory in Kpakungu area

3.4.2. Hydrogeological mapping

Sampling of wells, boreholes and households in the area was conducted using the grid-based approach. The area was divided into 250 m x 250 m grids and samples were taken within each alternative grid. Wells, boreholes and sanitary facilities within each grid were carefully recorded and questionnaires administered to respondents within the grid. Coordinates of locations were established using a hand-held Global Positioning System (GPS Garmin 72s). Depth and water levels of wells and boreholes were determined using a water level dip meter. Some of the installed boreholes were lifted slightly to access the depth and water level.

30 water samples were taken in glass and plastic bottles across the area and taken to the laboratory for analysis using standard analytical methods (Atomic Absorption Spectrometry, Titrimetric and Flame Photometry). Physical parameters of pH, Electrical Conductivity, Temperature, Total Dissolved Solids, Dissolve Oxygen, Chemical Oxygen Demand and Biochemical Oxygen Demand were taken at the point of

sampling. Microbial analysis was conducted using the American Public Health Association (APHA, 2005) standards for the examination of water and wastewater. All other analyses were in conformity with this standard.

Questionnaires, oral interviews and visual inspection were used to determine water and sanitation facilities in 250 households, presence and nature of drainage systems, erosional features and household data.

3.4.3 Laboratory Analysis

Laboratory analysis involved the analysis of water samples for chemical and bacteriological composition using standard methods of analysis; Atomic Absorption Spectrometry (AAS), Colourimetry, Flame Photometry and Titrimetry for the chemical constituents and membrane filtration for the bacteriological composition.

Physical parameters like Temperature, pH, Electrical Conductivity and Total Dissolved Solids were taken at the point of sampling.

3.4.4 Measurement of Physical parameters

Physical parameters of groundwater consisting of Temperature, pH, Electrical Conductivity (EC), Colour, Turbidity and Dissolved Oxygen (DO) were determined using potable field meters, Plate IV.

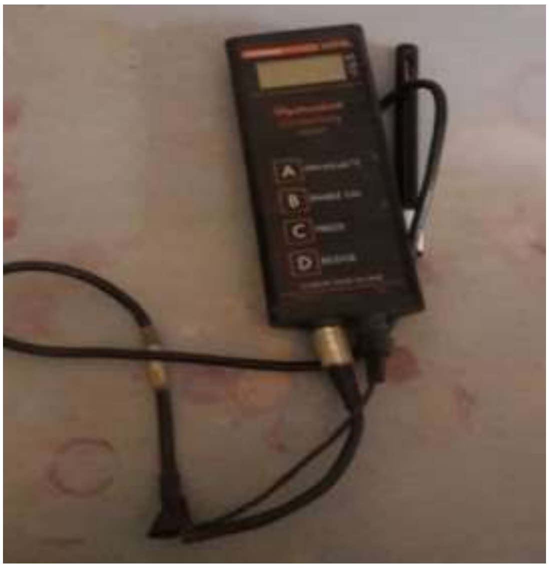

Plate IV: HACH Conductivity Meter **Plate V: Jwell DO Meter**

Plate VI: HACH BOD/COD Meter

3.5 Laboratory analysis

3.5.1 Water analysis

Evaluation of groundwater in the area was examined at the Upper River Basin Development Authority under the Ministry of Water Resources Minna, Niger State. Set of standard procedure describing the sampling manual, United Nations Environmental

Protection/World Health Organization (UNEP, 2008) was used to collect samples for the hydrochemical analysis delivered to the lab. Sodium (Na^{2+}), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (k^{+}) were examined with Titrimetry method of analysis.

Titrimetry

Chemical analysis was carried out quantitatively using Titrimetry method of analysis, measuring the substance amount in the volume occupied.

Hardness (Ethylene diamine tetra acetic acid (EDTA) Titrimetric method)

Reagents

0.780$MgSO_4.7H_2O$ and disodium salt of 1.179 EDTA using distilled water of about 50ml were cracked down for buffer solution blended together with 16.9g NH_4Cl and 143ml concentration NH_4OH, distilled water was diluted to 250ml while blending the solution together and it was stored using plastic stopper or safe glass compartment.

Hydrochloride was blended, using 0.5g of dye and 4.5g of hydroxylamine and broken up in a 100ml of 95% ethyl.

Standard EDTA Titrant, 0.01m, 3.723g EDTA disodium salt ($Na_2H_2Cl0OgN_2.2H_2O$) was dissolved in distilled water which was diluted to 1L (the blend was out away in a Pyrex bottle.

Procedure

A cup of 100ml Erlenmeyer was used to measure 125ml specimen, buffer of 2ml was added (giving a pH of 10.0 – 10.1). A drop or 2 of Eriochrome black t pointer was added and titrated gradually, blending constantly until the last reddish tinge disappears in the solution and a change of colour to sky blue. 1ml of 0.01m EDTA equals to 1mg $CaCO_3$

Computation: complete Hardness as $CaCO_3$

$$\text{Mg } CaCO_3/L = \frac{(X-Y)\times Z\times \beta\times 1000}{mlsample} yg$$

Where X = estimation of titrant (ml) utilized for the specimen

Y = estimation of titrant (ml) utilized for the blank. The value (ml) of the titrant utilized for the blank is typically dependably from 0 to 0.2ml)

Z = equivalent of a mg of $CaCO_3$ to 1.00 ml EDTA solution utilized

B = molarity of EDTA molar × mass of CaCO3

1000 = conversion element into litter

Calcium and Magnesium hardness (versenate EDTA Titration method)

Procedure

a. In a 125ml Erlenmeyer flask, 50ml sample was measured.
b. 1ml of sodium hydroxide and 1ml of iso-propyl alcohol is added. At that point 0.1 to 0.2g of murexide indicator is added and titrated against EDTA until pink colour changes to purple.

Calculation

mg Calcium hardness as $CaCO_3$/L= A x B x 1000

ml of sample

Calcium ion as mg Ca^{2+}/L = A x B x 400.8

ml of sample

Where: A = the titre value (ml) of the EDTA for sample after subtracting blank titre

B = mg $CaCO_3$ equivalent to 1 ml EDTA titrant at the calcium end point.

For 0.01M EDTA solution, B = 1 mg $CaCO_3$ for 1 ml of EDTA

Magnesium hardness (mg $CaCO_3$/l) = total hardness – calcium hardness

Calculate magnesium as mg^{2+}

mg mg^{2+}/l = magnesium hardness as mg $CaCO_3$/l X 0.244

Plate VII: Apparatus setup for Calcium and Magnesium at the national water quality laboratory, Minna 2017

Procedure

c. In a 125ml Erlenmeyer flask, 50ml sample was measured.

d. 1ml of sodium hydroxide and 1ml of iso-propyl alcohol is added. At that point 0.1 to 0.2g of murexide indicator is added and titrated against EDTA until pink colour changes to purple.

Calculation

$$\text{mg Calcium hardness as } CaCO_3/L = \frac{A \times B \times 1000}{\text{ml of sample}}$$

Calcium ion as mg Ca^{2+}/L = $\frac{A \times B \times 400.8}{\text{ml of sample}}$

Where: A = the titre value (ml) of the EDTA for sample after subtracting blank titre

B = mg $CaCO_3$ equivalent to 1 ml EDTA titrant at the calcium end point.

For 0.01M EDTA solution, B = 1 mg $CaCO_3$ for 1 ml of EDTA

Magnesium hardness (mg $CaCO_3$/l) = total hardness – calcium hardness

Calculate magnesium as mg^{2+}

mg mg^{2+}/l = magnesium hardness as mg $CaCO_3$/l X 0.244

Carbonate and Bicarbonate (Total Alkalinity)

Apparatus: Erlenmeyer flask of 250ml with a narrow mouth, Burette of 50ml, weighing Balance, Volumetric flask, Conical flask.

Procedure

In a 250ml beaker, a 100ml of specimen was placed and utilizing 0.02N H_2SO4 which was titrated. Addition of bromocresol green of about 2-3 drops pointer which was titrated until a change in colour from green to yellow indicating the finish line of titration.

Plate VIII: Apparatus setup for Alkalinity at the national water quality laboratory, Minna 2017

Calculation

Phenolphthalein alkalinity (mg/l as $CaCO_3$) = $\frac{\boldsymbol{A}\times\boldsymbol{N}\times\mathbf{50,000}}{\boldsymbol{Sample}\ (\boldsymbol{ml})}$

Where: A = ml 0.02N H_2SO4 used for methyl-orange end point

N = normality of H_2SO4, 0.02N

Total alkalinity (mg/l as $CaCO_3$) = $\frac{\boldsymbol{A}\times\boldsymbol{N}\times\mathbf{50,000}}{\boldsymbol{Sample}\ (\boldsymbol{ml})}$

Table 3.4: Total alkalinity

	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Concentration as $CaCO_3$
P = 0	0	0	T
P < $^1/_2$ T	0	2P	T – 2P
P = $^1/_2$T	0	2P	0
P > ½T	2P – T	2 (T-P)	0
P = T	T	0	0

Chloride

Method: Argentometric

Apparatus: Erlenmeyer flask of 250ml with a narrow mouth, conical flask, 50ml Burette, Volumetric flask, Weighing Balance

Reagents: Hydrogen peroxide (30%), Phenolphthalein indicator solution**,** Potassium Chromate Indicator Solution, Silver Nitrate (0.025N), Standard solution, Sodium Chloride (0.025N), Sodium Hydroxide Solution (10g/L) and Sulphuric acid (1 + 19)

Plate IX: Apparatus setup for chloride at the national water quality laboratory, Minna, 2017

Procedure

In a conical flask, 50ml of distilled water is measured to which about 1.0ml of potassium chromate indicator solution is added and mixed and titrated to standard $AgNO_3$ solution from a burette of 50 ml until the brick-red (or pink) colour persists throughout the sample**.**

CALCULATION: Chloride ion concentration in sample, mg/L is as follows:

$$\text{Chloride, mg/l} = \frac{(V1 - V2) \times N \times 35{,}450}{S}$$

Where: V_1 = Standard solution $AgNO_3$ added in titrating sample, ml

V_2 = Standard solution, $AgNO_3$ added in titrating blank ml

N = normality of standard $AgNO_3$ solution

S = original sample volume in the 50-ml test specimen prepared, ml

Colorimetry Method

Using the colorimetry technique of analysis, the following chemical analysis was conducted;

Plate X: Digital Colorimeter HACH DR/890 (National Water Quality Laboratory, Minna, 2017)

Phosphate

Reagents utilized

Sulphuric acid, H_2SO_4.5N; 70ml of concentrated H_2SO_4 was diluted with distilled water of 400ml in a volumetric flask of 500ml while breaking 1.3715g K (SbO) $C_4H_4O_6$.1/2H_2O of potassium antimonyl titrate solution. The solution was kept away in a glass stopper bottle.

Ammonium molybdate solution: distilled water of 500ml was used to dissolve 20g of (NH4)6 MO_7O_{24} $4H_2O$ and stored in a glass stopper bottle

Ascorbic acid, 0.1m: 1.76g ascorbic acid was dissolved in 100ml of diluted water. The solution close to 7days was stacked under temperature of $4^{O}C$**.**

Mixed reagent: mixture of the above reagents was in the following proportions for every 100ml of the mixed reagent: 50ml 5N H_2SO_4, 15ml ammonium molybdate solution, 5ml potassium antimonyl titrate solution and 30ml ascorbic acid solution, after addition of each reagent, the solution was blended. Before blending all reagents were allowed to achieve room temperature which was stabilized for 4 hours. Stock phosphate solution was dissolved using distilled water then 219.5mg anhydrous KH_2PO_4 was added and diluted to 1000ml, 1.00ml = 50.0ugPO_4^{3-} - P

Procedure

Phenolphthale solution was dropped in a50ml of pipette. 5N $H_2SO_4$was then added drop by drop on observation of red coloration to clear it. Mixed reagent of 8ml was added and thoroughly blended, (it was carefully noted not to exceed 30minutes)

Specimen absorbance was measured at 880nm, using reagent blank wavelength of 710nm as reference solution

Cell = 1cm cuvette

Computation

Mg (PO_4^{3}- - P)/1 = $\frac{mg(PO43--P)[inapproximately58mlfinalvolume]\times 1000}{1mlofsample}$

Iron (Fe)

Reagents

Concentrated HCL, containing less than 0.00005% iron

Hydroxylamine hydrochloride solution: 10g $NH_2OH.HCL$ which was broken up to 100ml water.

