IMPACT OF ANTHROPOGENIC ACTIVITIES ON WATER QUALITY AND ITS HEALTH IMPLICATIONS IN PARTS OF MINNA METROPOLIS, NIGER STATE, NIGERIA

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ABSTRACT

This work assessed the impact of anthropogenic activities on water quality and its health implications in parts of Minna Metropolis. The study analyzed physicochemical and bacteriological parameters of water from various sources which include Boreholes, Hand Dug Wells and Water Vendors. The study collected twelve water samples of which the parameters analyzed were pH, Hardness, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Phosphate, Ammonia, Nitrate, Nitrite, Escherichia Coli (E.Coli), Salmonella Typhimurium, Staphylococcus Aureus and Pseudomonas Aeruginosa. The study equally examined the level of residents access to potable water supply in the study area, evaluated the health implications of consuming contaminated water and compared laboratory analyses of water parameters with Nigerian Standards for Drinking Water Quality (NSDWQ) and World Health Organization(WHO). Water quality parameters were analyzed using standard method. The study used simple summary statistics which include mean, range and percentages. The results were presented in tables and graphs. The results showed that the pH for all the water sampled were within both NSDWQ and WHO range of 6.5-8.5. *Hardness ranged from 40-500mg/l in all the twelve water sampled. Seven water samples out of twelve were above the 150mg/l NSDWQ threshold, while five were within the limit. Dissolved oxygen in all the water sampled were below both NSDWQ and WHO threshold of 10mg/l and 5mg/l. Biological oxygen demand of all the water sampled equally fell below both NSDWQ and WHO limit of 6mg/l and ≥6mg/l, respectively. Nitrate concentrations in all the water sampled were below 50mg/l WHO threshold, while Nitrite concentrations in all the water sampled were above the 0.2mg/l Nigerian Industrial Standard threshold. Bacteriological analysis revealed that majority of the water sampled were contaminated by bacteria which include E.coli, Pseudomonas aeruginosa and Salmonella typhimurium. For instance, Ten out of 12 water samples were contaminated by E. coli. Three out of 12 water samples were contaminated by Pseudomonas aeruginosa, while Nine out of 12 water samples were contaminated by Salmonella typhimurium. Human activities identified as contributors to water contamination include concrete blocks making industries, trading such as selling of water by vendors popularly known as (Mairuwa), refuse dump sites, sewage, sinking of Boreholes near septic tanks. The results equally showed that the residents had reasonable access to domestic water supply. This was however attributed to the proliferations of both private and commercial Boreholes in the study area. The results also showed that there is prevalence of water-borne diseases as revealed by both respondents and hospital records. Hospital records revealed that 344 cases of typhoid, 1294 diarrhea, 1882 dysentery and 25 cases of ringworm were reported and recorded in 2018. Owing to contamination of most of the water sampled by bacteria, it was concluded that most of the water sources are not safe for drinking. It was observed and concluded that anthropogenic activities surrounding the water sources contributed to the contamination of the water sources. The study recommended that existing policies on water quality control should be strengthened in order to safeguard public health; Governments at all levels should be organizing sensitization workshops and public awareness programmes on the importance of consuming safe drinking water.*

TABLE OF CONTENTS

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The environmental pollution rate attributed to anthropogenic activities has increased tremendously in recent time (Ogaga *et al*., 2018). These activities are mostly socio-economic in nature. The intensification of anthropogenic activities witnessed in recent time could probably be attributed to human population explosion, which in turn led to the intensification of agricultural activities, industrialization, food production and unplanned urbanization, mostly in developing countries (Adekunle and Eniola, 2008). Several projects are embarked upon for developmental purposes in different parts of the globe; in developing nations, the magnitude of environmental deterioration attributed to anthropogenic activities is enormous (Ogaga *et al*., 2018). In search for sources of energy such as fuel wood, wildlife and timber, the natural ecosystems are decimated or degraded (Ogaga *et al*., 2018). Oil exploration, unhygienic practices, water transportation, sand mining, chemicals uses, inorganic fertilizers, processing of foods, indiscriminate disposal of wastes and poor waste management, and emissions from vehicles and machineries, textile, mining, construction, automobile works are other human activities that have effect on water quality (Ogaga *et al.* 2018).

Water is an essential substance that plays a critical role in sustaining life on Earth. Among the resources bestowed on man by nature, water is undoubtedly the most important and essential resource for the survival of organisms (Ajayi and Akpan, 2012). Despite the fact that other resources such as oil and coal have substitutes, there is no alternative to water (Aremu *et al.*, 2011). The overall wellbeing and continued survival of all human beings relies considerably on quality drinking water (Maitera *et al*., 2011). Water is essential and indispensable to life on earth; its spatial coverage is approximately, 70% of the globe. Approximately, 70% of human mass is made up of water (Adesuyi *et al*., 2015). Water is one of the substances needed for life sustenance and has long been suspected of being the medium for the transfer of many diseases afflicting man (Abd-Alla *et al*., 2011). World Health Organization (WHO), in their 2009 report, reported that approximately 80% of global infectious diseases are attributed to inadequate and unsafe water. United Nations International Children's Education Fund (UNICEF, 2009) reported that 39% of the world human populations (above 2.6 billion humans) had no improved sanitation while some 884 million persons have no access to adequate water supplies. Consequently, over 3.8 million people, majorly children below age five die every year from pneumonia and diarrheal diseases (WHO, 2009). Nigeria, being one of the developing countries, suffers considerable great deal of water contamination from human activities (Aliyu, 2014).

Different researches have revealed that the Nigerian water sources have experienced contamination from anthropogenic activities like manufacturing, industrial, construction, agricultural, mining and domestic in both rural and urban areas (Aliyu, 2014; Ogaga *et al.*, 2018). The main contaminations affect physicochemical and micro-biological properties. The contaminants include trace elements, heavy metals, nutrients and coliforms. Some heavy metals like nickel, iron, zinc, copper, manganese, constitute significant elements owing to their biological functions; others like cadmium, lead, mercury, arsenic are insignificant because they render no biological function (Ogaga *et al.,* 2018). Essential heavy metals become toxic and detrimental to human health when their level of concentration hovers above permissible limits; non-essential metals are highly toxic and detrimental to human wellbeing, even at low concentration level (Ogaga *et al.*, 2018).

Water pollution is a crucial part of environmental pollution owing to the significance of water for living and sustenance. The effect of Water pollution is not limited to humans alone, it also affect animals, plants and micro-organisms through water ingestion by the living organisms (Aliyu, 2014). Furthermore, water has been adjudged as being the source of many man sicknesses such as the devastating outbreak of *E .Coli* in Canada (Kondro, 2000) and Cryptosporidium in Milwaukee, Wisconsin, USA in 1993. Ground or surface water body's quality is a function of either natural or anthropogenic causes or both (Abd-Alla *et al.*, 2011*)*. Without man's influences, quality of water would solely be determined by the disintegration of bedrock minerals, deposition of dust, particles and salt by wind, natural nutrients leaching from soil. Naturally, water contains many dissolved substances and non-dissolved particles in their natural environment (Abd-Alla *et al.*, 2011). Dissolved minerals in water, are significant and constitutes integral parts of quality water considering that they help in maintaining the wellbeing of organisms and organism's vitality (Stark *et al.,* 2000). The challenges of groundwater quality may occur from natural or as a result of anthropogenic activities. The main issues as regards to groundwater quality relates to much water hardness and the availability of some metals and pathogens, iron, chloride, manganese and *coli forms* (Purcell, 2003). Surface water on the other hand, is affected by microbiological contamination through anthropogenic activities that produce wastes of humans both in rural and urban areas. Municipal wastewaters, industrial wastewaters as generated by abattoirs in meat packaging, processing of food and beverages when washed into surface water bodies, they become contaminated. These socio-economic activities invariably generate wastes which may contain fecal materials, including pathogens (Aliyu, 2014). The severing of water is often regarded as impairment, contamination, nuisance, pollution or water quality deterioration (Novtony, 2003).

Water pollution is a global problem and challenge facing countries be it affluent or poor, developing or developed countries; rural and civilized areas (Aliyu, 2014). Pollution in rural areas is mostly caused by mining and agricultural activities. In urban areas however, industries, manufacturing and other activities like power production are responsible for pollution majorly in affluent countries (Aliyu, 2014). Younger (2001) reported that coal and abandoned mines are the second freshwater pollution sources after sewage in Scotland. In developing countries on the other hand, pathogens attributed to indiscriminate disposal of human wastes and unhygienic practices constitutes major sources of water pollution causing waterborne diseases such as amoebic dysentery, dysentery, cholera, aneamia, ringworm, guinea worm, hepatitis A, typhoid and polio (Aliyu, 2014). In developed countries, there exist policies regulating the discharge of effluents into the courses of water. Those regulations are virtually not existing or inadequately enforced in developing nations, especially in sub-Saharan Africa. The common sources of water at the disposal of most local communities in Nigeria are steadily being affected by various human activities, as a result of which pollution constitutes the most dominant and daunting challenge (Ayobahan *et al*., 2014). The abstraction of water for uses like domestic, agriculture nand other economic activities can result to degradation in water quality and quantity that affect both aquatic ecosystem and availability of potable water for human uses (United Nations Environment Programs, 2006).

This study assessed the anthropogenic activities impact on water quality and its health implications in parts of Minna Metropolis, Niger State, Nigeria.

1.2 Statement of the Research Problem

It is apparent that numerous researches have been conducted on human activities impact on water quality in Nigeria in recent times Aliyu, (2014); Ogaga *et al.,* (2018); Ayobahan *et al.* (2014); Enitimi and Sylvester (2017); Ohwo and Abel (2014). Many of these studies have documented the failure of various water supply sources in Nigeria to meet the minimum water quality standards of World Health Organization (WHO) as well as Nigerian Standards for Drinking Water Quality. Many of these studies linked the failure to influence of anthropogenic activities. However, based on the literatures reviewed, little studies were conducted in the study area on human activities impact on water quality. Also based on the literatures reviewed, fewer studies were conducted on the health implications of consuming contaminated water in parts of Minna Metropolis.

Adequate safe water supply, hygienic and sanitized freshwater is a crucial factor in man's economic development quest. Thus, there exist a need for the conservation of both surface and groundwater quality. Good and safe drinking quality water is important for the physical wellbeing of all people. Sustained water pollution inevitably, results in the degradation of water resources with its attendant consequences such as aquatic habitat destruction, death of fisheries and most importantly, scarcity of water resources which further hampers human socio-economic development. Therefore, this research work assessed the impact of anthropogenic activities on water quality and its health implications in parts of Minna metropolis with a view to contributing to the ways of enhancing water quality in the city and the state at large.

1.3 Research Questions

The fundamental questions that readily come to the researcher's mind include:

- **i.** What are the physicochemical and bacteriological properties of water sources in Minna Metropolis?
- **ii.** What comparisons exist between the physicochemical and bacteriological properties of water sources in the study area and World Health Organization's standards?
- **iii.** What is the level of residents access to potable water supply in Minna Metropolis?
- **iv.** What are the health implications of consuming unsafe water on the health of the study area's residents?

1.4 Aim and Objectives of the Study

The research's aim is to assess anthropogenic activities impact on water quality and its health implications in parts of Minna Metropolis. The specific objectives are to:

- **i.** Analyze the physicochemical and bacteriological parameters of different water sources in parts of Minna Metropolis;
- **ii.** Compare the physicochemical and bacteriological properties of water sources in the study area with World Health Organization (WHO) standards.

iii. Examine the level of residents access to potable water supply in parts of Minna Metropolis;

iv. Evaluate the health implications of consuming contaminated water in the study area;

1.5 Justification for the Study

The contributions of water resources to economic development of a nation and social wellbeing of people cannot be overemphasized. Unequivocally, economic and social activities of modern man heavily rely on adequate quality and quantity of freshwater supplies. However, the quality of water has come under serious threats from various activities of man as revealed by various researchers which include Aliyu, 2014; Ogaga *et al.* 2018; Ayobahan *et al.* 2014 among others. Water pollution constitutes global challenge which affects affluent and poor, rural and civilized environments (Aliyu, 2014). Food and Agricultural Organization (FAO) reports showed that in African countries, especially Nigeria, diseases connected to water have been impeding basic human development (FAO, 2007). Furthermore, researches in various regions of Nigeria documented the failure of various water supply sources in meeting the minimum water quality standards of World Health Organization (WHO). The health implication of consuming contaminated water is a crucial and motivating factor in conducting this research.

This study therefore provided empirical evidence on human activities impact on water quality and its health implications in parts of Minna Metropolis, which would assist in guiding policy makers on water resources management, and in making adequate policies that will improve water supply quality in the study area, state and the nation at large.

1.6 Scope and Limitation of the Study

The research work's scope focused mainly on assessing the impact of anthropogenic activities on water quality in parts of Minna Metropolis. Of specific interest to this research work is the impact of anthropogenic activities (industries, agriculture, domestic, food processing, construction, trading and transportation) on water quality. This study analyzed the physicochemical and bacteriological parameters of some water sources in parts of Minna Metropolis, compare the results with World Health Organization, examine the level of resident's access to potable water supply, and evaluate the health implications of consuming contaminated water.

The study took water samples from 12 sampling locations and only water sources cited within close range of human activities were sampled. The study took water samples from wells, boreholes and water vendors popularly known as Mairuwas in the selected areas. The physicochemical and bacteriological parameters analyzed include dissolved oxygen (DO), pH, biological oxygen demand (BOD), hardness, phosphate, nitrate, nitrite, ammonia, *pseudomonas aeruginosa, staphylococcus aureus, salmonella typhimurium* and *Escherichia Coli*. The spatial coverage of the study focused on Kpakungu, Maitumbi, Tayir and Chanchaga areas, respectively.

Like most research works, this study had its limitation. Data collection constituted some of the challenges faced by the study as the author faced communication challenge with some of the respondents. Suspicion was another challenge faced by the study in that some respondents were not positively disposed to the idea of granting interview.

1.7 The Study Area

1.7.1 Location and extent

The four selected study areas are located in Bosso and Chanchaga Local government Areas (LGA) in Minna, the capital of Niger State, Nigeria. Niger state lies on Longitude 3˚30' and 7˚20'E, and Latitude 8˚22' and 11˚30'N. It has a land area of about 6,784km². It is located in the North-Central geo-political zone of Nigeria and it is located about 150km from Abuja and 495km from Lagos. Minna Metropolis lies on lowland and bordered in the East by Paida hill that extended eastwards towards Maitumbi and it supports farming. To the West, it is bordered by Wushishi and Gbako, Shiroro to the North, Paikoro in the East and Katcha in the South (Simon *et al*., 2018).

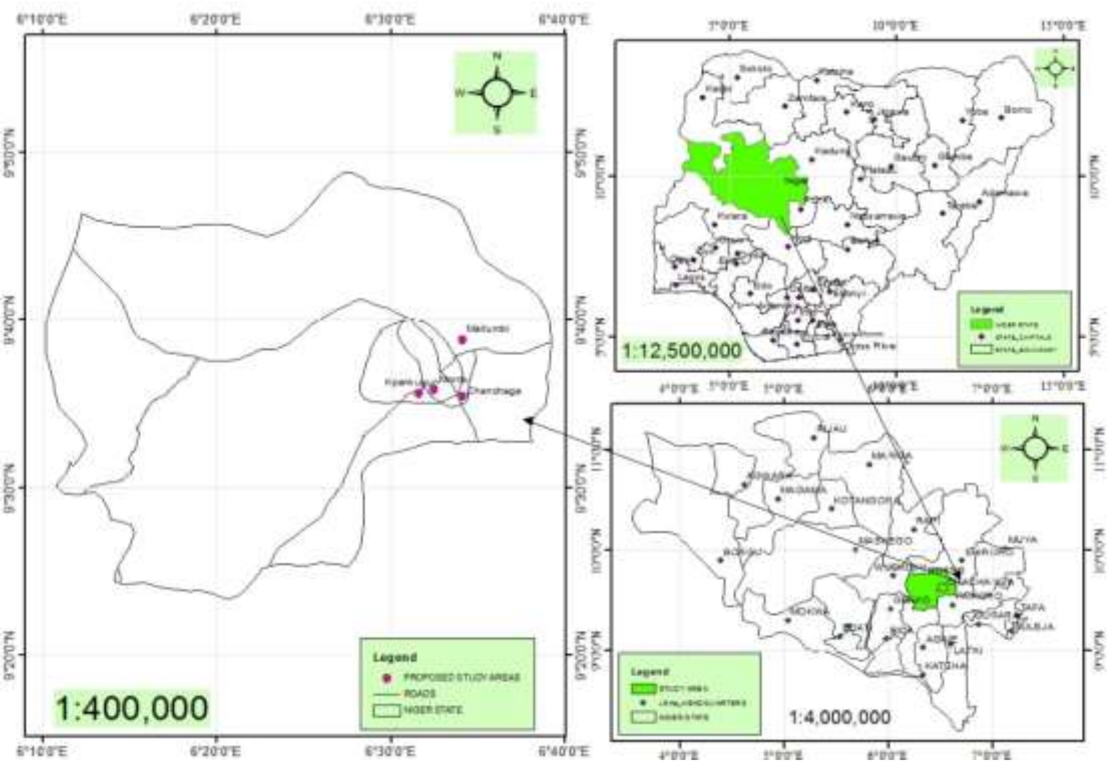

Figure 1.1 Niger State Map Showing the Study Area

Source: Remote Sensing Laboratory, FUT. Minna, 2019

1.7.2 Climate

The climate of Minna is tropical with average annual temperature of 27.5°c (Simon *et al*., 2018). The annual rainfall on average is 1229 mm. The least rainfall amount is recorded in January. The average rainfall in this month is 1mm. The month of September receives the highest amount of precipitation, with monthly average of 260 mm. The month of March records the highest amount of temperatures. On average, around 30.5°c is recorded (Simon *et al*., 2018).The coldest month is August, whose average temperature is 25.3°c. Minna is found within the tropical hinterland and the tropical continental climate of Nigeria. Thus, Minna and its environs essentially fall in the tropical continental climate as outlined by Koppen's climatic classification scheme.