Ammonium acetate buffer solution: 150ml water added to dissolve 125g $NH_4C_2H_2O$ and an addition of 700ml concentrated (glacial) acetic acid

Phenanthroline solution: 100ml was added to dissolve 100mg 1, 10 phenanthroline monohydrate $C_{12}H_8N_2O$, it was heated to 80oc while stirring (caution was taken as to avoid boiling point) for 100µgFe

Stock iron solutions: concentrated H2SO4 of 20ml was gradually and gently added to broken down 1404g Fe $(NH_4)_2(SO_4)_2.6H_2O)$ and 50ml distilled water, 0.1 mol of 1.1 potassium permanganate ($KMnO_4$) was added drop by drop to the solution and a light pink coloration was achieved. Which was diluted to 1liter of distilled water mixed such that 100ml equivalent to 200µgFe.

Standard iron solution: pipette was used to add 50.00ml into 1L volumetric flask and diluted with distilled water to the point marked 1ml = 10.0µgFe. 5.00ml of stock solution was pipette into 1L volumetric flask and diluted with distilled water to the point mark 1ml = n1.00µgFe

Procedure

In a 125ml flask place 50ml.0ml and mix the sample thoroughly. A sample content greater than 200µm (grain size) iron (Fe), smaller unit correctly measured and an inclusion of 1ml hydroxylamine hydrochloride solution and 2ml of concentrated to a 10-20ml. cooled at room temperature (25^{o}C) later exchanged to a 100ml volumetric flask.

10ml of ammonium acetate buffer was added and 2ml of phenanthroline solution was done and diluted to a stage with distilled water. The solution was mixed thoroughly and set aside for 10-15minutes for full colour development. Colour absorbance power was measured photometrically at 510nm.This represented as:

Net Absorbance = Absorbance – Blank Absorbance.

Calculation:

Concentration of Fe = $\frac{\mu gFemg1-1}{mlsample}$

Nitrate (NO^{-}_{3}) (Colorimetric Method)

Reagents

Buffer-colour Reagent: free distilled water of Nitrite and Nitrate was utilized in the preparation of the reagent. Distilled water of up to 250ml was introduced to 0.5g N-(1-

naphty1)-ethylene diamine dihydrochloride, 5.0g sulphanilamide and 105ml of concentrated HCL.

The solution was blended until broken and 136g of sodium acetate ($CH_3COONa.3H_2O$) was added and blended again until broken.

500ml was diluted using distilled water. The solution is usually stable for several weeks if placed in the dark only.

Procedure

2ml of buffer-colour reagent was included to individual standard and specimen, Stirred and colour left to develop for minimum of 15minutes. Measurement of the absorbance of the standard and specimen were read off around 540nm.

Sodium (Na) and Potassium (K) (Flame Photometry Method)

Flame photometry is a procedure of analysing chemicals which uses atomic emission to detect metal salts routinely; Ca, Na, Ba, K and Li.

Plate XI: Apparatus setup for Flame photometry at the national water quality laboratory, Minna, 2019.

Procedure

Procedure for analysis includes;

a. The source of fuel was kept on while the switch of air compressor was off.

b. As the flame photometer was on, the power switch was gloomy and the LED power was light up to start ignition cycle.

c. The filter chooser was kept at its position using the required setting.

d. Inside a beaker containing a100ml diluents was placed the nebulizer inlet tube which was left for 15minutes to stabilize temperature operations. It is carried out to keep constant temperature of the burner against subsequent time.

e. In warming procedure, set calibration solution was put in place for proper range estimation range security. In achieving peak period, Sherwood recommends scientifically maximum concentration standard allowed should be 10mg/l upward for potassium and 30mg/l for sodium.

f. The blank solution was controlled such that the reading was 0.0.

g. Given 20 second spacing, adjustment of fine and coarse control was done to allow easy and accurate reading.
h. Interval was given at 10seconds while setting the standard solution before aspiration of diluents blank solution for 20 seconds, it controls the blank solution in a manner the reading becomes 0.0.
i. Step f, g and h was conducted on waiting for the blank reading to be 0.0
   Proper check of calibration standards and reading for blank was done
j. Under examination, unknown solution was diluted using diluents to produce component concentration which is in standard calibration is bounded
k. For 20 seconds was an unknown dilution suctioned and values recorded. Elements concentrated in an anonymous specimen were computed applying the specimen values on the calibration curve multiplied by the dilution factor.

3.6 Data interpretation tools

Microsoft Office (Word, PowerPoint and Excel), ArcGIS for map production, GW Chart for Piper plots and other hydrochemical calculations.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Geology

The area is underlain by rocks belonging to the Basement Complex of Nigeria.

Figure 4.1 is the geological map of parts of Minna Sheet 164 that covered the studied areas. The main rock types are granite and schist, the granite is medium grained while the schist belongs to the Birnin Gwari Formation.

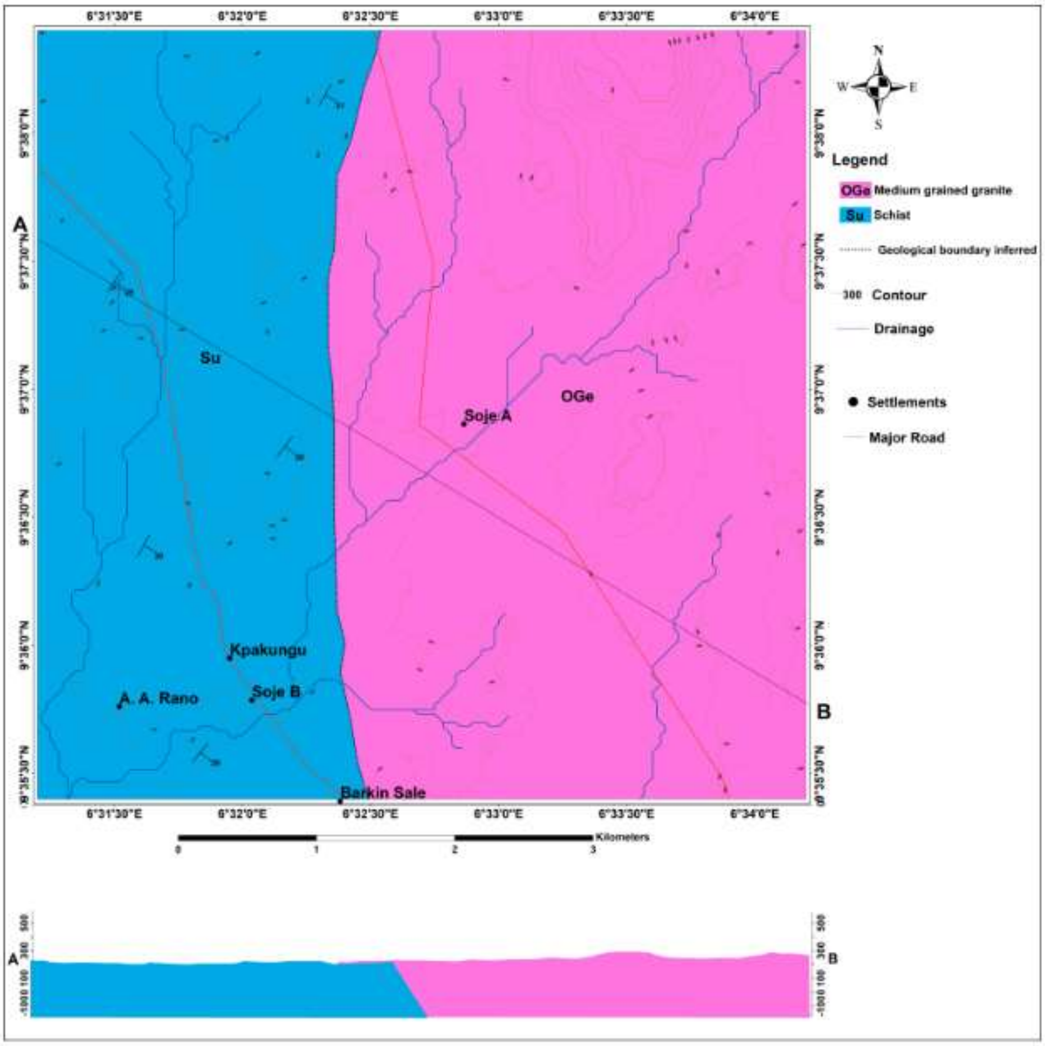

Figure 4.1: Geological map and cross section of parts of Minna Sheet 164 covering Kpakungu, Soje and Barikin Sale.

Schist is the predominant rock type and covers about 60% of the area. The rock has a weathering profile of between 15m to 20m.

The next dominant rock type is Granite, it covers about 40% of the area. The rock is highly weathered in some places with a weathering profile ranging from 10 to 15m.

4.2 Hydrogeology

Groundwater occurrence in the area is basically controlled by weathering profile of the rocks in terms of its intensity and thickness, and also on fracturing in the rocks.

Potability of the water is based on the quantity, quality and timing of availability.

Groundwater development is through the use of hand dug wells which tap water from the weathered portion of the rocks, they are dug to a depth of between 3m to 15m.

Drilled wells are to a depth of between 40m to 60m, some few boreholes though, were drilled to depths of 130m to 160m.

Some of the wells are well constructed while some others are not.

4.3 Questionnaires

4.3.1 The size of household

The Table 4.1 shows the responses on the size of households in the study area. The study shows that more people live in a two-bedroom apartment in the study area.

Table 4.1: Size of households in the study area

Options	Frequency	Percentage

Single Room	137	39
Two bedrooms	151	43
Three bedrooms	46	13
Four bedrooms	5	5
TOTAL	**350**	**100**

4.3.2 The size of Family

The Figure 4.2 below shows the responses on the size of the respondents' family. The study reveals that about 50% of the family sizes are between four to six.

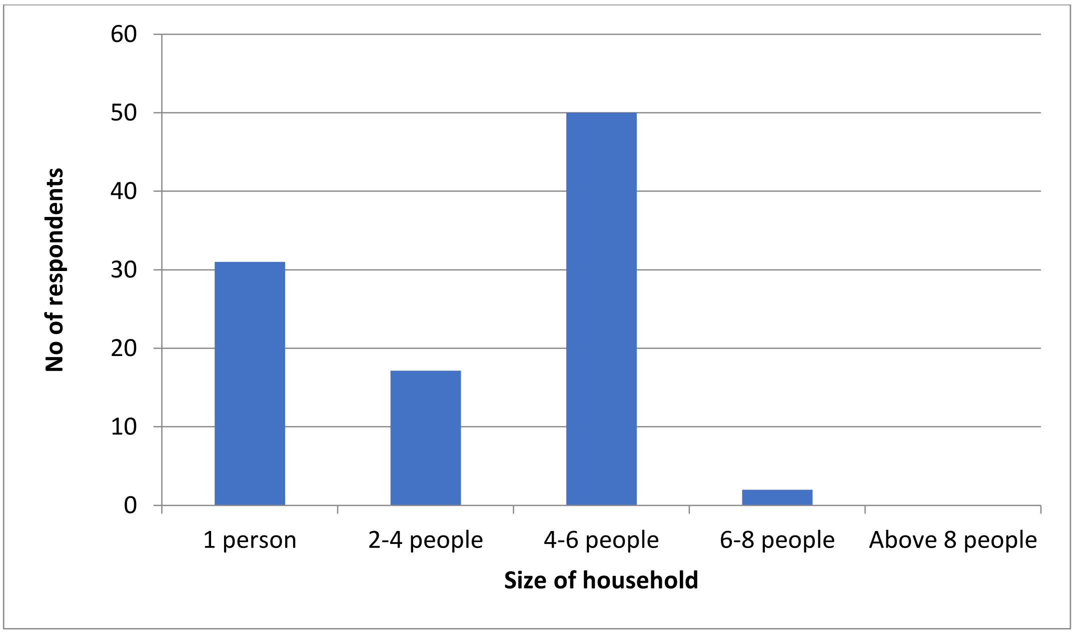

Figure 4.2: The size of family

4.3.4 Marital status per households

Table 4.2 presented below shows the response on the composition of their household. The study reveals that those married with children are far more in the study area.

Table 4.2: Marital Status per households

Options	Frequency	Percentage

Single	86	24.5
One parent family	12	3.5
Married with kids	252	71
TOTAL	**350**	**100**

4.3.5 The number of children

Figure 4.3 below shows the responses on the number of children they have in their household. The study reveals that those with more than four children have the highest percentage of 58% followed by those with between two to three children.

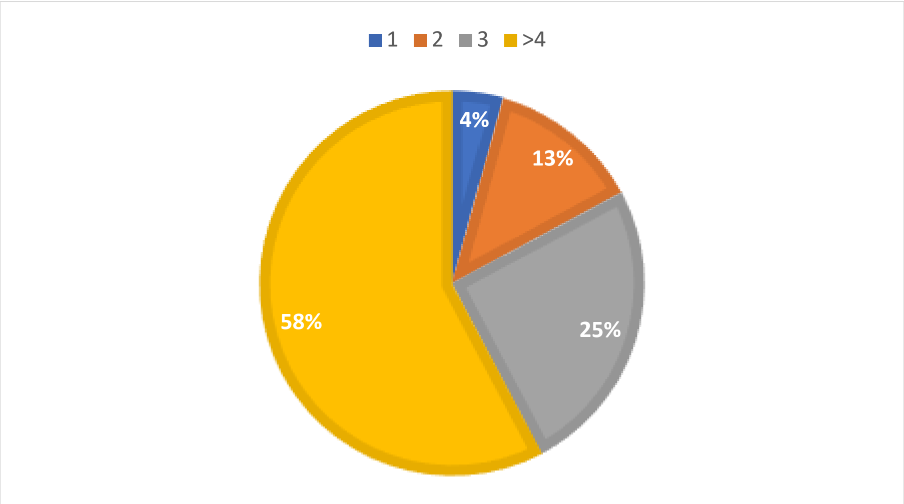

Figure 4.3: Number of children per household.

4.3.6 Water source for domestic use

Table 4.3 below shows the responses on the water source for use for domestic purpose. The study shows that water vendors (meiruwa) are the major source of water supply in the study area followed by hand dug wells, boreholes and pipe borne water. However, respondents say they depend more on hand dug wells and rain water during the rainy season for their water supply.

Table 4.3: Water source for domestic use

Options	Frequency	Percentage
Borehole	55	16
Waterboard/Tap water	36	10
Well water	92	26
Water vendor (*meiruwa*)	167	48
TOTAL	**350**	**100**

4.3.7 The daily water requirement per day

Figure 4.4 as represented below shows the responses on the daily water requirement per day. The study reveals that more respondents require 50-200 litres per day.

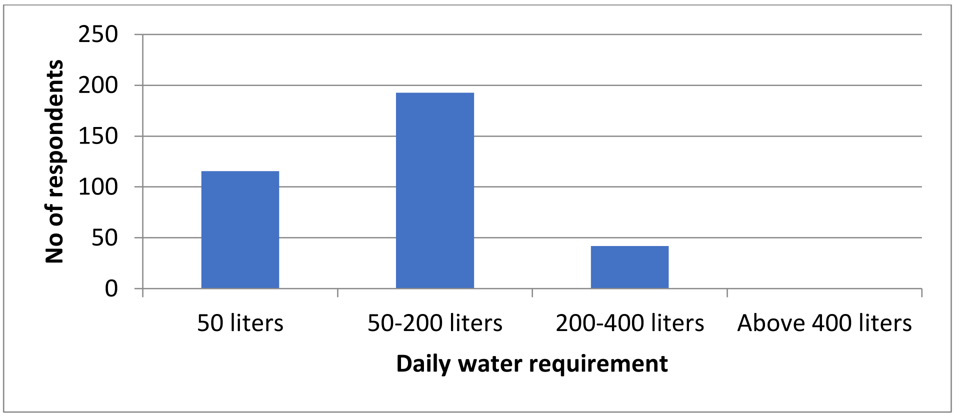

Figure 4.4: Daily water requirement per day.

4.3.8 Domestic use of water

The Table 4.4 below shows the responses on what they use water mostly for. The study reveals that more respondents use water for bathing and laundry which drains into open drains as wastewater.

Table 4.4: Domestic uses of household water

Options	Frequency	Percentage
Cooking	14	4
Washing dishes	35	10
Laundry	130	37
Bathing	172	49
TOTAL	**350**	**100**

4.3.9 Discharge of domestic wastewater

The Table 4.6 shows responses on how they discharge the wastewater they produce after use. The study reveals that more people discharge their wastewater in the common/public drainage.

Table 4.5: Discharge of domestic wastewater

Option	Frequency	Percentage
Domestic wastewater discharge into public drain	179	51
Domestic wastewater discharge into soak away pit	123	35
Domestic wastewater discharge on the surface	49	14
TOTAL	**350**	**100**

Wastewater consisting of water from kitchens, bathrooms, dishwashing and other sources run into unplanned drains and often pond in some locations causing smells, unpleasant sights and eventual infiltration into the groundwater.

4.3.10 Health problems in the household

Figure 4.5 depicts the responses on the health problem related in their household. The study revealed that malaria is the most common health problem followed by typhoid, these are commonly associated with poor sanitation and hygiene.

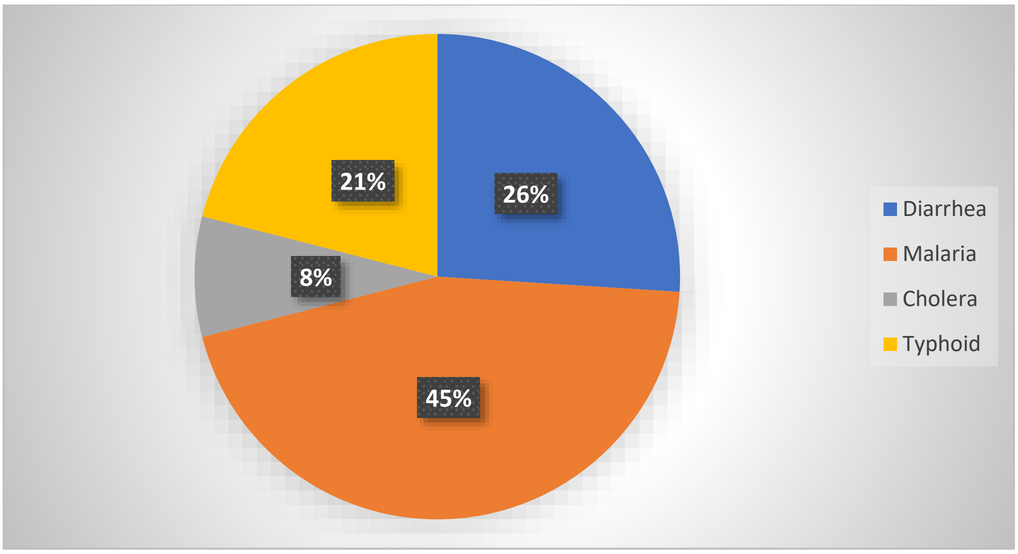

Figure 4.5: Health problems in households.

4.3.11 The state of water drainage infrastructure

Figure 4.6 represents the views of the respondents as to the state of water drainage infrastructure in the area. The result shows that respondents agree that state of wastewater drainage infrastructure is poor and does not protect the environment.

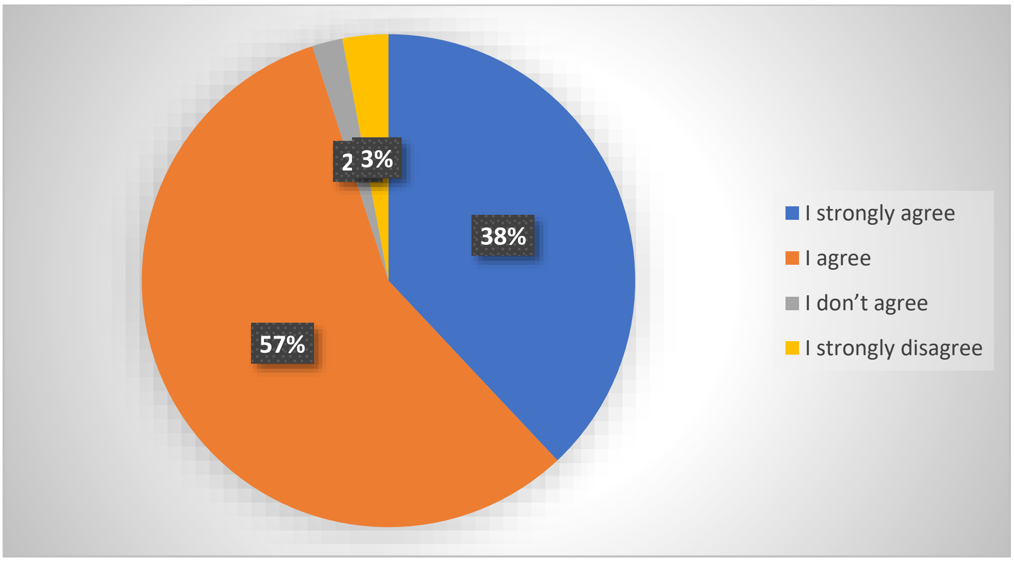

Figure 4.6: The views on water drainage infrastructure.

4.3.12 Type of sanitation facilities

Figure 4.7 shows the response on the type of sanitation facilities in the study. Results show that soakaway is the commonest system of toilet facilities, these consists of cemented holes in the ground with perforations that allow sewage to move into the environment. Casual observations show that they are mostly not properly designed to protect groundwater from contamination.

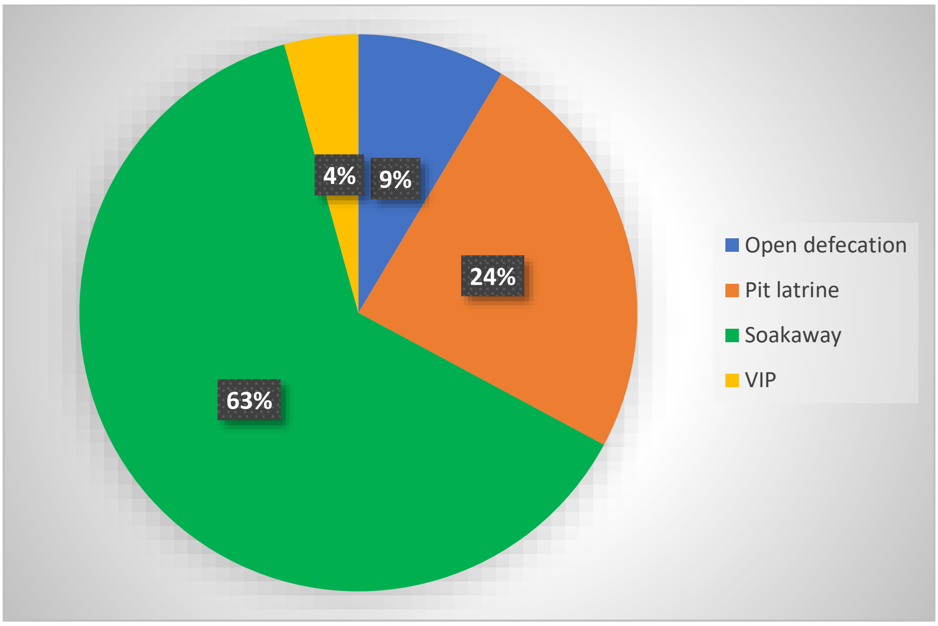

Figure 4.7: Type of toilet facilities in the study area.