1.7.3 Geology

The geological structure of Minna Metropolis shows a steep sloppy hills outcrop on the North and Eastern edges. The entire land area of the city is such that is characterized by undulating topographies and underlain by basement complex granitic and sedimentary rocks. Over the hills in the North, there are lands that are developable but are interspersed with poor land spaces. The southern part presents reasonable and potential development possibilities but is however, curtailed by River Chanchaga (Simon, *et al.*, 2018).

17.4 Vegetation

The vegetation cover of Minna Metropolis consists of open savanna wood and grasslands. It is interspersed with short to medium trees. The height of the trees ranges between 10 to 16 meters. The dominant tree in the city is leam tree. Others include Malayna, Mango, Mahogany, etc. The bank of River Chanchaga is covered by dense riparian woodlands or vegetation (Simon *et al.*, 2018).

1.7.5 Population

The 1991 population census conducted by the National Population Commission (NPC), put the population figure of Minna Metropolis at 189,188. It rose to 291,900 in 2015. It is estimated at about 500,000 as at 2017. The population is projected with an annual growth rate of 0.85% per year (NPC, 2017).

1.7.6 Socio-economic activities and infrastructure

Minna Metropolis developed as an administrative centre. In recent times however, both economic and social activities have significantly influenced its growth (Simon *et al.*, 2018). The major occupations of the people include farming, trading, brick-making, pottery making and weaving.

In terms of amenities, Minna Metropolis has various financial institutions and credit houses, educational institutions and health facilities. There are television stations and radio houses. It is connected by road to Lagos, Ibadan, and Abuja-Lokoja. There is also a railway linking the city to the core north and southern part of Nigeria (Simon *et al.*, 2018).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Framework

Minna Metropolis and environs have witnessed tremendous increase in both human population and size. This could probably be due to its status as the administrative capital of Niger state of Nigeria. Being part of a system in the system approach therefore, the water resources of Minna Metropolis, both surface and groundwater have increased their interactions and usefulness to man. Water resources sources both surface and groundwater seems to have increased interaction with anthropogenic activities such as industries, irrigation agriculture, mining activities, foods processing and human settlements. In view of this, water resources and their environments, the dependents on these valuable resources in this case the residents therefore forms the theoretical framework for the research. This theoretical framework was therefore formed around Integrated Water Resources Management Theory and Ecosystem Modeling Theory

2.1.1 Integrated water resources management theory

Global water partnership (GWP, 2009) defined integrated water resources management as a process that ensures the promotion of development and management of fresh water, land and other resources, so as to enjoy the resultant economic and social welfare equitably in such a way that it does not compromise vital ecosystems sustainability. Water resources play a vital role in man-environment interactions and interrelationships. Man depends on water resources for many uses which include drinking, industrial, agriculture and other domestic uses. This will substantially lead to maximization of equity, efficiency of the economy and ecological sustainability. Social equity will in turn enhance uniform access for all users, particularly the marginalized and poorer user groups to sufficient quantity and quality of water needed to sustain human well-being and development (GAP, 2009).

2.1.2 The ecosystem modeling theory

Based on the ecosystem modeling theory, reduction in water pollution in Minna Metropolis and Environs would improve the status of water resources especially ground and surface water resources of Minna; where anthropogenic activities are effectively sensitized on the effects they posses on the quality of water resources in Minna; an aspect that would stimulate conservation efforts thus improving the living and quality of lives of the residents.

The two theories thus focused on sustainable utilization of resource and socio-economic development.

2.2 Anthropogenic Activities and its Potential Effects on the Quality of Water Resources

Anthropogenic activities affect water quantity and its quality (Abd-Alla *et al*., 2011). Several human activities have potential effects on water quality. These activities can be described as follows:

2.2.1 Agriculture

Agricultural sector is a critical sector of the economy of a nation. Agriculture is one of the human development activities. Until the discovery of crude oil in commercial quantities in the early 1950's in Nigeria, Agriculture was the main pillar of the economy where it employed more than half of the population. Increased human population growth coupled with substantial technological advancement, the nation has witnessed intensification of agricultural production. Agricultural chemicals such as pesticides, herbicides, fungicides, fertilizers are integral to modern agricultural practices. However, these agricultural practices have impact on the environment. The use of pesticides indiscriminately in agriculture is capable of causing environmental challenges (Abd-Alla *et al*., 2011). Various publications in Egypt showed the presence of pesticides remains majorly organochlorine compounds in different aquatic ecosystems components (El-Kabbany *et al.*, 2000; Radwan and Atalla, 2005).

Pesticides connection to human and animal health challenges have been established. Direct exposure usually occurs during the usage. Oftentimes, exposure occurs during the intake of contaminated foods. Humans are exposed to pesticides through ingestion of fish or shellfish that are contaminated, a process known as bio-accumulation or by consuming contaminated water. Diseases like cancer, damage to the neurons, deficiencies in the immune system, and challenges with the endocrine system in human beings have been linked to pesticides exposure (Mineau, 2005).

The use of fertilizers is very popular among farmers today. Majority of the fertilizers containing chemicals used in modern agriculture contains nitrogen, phosphorus and potassium (N, P, K), which constitutes significant micronutrients for crop growth and yield. In developing countries, Nigeria inclusive, farmers often apply these fertilizers indiscriminately to boost up and enhance crop yield. Nitrogenous fertilizers used in the field usually leach deep into the soil and eventually pollute the groundwater when applied indiscriminately. Nitrates get accumulated in water and when it exceeds 25 mg/l in water, they tend to trigger a serious health hazard referred to blue baby syndrome.

2.2.2 Industry

Industry is described as the organized action of making goods and services for sale. Industrialization is seen as the pillar for development strategies owing to its role in the economic development, growth, human welfare and development. Invariably, it is a criterion for ranking countries in the leagues of Nations and a measure of its political strength (FEPA, 1991). Industrialization, as other activities of man that affect the environment negatively, contributes to environmental pollution and deterioration if not adequately regulated (Adekunle and Eniola, 2008). It is usually accompanied by unavoidable challenges in terms of air pollution, pollution of resources of water and general deterioration of the environment (Adekunle and Eniola, 2008).

Prior to the industrial revolution in the 1750's, human wastes, agricultural wastes, production wastes were easily assimilated by the natural environment. However, the increased human population growth coupled with technological advancement witnessed in recent decades has led to intensification of industrialization and consequently, increased level of industrial wastes known as industrial effluents. Globally, water bodies serve as the primary means for the discharge of wastes, especially from industries near the water bodies. Industrial effluents exercised significant influence on the contamination of water bodies. These effluents can change the physicochemical and bacteriological components of the host water body (Adekunle and Eniola, 2008). Initially, waste effect usually results in the degradation of physical water quality. Later biological deterioration becomes apparent and evident in quantity, variety and organization of organisms dwelling in the water (Aliyu, 2014). Usually, the water bodies conveniently absorb wastes materials and records no significant degradation of some quality criteria; this is regarded as its assimilative capacity (Ifabiyi, 2008). Discharge of effluents into water bodies always does not have effects on aquatic environment. This is attributed to the self purification characteristics of water bodies (Ifabiyi, 2008). Industrial effluent is the most common source of water pollutants recently (Ogedengbe and Akinbile, 2004). It is increasing annually because most nations of the world are intensifying industrialization. The magnitude of discharge of industrial and domestic wastes is that water bodies receiving untreated industrial effluents lack the capacity to provide dilution necessary for the survival of the water bodies as quality water sources. The release of effluents into water bodies by industries is harmful to human and animal health, safety and survival (Adekunle and Eniola, 2008). Some of these wastes generated by industries include wastes from mining, pharmaceutical wastes, waste waters from food processing plants, waste waters from abattoir and meat processing and packaging, chemicals used for dying, fertilizers, petrochemicals, construction, sugar refinery, engineering works, energy and power, leather and mechanical activities (Aliyu, 2014).

Mining being one of the industrial activities is generally very destructive to the environment. Mining cause imbalance to hydrological processes and it thus, contaminate water in the ground. Sulphur, as a dirt in most ores gets converted into sulphuric acid usually with the help of microbial action, thereby rendering the water acidic. In the mining process, some heavy metals could get leached into the groundwater and pollute it thus posing serious health challenges (Ogaga *et al*., 2018). Mining also contaminate surface water like streams, lakes and rivers through acid mine drainage. The acidic water is harmful to different forms of lives in the aquatic environment. At times, radioactive substances such as uranium do pollute water bodies through waste from uranium mine thereby killing aquatic organisms. Heavy metal contamination of water bodies close to mining areas is a common attributes causing health problems to both animals and humans.

2.2.3 Transportation

Transportation is increasingly becoming linked to environmental problems and Challenges (Nathaniel and Christine, 2000). Being a technology that relies greatly on hydrocarbons combustion, especially the combustion of engine internally, the effect of transportation on environmental systems has increased with modern heavy motorization triggered by human population explosion and improved technology (Nathaniel and Christine, 2000). Apparently, transportation activities enhance increasing mobility demands for people and consequently, support economic growth and development of a nation. Activities associated with transportation such as fuel consumption, wears and tears of vehicles, road wears and tears can have detrimental effect on groundwater quality of roadside wetlands environments (Hong *et al*., 2018). Chemicals, fuel and numerous harmful materials discarded from vehicles, aircraft, long vehicles and trains can pollute water sources like rivers, lakes, wetlands and oceans (Nathaniel and Christine, 2000). Water contaminations by transportation activities take two distinct forms. The contaminants could directly be leached into natural water system, or contaminants could be air-borne, thus transported by air and invariably, deposited. Runoff contaminants from vehicles include heavy metals and particulates; exhaust fumes, copper from brake pads, tyres and deposits of asphalt wears, and grease drips, oil. Indirectly, vehicles contribute to contaminated runoff by carrying solid particles from mechanic workshops, car parks; especially in urban areas (Nathaniel and Christine, 2000).

2.3 Water and Public Health

Availability of safe and qualitative water has a direct influence on human health, economic development and quality of life of the people. Most significantly, the prevention of ill-health has direct links with the quality of water (UNICEF and WHO, 2008; 2012). Poor quality water can lead to outbreaks of water-borne diseases and may cause devastating epidemics. For instance, about 4 billion cases of diarrhea annually resulted to 1.5 million deaths, mostly children below 5 years of age, of which 88% are attributable to unsafe water, poor sanitation or a lack of hygiene (Schuster-wallace *et al*., 2008). In rural areas of developing nations such as Nigeria, aside from these causes of public health, other issues associated with public health include water contamination due to people bathing, washing, defecating, and urinating in water sources such as rivers and streams.

These forms of contamination are further exacerbated by inadequate sewage facilities. In communities where sewage facilities are unavailable, the water that runs from local bathrooms has no source into which it is drained (Herero, 2008). In many communities, sewage runs into stagnant water channels that serve as breeding sites for mosquito, creating further severe health risks in the form of insect-borne diseases such as malaria (Herero, 2008). The common sources of water that are available to most local communities in Nigeria are fast being affected by a number of human factors, of which pollution remained the most dominant challenge (Ayobahan *et al*., 2014). There is a closer link between pollution and health damages (Aliyu, 2014). Five million people die annually due to contaminated drinking water, poor sanitation and domestic unhygienic practices around the globe (Jibrin *et al*., 2018). FAO (2007), reported that in African countries particularly Nigeria, water related diseases had been interfering with basic human development.

2.4 Water Pollution

Water pollution usually refers to natural processes and events that cause the contamination and impairment of water for its intended use. These natural events such as hurricane and torrential rainfall is capable of causing excessive erosions, flooding, tsunamis and landslides, which in turn increases the content of solid materials in affected rivers, streams and lakes which invariably leads to little or no dissolved oxygen among other consequences (Abd-Alla *et al*., 2011). The impairment of water is usually referred to as pollution, contamination, nuisance or water degradation (Novteny, 2003).

Irrespective of the terminology used, water pollution can be classified as either point or non-point sources (Masters and Ela, 2000). Point sources are based on the human activities that produce the pollutants such as from a specific, identifiable source, mostly a facility or factory and is usually released at a known discharged point, usually a pipe or ditch, a ship, municipal sewer system, industry and power plants (Masters and Ela, 2008). On the other hand, non-point source pollution arises from the way the pollutants are discharged into the environments and are not specific. Amongst these are agricultural activities such as the application of pesticides that are transported far away as runoff which in most case, inevitably contaminate groundwater through the soil profile particularly the pore spaces in the unsaturated soil zone (Estevez *et al*., 2008).

Water pollution is a significant aspect of environmental pollution considering the necessity of water for life sustenance. Water pollution has impact on not only humans but as well as animals, micro-organisms and plants through the intake of water by the living organisms (Aliyu, 2014). The importance of water notwithstanding, it has long been recognized as a vehicle for the spread of many diseases (Wijk-Sijbesma, 2002, Sawyer *et al.,* 2003 and Abd-Alla *et al.*, 2011).

A number of studies have shown that in developing nations such as Nigeria, water pollution occurs in diverse ways, including the effects of industrialization and urbanization, as well as air and soil from oil spills or other contaminants (Akinibile and Yusoff, 2011; Babanyara *et al.*, 2010; KapilaTharangaRathnayaka and Wang, 2012). There is equally a high percentage of untreated and inadequately treated wastes discharged into water bodies in urban and sub-urban areas (Ogwueleka, 2009; UNICEF and WHO, 2012). It is usually common for rivers and streams running out of the urban settlements to carry and transport along mixtures of contaminants from domestic and industrial wastes laden with chemicals, heavy metals, and other pollutants that have adverse effects on drinking water and agriculture as well as the physical environment (Babayemi and Dauda, 2009; Fasunwon *et al*., 2008). For environments that are saturated with such pollutants or contaminants, it is very easy for such contaminants to be taken up by plants and fruits, which may in turn, lead to the poisoning of consumers of such produce (Omowaye and Audu, 2012). Nigeria as a developing nation, suffers from water contamination from anthropogenic activities. Studies have shown that the country's water resources have been contaminated from anthropogenic activities such as industrial, agricultural and domestic activities in both rural and urban areas (Aliyu, 2014). The major contaminations affect chemical and microbiological parameters with contaminants ranging from trace elements, nutrients to coliforms (Aliyu, 2014).

2.5 Review of Related Literatures

2.5.1. Analyses of chemical and bacteriological parameters of water

A research carried out by Aliyu (2014) examined anthropogenic activities impact on the quality of water resources in Kaduna metropolis. The research investigated anthropogenic activities impact on water quality in Kaduna Metropolis with a view to contributing to the ways of improving water quality in Kaduna state. The study employed the use of systematic sampling. Water samples were collected from both surface and groundwater, precisely river Kaduna and hand dug wells. Eight (8) groundwater and seven (7) surface water samples collected at different locations and points were used for the study. The water samples were analyzed for physicochemical, microbiological parameters, lead, oil and grease. The results from laboratory analyses were processed using statistical analysis.

The study concluded that the heavy metal concentration fell within the guideline for drinking water except for lead and cadmium. The study further pointed out that concentration of cadmium and lead in the river could result in the bioaccumulation in aquatic organisms like fisheries. The study recommended that care should be taken in the drinking of surface water in the study area owing to probable cadmium and lead toxicity over a long period of time.

Muhammad *et al*. (2015) studied the water pollution sources for hand-dug wells in the ancient city of Bauchi Metropolis, Nigeria. The study was undertaken to determine the sources of water pollution for hand-dug wells in Hardo ward of Bauchi metropolis. Secondary data on pollution by coli form concentration in water from hand – dug wells in the study area was used as the dependent variable while primary data was collected on four parameters as potential sources of water pollution.