Figure 4.8 shows the proximity of toilet facilities including pit latrines. Results show that the distance between toilet facilities and groundwater sources is between 5 – 10m. This distance is considered inadequate to protect groundwater from coming in contact with contaminants in the toilet system.

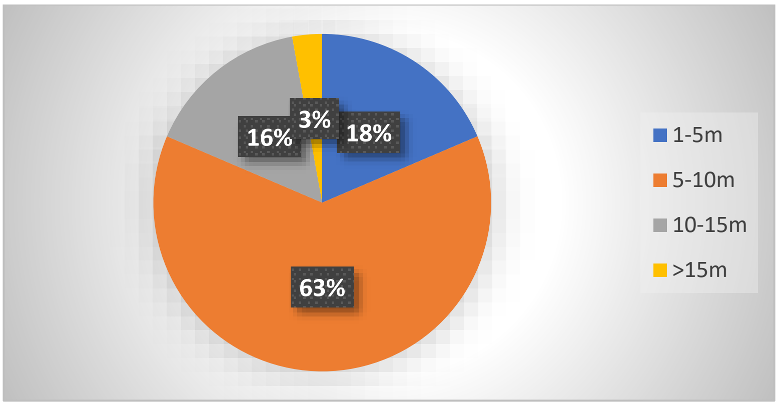

Figure 4.8: Proximity of toilet facilities to wells in the study area

Sanitation facilities in the area are of two types; Pit latrines and Water Closets with septic tanks.

The pit latrines are found in most houses with many occupants. They are commonly unlined and are dug to the same depth as the hand dug wells, mostly to the basement rock.

Septic tanks are constructed in some households, mostly they consist of two chambers, the waste pit and the soak away that is transmits the effluents directly into the environment.

Effluents from both the pit latrines and septic tanks eventually find their way into both surface and groundwater system.

4.3.13 Waste disposal method

Figure 4.9 shows the results of respondents on the type of waste disposal systems in the area. The results show that open dumps are the commonest refuse disposal system, followed by dumping of refuse in open drains with a few using drums supplied by the state sanitation agency and dumping in designated collection centres.

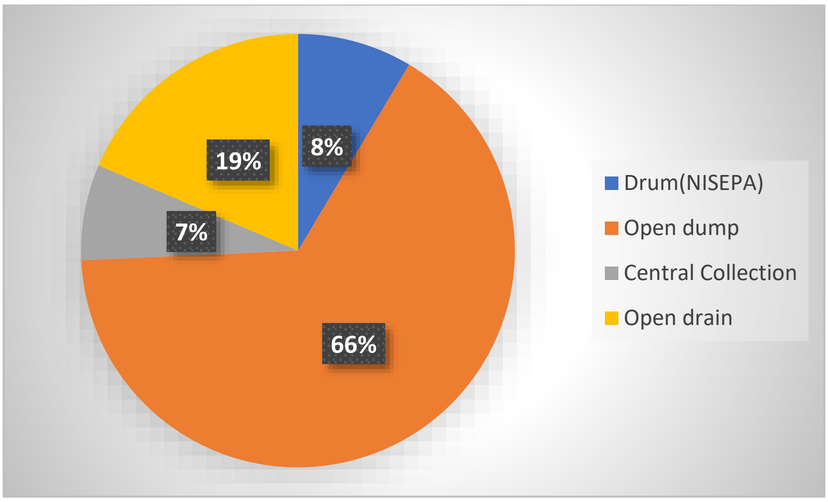

Figure 4.9: Types of waste disposal method in the study area

Solid waste is commonly disposed in open dumps, drainages, uncompleted buildings, water courses and other areas which bring them directly in contact with water sources including groundwater.

The waste consists of polythene bags, food products, garbage, clothing, batteries etc. The leachate generated by this waste eventually finds its way into groundwater and surface water.

4.4 Water Quality

The quality of both surface water, groundwater and wastewater were analysed based on three criteria;

I. Physical composition

II. Chemical composition

III. Bacteriological composition

I. Physical Composition

Table 4.6: Physical properties of all sampled water sources in the study area

Parameters	Wastewater	Borehole	Wells	Stream
pH	8.44	6.4	6.22	6.8
Temp (^{o}C)	29.66	29.1	29.6	27.9
TDS (mg/l)	1267.71	450	980	300
Cond (µS/cm)	1899.47	400	787	220
DO (mg/l)	0.764	1.78	3.94	0.55
BOD5 (mg/l)	684.44	0	0	325
COD (mg/l)	2391.98	0	0	985
Total hardness (mg/l)	230.24	162	219.4	157.85
Turbidity (NTU)	ND	1.22	2.56	ND
Total alkalinity (mg/l)	1703.69	516	1008	985
Nitrite (mg/l)	0.2896	0.101	0.215	0.098
Nitrite as Nitrogen (mg/l)	0.04625	0.031	0.0256	0.022
Salinity (mg/l)	1277.2	350	778	355

Table 4.6 shows the mean values for the physical parameters in various water media analysed consisting of wastewater form open drains and sewage, borehole, hand dug wells and stream. Figure 4.10 is the comparison of the physical parameters of these sources, it shows that physical composition of Wastewater has the highest mean values with Chemical Oxygen Demand (COD) being the highest (2391mg/l) occurring in only wastewater and surface water. All measured parameters are higher in wastewater followed by well water and borehole and least in the stream.

The physical composition of wastewater is higher than other sources, this is closely followed by the wells and stream with that of the borehole being the least (Figure 4.10). The likely indication here is that the physical characteristics of groundwater in the area is influenced to some extent by that of wastewater and stream, this is manifested in the hand dug wells and eventually deeper sources like the boreholes.

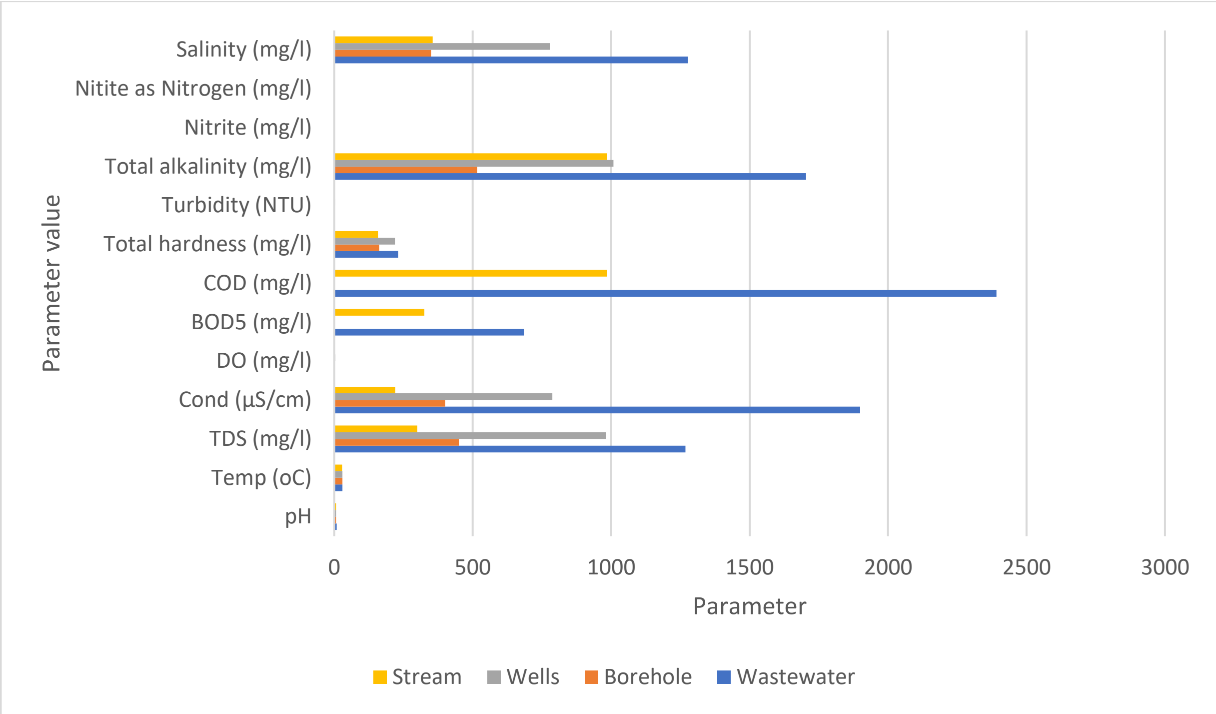

Figure 4.10: Comparison of physical parameters in wastewater, borehole, well and stream

II. Chemical Composition

Table 4.7 is the results of all analysed chemical constituents of groundwater and stream in the studied area while Table 4.8 is the results of chemical composition of wastewater including sewage from a septic tank and other sources as leachate, sewage, borehole and stream.

Table 4.7: Results of chemical parameters of water sources in the study area

S/No	Sample ID	**Ca**	**Mg**	**Na**	**K**	**SO_4**	**Cl**	**F**	**HCO_3**	**NO_3**	**PO_4**	**Fe**	**Mn**	**Cu**	**Cr**	**Zn**
1	KPG 1	24.01	24.4	72.03	12.35	10	98	0.42	24	30	1.2	0.33	0.13	0.1	0.12	0.62
2	KPG 2	40.01	39.04	94.73	27.34	11	118	0.27	25	25	1	0.47	0.14	0.12	0.09	0.1
3	KPG 3	24.05	48.8	98.68	23.53	11	128	0.16	20	22	1.22	0.73	0.15	0.11	0.23	0.52
4	KPG 4	32.06	24.8	93.74	14.22	19	98	0.08	18	38	1.23	0.64	0.14	0.09	0.07	0.09
5	KPG 5	48.1	39.04	96.7	27.34	18	88	0.18	22	34	1.8	0.68	0.15	0.12	0.09	0.12
6	KPG 6	34	35	91	21	14	106	0.52	15	28	1.3	0.75	0.12	0.14	0.12	0.1
7	KPG 7	63.5	4.39	32	8	23	42	0.11	25	25	1.45	0.55	0.14	0.1	0.1	0.13
8	SOJ 1	21.01	21.4	51	14	17	56.2	0.42	24	35	1.2	0.33	0.13	0.1	0.12	0.21
9	SOJ 2	37.01	36.04	25	10	22	28.4	0.27	25	38.3	1	0.47	0.14	0.12	0.09	0.1
10	SOJ 3	21.05	45.8	71	9	32	100	0.16	20	32.5	0.98	0.73	0.15	0.11	0.57	0.33
11	SOJ 4	29.06	21.8	27	14	31	28.3	0.08	18	33.6	0.97	0.64	0.14	0.09	0.07	0.09
12	SOJ 5	45.1	36.04	53	29	25	53.5	0.84	63	25.9	1.21	0.55	0.14	0.13	0.58	0.23
13	SOJ 6	31	32	94	65	55	13	0.55	32	30.15	1.14	0.31	0.13	0.9	0.94	0.15
14	SOJ 7	60.5	1.39	48	20	26	21.4	0.32	28	25.8	1.12	0.32	0.15	0.08	0.085	0.12
15	BKS1	29.61	30	47.63	16.95	15.6	84.6	0.51	30	32	1.3	0.42	0.15	0.09	0.13	0.63
16	BKS2	45.61	44.64	70.33	31.94	16.6	105	0.32	35	38	1.15	0.38	1.6	0.11	0.10	0.11
17	BKS3	29.65	54.4	74.28	28.13	16.6	115	0.75	58	29	1.28	0.52	0.18	0.13	0.59	0.95
18	BKS4	37.66	30.4	69.34	18.82	24.6	84.6	0.48	41	30	1.18	0.35	0.17	0.09	0.95	1.11
19	BKS5	53.7	44.64	72.3	31.94	23.6	74.6	0.66	28	38	1.7	0.23	0.19	0.1	1.21	2.11
20	BKS6	39.6	40.6	66.6	25.6	19.6	92.6	0.35	21	27	1.62	0.25	0.15	0.1	0.53	0.11
21	BKS7	69.1	9.99	56.4	28.5	28.6	78.5	0.64	52	22	1.2	0.18	0.14	0.08	0.61	1.89

Table 4.8: Results of chemical parameters of wastewater, sewage and other sources in the study area

Constituent (mg/l)	WW1	WW2	Leachate	WW3	Sewage	Borehole	Stream
Calcium	18.21	33	45.7	28.9	65.5	63.5	21.86
Magnesium	18.6	35	55.8	23.3	50.85	4.39	22.25
Sodium	146.23	115	225.6	167.8	245.5	8	69.88
Potassium	78.55	89	101.35	75.5	115.6	0.97	10.2
Sulphate	4.2	9	22	15	32	23	7.85
Chloride	244.2	221	311	234	455	64.5	95.85
Fluoride	0.35	0.58	0.55	0.63	1.05	0.065	0.095
Carbonate	364.7	385	436.5	415.8	420.5	0	0
Bicarbonate	939.95	1246	1375.8	1298	1522.4	171	30
Nitrate	45	50	48	55	85	25	11
Phosphate	4.32	5.75	8.95	5.85	5.56	0.75	25
Iron	0.08	0.05	0.67	0.23	0.45	0	0.22
Manganese	0.18	0.12	0.17	0.14	0.25	0.02	0.08
Copper	2.4	3.2	1.56	1.76	1.22	0	0
Chromium	0.85	0.95	1.35	1.78	1.95	0.085	0.05
Zinc	0.45	0.58	1.15	1.23	0.98	0.02	0.03

The dominant cations in groundwater are sodium (66.89mg/l), calcium (38.83mg/l) and potassium (31.65mg/l) while the dominant anions are chloride (76.81mg/l), nitrate (30.44mg/l) and bicarbonate (29.71mg/l). Minor and trace elements that occur in higher concentration are zinc (0.47mg/l), iron (0.47mg/l), fluoride (0.39mg/l) and chromium (0.35mg/l).

Figure 4.11 is the results of the chemical composition of wastewater consisting of water from open drains, leachate from open dump site and sewage. Comparison of the sources of wastewater in the area show that the dominant cations are sodium (188.48mg/l), potassium (95.36mg/l) and calcium (43.28mg/l) and magnesium (41.24mg/l) which occur in almost equal proportion. Anions that occur in higher concentrations are bicarbonate (13650.55mg/l), carbonate (414.45mg/l) and chloride (305.25mg/l).

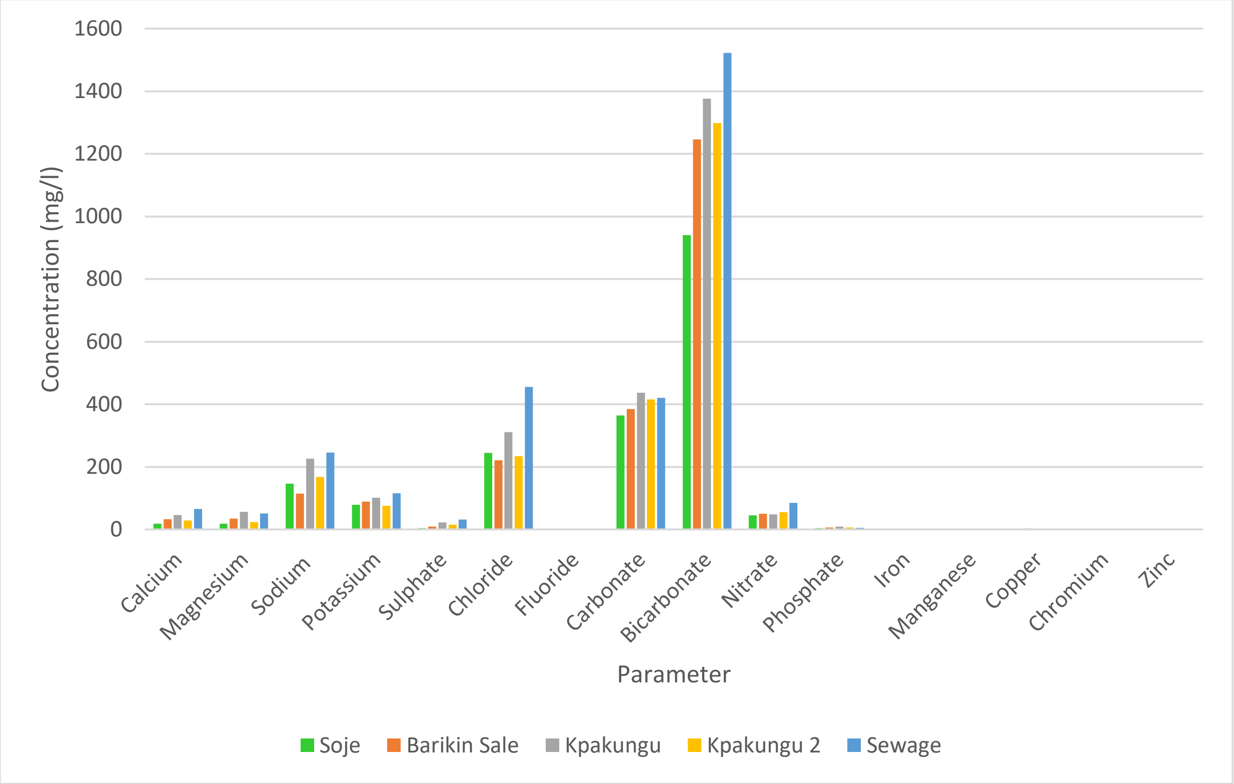

Figure 4.11: Chemical concentration of wastewater across the study area

Figure 4.14 is the result of the minor and trace elements in wastewater across the study are. Minor and trace elements that occur in higher concentration in wastewater across the area are copper (1.94mg/l), chromium (0.83mg/l), zinc (0.47mg/l) and fluoride (0.43mg/l).

Comparison of the results from the various sources show that sewage generally has the highest concentration of major, minor and trace constituents as against the other sources. Kpakungu has the highest concentration of all analysed parameters except for copper which was found to be higher at Barikin Sale which closely follows Kpakungu, Soje generally has the least.

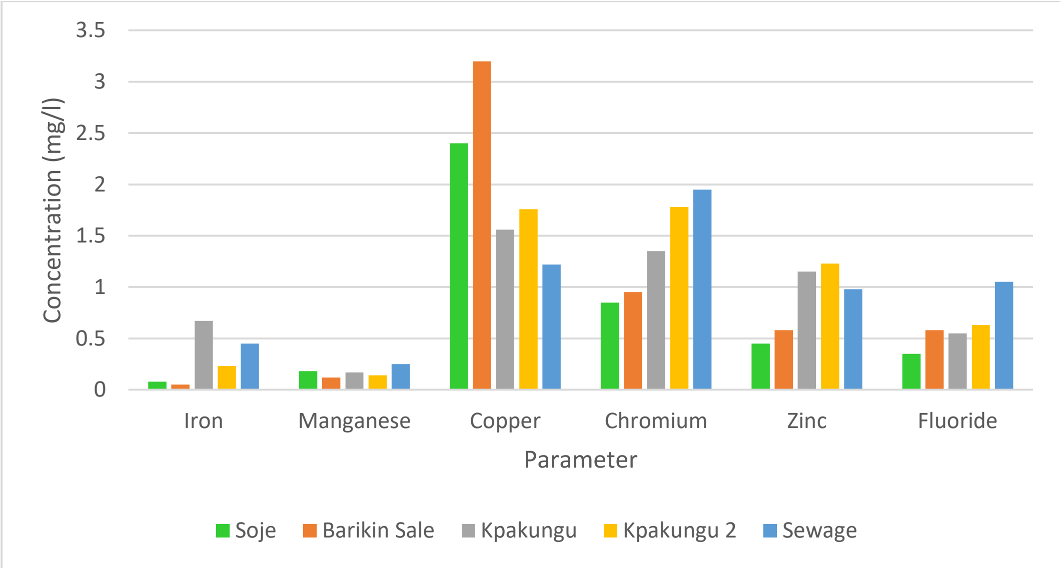

Figure 4.12: Chemical concentration of minor and Trace Elements wastewater across the study area.

Figures 4.13 and 4.14 are the concentration of major, minor and trace constituents in groundwater in Kpakungu, Soje and Barikin Sale areas.

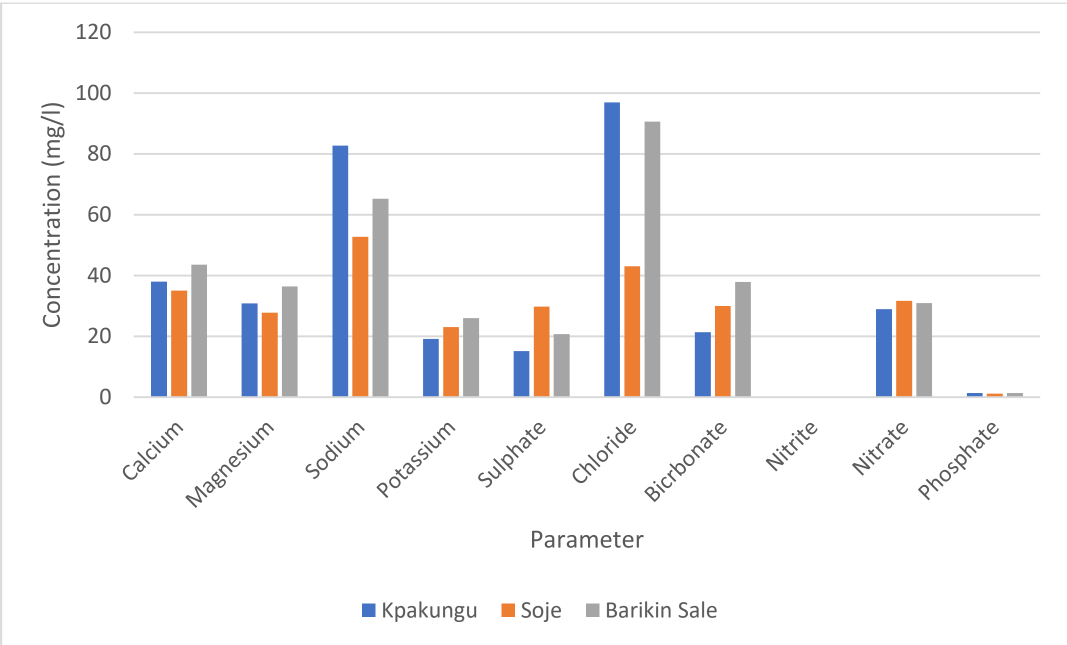

Figure 4.13: Comparison of concentration of analysed major constituents in groundwater in the study area.