The study concluded by recommending the use of community boreholes for water supply in the area as well as 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 hand dug wells from all the pollution sources in general.

Enitimi and Sylvester (2017) reviewed anthropogenic activities impact on surface water resources in the Niger Delta Region of Nigeria. The study identified human activities that pollute surface water resources to include oil and gas, wastes, flooding, dredging and marketing. The study analyzed some physicochemical and heavy metals. Secondary data sourced from internet were used for the study. Journal articles published on water quality of various surface water resources in Bayelsa state, Nigeria, between 2001 and 2017, were assessed and reviewed. The mean and/or range data obtained were presented based on seasons like rainy (April to October) and dry (November to March of the subsequent year). The data were compared with SON and WHO thresholds.

The study concluded that the distortion of water quality parameters may considerably distort biodiversity abundance and composition such as fisheries and planktons, downstream utilization of the water and its portability. The study recommended adequate regulation and enforcement of regulation policies by the relevant regulatory agencies.

Ajai *et al*. (2011) examined the physicochemical properties and trace metal concentration of Hand dug wells in Tunga area of Minna, Niger State, Nigeria. The aim of the study was to determine the physicochemical properties and trace metal concentration of Hand dug wells in part of Minna Metropolis and to ascertain the safety and portability of water from locally dug wells for domestic purposes. The physicochemical properties and levels of trace metals in locally dug wells were investigated employing titrimetric and instrumental method. Results of the study revealed that industrial and other anthropogenic activities in the study area posed no serious health challenges to their well water, and thus suitable for domestic purposes. The study concluded by suggesting that there should be constant monitoring of trace metal levels in the wells of the study area by regulatory bodies.

Adesuyi *et al*. (2015) assessed the quality of groundwater in Eliozu community in Port Harcourt, Rivers state, Nigeria. The study investigated contamination level and groundwater quality of boreholes that were randomly selected. Laboratory analysis was carried out on thirty (30) boreholes water sampled in the study area. Physicochemical parameters analyzed include temperature, pH, total hardness, electrical conductivity, total dissolved solids (TDS), dissolved oxygen (DO), salinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate, chloride, copper and zinc employing the use of standard methods. The study concluded by recommending regular monitoring of physicochemical parameters in groundwater sources in the study area and its Environs.

Ayobahan *et al*. (2014) assessed human activities impact on the quality of water of Benin River. The study's aim was to determine the source of human activities affecting River Benin. The study monitored Twenty-four parameters at five sampling points on a monthly-day-trip basis. The study compared inter-stations and identification of serious variations were conducted employing parametric ANOVA and Duncan Multiple Range Tests.

The study harped on the importance of Principal Components Analysis (PCA) methods in the quality of water assessment and sources of pollution fingerprinting. The result of the PCA affirmed that human activities were culpable for quality of water variations in the sampled stations of Benin River and was solely attributed to organic pollution and effluents from industries. The study concluded by recommending that government at both Federal and State levels should intensify monitoring the quality of Benin River water so as to prevent water quality deterioration and consequently, avoid direct threats to human health and aquatic ecosystems inhabitants.

Owhonda *et al*. (2018) studied the urban effluent effects on River water quality in the Niger Delta. The research studied one of the rivers in the Delta region of Niger under the influence of urban effluent that spanned four months, that is, two months in the dry season and two months in the dry season. The dry season covered February to March, while wet season covered April to May. Sampling was conducted on weekly basis at four sites identified along the River. In-situ measurements of salinity were collected weekly.

The study concluded by attributing the pollution of the river to the influence of urban effluent and that the river's water is unfit for consumption by humans and not conducive for habitation by some aquatic organisms. The research recommended development of proper sewage systems or wastewater treatment system by the municipalities. The study further recommended a more detailed assessment of the river which will look into the effect of the urban effluent into this river on the survival of some aquatic organisms.

In similar vein, Irfan and Shakil (2012) assessed human activities impact on the quality of Lidder River's water in Kashmir Himalayas. The study investigated Lidder River water quality deterioration causes. Lidder River is one of the main tributaries of Jhelum River in Kashmir Himalaya. Twelve water parameters were analyzed spanning one year period. Water samples were collected at eight different locations with a different relief and very distinct land use/land cover each, along Lidder River. The study concluded that the main reasons for the deterioration of quality of water of Lidder River were increase in the silt and nutrient load from the adjoining areas due to indiscriminate application of fertilizers and pesticides and encroachment in the premises of the river.

Chamara and Koichi (2017) evaluated population growth impact on the quality of water of natural water bodies in Asian countries. The study opined that the assessment of human population capacities sustainability in river watersheds is imperative in order to sustain adequate freshwater ecosystems in a nation and at the same time, achieve its national developmental goals. The study assessed the relationship between the population growth rate in a watershed area and water quality parameters of a river ecological system.

The result revealed worst water quality in densely populated areas, average in areas that are moderately populated and mild serious in less populated areas. Population density was pinpointed as the main factor that ought to be well regulated so as to overcome the increasing degradation of the water. Finally, the study evaluated the population impact on quality of rivers water based on a water quality classification model and identified the possibility of regulating pollution by raising stakeholders awareness and concerned agencies saddled with the responsibility of maintaining natural water bodies.

Olukosi *et al*. (2016) assessed some physicochemical quality parameters of different sources of drinking water in Kaduna. The study's objective was to determine some physicochemical parameters of water used by residents in the study area. The study's results were compared with the W H O and N I S thresholds for all the parameters. The study concluded that water used for drinking in parts of Kaduna state studied were considerably of good quality and that, the values for Nitrate, pH, Biological Oxygen Demand, and Total Dissolved Solids were within the thresholds stipulated. Conductivity and TDS values of the Borehole water samples were considerably higher than the other sample types, while the Nitrate and pH values were considerably higher in the wet season.

Idris *et al*. (2013) assessed contamination level of surface water by heavy metal in Minna, Niger State, Nigeria by pharmaceutical industrial effluent. The study used River Gorax, Maitumbi as its study area. Samples of water were collected at eight different sites along the river, located about One hundred and sixty (160) meters away from the pharmaceutical company tagged as S1 to S8.

The study concluded that the concentrations of heavy metals analyzed were above the thresholds of NSDWQ, WHO and FEPA. The study recommended the enforcement of appropriate treatment of effluent prior to their release into surface water in order to curtail their potential environmental consequences.

Maureen (2018) examined the human activities impact on the quality of water of Athi River in Machakos County, Kenya. The study focused mainly on industrial activity on the quality of water of River Athi within the Athi River locality in Kenya. The study analyzed the level of hydrocarbon pollution, the industrial activities and its relationship with proximity to the river and the level of *Coli Forms* in the river. The study's investigation revealed that the contamination of the river decreases with increasing river flows downstream, an aspect attributable to the natural filtration processes as the river flows through rocks and pebbles resulting to decreased pollution. The results provided evidence in support of the null hypothesis in the case of hydrocarbon pollution that provided no evidence in favour of hydrocarbon pollution. The results however provided evidence towards a significant correlation between the distance from industries to the river and the pollution level where a reduction in distance led to an increase in pollution leading to increased pollution load. However, based on the regression analysis, various factors combined to form a considerable impact on the water quality of the river. The results also revealed no evidence of any *Coli Forms* or *Coli Form* counts.

The study recommended the intensification of recycling efforts by governments in that, recycling efforts plays a very pertinent role in minimizing the effect of pollution on the quality of water resources. The study also admonished government to embrace incentive-based pollution control measure by rewarding industries that wholeheartedly embraced recycling.

2.5.2. Examination of potable water accessibility

Ohwo and Abel (2014) assessed access of residents to the supply of potable water in Yenagoa Metropolis. The study's aim was to determine household access to the supply of potable water in the study area in terms of quantity and quality.

The study concluded that the access of residents to the supply of potable water in the study area in quality and quantity dimensions wise was insufficient and inadequate as revealed by the result. The study recommended the revival and enhancement of the capacity of the state water corporation to deliver potable water supply to the residents of the study area at affordable cost.

Abaje *et al*. (2009) examined the supply of potable water and demand nature in Jema'a Local Government Area of Kaduna State. Overall, 220 questionnaires were administered to households in five wards of the study area. The aim was to seek the views of residents on supply of potable water and demand nature in the study area.

The study concluded that there was the challenge of insufficient supply of water in the study area. The study however made the following recommendations: provision of alternative water supply sources like boreholes and public taps at some strategic sites in the study area; earn mark sufficient funds for water resources development, public enlightenment against over consumption and misuse of water, water policies should strive to factor in the issue of population growth and improved standards of living in projecting water demands by the populace.

Stephen (2016) evaluated the impact of potable water availability on economic development of North Senatorial District of Benue State. The aim of the study was to evaluate the statistical relationship between availability of potable water and the economic development of the North Senatorial district of Benue state. The results showed that there was significant relationship between potable water supply and economic development of the senatorial district. The finding of the study revealed that only five out of Eighteen water supply projects in the senatorial district were in good working conditions which only represent about 42%. The results further revealed that about 75% which represented the majority of water supply projects in the Senatorial district offered poor quality of water supply services to the residents. The findings of the study also revealed that inadequate political will has negatively affected the State's water sub-sector, overall water supply and quality of services offered as well as its attendant impact on the economic development of the study area.

The study thus recommended the development of a state model that would improve water supply to communities of the study area. This may no doubt have a positive health, economic, and social impacts for the state and potentially, the country.

Ibrahim *et al.* (2014) assessed alternative water supply sources for domestic uses in Minna Metropolis, Niger State, Nigeria. The study opined that population growth occasioned by the trooping of people from different regions to seek better life in Minna, has compounded water supply challenge to the populace by conventional means. These challenges have triggered individual efforts to meet their daily water demand.

The study concluded that inadequate funds for the ministry of water resources contributed considerably to the poor management of water supply for domestic uses in the study area. The ministry could not replace the obsolete water equipments nor was it able to embark on new water works. The study further revealed that if the water supply situation is not urgently addressed, Minna Metropolis may end up in acute water problems in no distant future. The study made the following recommendations: adequate funding of the ministry of water resources should be prioritized. This is not restricted solely to budgetary allocation but a policy framework that attracts investors to the water sector; adequate implementation and management of the resources allocated to the ministry of water resources way in enhancing adequate and good quality water provision; the formulation and regulation of policies on private water provision should be taken seriously, especially Well water since this water form significant water supply to the study area. This will help ensure and enhance the portability of well water source.

2.5.3. Evaluation of health implications of consuming contaminated water

Jibrin *et al*. (2018) examined the causes and health implications of water pollution on domestic water sources in Hadeija Metropolis, Nigeria. The research objectives were to evaluate the causes of water pollution in domestic water sources at Hadeija metropolis, Nigeria, and the consequence of use of polluted water for domestic purposes on the health and safety of the community.

The study concluded that industrial activities, farming and sewage systems accounted for the major causes of water pollution in the study area and there is a closer link between pollution and health damages. The study thus recommended that the construction of domestic water supply pump units within quarters should be avoided. Rather, it should be connected with water link pipeline as a booster. The study also recommended that the construction of proper designed domestic water supply units and regular hygienic practices in and around the sources of water should be maintained. The study also suggested that filtering and boiling domestic water (especially for drinking purposes) before use, is crucial and will reduce waterborne diseases.

Kuta *et al*. (2014) examined sources of domestic water and its health consequences in Lapai Local Government Area of Niger State, Nigeria. The study concluded that most neighbourhoods in the study area suffers inadequate safe drinking water access and the condition is compounded by the existence of water related diseases, less physical and economic development, a condition which invariably made the communities poverty-ravaged with substantial number of residents deserting the communities. The study recommended adequate arrangement for water supply facilities at all government levels in the State, community involvements in the management of water supply facilities, employment of adequate, relevant and qualified staff at all levels such as management, technologists, technicians and other administrative professionals.

Gonfa *et al*. (2019) carried out an investigation of physicochemical and bacteriological parameters of water from sources to household connection in Nekemte town, Ethiopia. All water samples collected were analyzed for chemical, bacteriological and physical quality parameters employing standard procedures. The study concluded that the deterioration of water quality occurred at both the sources and in the supply networks and as a result, constitute serious health implication for the population who consume these low quality waters. The study attributed the occurrence of waterborne diseases to the consumption of contaminated water by human or animal feaces or urine that contains pathogenic bacteria such as cholera, typhoid, bacillary dysentery, adenoviruses, retroviruses, and other diseases. The study concluded that adequate drainage, sewage and refuse disposal systems, and adequate water disinfection with chlorine are highly significant to delivering safe drinking water to the people of Nekemte town.

Hadler and Islam (2015) examined the situation of pollution of Turag River and the health implications of the inhabitants of surroundings communities in Dhaka, the capital city of Bangladesh. The study used primary and secondary data.

The study concluded that its results have been confirmed by rigorous epidemiological studies. The study recommended that further studies including epidemiological studies should be embarked upon so as to have a better understanding of industrial activities effects on the environment and the people who interact with the environment.

Otufale and Coster (2012) evaluate water scarcity impact and water collection drudgery on women health in Ogun State, Nigeria. The study focused on effect and drudgery of water collection on women's health. The study used simple random technique in selecting 120 study's population (female) in the study area. Descriptive statistics and Pearsons Product Moment correlation were used in analyzing data by the study. The study concluded that improved access of women to adequate sources of water supply would help in maximizing their potentials; deplete stress and diseases that are occasioned by inadequate potable water.

2.6 Research Gap

As seen in the review of previous literatures, many researchers have focused in the past on the impact of human activities on quality of water in various parts of the world: Abd-Alla *et al.* (2011), Ayobahan *et al.* (2014), Aliyu (2014), Ogaga *et al.* (2018), Enitimi and Sylvester (2017), Idris *et al.* (2013), Irfan and Shakil (2012) all reported significantly high correlation between anthropogenic activities and water quality in Nigeria and other parts of the world. Additionally, majority of the researches observed that pollution of water resources posed significant risks to developmental sustainability especially in developing nations whose economies are resource based. These developing economies depend heavily on both surface and groundwater for domestic, industrial and agricultural uses.

Researchers explored various classes of human activities where Idris *et al.* (2013), examined heavy metal contamination of surface water by pharmaceutical industrial effluent. His results showed a significant correlation between industrial activities and water quality. While Aliyu (2014) explored numerous human activities such as agriculture, food processing, industries, etc, Irfan and Shakil (2012), focused on agriculture, Jibrin *et al.* (2018) focused on industrial, agriculture and domestic, Owhonda *et al.* (2018) explored urban effluent. All these activities according to the researches were reported to have effect on water quality.

Narrowed down to Nigeria in particular, researchers such as Ayobahan *et al.* (2014), Aliyu (2014) Ogaga *et al.* (2018) studied anthropogenic activities impact on water quality in various parts of the country and their results agreed with those of researchers around the globe where a considerable negative link was established between anthropogenic activities and water quality.

Although the researchers mentioned have carried out thorough researches on different water sources and their qualities in different parts of Nigeria and their results are considerably indicative of a deteriorating water quality. However, not enough interest seems to have been accorded to drinking quality water accessibility by residents and health consequences of poor water quality in the study area. In addition, Minna Metropolis and environs have grown significantly in terms of residence and human population in the last three decades implying that human activities will continue to grow which may lead to environmental degradation of which water is a component.

These constitute the reasons behind the choice of Minna as the study area. Therefore, this research strived to close this gap by examining the level of resident's access to quality drinking water, and the health implication of consuming polluted water.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Preamble

This chapter emphatically explains the materials and methods employed by this research in the evaluation of various pollution parameters (chemical and bacteriological) of some water sources in parts of Minna Metropolis with the aim of addressing the problems under investigation. This includes the techniques adopted for data collection, data sources, data analysis, sampling and sample collection, sample size, research design, presentation, determination and analysis of physicochemical and bacteriological parameters of sampled water. Thus, this research employed the use of sample survey method. The sample survey entails questionnaires administration, direct field observation, water samples collection and laboratory analysis of the sampled water.

3.2 Sources of Data

Both the primary and secondary data were explored in this research. The primary data were sourced through reconnaissance survey, laboratory analyzes, questionnaire administration, photographs, Global positioning system (GPS) usage, water samples and water sampling form. The secondary data were sourced from General Hospital, Minna, National Population Commission (NPC), Journal articles, W H O, N S D W Q, relevant textbooks and the internet.

3.3 Selection of Sampling Sites

The study collected water samples from that part of the study area where water sources such as Hand dug- wells, Boreholes were located at close proximity to the sites of human activities. Water Vendors also formed part of the water sources. The areas selected for water samples collection includes Chanchaga, Maitumbi,Tayir and Kpakungu respectively. Purposive sampling technique was adopted in the selection of the four areas. Purposive sampling (also known as judgment, selective or subjective sampling) is an acceptable kind of sampling for special situations.