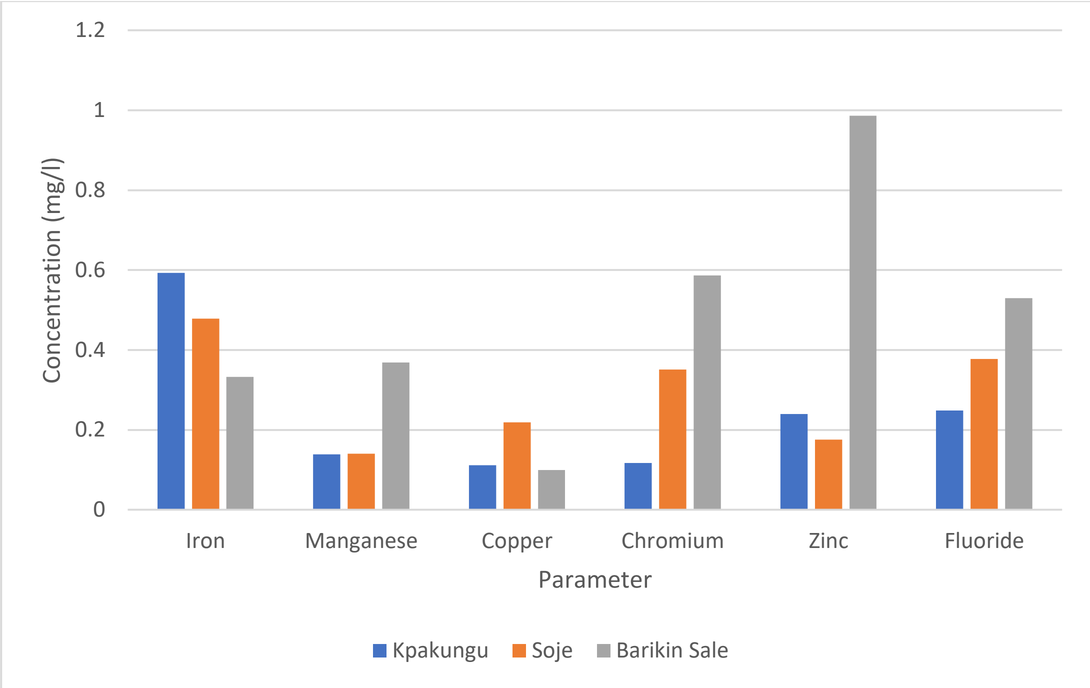

Figure 4.14: Comparison of concentration of minor and trace constituents in the groundwater of the study area.

Cations that occur in higher concentration and their range are sodium (25 – 98mg/l), calcium (21 – 69mg/l) and magnesium (1.4 – 54mg/l), while the anions are chloride (13 – 128mg/l), nitrate (22 – 38mgl/), bicarbonate (15 – 63mg/l) and sulphate (10 – 55mg/l). Minor and trace constituents that occur in higher concentration are iron (0.18 – 0.75mg/l), zinc (0.09 – 2.11mg/l) and fluoride (0.08 – 0.84mg/l), others are copper (0.07 – 1.21mg/l) and manganese (0.12 – 1.6mg/l).

These constituents are however not evenly distributed in groundwater across the three areas that make up the study. They are found to occur in higher concentration in Barkin Sale area than in other areas.

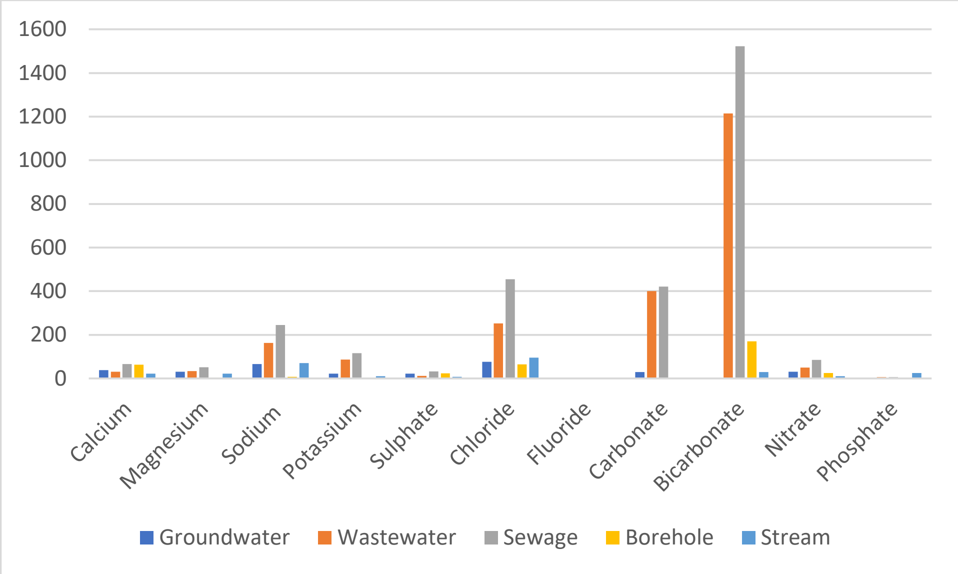

Figure 4.15: Comparison of major chemical constituents in water sources in the study area.

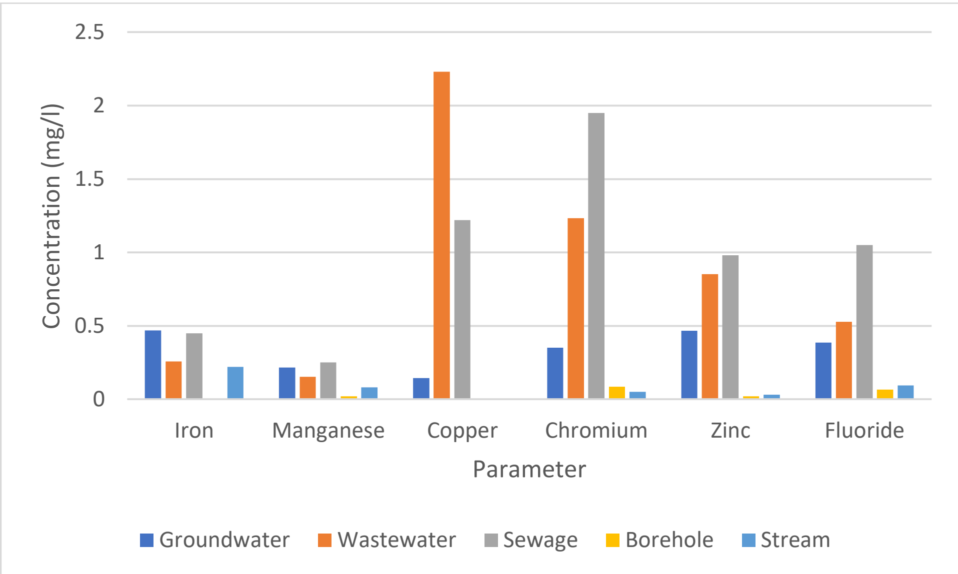

Figure 4.16: Comparison of minor and trace chemical constituents in water sources in the study area.

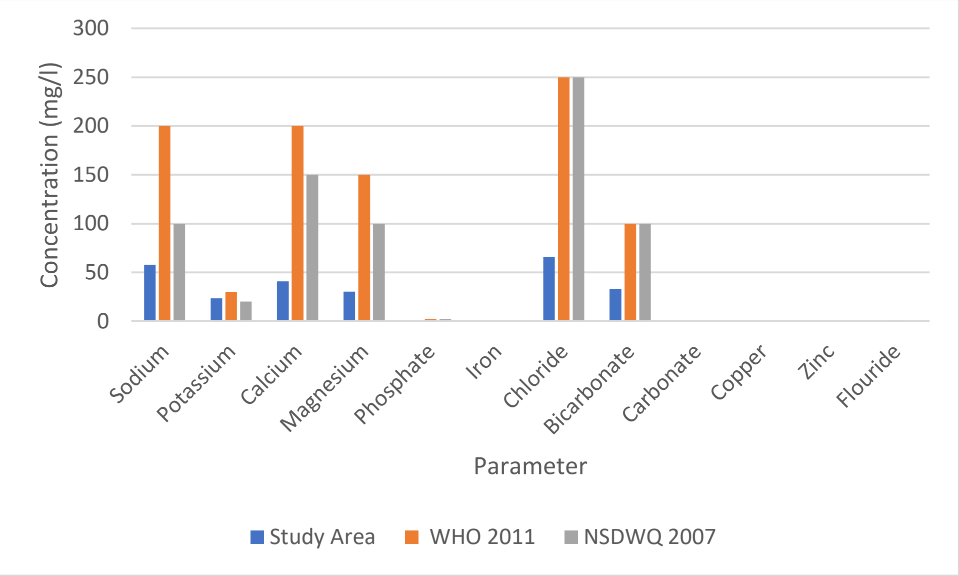

Figure 4.17: Comparison of chemical composition of groundwater with national and international standards.

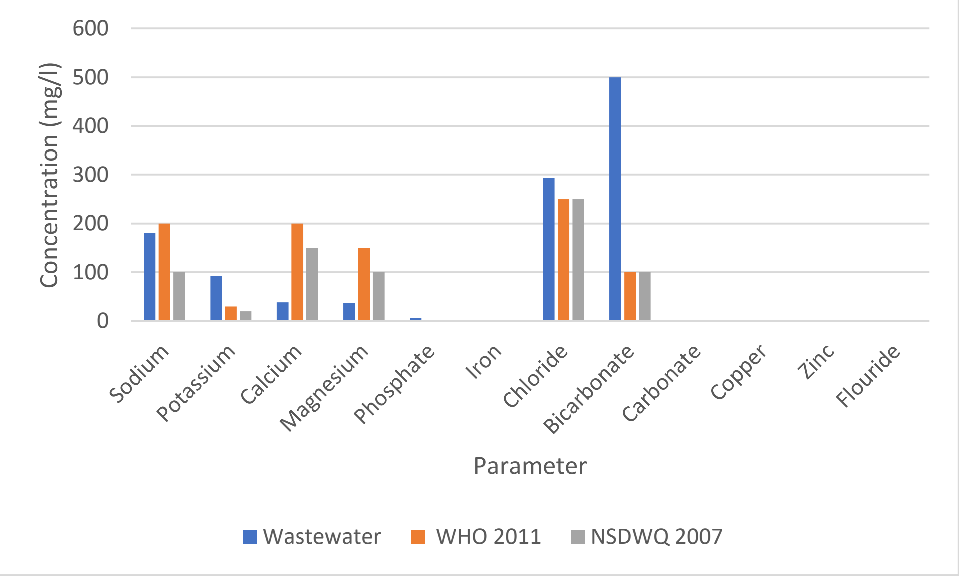

Figure 4.18: Comparison of chemical composition of wastewater with national and international standards.

4.5 Statistical Summary and Correlations Analysis

The statistical summary of chemical composition of groundwater in the study area is presented in Table 4.9.

Table 4.9: Statistical summary of chemical composition of groundwater in the study area

	Calcium	Magnesium	Sodium	Potassium	Sulphate	Chloride	Fluoride	Bicarbonate	Nitrite	Nitrate	Phosphate	Iron	Manganese	Copper	Chromium	Zinc
Mean	38.83	31.65	66.89	22.70	21.87	76.81	0.39	29.71	0.03	30.44	1.25	0.47	0.22	0.14	0.35	0.47
Standard Error	3.03	3.09	5.05	2.70	2.16	7.45	0.05	2.89	0.00	1.14	0.05	0.04	0.07	0.04	0.08	0.13
Median	37.01	35.00	70.33	21.00	19.60	84.60	0.35	25.00	0.03	30.00	1.20	0.47	0.14	0.10	0.12	0.15
Mode	#N/A	39.04	#N/A	27.34	11.00	98.00	0.42	25.00	0.03	38.00	1.20	0.33	0.14	0.10	0.12	0.10
Standard Deviation	13.89	14.18	23.13	12.39	9.88	34.16	0.22	13.26	0.01	5.23	0.23	0.18	0.32	0.17	0.35	0.59
Sample Variance	193.02	201.12	535.16	153.44	97.68	1166.61	0.05	175.91	0.00	27.37	0.05	0.03	0.10	0.03	0.12	0.35
Kurtosis	-0.21	0.00	-0.85	6.13	5.56	-0.88	-0.72	1.39	-0.28	-1.05	0.99	-1.21	20.87	20.56	0.23	3.06
Skewness	0.75	-0.68	-0.30	1.95	1.90	-0.53	0.38	1.47	0.57	0.07	1.15	0.16	4.56	4.51	1.15	1.93
Range	48.09	53.01	73.68	57.00	45.00	115.00	0.76	48.00	0.03	16.30	0.83	0.57	1.48	0.82	1.14	2.02
Minimum	21.01	1.39	25.00	8.00	10.00	13.00	0.08	15.00	0.02	22.00	0.97	0.18	0.12	0.08	0.07	0.09
Maximum	69.10	54.40	98.68	65.00	55.00	128.00	0.84	63.00	0.04	38.30	1.80	0.75	1.60	0.90	1.21	2.11
Sum	815.39	664.61	1404.76	476.66	459.20	1613.00	8.09	624.00	0.54	639.25	26.25	9.83	4.53	3.01	7.38	9.81

Table 4.10: Statistical summary of chemical composition of wastewater in the study area

	Calcium	Magnesium	Sodium	Potassium	Sulphate	Chloride	Carbonate	Bicarbonate	Phosphate	Iron	Copper	Chromium	Zinc
Mean	43.28	41.24	188.48	95.36	19.50	305.25	414.45	1360.55	6.53	0.35	1.94	0.83	0.47
Standard Error	8.23	7.44	29.52	8.57	4.94	53.72	10.77	60.18	0.81	0.13	0.44	0.46	0.26
Median	39.35	42.93	196.70	95.18	18.50	272.50	418.15	1336.90	5.80	0.34	1.66	0.66	0.44
Standard Deviation	16.45	14.89	59.04	17.13	9.88	107.44	21.54	120.36	1.62	0.27	0.87	0.93	0.52
Sample Variance	270.68	221.71	3485.38	293.47	97.67	11544.25	463.98	14487.40	2.62	0.07	0.76	0.86	0.27
Kurtosis	0.05	-2.75	-2.03	-0.87	-0.56	0.98	1.83	0.38	3.89	-1.44	2.87	-3.23	-5.70
Skewness	1.04	-0.41	-0.55	0.05	0.50	1.29	-0.97	0.95	1.97	0.17	1.61	0.49	0.05
Range	36.60	32.50	130.50	40.10	23.00	234.00	51.50	276.40	3.39	0.62	1.98	1.90	0.96
Minimum	28.90	23.30	115.00	75.50	9.00	221.00	385.00	1246.00	5.56	0.05	1.22	0.05	0.02
Maximum	65.50	55.80	245.50	115.60	32.00	455.00	436.50	1522.40	8.95	0.67	3.20	1.95	0.98
Sum	173.10	164.95	753.90	381.45	78.00	1221.00	1657.80	5442.20	26.11	1.40	7.74	3.32	1.88
Confidence Level(95.0%)	26.18	23.69	93.94	27.26	15.73	170.97	34.28	191.53	2.58	0.43	1.39	1.48	0.82

Table 4.11: Correlation Matrix of groundwater in the study area

	Calcium	***Magnesium***	***Sodium***	***Potassium***	***Sulphate***	***Chloride***	***Fluoride***	***Bicrbonate***	***Nitrite***	***Nitrate***	***Phosphate***	***Iron***	***Manganese***	***Copper***	***Chromium***	***Zinc***
Calcium	1															
Magnesium	-0.47771	1														
Sodium	-0.23889	0.49814	1													
Potassium	0.12628	0.26716	0.47418	1												
Sulphate	0.12202	-0.20247	-0.13011	**0.52915**	1											
Chloride	-0.27422	**0.58272**	**0.62902**	-0.12156	-0.67529	1										
Fluoride	0.14273	0.18040	0.02308	0.46143	0.11604	-0.00602	1									
Bicrbonate	0.30912	0.07221	-0.13814	0.33106	0.15723	-0.03769	**0.76635**	1								
Nitrite	-0.14501	-0.04541	0.12199	-0.20391	-0.30127	0.29802	-0.14995	-0.13814	1							
Nitrate	-0.27560	0.23767	-0.10068	-0.11496	0.03876	-0.13053	-0.17827	-0.27715	0.17290	1						
Phosphate	0.34484	0.13465	0.23817	0.14997	-0.19106	0.16789	0.13832	-0.05830	0.13480	0.05402	1					
Iron	-0.37664	0.28313	0.22793	-0.32853	-0.20050	0.27698	-0.45846	-0.32972	0.21506	0.01115	-0.11719	1				
Manganese	0.12060	0.23036	0.03596	0.17437	-0.12469	0.19725	-0.05325	0.10818	0.06588	0.33883	-0.08225	-0.12394	1			
Copper	-0.15404	0.06554	0.29809	**0.79216**	**0.74121**	-0.39613	0.18911	0.05013	-0.22219	-0.01454	-0.10722	-0.15262	-0.05602	1		
Chromium	0.12211	0.29019	0.17577	**0.52787**	**0.51823**	-0.06075	**0.59265**	0.44471	-0.40651	-0.03431	0.22386	-0.42007	-0.13480	0.37269	1	
Zinc	0.31881	0.05847	0.01736	0.13880	0.03031	0.17569	**0.53740**	0.42432	0.06101	-0.07153	0.26256	-0.48165	-0.10696	-0.15369	**0.66589**	1

4.6 Hydrochemical Facies

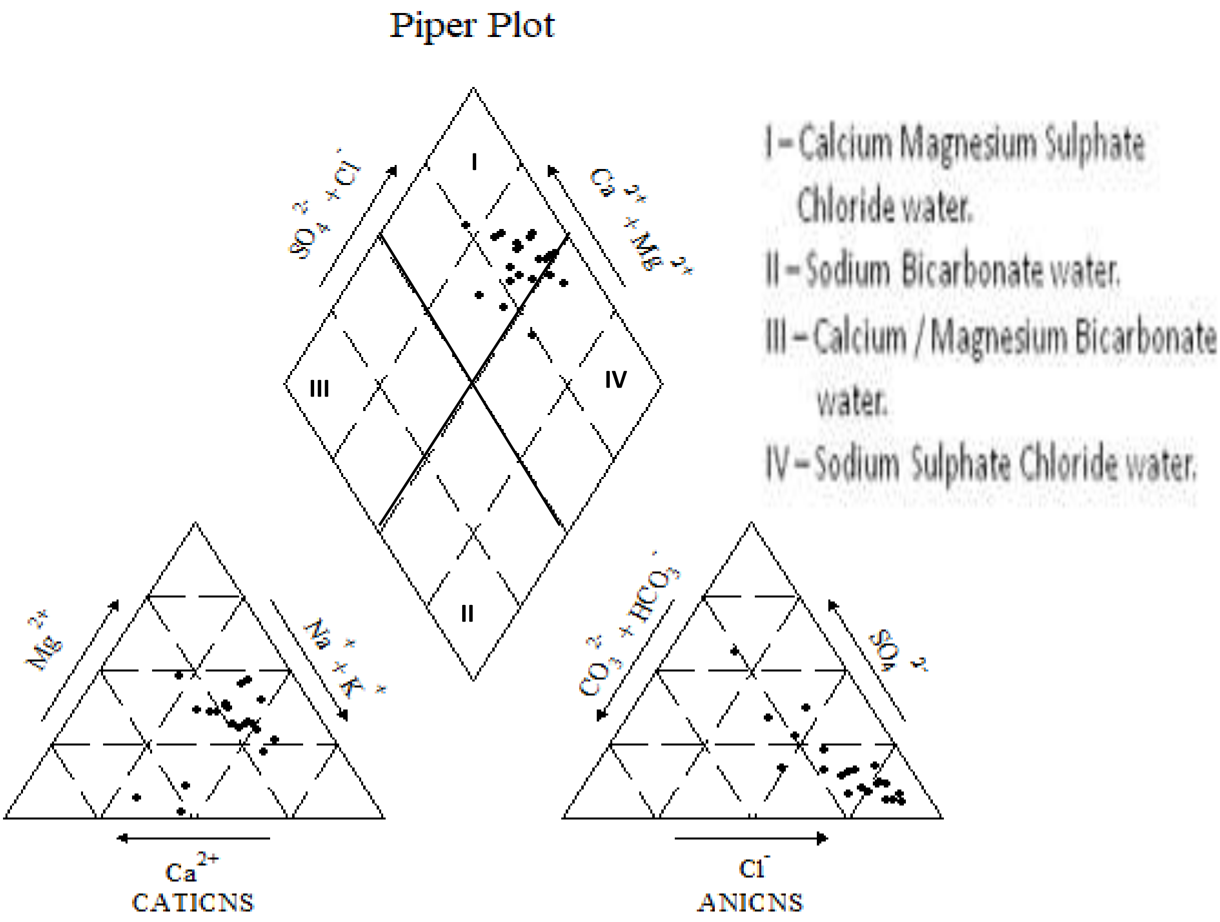

Figure 4.19: Groundwater characterisation in the study area (Piper, 1964)

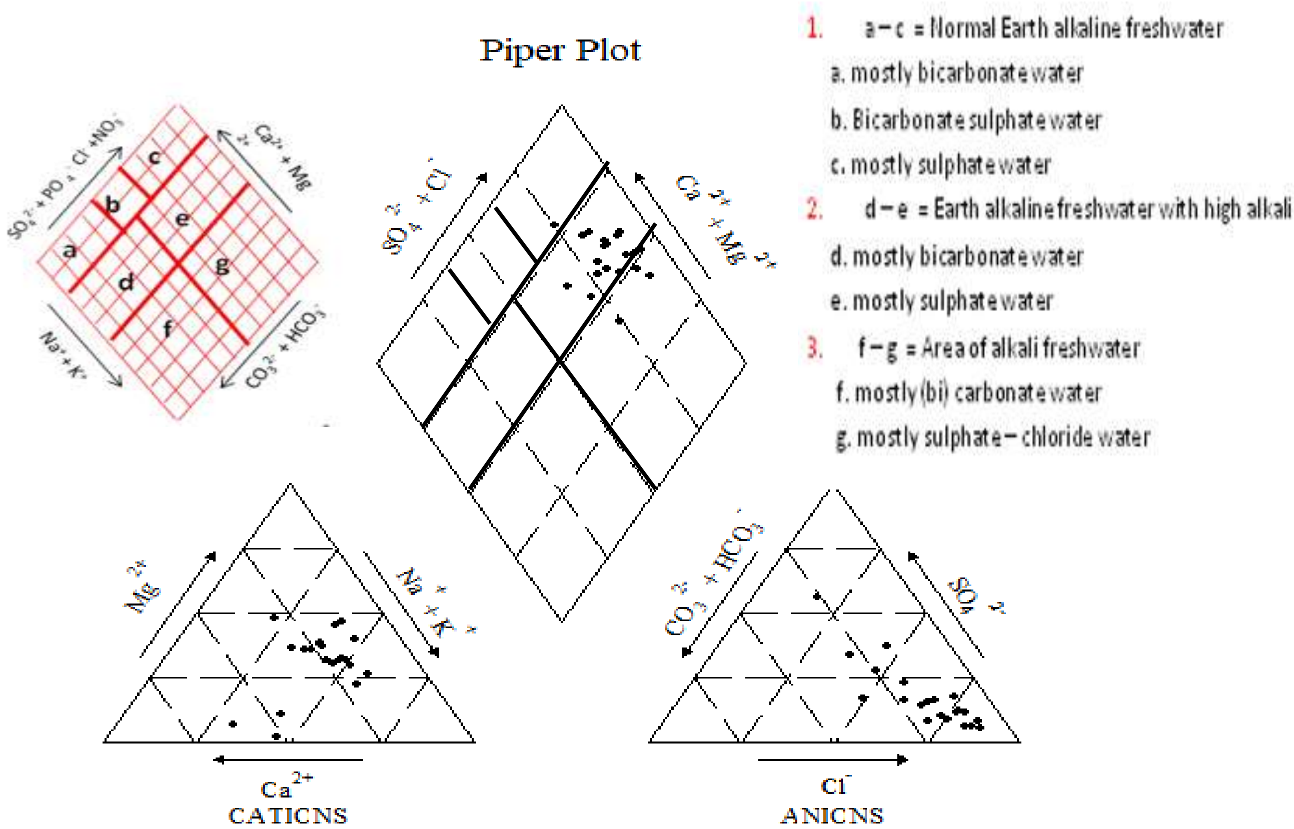

Figure 4.20: Groundwater characterisation in the study area (Langguth, 1964).