Table 3.1: Sampled Water Sources and Global Positioning System Points

Sample Identification	Water Sources	GPS Points
CHG 1 (Chanchaga)	Hand dug well	9º32'45.9"N, 6º34' 47.9"E
CHG 2	Water Vendor	9º32'09.8"N, 6º34'47.4"E
CHG 3	Borehole	9º32'39.0"N, 6º34'54.5"E
MB 1 (Maitumbi)	Borehole	9º37'29.6"N, 6º34'48.9"E
MB 2	Hand dug well	9º38'28.7"N, 6º34'47.2"E
MB 3	Water Vendor	9º37'42.4"N, 6º34'05.4"E
TYR 1 (Tayir)	Borehole	9º38'28.0"N, 6º32'57.9"E
TYR 2	Water Vendor	
TYR 3	Hand dug well	9º38'42.3"N, 6º32'50.3"E
KPG 1(Kpakungu)	Hand dug well	9º36'02.8"N, 6º31'33.5"E
KPG 2	Borehole	9º35'52.2"N, 6º31'33.5"E
KPG 3	Water Vendor	

Source: Author's Fieldwork, 2019

3.4 Water Sample Collection

Global positioning system was employed in taking the coordinates of the locations of sampling. In all, twelve water samples were collected from the sampling points, adopting Purposive Sampling Technique. Hand-dug wells, Boreholes and Water Vendors water were collected as samples. The fresh water samples were manually collected in clean 1 litre plastic containers from Chanchaga (CH), Maitumbi (MB), Tayir Village (TV) and Kpakungu (PK) respectively. Every necessary attributes of the water samples sources were dully on the water sampling form. The water containers were labeled accordingly and stored in plastic cooler (Ice pack). The cooler was cooled with ice cubes and immediately transported to the laboratory for test and analyses.

3.5 Sampling and Sample Size

The selection of accurate sample size is very crucial in order to arrive at a reliable result. A sample size therefore is the number of the population elements selected for the research. The study used the 1991 population figures of Chanchaga, Tayir Village, Maitumbi and Kpakungu and then, projected the total population figures of the areas up to 2018.

Sample size was obtained using Yamani's sample size formula. Yamani's formula is focused on applying a normal approximation with 95% confidence level and a limit of tolerance level (error level) of 5%. According to 1991 population census, Chanchaga area had a population figure of 14777, Tayir had 3726, Maitumbi had 366 while Kpakungu had 11298. Therefore, the four areas had a total population figure of 30167. Therefore, the total population figures of the four areas which stood at 30167 were projected up to 2018.

Population projection:

$$\mathrm{PF} = PP\left(1 + \frac{\mathrm{r}}{100}\right)^{\mathrm{n}} \tag{3.1}$$

Where:

PF= Future Population (2018)

PP= Present Population (30167)

r = Annual Growth Rate (3.2%)

n = difference (27 years).

Therefore, $\mathrm{PF} = 30167\left(1 + \frac{3.2}{100}\right)^{27}$

$$\mathrm{PF} = 30167(1 + 0.032)^{27}$$

$$\mathrm{PF} = 30167(1.032)^{27}$$

PF = 30167x 2.341

PF = 70621

The 2018 projected population of Chanchaga, Tayir Village, Maitumbi and Kpakungu at 70621 was used in determining the sample size using Yamani's population sample size formula given as:

$$n = \frac{N}{1 + Ne^2}$$

n = the sample size; N = population figure; e = the limit of tolerance (0.05)

$$n = \frac{70621}{1+70621(0.05)^2} = \frac{70621}{1+70621(0.0025)} = \frac{70621}{1+176} = 398 \text{ respondents}$$

Therefore n = 398

The study population was 398 and simple random sampling was employed in distributing the questionnaires among the residents of the study area. This data source was used to achieve objectives two and three of the study.

3.6 Method of Laboratory and Data Analysis

Water samples were analyzed for relevant water quality parameters at an accredited laboratory in Minna, Niger State. Physicochemical and Bacteriological analysis were done using standard method. Method of data analysis adopted for the research objectives are described as follow:

3.6.1 Analyses of physicochemical and bacteriological parameters of water sources

The determination of physicochemical and bacteriological Parameters relied on the laboratory standard procedures for determining water quality parameters. The physicochemical and bacteriological results from the laboratory were analyzed employing descriptive statistics. The results were compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) standards. The results were presented in table. Objective two which sought to compare the physicochemical and bacteriological parameters of water with world Health Organization standards were also presented in table.

Objective three which examined the level of resident's access to potable water supply was analyzed using descriptive statistical tools. The results were presented using tables and graphs. Objective four which sought to evaluate the health implications of consuming contaminated water in the study area was analyzed using descriptive statistics. The results were presented in tables and graphs.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Analyses of Physicochemical and Bacteriological Parameters of Water

The result of physicochemical analysis of water revealed that the pH of the twelve water samples from the four selected areas falls within the range permissible by the Nigerian standards of (6.5-8.5) for drinking water. The lowest value of 6.67 was reported at Chanchaga; while the highest value of 7.38 was obtained at Tayir village. Although pH does not have health implication on humans, however, it has indirect action on physiological process (Adekunle *et al*., 2007). This result agreed with the work of Ojutiku *et al.* (2014) where it was reported that the pH values of the six selected areas in Minna Metropolis and Environs fell within the range stipulated by the N S D W Q. The result also agreed with the work of Ajai, *et al*. (2011) where it was reported that all except 1water sample source fell in line with the permissible pH range recommended by NSDWQ.

Analysis showed that Hardness ranged from 40 mg/l – 500 mg/l. The level of hardness of the water sampled were high for seven water samples as they were above 150 mg/l specified by NIS. The least value of hardness, 40 mg/l was recorded at Maitumbi 1 whose water sample was collected from Borehole. The highest value of 500 mg/l was reported at Kpakungu tagged as KPG 2 whose water sample was collected from Borehole. As reported by Adeyeye and Abulude (2004), water hardness is often categorized as soft water if its hardness ranged from 0-75 mg/l $CaCO_3$/l, as hard water if its hardness ranged from 75-150 mg/l $CaCO_3$/l and as very hard water if its hardness is over 350 mg/l $CaCO_3$/l. In view of this, majority of the study’s water samples may be categorized as hard water since they have values above 75 mg/l $CaCO_3$/l except one water sample where a value of 40 mg/l was recorded. The Nigerian Industrial Standards did not specify health implications of excess hardness in water on human beings.

This result agreed with the study of Ajai *et al*. (2011) who submitted that most water samples had hardness that ranged from 103-247 mg/l $CaCO_3$/l.

Dissolved Oxygen ranged from 1.11to 2.10 mg/l, indicating low dissolved oxygen for all the water samples. The probable reason for the low values of dissolved oxygen recorded in all the sampled water could be because of the fact that the sampled waters were mostly groundwater with covers. The least value of 1.11mg/l was reported at Tayir Village while 2.10mg/l being the highest value was obtained at Chanchaga and Maitumbi, respectively. Dissolved Oxygen in all the water samples from the four selected areas recorded values below the 10mg/l NIS threshold. This result is similar to the work of Ohwo and Abel (2014) where they reported that all except one water sample had Dissolved Oxygen below the 6mg/l WHO threshold in Yenagoa, Bayelsa State. Furthermore, they reported that adequate dissolve oxygen is paramount for quality water and the insufficient of it in body tissues gives rise to red blood cells defect. Drinking water with insufficient dissolved oxygen level further compounds the condition by the constriction of blood vessels in the lungs (Ohwo and Abel, 2014).

Biological Oxygen Demand ranged from 0.50mg/l -1.22 mg/l. The least BOD value of 0.50mg/l was reported at Chanchaga, tagged as CHG 3 whose source of water sample is Borehole. The highest value of biological oxygen demand was reported at Tayir village, whose source of water sample was a Hand Dug Well. All the water samples from the four selected areas fell below the $\geq$6 mg/l WHO limit for potable water. This result is in agreement with the result of the work of Eseigbe *et al*. (2018) work in Abeokuta Metropolis where it was reported that the 50 water samples analyzed recorded biological oxygen demand values below ≥6 mg/l WHO threshold for potable water. They further reported that the low biological oxygen demand values recorded for the 50 water samples implied that the samples witnessed low organic pollution, and that the analyzed water samples connoted aquatic habitats that are capable of supporting the marine organisms.

Laboratory analysis of phosphate showed that it ranged from 0.22 mg/l – 1.20mg/l. The lowest value of 0.22mg/l was obtained at Tayir Village whose source of water sample was water Vendor. The highest value of 1.20mg/l was obtained at Kpakungu, whose source of water sample was Hand Dug Well. The limit of phosphate concentration in drinking water is not specified by the N S D W Q. However, Fadiran, Dlamini and Mavuso (2007) reported that the natural phosphates concentrations in surface and groundwater bodies posed no harm to the health of humans, animals or the environment. However, excessive concentration of phosphates can cause digestive challenges (Fadiran, *et al*., 2007).

Laboratory analysis revealed that Ammonia ranged from 0.34mg/l-1.15mg/l with mean value of 0.75mg/l. The lowest Ammonia value of 0.34mg/l was recorded at Tayir village whose source of water sample is water vendor. The highest value of 1.15mg/l was obtained at Chanchaga, whose source of water sample is Borehole. The maximum contamination level is not specified by both the Nigerian Industrial Standards and World Health Organization. However, the National Academy of Science (NAS) recommends a threshold of 0.5mg/l in drinking water. In view of this recommendation, it can be concluded that nine out of the twelve water samples from the four selected areas had values above the 0.5mg/l of NAS threshold. Only three water samples recorded values that fell within the NAS threshold of

0.5mg/l. As reported by Oregon Department of Human Services' Environmental Toxicology Section (2000), humans and advanced animals have low sensitivity to Ammonia in water, prolonged intake of water that contains more than 1mg/l Ammonia may be detrimental to internal organ systems.

The result of laboratory analysis revealed that Nitrate ranged from 0.11mg/l-0.92mg/l. The least value of 0.11mg/l nitrate was obtained at Tayir village while the highest value of 0.92mg/l was reported at Maitumbi. All the water sampled recorded values well below the WHO and NSDWQ threshold of 50mg/l for potable water as shown in 4.1. The low values of nitrate recorded in all the study's water samples may be due to the fact that all the water samples, except those from water vendors whose sources were not clearly stated, were groundwater. This conforms to findings in literature where it was reported that nitrate in groundwater decreases as depth increases (Akinwum *et al*., 2012). According to Environmental Protection Agency (EPA, 2014), nitrate is a form of nitrogen that is most highly oxidized. The main sources of nitrate in drinking water include runoff from fertilizer application; septic tanks leakage; sewage; and natural deposits erosion (EPA, 2014). Health implication of excess of nitrate in drinking water is Cyanosis and Asphyxia known as ("blue-baby syndrome'') in infants less than 3 months. Furthermore, high concentration of Nitrate in drinking water may likely trigger cancer risk in adults because Nitrate is endogenously depleted to Nitrite and subsequent nitrosation reactions leads to N-nitroso compounds (NOCs), which contains high cancer risk and can act systematically (Njeze *et al*., 2014). However, in view of the result of this study, it may be concluded that all the water sampled had low concentration level of nitrate, well below the 50mg/l of nitrate NIS threshold.

Table 4.1showed that nitrite values ranged from 0.10mg/l-0.76mg/l, with the least value of 0.10mg/l nitrite obtained at Tayir village. The highest value of 0.76mg/l was reported at Maitumbi. The values of nitrite recorded in nine water samples were above the optimal value of 0.2mg/l specified by the N S D W Q. Only three water samples had values below the NSDWQ threshold of 0.2mg/l. Health implication of drinking water containing high concentration of nitrite is Cyanosis and Asphyxia known as (Blue-baby syndrome) in toddlers less than 3 months (NIS, 2015). Like Nitrate, the main Nitrite sources in drinking water include runoff from fertilizers, sewage and mineral deposit. The probable reasons for the high level of Nitrite in the study's area groundwater could be due to lack of health privacy of Hand dug wells and Boreholes; the impact of sinking of Boreholes and Hand dug wells without proper compliance with the minimum 15 metres setbacks distance between Hand Dug Wells and soak away or pit latrines on one hand, and between Boreholes and soak away or pit latrines on the other. Therefore, high concentration levels of nitrite in the sampled water could be due to human activities such as placement of Boreholes and Hand Dug Wells in the direction of flow of groundwater.

Table 4.1: Laboratory Analyses of Physicochemical and Bacteriological Parameters of Water

	Sampling Points and Water Sources														
	TAYIR			CHANCHAGA			KPAKUNGU			MAITUNBI					
Parameters	BW	WV	HDW	HDW	WV	BW	HDW	BW	WV	BW	HDW	WV	Mean	Range	NIS
Ph	7.38	6.96	6.74	6.67	7.25	7.42	6.72	7.23	6.89	6.82	7.08	6.72	6.99	0.75	6.5-8.5
Hardness (mg/l)	110	210	60	80	160	120	250	500	180	40	210	170	174.2	460	150
DO (mg/l)	1.11	1.40	1.90	2.10	1.22	1.35	1.90	1.99	1.84	1.80	2.05	2.10	1.73	0.99	10
BOD (mg/l)	0.60	1.04	1.22	1.02	0.60	0.50	1.14	1.2	0.88	0.44	0.55	0.80	0.83	0.78	6
Phosphate (mg/l)	0.22	0.61	0.52	0.40	0.31	0.38	1.20	1.19	1.13	0.88	0.62	0.74	0.68	0.98	-
Ammonia (mg/l)	0.34	0.47	0.59	0.40	0.69	1.15	0.90	0.62	0.55	1.09	1.07	1.02	0.75	0.81	-
Nitrate (mg/l)	0.11	0.15	0.19	0.40	0.37	0.71	0.23	0.35	0.43	0.77	0.89	0.92	0.46	0.81	50
Nitrite (mg/l)	0.14	0.10	0.12	0.33	0.29	0.61	0.18	0.28	0.31	0.57	0.76	0.73	0.36	0.66	0.2
E.Coli (cfu/ml)	12	18	6	NIL	NIL	TNTC	22	20	39	36	11	22			0
S.Typhi (cfu/ml)	TNTC	NIL	10	19	20	TNTC	42	NIL	TNTC	30	NIL	TNTC			0
S.Aureus (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL			0
P. Aeruginosa (cfu/ml)	6	NIL	NIL	NIL	NIL	4	NIL	NIL	NIL	NIL	NIL	5			0

Source: Author's Field work, 2019

Laboratory analyses of the study's water samples showed that some domestic water sources are contaminated by pathogenic bacteria as shown in Table 4.1. The unavailability of pathogenic bacteria contaminants in a water source account for the main factors for tagging such water as safe source of drinking (potable) water. Laboratory analysis showed that *Escherichia Coli* known as *E .Coli* ranged from 6cfu/ml-39cfu/ml, to Too Numerous to Count in one of the samples. Two of the study's water samples recorded Zero value of cfu/ml. The lowest value of 6cfu/ml was recorded at Tayir village, whose source of water sample was from an Hand Dug Well. The 39cfu/ml was recorded at Kpakungu, whose water source was from a water vendor. The TNTC cfu/ml was recorded at Chanchaga, whose source of water sample was from a Borehole as shown in Table 3.1. Going by this result, 10 water sources out of 12 were contaminated by *E .Coli*. This implies that only 2 water sources out of the 12 water sources met the Nigerian Industrial Standard of Zero *E .Coli.* in drinking (potable) water. This result is similar to the result of Eseigbe *et al*. (2018) where it was reported that 5 out of 50 water samples were contaminated by pathogenic bacteria. Water sources contaminated by pathogenic bacteria such as E Coli are classified as unsafe for drinking purpose (NIS, 2015). Health implications of consuming water contaminated by *E.Coli* include infections of the urinary tract, bacteraemia, meningitis, diarrhea, morbidity and mortality among kids, acute renal dysfunction and haemolytic anaemia (NIS, 2015).

Laboratory analysis result as shown in Table 4.1 revealed that Salmonella typhimurium ranged from 0cfu/ml-42cfu/ml. Zero cfu/ml was recorded in 3 out of 12 water samples sources. Four water samples recorded Too Numerous to Count (TNTC) cfu/ml, while 5 water samples had values that ranged from 10cfu/ml-42cfu/ml. The 3 water samples that recorded 0cfu/ml of Salmonella Typhimurium conform to the Nigerian Standards for Drinking Water

Quality (NSDQW, 2015) threshold of 0cfu/ml in drinking water. However, the remaining 9 samples with values ranging from 10cfu/ml-TNTC were well above the NIS threshold of 0cfu/ml in drinking water. This study's result is similar to the study carried out by Oyedum *et al*. (2016) where it was reported that 100% of Wells water sampled in Bosso town were all contaminated by *Coli form* counts above 10cfu/100ml. Furthermore, it was reported that *Salmonella Typhimurium* ranked 4th among the organisms isolated in descending order of contamination levels. The presence of *Salmonella Typhimurium* in the sampled water sources is clear case of feacal contamination and the probable reasons for fecal contamination of water include unhygienic practices, sinking of Boreholes some few meters from septic tanks or pit latrines, indiscriminate refuse dumps, open defecation. Unprotected Wells could easily be contaminated by fecal particles which could be washed into the Wells by rain or floods. Health implications of consuming water contaminated by *Salmonella Typhimurium* include typhoid fever and internal bleeding (Oyedum *et al*., 2016). Furthermore, infants and young children are more vulnerable to infection, easily achieved by taking in a small number of bacteria (Bharawaj and Sharma, 2016). Infants may be infected through inhalation of bacteria-laden dust (Bharawaj and Sharma, 2016).

As seen in Table 4.1, all the water samples (100%) from the four selected areas recorded 0cfu/ml of *Staphylococcus aureus*. The 0cfu/ml of *Staphylococcus Aureus* recorded in all the water samples met the NIS 0cfu/ml of *Staphylococcus Aureus* threshold. *Staphylococcus Aureus* does not always mean pathogens, rather, it causes infections of the skin such as abscesses, respiratory infections such as sinusitis, and poisoning of food (Bharawaj and Sharma, 2016). Particularly, Staphylococcus accounts for main common causal agents of bacteremia and infective endocarditis (Bharawaj and Sharma, 2016). Additionally, it is capable of causing different skin and soft tissue infections (Tong *et al.*, 2015).

As shown in Table 4.1, *Pseudomonas Aeruginosa* ranged from 0cfu/ml-6cfu/ml. Nine out of 12 water samples which represent 75% recorded 0cfu/ml *Pseudomonas Aeruginosa* while 3 water samples which represent 25% recorded values that ranged from 4cfu/ml-6cfu/ml *Pseudomonas Aeruginosa*. This implies that 9 water samples sources met the NIS 0cfu/ml *Pseudomonas Aeruginosa* in potable water. However, 3 water samples sources recorded values above NIS 0cfu/ml *Pseudomonas Aeruginosa* in drinking water. The water samples that met the 0cfu/ml NIS threshold were recorded at Tayir 2 and 3, Chanchaga 1 and 2, Kpakungu 1, 2 and 3, and Maitumbi 1 and 2 as shown in Table 3.1. This result is similar to the work of Shittu *et al*. (2014) where it was reported that out of 288 water sampled for Pseudomonas Aeruginosa, positive results were recorded in 1(2.4%) bottled water; 5(12.2%) sachet water; 6 (14.6%) tap water; 12 (29.3) well water; 9 (22.0%) swimming pool and 8 (19.5%) hospital storage tank. They further reported that isolation of *Pseudomonas Aeruginosa* in drinking water implies the impairment of water quality. *Pseudomonas Aeruginosa* is a multi-drug resistance pathogen (Shittu *et al*., 2014). The organism is mostly present in natural waters such as rivers and lakes in concentrations of 10/100ml to >1000/100ml (Mena and Gerba, 2009). *P. Aeruginosa* is not usually exists in drinking water; its occurrence in drinking water may be attributed to its capability to colonize bio-films in plumbing materials such as faucets, shower caps (Mena and Gerba, 2009). The health impact of *Pseudomonas Aeruginosa* in drinking water include Endocarditis, Osteomyelitis, Pneumonia, infections of the urinary tract, gastrointestinal infections, and Meningitis, and it is a major cause of Septicemia (Mena and Gerba, 2009). Other infections associated with *Pseudomonas Aeruginosa* are Keratitis; especially in patients that wears lenses, Folliculitis and ear infections contracted through contact with recreational waters containing the bacterium (Mena and Gerba, 2009).

4.2 Comparison of Physicochemical and Bacteriological Parameters with World Health Organization (WHO) Standards

This section essentially compares the results of laboratory analysis of physicochemical and bacteriological parameters of water sampled with World Health Organization standards. This is aimed at ascertaining the water sampled suitability for domestic and drinking purposes.

The result of physicochemical analysis of water showed that the pH of the twelve water samples from the four selected areas fell within the range of 6.5-8.5W H O’s threshold for potable water. The least value of 6.67 was obtained at Chanchaga; while the highest value of 7.38 was reported at Tayir village.

Analysis showed that Hardness ranged from 40 mg/l – 500 mg/l in the 12 water samples. The lowest value of 40mg/l was obtained at Maitumbi tagged as MB 2 in Table 3.1, while the highest value of 500mg/l of hardness was obtained at Kpakungu, tagged as KPG 2 in Table 3. The maximum limit of the degree of hardness in drinking water is not specified by World Health Organization. The health implication of excessive hardness of drinking water is not specified by W H O. However, diseases associated with excess water hardness include cardiovascular challenges, diabetes, reproductive dysfunction, neural diseases and renal malfunction (Pallav, 2013).

As shown in Table 4.2, Dissolved Oxygen ranged from 1.11-2.10mg/l, with average value of 1.73mg/l for the 12 water sampled. The least value of 1.11mg/l was obtained at Tayir village tagged as TRY 1 in Table 3.1, with the highest value of 2.10mg/l reported at Tayir Village and Maitumbi, tagged as TRY 2 and MB 3, respectively. All the water sampled from the four selected areas had values below the 6 mg/l W H O threshold. It can be inferred from this result that all the water sampled in the four selected areas had low concentration of dissolved oxygen. The probable reason for this could be likened to the fact that water sampled were mostly groundwater sources which were mostly not opened. Ohwo and Abel (2014) reported in their work that sufficient dissolved oxygen is paramount for quality water and that insufficient oxygen in body tissues causes red blood cells defect and constrict blood vessels in the lungs (Ohwo and Abel, 2014).

Table 4.2: Comparison of Physicochemical and Bacteriological Parameters with WHO Standards

	Sampling Points and Water Sources														
	TAYIR			CHANCHAGA			KPAKUNGU			MAITUNBI					
PARAMETERS	BW	WV	HDW	HDW	WV	BW	HDW	BW	WV	BW	HDW	WV	Mean	Range	WHO
pH	7.38	6.96	6.74	6.67	7.25	7.42	6.72	7.23	6.89	6.82	7.08	6.72	6.99	0.75	6.58.5
Hardness (mg/l)	110	210	60	80	160	120	250	500	180	40	210	170	174.2	460	150
DO (mg/l)	1.11	1.40	1.90	2.10	1.22	1.35	1.90	1.99	1.84	1.80	2.05	2.10	1.73	0.99	10
BOD (mg/l)	0.60	1.04	1.22	1.02	0.60	0.50	1.14	1.2	0.88	0.44	0.55	0.80	0.83	0.78	6
Phosphate (mg/l)	0.22	0.61	0.52	0.40	0.31	0.38	1.20	1.19	1.13	0.88	0.62	0.74	0.68	0.98	-
Ammonia (mg/l)	0.34	0.47	0.59	0.40	0.69	1.15	0.90	0.62	0.55	1.09	1.07	1.02	0.75	0.81	-
Nitrate (mg/l)	0.11	0.15	0.19	0.40	0.37	0.71	0.23	0.35	0.43	0.77	0.89	0.92	0.46	0.81	50
Nitrite (mg/l)	0.14	0.10	0.12	0.33	0.29	0.61	0.18	0.28	0.31	0.57	0.76	0.73	0.36	0.66	0.2
E. Coli (cfu/ml)	12	18	6	NIL	NIL	TNTC	22	20	39	36	11	22			0
S. Typhi (cfu/ml)	TNTC	NIL	10	19	20	TNTC	42	NIL	TNTC	30	NIL	TNTC			0
S. Aureus (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL			0
P. Aeruginosa (cfu/ml)	6	NIL	NIL	NIL	NIL	4	NIL	NIL	NIL	NIL	NIL	5			0

Source: Author’s Field work, 2019

Laboratory analysis revealed that Biological Oxygen Demand (BOD) ranged from 0.44-1.22mg/l with average value of 0.83mg/l. The least value of 0.44mg/l was obtained at Maitumbi, tagged as MB 1 in Table 3.1, with the highest value of 1.22mg/l obtained at Tayir village, tagged as TRY 3 in Table 3.1. This implies that all the water sampled recorded values well below ≥6.00mg/l W H O threshold, and the water sources are thus considered good for drinking as it is an indicative of less organic pollution. The probable reason for the low values of BOD recorded in all the water sampled could be attributed to less organic pollution of the water sources. The water analyzed thus implied aquatic habitats that are conducive for the existence of marine organisms (Eseigbe *et al*., 2018).

Table 4.2 showed that Phosphate ranged from 0.22mg/l-1.20mg/l with average value of 0.68mg/l. The least value of 0.22mg/l phosphate was obtained at Tayir village, tagged as TRY 1 in Table 3.1, while the highest value of 1.20mg/l obtained at Kpakungu, tagged as KPG 1. The limit of phosphate concentration in drinking water is not specified by World Health Organization. However, Fadiran *et al.* (2007) reported that the natural occurrence amount of phosphates in surface and groundwater bodies posed no harm to health of humans, animals or the environment. Conversely, extremely high concentration of phosphates is capable of causing digestive challenges (Fadiran *et al*., 2007).

The values of Ammonia as analyzed ranged from 0.34mg/l-1.15mg/l with average value of 0.75mg/l. The least value of 0.34mg/l was obtained at Tayir village, tagged as TRY 1 in Table 3.1, with the highest value of 1.15mg/l reported at Chanchaga, tagged as CHG 3.The maximum concentration level of Ammonia is not specified by World Health Organization. However, the National Academy of Science (NAS) recommends a threshold of 0.5mg/l in drinking water. In view of this recommendation, it can be concluded that nine water samples from the four selected areas had values above the 0.5mg/l of NAS threshold. Only three water samples fell within the limit of 0.5mg/l NAS threshold. As reported by Oregon Department of Human Services' Environmental Toxicology Section (2000), human beings and advanced animals are less sensitive to Ammonia in water, but sustained ingestion of water containing more than 1mg/l Ammonia may be detrimental to internal organ systems.

Table 4.2 revealed that Nitrate ranged from 0.11-0.92mg/l with average value of 0.46mg/l. The least value of 0.11mg/l of nitrate was obtained at Tayir village tagged as TRY 1 in Table 3.1 the highest value of 0.92mg/l of nitrate was obtained at Maitumbi, tagged as MB 3 in Table 3.1. The values of nitrate recorded in all the water sampled were below 50mg/l W H O threshold for potable water. The low values of nitrate recorded in all the study's water sampled could be attributed to the fact all the water sampled were mostly groundwater. This conforms to findings in literature where it was reported that nitrate in groundwater decreases as depth increases (Akinwumi *et al*., 2012). Health implication of too much nitrate in drinking water is Cyanosis and Asphyxia known as ("blue-baby syndrome'') in toddlers below 3 months.

Laboratory analysis showed that Nitrite ranged from 0.10mg/l-0.76mg/l with average value of 0.36mg/l. The least value of 0.10mg/l was obtained at Tayir village, tagged as TRY 2 in Table 3.1, and the highest value of 0.76mg/l was obtained at Maitumbi, tagged as MB 2. The limit of nitrite concentration in drinking water is not specified by World Health Organization. No health implication was specified for nitrite by the WHO. The major nitrite sources in drinking water include runoff from fertilizers, sewage and mineral deposit.

Bacteriological analysis of the water sampled showed that *E .Coli* ranged from 0-Too Numerous to Count (TNTC) cfu/ml. The lowest value of E. coli, that is, 6cfu/ml was recorded at Tayir village, tagged as TRY 3 in Table 3.1, while Too Numerous to Count cfu/ml was recorded at Kpakungu, tagged as KPG 3. However, 2 water samples recorded 0cfu/ml, and were recorded at Chanchaga, tagged as CHG 1 and Chg 2, respectively. This result showed that only 2 water sampled values were within the 0cfu/ml W H O threshold. Ten water sampled had values well above W H O's threshold of 0cfu/ml in drinking water. In view of W H O's standard requirement for drinking water, a quality water source should be absolutely free from bacteria. From the result, however, the 10 water sampled with *E .Coli* concentration are thus considered not safe for drinking as recommended by W H O. Health implications of consuming water contaminated by *E.Coli* include infections of the urinary tract, bacteraemia, meningitis, diarrhea, morbidity and mortality among kids, acute renal collapse and haemolytic anaemia (WHO, 2012).

Result of the laboratory analysis showed that *Salmonella Typhimurium* ranged from 0cfu/ml-TNTCcfu/ml. The least value of 0cfu/ml was recorded at Tayir village, Kpakungu and Maitumbi, tagged as TRY 1, KPG 2 and MB 2, respectively as shown in Table 3.1. Too Numerous To Count values were recorded in the four selected areas, tagged as TRY 1, CHG 3, KPG 3 and MB 3 as shown in Table 3.1. Three water sampled recorded 0cfu/ml of *Salmonella Typhimurium,* four water sampled recorded TNTC cfu/ml, while the remaining five water sampled recorded values that ranged from 10cfu/ml-42cfu/ml. In view of this, only three water samples out of 12 were within the W H O' limit of 0cfu/ml of bacteria in drinking water. Nine water sampled had *Salmonella Typhimurium* values well above W H

O’s 0cfu/ml of bacteria in drinking water. Therefore, going by World Health Organization’s standard, water sampled that contained *Salmonella Typhimurium* are considered not safe for drinking. The presence of *Salmonella Typhimurium* in the sampled water sources is clear case of feacal contamination and the probable reasons for fecal contamination of water include unhygienic practices, sinking of Boreholes some few meters from septic tanks or pit latrines, indiscriminate refuse dumps, open defecation. Health implications of consuming water contaminated by *Salmonella Typhimurium* include Typhoid fever and internal bleeding as reported by Oyedum *et al*. (2016). Infants and kids are more susceptible to infections, easily made possible by ingesting a small number of bacteria (Bharawaj and Sharma, 2016).

Laboratory analysis of the water sampled revealed that Staphylococcus Aureus was not present in all the water sampled. The 12 water sampled recorded 0cfu/ml of Staphylococcus Aureus. This implies that the 0cfu/ml of *Staphylococcus Aureus* recorded in all the water samples met the W H O’s 0cfu/ml of *Staphylococcus Aureus* threshold. Staphylococcus Aureus is the most prevalent causes of bacteremia and infective endocarditis (Bharawaj and Sharma, 2016). Additionally, it is capable of causing different skin and infections of soft tissues (Tong *et al*., 2015).

As shown in Table 4.2, *Pseudomonas Aeruginosa* ranged from 0cfu/ml-6cfu/ml. Nine out of 12 water sampled recorded 0cfu/ml, while the remaining 3 water sampled recorded values that ranged from 4cfu/ml-6cfu/ml. This implies that 9 water samples sources met the W H O’s 0cfu/ml *Pseudomonas Aeruginosa* in potable water. However, 3 water samples sources recorded values above W H O’s 0cfu/ml *Pseudomonas Aeruginosa* in drinking water. The health impact of *Pseudomonas Aeruginosa* in drinking water include Endocarditis, Osteomyelitis, Pneumonia, infections of the Urinary tract, infections of gastrointestine, and

Meningitis, and it is a leading cause of Septicemia (Mena and Gerba, 2009). Other infections associated with *Pseudomonas Aeruginosa* are Keratitis, specifically in lenses wearing patients, Folliculitis and ear infections contracted by exposure to recreational waters containing the bacterium (Mena and Gerba, 2009).

4.3 Examination of the Level of Resident's Access to Potable Water Supply in parts of Minna Metropolis

The World Health Organization and United Nations International Children and Education Fund's joint monitoring (WHO/UNICEF, 2006) defined access to potable water as the proportion of persons with access to improved sources of drinking water. Reasonable access is seen as the presence of at least 20 litres of water per person per day from a safe source within one kilometer of the user's abode. Access to safe water is quantified by the number of population who possessed considerable means of accessing sufficient quantity of water deemed safe for drinking, washing and performing other necessary household chores, expressed as a percentage of the total population.

4.3.1 Sources of domestic water supply to the population

From Table 4.3, it can be revealed that 14.1% of the sampled populations depend on Pipe-Borne water as their domestic water supply source. 20.6% of the residents used Hand Dug Well as their source of domestic water supply from. 2.3% of the populations sampled depend on River for their domestic water supply sources and 25.8% depend on Water Vendors for their water supply sources. However, the majority of the populations sampled rely on Borehole water for their domestic water supply sources. This clearly showed that the majority of the populations depend on alternative sources of water supply for domestic purposes. This is in alignment with the work of Ibrahim *et al*. (2014) where it was reported that 88% of the sampled populations in Chanchaga depend on Well- water as alternative source to Pipe-borne water, 53% of the sampled populations at Keteren Gwari depend on Water Vendors and 27% use water from wells while 20% depend on Borehole water.

This clearly showed that the supply of Pipe-borne water that is regarded as potable water is grossly inadequate. This is capable of inflicting more sufferings on the residents.