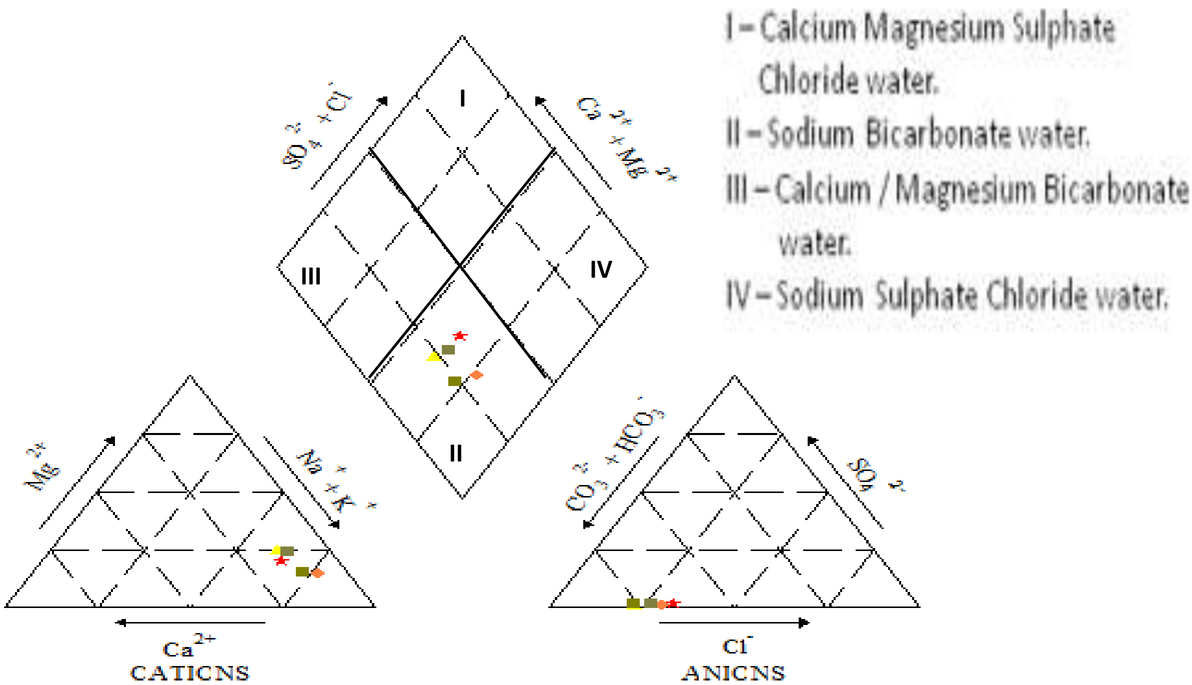

Figure 4.21: Wastewater Characterisation in the Study Area (Piper, 1964).

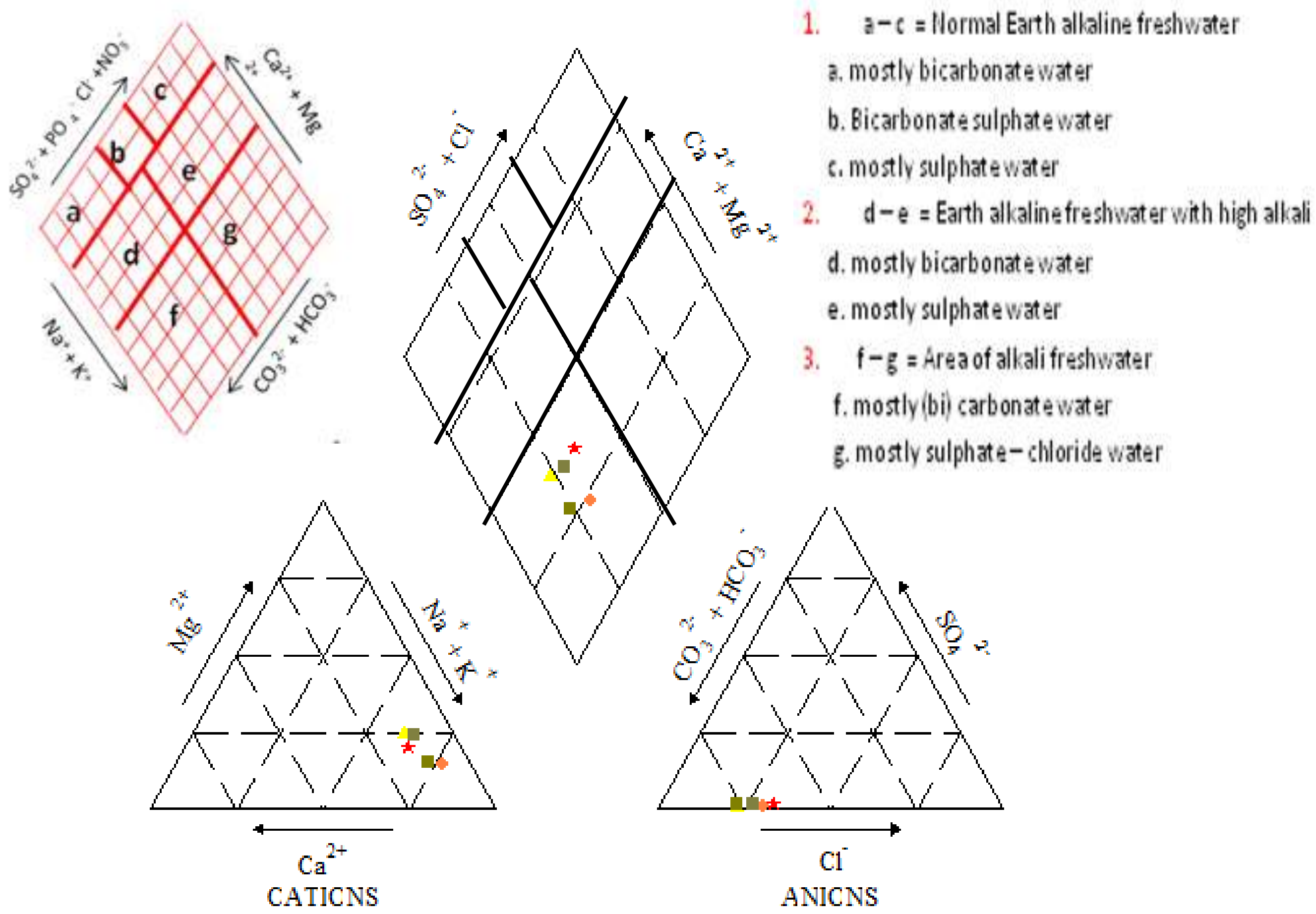

Figure 4.22: Wastewater Characterisation in the Study Area (Langguth, 1964).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Increase in population growth and urbanization yields to increase in demand for water domestically, commercially or industrially. The parts of Minna metropolis studied are underlain by rocks belonging to the Basement Complex of Nigeria of which granite, gneisses and schist predominate. Pit latrines and Water closets with septic tanks are the major kinds of sanitation facilities used in the area hence, the poor sanitary facilities and wastewater may be in direct contact with groundwater sources due to the shallow nature of the water table. Parameters that occur in higher concentration in the groundwater are; bicarbonates, sodium and chlorides. Bacteriological presence in the groundwater is reflected by the presence of coliforms, E. coli and faecal coliforms.

Because there is inadequacy in the management of industrial and household waste, Government agencies like National Environmental Standards and Regulations Enforcement Agency (NESREA) are saddled with the responsibility of proper waste management, protection of water sources, construction of sanitary landfills, and treatment of water. They should therefore make consequential laws and enforce them.

5.1.1 Recommendations

- Sensitization and awareness should be done to enable better lifestyle among the inhabitants of these areas.
- There should be sponsored water supply schemes to enhance provision of water in the environment.
- Drinking water should be boiled before consumption.
- Law enforcement agencies should guard against open defecation as it is commonly practiced thus posing great risk of contamination of the groundwater.
- Siting of wells close to cemeteries, dumpsites and latrines should be discouraged.
- Rainwater harvesting should be encouraged among the community dwellers especially during rainy seasons.
- Public-private partnerships should be created to provide services such as waste disposal management and mass housing to combat the risk of overpopulation.

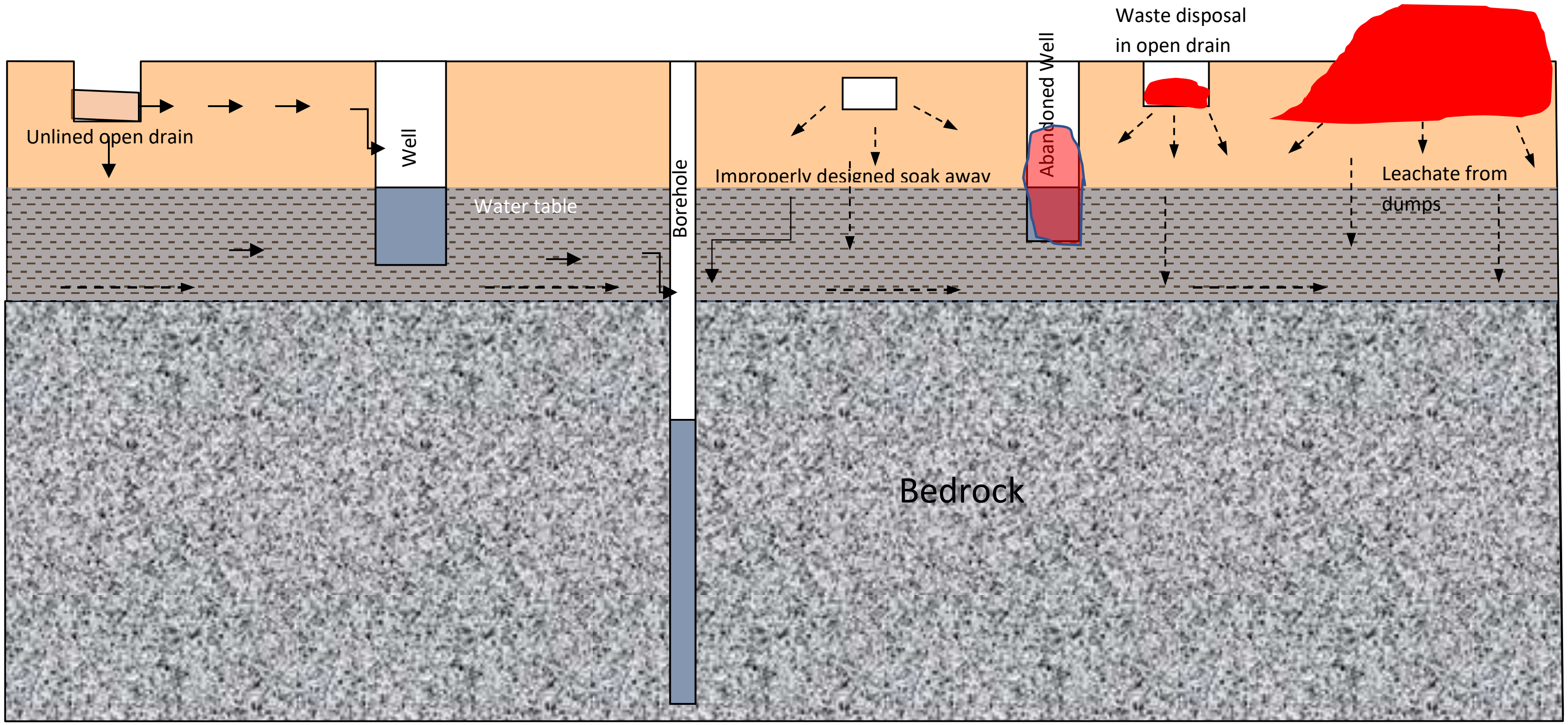

Figure 4.23: Schematic Diagram of Sources of Groundwater Contamination from Urbanisation.

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