Table 4.3: Sources of Domestic Water Supply to the Residents

Sources of Water	Frequency	Percentage (%)
Pipe-borne water	56	14.1
Borehole	148	37.2
Hand dug well	82	20.6
River	9	2.3
Water Vendor	103	25.8
Total	**398**	**100**

Source: Author's Fieldwork, 2019

4.3.2 Factors influencing sources of domestic water supply

As revealed by the residents in Table 4.4, frequency of availability of water supply influenced water supply access in parts of Minna Metropolis. As showed in the table, 45.9% of the sampled populations attested to the fact. Meanwhile, 36.7% of the residents were of the opinion that proximity to residence is a factor that influences access to source of water supply and 17.4% of the sampled populations attested to the fact that cost is a major that influences water supply access. This result is in line with the distance decay theory which is of the main idea that as the distance increases, utilization of facility reduces.

Table 4.4: Factors Influencing Source of Domestic Water Supply

Factors	Frequency	Percentage (%)
Proximity to Residence	146	36.7
Frequency of Availability	183	45.9
Cheap and Affordable Source	68	17.4
Total	**398**	**100**

Source: Author's Study, 2019

4.3.3 Major provider of domestic water supply

As revealed in table 4.5, 22% of the respondents sampled attested Niger State Water Board (NSWB) is the major provider their domestic water supply, while 23.8% of the sampled populations identified self-help and 7.1% pointed to community effort as responsible for their water supply sources. However, majority of the populations identified commercial water vendors as the major domestic water supply sources. This result agreed with the works of Ibrahim *et al*., (2014) and Adegbehin *et al*. (2016) where Boreholes operated by the commercial water vendors were identified as the major alternative domestic water supply sources to the residents of Minna.

Table 4.5: Major Provider of Domestic Water Supply

Provider	Frequency	Percentage (%)
NSWB	89	22.4
Self-help	95	23.8
Community Efforts	28	7.1
Water Vendors	186	46.7
Total	**398**	**100**

Source: Author's Study, 2019

4.3.4 Efficiency of domestic water supply

From Table 4.6, it can be seen that 36.2% of the sampled populations which represent the majority agreed that they have access to sufficient domestic water supply. This may be likened to the proliferation of commercial Boreholes in the study area by both individuals for private uses and the water Vendors for commercial purpose. Evidence to this result can be found in the work of Ibrahim *et al*. (2014) where it found that majority of the respondents of Minna Metropolis rely on Borehole water as the alternative source of water to Pipe-borne water. 34.4% of the sampled populations strongly agreed that they have access to domestic water supply. This is attributable to the proliferations of Boreholes in the study area. However, 62 residents which represent 15.6% of the sampled populations disagreed that they have access to sufficient water supply and 55 residents which represent 13.8% of the respondents strongly disagreed with the view that they have access to sufficient domestic water supply.

Table 4.6: Efficiency of Domestic Water Supply

Residents Opinion	Frequency	Percentage (%)
Agreed	144	36.2
Strongly Agreed	137	34.4
Disagreed	62	15.6
Strongly Agreed	55	13.8
Total	**398**	**100**

Source: Author's Study, 2019

4.3.5 Residents daily quantity of water usage

Resident's average quantity of water utilization per capita per day as seen in Figure 4.1, showed that all the residents sampled consumed above the WHO/UNICEF crucial limit of 20 litres per capita per day. As shown in Table 4.6, 153 residents that represent 38.4% of the sampled populations use between 50-100 litres of water per capita per day. 128 residents that represent 32.2% of the population consumed between 101-150 litres of water per capita per day. 64 residents which represent 16.1% of the respondents uses between 151-200 litres of water per capita per day, while 53 residents that represent 13.3% of the population use above 200 litres of water per capita per day. The accessibility of the sampled populations to more than the WHO/UNICEF critical threshold of 20 litres of water per capita per day is attributable to the resident's access to alternative sources of water such as Hand dug wells and Boreholes in the study area. This is in line with the work of Ibrahim *et al*. (2014) where it was reported that the majority of the sampled residents in Chanchaga and Keteren Gwari depend on alternative domestic water supply sources.

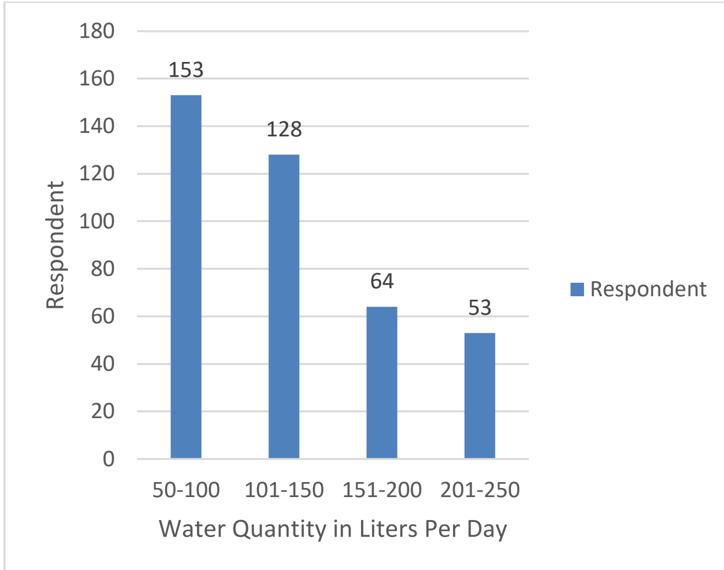

Figure 4.1: Residents Quantity of DailyWater Usage

Source: Author's Field work, 2019

4.3.6 Accessibility to water supply

Accessibility to water supply is a function of distance cover from individual's residence to the water collection location and the time spent. Reasonable water supply access is the presence of at least 20 litres of water per person per day from a source not more than 1 kilometer of the consumer's residence (WHO/UNICEF, 2006). In view of this definition, one may conclude that considerable numbers of residents in the study area enjoyed considerable access to water supply in that, the distance of majority of the population to their water supply sources falls within 1 kilometer. This is shown in Table 4.7, where 96.3% of the population covers less than 1 Kilometer to water collection points. 3.7% of the respondents covered 1-2 km to water collection points. No resident travels above 2 km to collect water. In relation to time taken, 27.2% of the sampled respondents spend between 5-10 minutes on water collection daily. 34.9% of the sampled residents which represent the majority spend between 11-20 minutes daily on water collection. 24.4% of the sampled respondents spend between 21-30 minutes daily on water collection, while 13.5% of the sampled respondents spend above 30 minutes daily on water collection. Considering the distance to water collection locations and the time spent to collect water, one may conclude that the residents enjoyed access to water supply. The activities of commercial water vendors plays critical role in this. However, the reasonable access being enjoyed by the residents is at a financial cost. Depending on resident's number of households, a truck of water sold by the mobile water vendors popularly referred to as *Mairuwa* goes for Two hundred and fifty to Three hundred (#250- #300) naira. Some buy one to two trucks of water on daily basis, especially during the dry season when majority of the Hand dug wells have dried up and rain water has ceased to supplement other water sources such as tap and borehole.

Table 4.7: Accessibility to Water Supply

Distance to Major Sources of Water Supply	Frequency	Percentage (%)
0-km	383	96.3
1-2 Km	15	3.7
2-3 Km	0	0
Above 3 Km	0	0
Total	**398**	**100**
Time Spent on Water Collection	**Frequency**	**Percentage**
5-10 Minutes	108	27.2
11-20 Minutes	139	34.9
21-30 Minutes	97	24.4
Above 30 Minutes	54	13.5
Total	**398**	**100**

Source: Author's Fieldwork, 2019

4.3.7 Residents cost of daily water supply

The amount of money expended daily by residents on water supply in parts of Minna Metropolis is a function of many factors such as sources of water supply (Pipe-borne, Borehole, Vendors), quantity demanded, size of family and income. Figure 4.2 showed that 42.2% of the respondents which is the majority of the sampled respondents spend between N200-N300 daily on water supply. 28.1% of the respondents spend between N100-N200 daily on water supply, 21.6% spend between N300-N400 daily on water supply and 8.1% of the respondents spend between N400-N500 daily on water supply respectively. In view of this result, one is obliged to conclude that the amount of money expended daily by the residents on water supply is considerably high when compared to the national minimum wage of N18000 per month. This high cost of water supply may affect the quantity of water consumption. Additionally, the high cost of water supply is capable of robbing residents of potential investment capital.

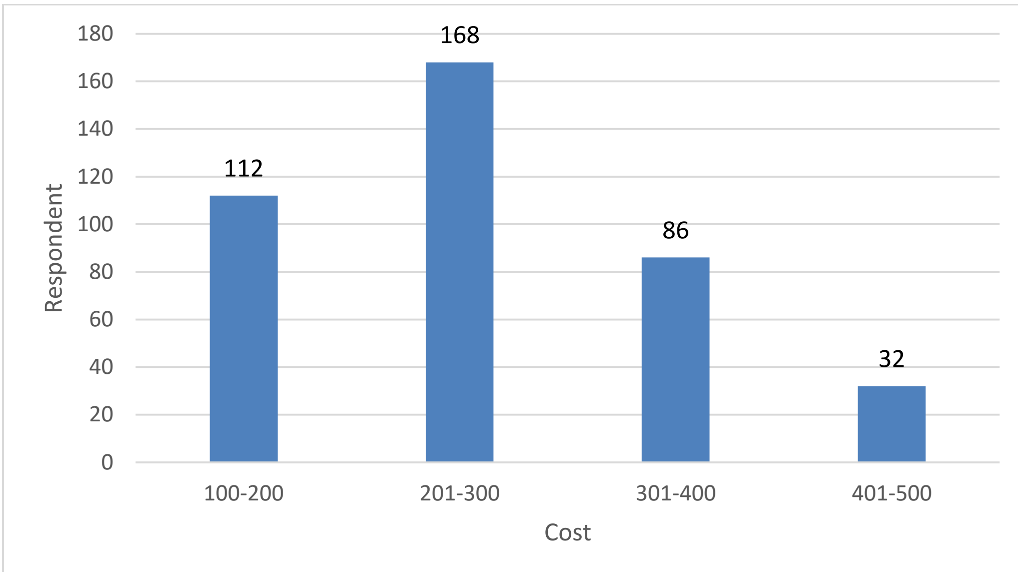

Figure 4.2: Residents Cost of Daily Water Supply

Source: Author's Work, 2019.

4.3.8 Water scarcity period

Seasonal variations affect water availability considerably as most Hand dug wells tends to dry up in the dry seasons. Hand pump Boreholes are equally not exempted from the effect of dry seasons. From Figure 4.3, it can be revealed that water scarcity is experienced more in the months of January to March. This is indicated by the number of the respondents that attested to the fact that they experienced water scarcity between January to March of every year. 259 residents which represent 65.1% of the sampled respondents attested to this fact. 124 respondents which represent 31.2% of the respondents said they experienced water scarcity in the months of April to June, while 15 respondents which represent 3.7% of the respondents experienced water scarcity in the months of September to December. However, no respondent experienced water scarcity in July to August. This is largely linked to seasonal variations. The study area does witness onset of rainfall around late April and ceases in October (Simon *et al*., 2018).

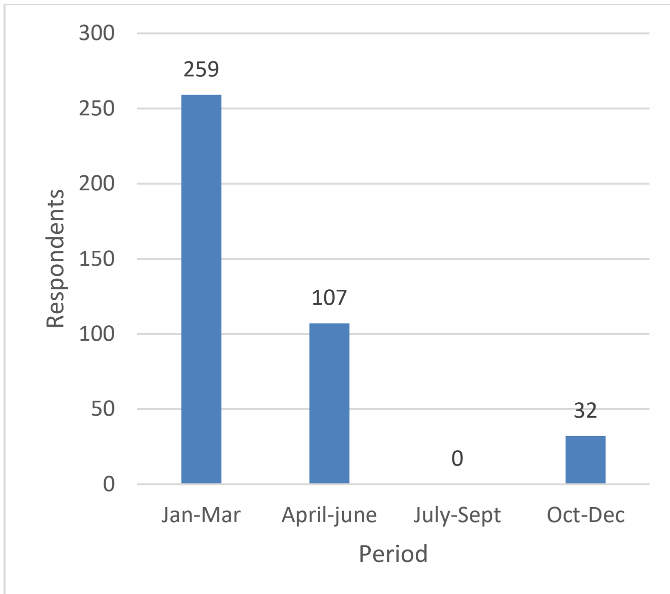

Figure 4.3: Water Scarcity Period
Source: Author's Work, 2019.

4.4 Evaluation of Health Implications of Consuming Contaminated Water

4.4.1 Contraction of waterborne diseases

Table 4.8 revealed that 314 respondents which represent 78.8% of the respondents said that they had ever contracted water-borne diseases, while 84 respondents which represent 21.2% of the population said they had never suffered from water-borne diseases. Therefore, majority of the sampled population have experienced water-borne diseases at one point or the other. This agreed with the study of Adegbehin *et al*. (2016) where it was reported that

66.6% of the sampled population at Dutsen Kura Gwari in Minna experienced and suffered from water-borne diseases.

Table 4.8: Contraction of Water-Borne Diseases

Response	Frequency	Percentage (%)
Yes	314	78.8
No	84	21.2
Total	**398**	**100**

Source: Author's Fieldwork, 2019

4.4.2 Water-borne diseases suffered in 2018

Figure 4.4 showed the existence of water-borne diseases in the study area. 8 respondents that represent 2.6% of the population suffered from Cholera in 2018, 67 respondents which represent 21.4% of the population suffered from Dysentery in 2018. Although, Dysentery is not solely caused by contaminated water, physical contact with surface that has Shigella bacteria on it such as toilet handle or sink knob, contaminated food or swimming in contaminated water such as lakes or pools are other causes of Dysentery contraction (WEBMD, 2020). 61 respondents, which represent19.5% of the sampled population suffered from Diarrhea in 2018. However, foods, fruits and even medications have been largely identified as major causes of Diarrhea (Medical News Today, 2020). 14 respondents, which represent 4.5% of the population suffered from Guinea worm in 2018. 21 respondents, which represent 6.6% of the population suffered from Schistosomiasis in 2018. 15 respondents, which represent 4.7% of the population suffered from Ring worm in 2018. However, 128 respondents which represent 40.7% of the population suffered from Typhoid in 2018. Evidence to this is the result of the work of Adegbehin *et al*. (2016) which revealed that

66.6% of the sampled population at Dutsen Kura Gwari experienced water-borne diseases. Similarly, Abaje *et al*. (2009), although the study area differs found that residents of Kafanchan in Jema'a Local Government Area of Kaduna State suffers from water-borne diseases like Cholera, Typhoid Fever, Schistosomiasis, Dysentery, Poliomyelitis (Polio), and Guinea Worm.

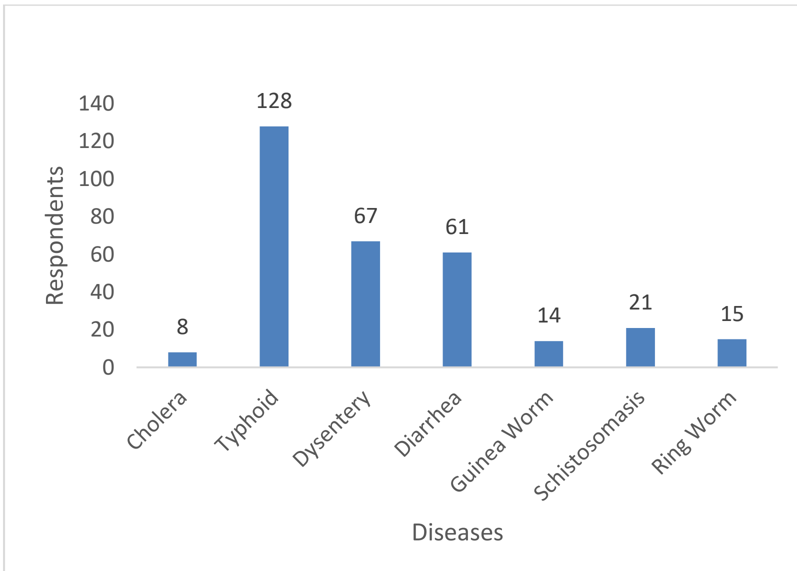

Figure 4.4 Water-Borne Diseases Suffered in 2018
Source: Author's Study, 2019.

4.4.3 Cost of diseases treatment

Table 4.9 showed that 12.5% of the respondents with water-borne diseases experience spend between N1000-N2000 on treatment. 17.8% of the population with water-borne diseases experience spends between N2001-N3000 on treatment. 44.9% of the population with water-borne diseases experience spends between N3001-N4000 on treatment. 19.7% of the sampled population with water-borne diseases experience spends between N4001-N5000 on treatment, while 5.1% of the sampled population with water-borne diseases experience spends above N5000 on treatment. Considering the fact that some of the residents had cause to treat illnesses two-four times in a year and considering that residents have other competing needs, these costs of illnesses treatment are capable of inflicting more sufferings on the residents. In addition to this, the residents could be robbed of potential investment capital which may in turn, affect economic productivity.

Table 4.9: Cost of Diseases Treatment

Cost of Treatment	Frequency	Percentage (%)
N1000-N2000	39	12.5
N2001-N3000	56	17.8
N3001-N4000	141	44.9
N4001-N5000	62	19.7
Above N5000	16	5.1
Total	**314**	**100**

Source: Author’s Study, 2019

4.4.4 Occurrence of water-borne diseases suffered by residents in 2018

Table 4.9 revealed that 29.6% of the sampled population with water-borne diseases experience in 2018, suffered once from water-borne disease in 2018. 17.2% of the sampled population with water-borne diseases experience suffered twice from water-borne diseases in 2018. 32.5% of the sampled population with water-borne disease suffered three times from water-borne disease in 2018. 20.7% of the sampled population with water-borne disease experience suffered four times from water-borne diseases in 2018. As shown in table 4.9, some residents suffered more than once in a year from water-borne diseases. The contraction of water-borne diseases more than once in a year implies that the residents will spend more on treatments. This is capable of hampering economic development due to diversion of potential investment capital to settling medical bills.

Table 4.10: Occurrence of Water-Borne Diseases in 2018

N0 of Occurrence in 2018	Frequency	Percentage (%)
Once	93	29.6
Twice	54	17.2
Three Times	102	32.5
Four Times	65	20.7
Total	**314**	**100**

Source: Author's Study, 2019

4.4.5 Hospital records on cases of water-Borne diseases reported/recorded

Water-borne diseases cases reported and recorded in 2018 as obtained from the Department of Health Information of General Hospital, Minna revealed that 344 cases of Typhoid fever was recorded in 2018. 1,294 cases of Diarrhea were recorded in 2018. Dysentery had the highest number of cases of water-borne diseases recorded amounting to a total number of 1882. Schistosomiasis recorded zero, while Ringworm cases recorded were 25 in 2018 as shown in Figure 4.5.

This result is similar to the result of the work of Kuta *et al*. (2014) where hospital records showed that Arewa/Yamma ward recorded 185 cases of water-borne diseases in 2008. 2550 was of water-borne diseases were recorded at Gulu Angwa/Vatsa in 2008. The reported/recorded water-borne diseases include Diarrhea, Typhoid, Malaria, Cholera, Guinea worm, Trachoma, Dysentery, Ringworm, Streptococci, Hepatitis B, Schistosomiasis, Onchocerciasis, Scabies.

The hospital records as reported in this study has further lend credence to the information obtained from respondents which showed that people suffers from one water-borne disease or the other in the study area. The work of Adegbehin *et al*. (2016) also testified to the fact that there exist water-borne diseases in the study area.

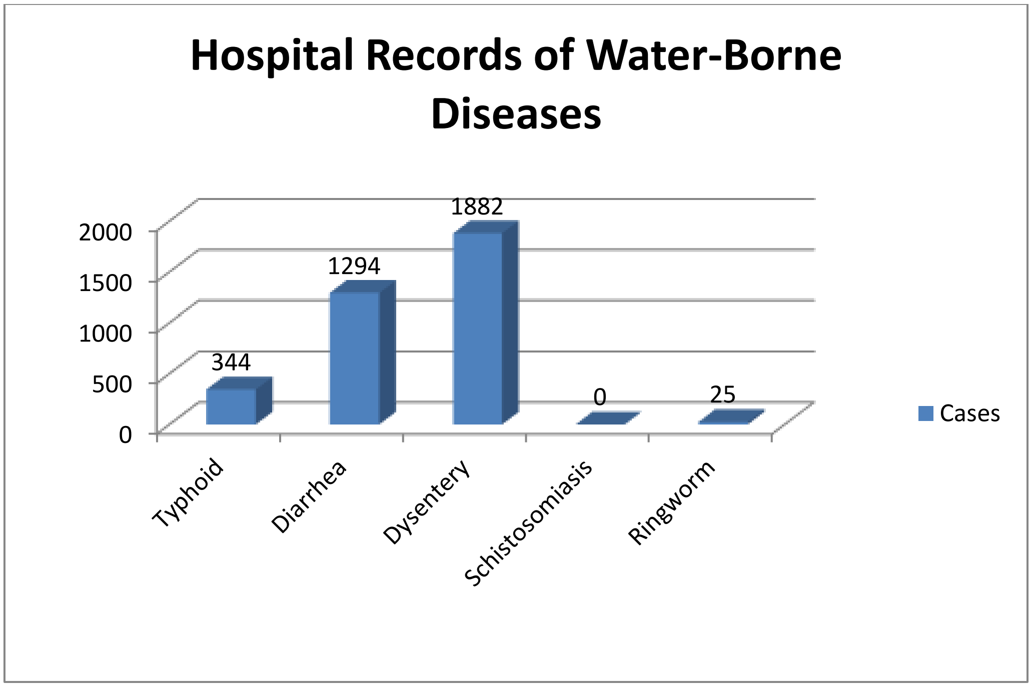

Figure 4.5: Hospital Records of Reported/Recorded Cases of Water-Borne Diseases

Source: Author's Study, 2019

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

This chapter essentially presents the conclusion drawn on the results of the research analysis and recommendations made concerning the findings of the study.

5.1 Conclusion

The study was able to establish relationship between anthropogenic activities and its impact on water quality through laboratory analysis of physicochemical and bacteriological parameters of water sampled. Based on the laboratory analysis of the water sampled, conclusion was reached that majority of the selected physicochemical parameters have concentrations above both the N S D W Q and W H O thresholds. Few of the water sampled had physicochemical parameters below threshold, while some were within limit or acceptable level of both NSDWQ and WHO. For example, pH values ranging from 6.67-7.42 in all the water sampled were within limit of 6.5-8.5 NSDWQ and WHO threshold. Five water samples which represent 41.7% had hardness values below NSDWQ threshold of 150mg/l, thus considered as soft water. Seven water samples that represent 58.3% had values above NSDWQ threshold, thus considered as hard and very hard water and not safe for drinking. Dissolved oxygen in all the water sampled were below both NSDWQ and WHO threshold of 10mg/l and 5mg/l. Biological oxygen demand of all the water sampled equally fell below both NSDWQ and WHO threshold of 6mg/l and ≥6mg/l, respectively. The maximum concentration level of Ammonia is not specified by World Health Organization. However, the National Academy of Science (NAS) recommends a threshold of 0.5mg/l in drinking water. In view of this recommendation, it can be concluded that 9 water samples out of 12 from the four selected areas have values above the 0.5mg/l of NAS threshold, while three water samples fell within the limit of NAS. Nitrate concentrations in all the water sampled were below 50mg/l WHO threshold, while Nitrite concentrations in all the water sampled were above the 0.2mg/l Nigerian Industrial Standard threshold.

Bacteriological analysis revealed that majority of the water sampled were contaminated by bacteria which include *E. Coli*, *Pseudomonas aeruginosa* and *Salmonella typhimurium*. For instance, Ten out of 12 water samples were contaminated by E. *Coli*. Three out of 12 water samples were contaminated by *Pseudomonas aeruginosa*, while Nine out of 12 water samples were contaminated by *Salmonella typhimurium.*

Owing to contamination of most of the water sampled by bacteria, the study opined that most of the water sources are not safe for drinking. It was observed and concluded that anthropogenic activities surrounding the water sources contributed to the contamination of the water sources. Human activities identified as contributors to water contamination include concrete blocks making industries, trading such as selling of water by vendors popularly known as (*Mairuwa*), refuse dump sites, sewage, sinking of Boreholes near septic tanks.

The study's results revealed that majority of study's population enjoyed adequate access to domestic water supply. Borehole is the major domestic water supply source, followed by self-help and Niger State Water Board (NSWB). The relative adequacy of water supply enjoyed by majority of population in the study area was linked to the proliferations of both private and commercial Boreholes in parts of Minna Metropolis. However, despite the proliferations of both private and commercial Boreholes in the study area, the residents do suffer great deal of water scarcity and shortage mostly around January-May of every year which coincides with dry season.

5.2 Recommendations

Having assessed anthropogenic activities impact on water quality in parts of Minna Metropolis, the following recommendations were made for considerations by individuals, Government agencies and corporate bodies:

i. Existing policies on water quality control should be strengthened and enhanced in order to safeguard public health;

ii. There should be continuous and consistent monitoring the level of compliance of both corporate bodies and private businesses with Government policies on environmental protection and programmes;

iii. There should be continuous and consistent monitoring of water quality parameters and environmental polluters by Government agencies saddled with the responsibility;

iv. Governments at all levels should be organizing enlightenment workshops on the significance of consuming safe drinking water;

v. There should be synergy between Government agencies such as Federal Environmental Protection Agency (FEPA), Niger State Environmental Protection Agency (NISEPA) and NESREA. This will greatly enhance the achievement of various Government environmental policies and programmes;

vi. Government agencies responsible for towns planning should ensure adequate planning of towns. This would greatly help in checkmating the challenges of unplanned urbanization and its consequences;

vii. Government should ensure adequate provision of pipe-borne water so as to prevent indiscriminate sinking of Boreholes and Hand Dug Wells. When adequate pipe-borne water is provided, proliferations of Boreholes would be minimized, thereby preventing environmental problems such as land subsidence;

viii. Promotion of positive environmental attitude by Government, Academic Institutions, Research Institutes, Private Researchers through environmental education, would go a long way in stimulating sustainable development;

ix. Rain water harvesting could provide a rescue ticket for improved access to water in Minna and Environs. Vigorous campaign should be launched on the importance rain water harvesting. Proper management of water would help greatly in mitigating the effect of water scarcity, especially during the dry season.

REFERENCES

Abd-Alla, G., Ahmed, E., & Rafat, R. A. (2011). Negative Impacts of Man-Made Activities on Water Quality, Egypt. Conference paper on Water Quality Management Programme.

Abaje, I. B., Ati, O. F. & Ishaya, S. (2009). Nature of Potable Water Supply in Jema'a Local Government Area of Kaduna State, Nigeria. *Research Journal of Environmentaland Earth Sciences.* 1 (1), 16-21.

Abok, E.O., Micheal, W.O., Catherine, N. K., & Bernard, O. A. (2018). Microbiological Quality and Contamination Level of Water Resources in Isiolo County, Kenya. *Journal of Environmental and Public Health*. https://doi.org/10.1155/2018/2139867

Adegbehin, A. B.,Yusuf, Y. O.,Anumonye, E.N., & Shehu, A. U. (2016). Problems of Domestic Water Supply in Dutsen Gwari, Chanchaga Local Government Area of Niger State, Nigeria. *Journal of Geography, Environment and Earth Science International.* 7 (4), 1-9

Adekunle, A. S., & Eniola, I. T. K. (2008). Impact of Industrial Effluents on Quality of Segment of Asa River within an Industrial Estate in Ilorin, Kwara State, Nigeria. *New York Science Journal*. 1 (1): 17-21

Adekunle, I.M.,Adetunji, M. T.,Gbadebo, A. M., & Banjoko, O. B. (2007). Assessment of Groundwater Quality in a Typical Rural Settlement in Southwest Nigeria. *International Journal of Environmental Research and Public Health*. 44, 307-318.

Adesuyi, A. A., Nnodu, V. C., Akinola, M. O., Njoku, K. L., & Jolaoso, A. O. (2015). Groundwater Quality Assessment in Eliozu Community, Port Harcourt, Niger Delta, Nigeria. *International Journal of Science and Technology*. 4, 149-155.

Adeyeye, E. I., & Abulude, F. O. (2004). Analytical Assessment of some Surface and Groundwater Resources in Ile-Ife, Nigeria. *International Chemistry Society of Nigeria.* 2, 98-103

Ajai, A. I., Jacob, J. O., Ndamitso, M. M , & Abdulgafar, J. (2011). Physicochemical Characteristics and Trace Metal Levels of Locally Dug Wells in Tunga Area of Minna, Niger State, Nigeria. *Journal of Applied Science and Environmental Management*. 15(2),247-250

Ajayi. O., & Akpan, D. (2012). Adverse Effect of Water Contamination or Pollution to Human Health and Safety in the Niger Delta, Nigeria: An Environmental Case Study, 6(10), 91-94

Akinibile, O. C., & Yusoff, S. M. (2011). Environmental Impact of Leachate Pollution on Groundwater Supplies in Akure, Ondo State, Nigeria. *International Journal of Environmental Science and Development.* 2 (1), 19-31.

Akinwumi, O. O., Eletta, O. A., & Odebunmi, O. (2012). Analysis of Nitrates and Nitrites in Groundwater of Ilorin Environs. *Journal of Environmental Science and Engineering.* Vol. 1, 656-662. Retrieved from https://scholar.google.com/search.

Aliyu, D. G. (2014). Impact of Anthropogenic Activities on the Quality of Water Resources in Kaduna Metropolis, Kaduna State, Nigeria. Centre for Environmental Health Engineering, University of Surey, UK. *International Journal of Engineering and Science*. 3, 16-21.

Aremu, M.O., Atolaiye, B. O., Gav, B. L., Opaluwa, O. D., Sangari, D. U., & Madu, P. C. (2011). Metal Concentrations in Sediments and Water from Rivers Doma, Farinruwa and Mada in Nasarawa State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*. 3 (9), 244-251

Ayobahan, S.U., Ezenwa, I.M., Orogun, E.E., Ururi, J.E., & Wemimo, I.J. (2014). Assessment of Anthropogenic Activities on Water quality of Benin River. *Journal of Applied Sciences and Environmental Management.* 18 (4), 629-636

Babanyara, Y.Y., Usman, H.A., & Saleh, U.F. (2010). An Overview of Urban Poverty and Environmental Problems in Nigeria. *Journal of Human Ecology.* 3 (12), 135-143

Babayemi, J.O., & Dauda, K.T. (2009). Evaluation of Solid Waste Generation, Categories and Disposal Options in Developing Countries: A Case Study of Nigeria. *Journal of Applied Sciences and Environmental Management.* 13 (3), 83-88

Bharadwaj,N. D.,& Sharma, A.K.(2016). Detection of Escherichia Coli, Staphylococcus Aereus and Salmonella Typhi in Drinking Water of Government Institutions and Organizations of Gwalior City. *International Journal of Engineering Sciences and Research Technology*. 5,(7).

Chamara, P. L. & Koichi, Y. (2017). Impact of Population Growth on the Water Quality of Natural Water Bodies, doi: 10.33900/su9081405

El-Kabbany, S., Rasheed, M.M., & Zayed, M.A. (2000). Monitoring of the Pesticides Levels in some Water Supplies and Agriculture Land in El-Haram, Giza. *Journal of Hazardous Materials.* 72 (1), 11-21

Enitimi, I.S., & Sylvester, C.I. (2017). Review of Impact of Anthropogenic Activities in Surface Water Resources in the Niger Delta Region of Nigeria: A Case of Bayelsa State. *International Journal of Ecotoxicology and Ecobiology*.2 (17), 61-73.

Enitimi, I.S., Sylvester, C.I. and Solomon, O. (2017). Assessment of Water Quality from Sagbama Creek, Niger Delta, Nigeria.https://biotechnologicalresearch.com

Environmental Protection Agency (EPA, 2014). National Secondary Drinking Water Standards By Brian Oram, Water Research Centre. http://www.waterresearch.net/index.php/standards/secondary-standards.

Eseigbe, A. P., Ibhadode, O., Ayoola, A. R. & Sosanolu, O. M. (2018). Experimental Determination of Drinking Water Quality in Abeokuta Metropolis, South Western Nigeria. *International Journal of Advances in Scientific Research and Engineering.* 4(12). DOI: http://doi.org/10.31695/IJASRE.2018.33035.

Estevez, M.A., Lopez-Periago, E., Martinez-Carballo, E., Simal-Gandara, J., Mejuto, J.C., & Garcia-Rio, L. (2008). The Mobility and Degradation of Pesticides in Soils and the Pollution of Groundwater Resources. *Journal ofAgriculture, Ecosystems and Environment.* 123 (4),247-260

Fadiran, A. O., Dlamini, S. C., & Mavuso, A. (2008). A Comparative Study of the Phosphate Levels in some Surface and Groundwater Bodies of Swaziland. *Bulletin of Chemistry Society of Ethiopia.* 22 (2), 197-206.

Fasunwon, O., Olowofela, J., Akinyemi, O., Fasunwon, B. & Akintokun, O. (2008). Contaminants Evaluation as Water Quality Indicator in Ago-Iwoye, Southwestern Nigeria.

Food and Agricultural Organization (2007): Coping with Water Scarcity, 2007 World Water Day, 22nd March, 2007. http://www.fao.org/nr/water. Retrieved 15th April, 2019.

Global Water Partnership (GNP). (2009). A Handbook for Integrated Water Resources Management in Basins. https://www.inbo-news.org/www.gwpforum.org

Gonfa, D., Fassil, A. & Mulissa, J. (2019). Assessment of Bacteriological and Physicochemical Quality of Drinking Water from Source to Household Tap Connection in Nekemte, Oromia, Ethiopia. *Journal of Environmental and Public Health.* 2019. DOI: https://doi.org/10.1155/2019/2129792

Halder, J.N. & Islam, M.N. (2015). Water Pollution and its Impact on the Human Health, Dhaka, Bangladesh. *Journal of Environment and Human.* 2. DOI: 10.15764/EH.2015.01005.

Hong, W., Lei, N., Yan, X., Chao, D.,Tao, Z. & Yuzheng, W. (2018). Effects of Highway-Related Pollutant on the Groundwater Quality of Turfy Swamps in the Changbai Mountain Area of China. *International Journal of Environmental Research and Public Health.* DOI: 10.3390/ijerph15081652.

Herero, J.J. (2008). Towards Ecological Sustainable Sanitation in Oshiwana Penduka, an Informal Settlement. A Masters Thesis at Stellenbosch University

Ibrahim, I., Emigilati, M.A., Garba, I.K., Usman, B.Y. & Hassan, A.B. (2014). An Assessment of Alternative Water Source for Domestic Uses in Minna Metropolis, Niger State, Nigeria. *Journal of Environment and Health Science.* 4 (18).

Idris, M.A., Kolo, B.G., Garba, S.T. and Waziri, I. (2013). Pharmaceutical Industrial Effluent: Heavy Metal Contamination of Surface *Water* in Minna, Niger State, Nigeria. *Bulletin of Environment, Pharmacology and Life Sciences.* 2 *(*3*)*, 40-4

Ifabiyi, I.P. (2008). Self-purification of Freshwater Stream in Ile-Ife, Osun State, Nigeria; Lessons for Water Management. *Journal of Human Ecology*. 24 (2), 131-137.

Jibrin, G., Yusuf, A.Y., Garba, A., Sulaiman, A.G., Ahmad, M.I. & Kamaludeen, A. (2018). Causes and Health Effects of Water Sources in Hadeija Metropolis, Nigeria. *Nigerian Research Journal of Chemical Sciences.* 4. www.unn.edu.ng/nigerian-research-journal-of-chemical-sciences.

Kapila-Tharanga Rathnakaya,R. M., & Wang, Z.J. (2012). Prevalence and Effects of Personal Hygiene on Transmission of Helminthes Infection among Primary School Children Living in Slums. *International Journal of Multidisciplinary Research.* 2 (7), 2231-5780

Kirby, R.M., Bartram, J., & Carr, R.(2003). Water in Food Production and Processing: Quality Concern, Food Control

Kondro, W. (2000). Escherichia Coli Outbreak, Deaths Spark Judicial Inquiry in Canada, Lancet, 355 (9220), 2058. DOI:https://doi.org/10.1016/S0140-6736(05)73512-1

Kuta, G.I., Emigilati, M.A., Hassan, A.B., & Ibrahim, I. (2014). Domestic Water Sources and its Health Implication in Lapai Local Government Area, Niger State, Nigeria. *Ethiopian Journal of Environmental Studies and Management.* 7 (6), 686-694

Maitera, O.N., Ogugbuaga, V.O., & Barminas, T.J. (2011). Determination of Trace Metal Levels in Water and Sediments of River Benue in Adamawa State, Nigeria. *Journal of Ecology and Natural Environment.* 3 (4), 149-156.

Masters, G.M. and Ela, P.W. (2008). Introduction to Environmental Engineering and Science.*Pearson International*, 3rd Edition, New Jersey

Maureen, K. R. (2018). Impact of Anthropogenic Activities on Water Quality: The Case of Athi River in Machakos County, Kenya. *Journal of Environmental Science, Toxicology and Food*. *Technology.* 12 (4), 01-29.

Mena, K. D., & Gerba, C. P. (2009). Risk Assessment of Pseudomonas Aeruginosa in Water. Reviews of Environmental Contamination and Toxicology.

Medical News Today. (n.d). Causes of Diarrhea. Retrieved from https://www,medicalnewstoday.com on 5th August, 2020.

Mineau, P. (2005). Direct Losses of Birds to Pesticides: Beginnings of a Quantification, USDA, Washington D.C., USA. Forest Service General Technical Report. 2, 1065-1070

Muhammad, A.I., Muhammad, A.C., Adamu, I.H., & Bala, I. (2015). Water Pollution Sources for Hand-Dug Wells in the Ancient City of Bauchi Metropolis, Nigeria. *International Journal of Scientific and Research Publications.* 5, 6.

Nathaniel, T. & Christine, B. (2008). Transportation and Water Pollution: A Paper Presented at Centre for Transportation and the Environment, Institute for

Transportation Research and Education (ITRE), North Carolina State University.

National Population Commission (NPC, 1991). *Population Estimates of Bosso and Chanchaga Local Government Area of Niger state.*

Nigerian Standard for Drinking Water Quality (NSDWQ), "Guidelines for Drinking water Quality", ICS.13.060.20, *NSDWQ Publication,* Abuja, Nigeria, 2007.

Nigerian Standard for Drinking Water Quality (NSDWQ), "Guidelines for Drinking Water Quality" ICS.13.060.20, *NSDWQ Publication,* Abuja, Nigeria, 2015

Norman E., Meybeck, M., & Chapman, D. (2006). Effects of Human Activities on Water Quality. *Encyclopedia of Hydrological Sciences,* DOI: 10.1002/0470848944.hsa096.

Njeize, G. E., Dilibe, U., & Illo, C. (2014). Nitrate and Drinking Water from Private Wells: Will there be an Epidemic of Cancer of the Digestive Tract, Urinary Bladder and Thyroid? *Nigerian Journal of Clinical Practice.* 17(2), 178-182.

Novtony, V. (2003). Water Quality: Diffuse Pollution and Watershed Management, *John Willey and Sons Incorporations,* New York.

Ogaga, A.A., Ayakpo, F.M. and Sylvester, C.I. (2018). Impacts of Anthropogenic Activities on Heavy Metal Levels in Surface Water of Nun River around Gbarantoru and Tombia Towns, Bayelsa State, Nigeria. *Annals of Ecology and Environmental Science. (*2), 1-8.

Ogedengbe, K., & Akinibile, C.O. (2004). Impact of Industrial Pollutants on Quality of Ground and Surface Waters at Oluyole Industrial Estate, Ibadan, Nigeria. *Nigerian Journal of Tecnological Development.* 4 (2), 139-144.

Ogwueleka, C. (2012). Municipal Solid Waste Characteristics and Management in Nigeria. *Iran Journal of Environmental and Health Science Engineering.* 6 (3), 173-180.

Ohwo, O., & Abel, A. (2014). Access to Potable Water Supply in Nigerian Cities: Evidence from Yenagoa Metropolis. *American Journal of Water Resources.* 2 (3), 31-36. DOI: 10:12691/ajwr-2-2-1.

Ojutiku, R.O., Ibrahim, A., & Raymond, A. (2014). Assessment of Water Quality Parameters and Trace Metal Contents of Drinking Water Sources in Minna Metropolis, Niger State, Nigeria. *International Journal of Current Microbiology and Applied Sciences.*3 (5), 1029-1037.

Olukosi. O. M., Ameh, J. B., Abdullahi, I. O., & Whong, C. M. Z. (2016). Physicochemical Quality of Drinking Water from Various Sources of Kaduna State, Nigeria. *Bayero Journal of Pure and Applied Science.* 9 (2), 141-144. https://dx.doi.org/10.4314/bajopas.v9i2.26

Omowaye, O.S., & Audu, P.A. (2012). Parasites Contamination and Distribution on Fruits and Vegetables in Kogi State, Nigeria. *An Online International Journal*. 1(1), 4-16.

Oregon Department of Human Services (ODHS), Environmental Toxicology Section (2000). Health Effect Information

Otufale, G.A., & Coster, A.S. (2012). Impact of Water Scarcity and Drudgery of Water Collection on Women Health in Ogun State, Nigeria. *Journal of Human Ecology*. 39 (1), 1-9. DOI:https://doi.org/10.1080/09709274.2012.1190649.

Owhonda, I., Ekpendu, C., Mmedorenyin, O., Okorafor, I., Charles, O., & Chinedu, M. (2018). Effect of Urban Effluent on River Water Quality in the Niger Delta, Nigeria. *Frontiers in Environmental Microbiology*. 4 (4), 110-114. DOI: 10.11648/j.fem.20180404.13

Oyedum, U. M., Adabara, N. U., & Oloruntimilehin, B. J. (2016). A Survey of Bacteriological Quality of Well Water from Various Locations in Bosso Town, North Central Nigeria. *FUTA Journal of Research in Sciences.* 12 (2), 280-286.

Pallav, S. (2013). Potential Health Impact of Hard Water. *International Journal of Preventive Medicine.* 4 (8): 866-875

Purcell, P. (2003). *Design of Water Resources Systems.* London, 10-37: Thomas Telford

Radwan, O. A., & Atalla, I. E. (2005). Monitoring of Pesticides Residues in Drainage Water and Fish Samples Collected from Different Governorates, Egypt. Bull. Fac. Agric., Cairo University, 56, 189-200

Salvato, J.A., Nemerow, N. L., & Agardy, F.J. (2003). Environmental Engineering. *John Wiley and Sons Incorporations*, New York

Sarabjeet, S., & Luke. M. M. (2003). Trace Metal Levels in Drinking Water on Viti Levu, Fiji Islands. *South Pacific Journal of Natural Science.* 21, 31-34

Sawyer, C. N., McCarty P. L., & Parkin, G. F. (2003). Chemistry for Environmental Engineering and Science, McGraw-Hill, Boston, 5th Edition, 536-616

Schuster-Wallac, C. J., Grover, V. I., Adeel, Z., Confalonieri, U., & Elliott, S. (2008). Safe Water as the Key to Global Health, United Nations University. *International Network on Water, Environment and Health*

Shittu, O. B., Adeniran, S. A., Afolabi, O. R & Sam-Wobo, S. O. (2014). Risk Surveillance of Multidrug Resistant Pseudomonas Aeruginosa in Water and Plasmid Relatedness with Clinical Strains in Abeokuta, South West, Nigeria. *Journal of Natural Science, Engineering and Technology*. 13, 44-57.

Simon, R. F., Duntoye, D. B. & Oyewole, K. (2018). Effects of Urbanization on Micro-Climate of Minna Urban Area, Niger State, Nigeria. *Journal of Geography, Environment and Earth Science International*. 15 (1), 1-13.

Stark, J.R., Hanson, P. E., Goldstein, R. M., Fallon, J. D., Fong, A. L., Lee, K. E. *et al.*, (2000). Water Quality in the Upper Mississippi River Basin, Minnesota, Winsconsin, South Dakota, Iowa, and North Dakota, 1995-98. *United States Geological Survey Circular*. *1211*. http://pubs.usgs.gov/circ/circ1211/pdf/circular 1211.pdf

Stephen, S. A. (2016). Impact of Potable Water Availability on Economic Development of North Senatorial District of Benue State, Nigeria. *A Ph.D Thesis at Walden University, Minneapolis, Minnesota, USA.*

Tong, S. Y., Davies, J. S., Eichenberger, E., Holland, T. L., & Fowler, V. G. (2015). Staphylococcus Aureus Infections: Epidemiology, Pathophysiology, Clinical Manifestations, and Management. *Clinical Microbiology Review.* 28 (3), 603-661.

United Nations Environment Programme (UNDP). (2006).Water Quality for Ecosystem and Human Health. *A Publication of United Nations Environment Programme's Global Environment Monitoring System (*GEMS)/*Water Programme,* pp132.

United Nations International Children's Emergency Fund (UNICEF). (2009). Water, Sanitation and Hygiene Annual Report, *UNICEF WASH Sector*, New York, 2010.

United Nations International Children's Emergency Fund (UNICEF) and the World Health Organization (WHO). (2008). *Progress on Drinking Water and Sanitation: Special Focus on Sanitation*

United Nations International Children's Emergency Fund (UNICEF) and the World Health Organization (WHO). (2008). *Progress on Drinking Water and Sanitation: Special Focus on Sanitation:*2012 *Update*

WEBMD (n.d). Causes of Dysentery in Humans. Retrieved on https://www.webmd.com on 6th August, 2020.

World Health Organization (WHO). (2009). World Health Statistics, WHO Library Cataloguing-in-Publication Data, Geneva, Switzerland.

World Health Organization (WHO), "Guidelines for Drinking Water Quality-2nd Edition," *WHO Publication,* Geneva, Switzerland, 2004, 231-233.

World Health Organization (WHO), "Guidelines for Drinking Water Quality-2nd Edition," *WHO Publication,* Geneva, Switzerland, 2011.

World Health Organization (WHO) and United Nations International Children Education Fund (UNICEF), "Water and Sanitation Report" *The Guardian,* December 4, 2006.

Wijk-Sijbesma, C.V. (2002). Improved Health and Hygiene: Small Community Water Supplies, Technology, People and Partnership, *IRC Water and Sanitation Centre, Delft,Netherlands, Technical Papers*, Series40

Yamani, T. (1976). Statistics: *An Introductory Analysis*, 2nd Ed., New York: Harper and Row

Younger, P. L. (2001). Mine water Pollution in Scotland: Nature, Extent and Preventive Strategies. *The Science of the Total Environment*, 265, 309-326

APPENDIX A (QUESTIONNAIRE)

Department of Geography

School of Physical Sciences

Federal University of Technology, Minna, Niger State, Nigeria.

Dear respondent,

This questionnaire seeks to collect information on **"Impact of Anthropogenic Activities on Water Quality and its Health Implications in parts of Minna Metropolis, Niger State, Nigeria."** The questionnaire is to obtain information from you for the purpose of a postgraduate research work. Information provided here will be treated confidentially with utmost respect to the respondent and such will be used strictly for the purpose of this research work only.

Thank you for your anticipated cooperation

YUSUF, Abdulwasiu Adewale

SECTION A: INFORMATION ON RESIDENTS ACCESS TO POTABLE WATER SUPPLY

1. What is the source of domestic water supply to your household? i. Pipe-borne water ( ) ii. Bore-hole ( ) iii. Hand dug Well ( ) iv. River ( ) v. Others, specify
2. Why do you prefer this source of water? i. Proximity to my residence ( ) ii. Cheaper and affordable ( ) iii. Frequency of availability ( ) iv. Others, specify
3. In your own opinion, whose responsibility is to provide the people with potable water in your area? i. Individual ( ) ii. Niger State Water Board ( ) iii. Self-help ( ) iv. Community effort ( ) v. Non-governmental organizations (NGO) ( )
4. Do you have sufficient water for your daily use? i. Yes ( ) ii. No ( )
5. What quantity of water do you need daily? i. 100litres ( ) ii. 101-150litres ( ) iii. 151-200litres ( ) iv. Above 200litres ( )
6. In your own opinion, do you have access to the daily water need? i. Strongly Agree ( ) ii. Agree ( ) iii. Strongly Agree ( ) iv. Disagree ( )

7. If you disagree, what do you think could be responsible for the shortage?

   i.

   ii.

8. What is the average time you spend on water collection daily? i. 5-10minutes ( ) ii. 11-20minutes ( ) iii. 21-30minutes ( ) iv. Above 30minutes
9. What is the approximate distance between your residence and source of water supply? i. 0-1km( ) ii.2-4km ( ) iii. Above 4km ( )
10. Do you enjoy sufficient water supply year round? i. Yes ( ) ii. No ( )
11. If yes, what period of the year do you normally experience water shortage? i. January-March ( ) ii. April-June ( ) iii. July-September ( ) iv. October-November ( )

SECTION B: INFORMATION ON THE HEALTH IMPLICATION OF CONSUMING CONTAMINATED WATER

12. Have you suffered from any water-borne related disease? i. Yes ( ) ii. No ( )
13. If yes, what type of disease(s) did you suffered from? i. Typhoid ( ) ii. Dysentery ( ) iii. Diarrhea ( ) iv. Cholera ( ) v. Others, specify
14. How often do you suffer from the disease(s) i. Once in a year ( ) ii. Twice in a year ( ) iii. Thrice in a year ( ) iv. Four times in a year ( )
15. What is the average amount of money spent on treating such illness? i. N1000-N2000 ( ) ii. N2000-N3000 ( ) iii. N3000-N4000 ( ) iv. N4000-N5000 ( ) v. Above N5000
16. Which hospital or healthcare facility do you usually visit for the treatment of such illness? i. Government General hospital ( ) ii. Primary Healthcare ( ) iii. Private Hospitals ( ) v. Others, specify
17. Why do you prefer the healthcare facility? i. Proximity to place of residence ( ) ii. Quality of service delivery ( ) iii. Affordability ( ) iv. Others, specify