

**ASSESSMENT OF THE IMPACTS OF HUMAN ACTIVITIES ON WATER QUALITY
IN RIVER GALMA, ZARIA, KADUNA STATE**

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**BEING A DISSERTATION SUBMITTED TO THE DEPARTMENT OF
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MASTER OF SCIENCE IN NATURAL RESOURCES MANAGEMENT
AND CLIMATE CHANGE**

March, 2021

DECLARATION

I declare that this research work is the product of my effort under the supervision of Dr. Adnan Abdulhamid and has not been presented anywhere for the award of any certificate.

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CERTIFICATION

This is to certify that this dissertation titled “assessment of the impact of human activities on water quality of river Galma, Zaria, Kaduna State” by AsiyaJummai Muhammad with registration number: SPS/15/MGE/00028 meets the regulations governing the award of the degree of Master of Science of Bayero University, Kano and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This Dissertation is dedicated to the love of my life, my Mother Aisha Ahmed who basically sacrificed her life & comfort to make certain I got a life, and to the memory of my late brother Abdulra'ufBalarabe Muhammad.

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ABSTRACT

Over time, water quality has gained increased global concern, since water is essential for human survival, and safe drinking water is vital for good health. This study assessed the effect of human activities on water quality in river Galma, by determining some physico-chemical and biological parameters, in comparison with standards, explore variations over seasons and the effect of land use on the parameters. Water samples were collected downstream river Galma on different points based on the land use types/human activities, and analysed. GIS and field observations were employed in categorizing the land use types and human activities, from where five categories were arrived at namely; reservoir/river channel, treatment plant/farmland, industrial/farmland, residential/farmland and commercial/farmland. A total of twenty (20) water samples were collected at five points using the grab approach, over wet and dry seasons. Laboratory analysis was carried out on the water samples for physico-chemical, biological parameters and heavy metals. Descriptive statistics, Pearson correlation and ANOVA were used to present and analyse results. It was observed that most of the water quality parameters conform to WHO and NSDWQ standards except pH, coliform, nickel, chromium and cadmium. There was little variation between seasons. Heavy metal concentration was found to have positive relationship with industrial/farmland land use and TDS concentrations was found to have positive relationship with the reservoir/river channel land use. However, most of the relationship between the land use and water quality parameters was found to be insignificant. It is therefore concluded that the human activities/land use type has some effects on water quality of the river and that the water should be properly treated before being used for domestic purposes. This study recommends measures such as; minimizing industrial activities close to the river and treating the water for coliform and other heavy metals whose concentrations have been found to be over the recommended limits.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Decrease in quality of water is increasing globally as world population increases. Increasing scope of industrial and agricultural activities, have threatened hydrologic cycle and is causing climate change (UN-Water, 2011). Supply of safe drinking water is crucial to human life and safe drinking water should not impose a significant risk to human health (WHO, 2011).

For the survival of all living organisms and the smooth functioning of ecosystems, it is important to have clean, safe and adequate freshwater (UN-water, 2011). According to UNICEF (2008), contaminated water has led to the death of over three million (3 million) people annually, most of which are children. It is also found that two million of these deaths are caused by diarrhoeal diseases which occur through ingestion of contaminated water. It has been established that surface waters in river basins usually undergo pressures and changes caused by human activities. The activities lead to major degradation of water quality, which can constitute danger to public health (Oliveira, *et al.* 2005).

Water quality may be considered as a set of biological, chemical, and physical characteristics of water in combination with intended uses and also to be compared to standards. Water pollution is the contamination of natural water bodies by chemical, physical, radioactive or pathogenic microbial matter (Hogan, 2010). It is well known that natural aquatic systems have a capacity to receive a certain quantity of pollutants discharged into them, but when the pollutants discharged exceed their capacity of self-purification, the water body will be damaged. Today, approximately 90% of the sewage and 70% of the industrial wastes are produced and discharged untreated into watercourses in developing countries (Jing, 2013).

Land use particularly deforestation, agricultural activities and urbanization have been found to generate pollution which affects river water quality (Lee *et al.*, 2009). The study area comprises of different land use types which may affect the quality of the river in many different ways.

1.2 STATEMENT OF THE RESEARCH PROBLEM

The Galma river basin is booming with agricultural activities. Crops planted on both sides of the river bank throughout the year include Irish potato, sweet potato, vegetables (like carrot, garden egg, tomato, and chili), and cereals like maize and rice (Nnaji *et al.*, 2011). Agricultural run-off contains nitrogen compounds and phosphorus from fertilizers, pesticides, herbicides, salts, poultry wastes, coliform bacteria from other mammals and washes down into rivers (Omoigberale, *et al.* 2012). Petrol powered water pumps are used to irrigate the farmlands in the dry season and this enables petroleum wastes to get into the River. Most of the industries in Zaria which include tobacco, metal smelting, electricity meter manufacturing, ginnery, textile, vegetable oil mill, discharge their wastes directly into the River while others discharge into rivers and streams that empty into River Galma. The river also receives trade wastes from auto-mechanics, metal fabrication/finishing, abattoirs, and local tanneries. Domestic sewage and refuse also find their way into the river from the many settlements along the river through leaching, direct discharge and surface runoff (Nnaji *et al.*, 2011). According to the National Bureau of Statistics (NBS), 23.2% of rural households dispose their refuse within households and 48.6% in unauthorized refuse heaps. 16.1% of households have no toilet facilities, 6.3% defecate on water and 6.0% flush to sewage. People who reside in settlements within the drainage basin may engage in such practices which could lead to contamination of water bodies.

Additionally, the Galma River is dammed and used for irrigation and storage of water. Storage of water in dams and reservoirs as well as irrigation leads to changes to the physical and chemical

characteristics and temperature of the water released downstream (Wildi, 2010; Lin, 2010; McCartney, *et al.*, 2001; McCartney and Sally, 2000; Govorushko, 2006).

Furthermore, people tend to assume hydropower generation and other renewable energy sources have no negative impact on the environment, this is a misconception. Hydropower generation are significant sources of water pollution, by altering the temperature and chemical makeup of water bodies (Agrawal and Sikarwa, 2016; Bhatt, *et al.*, 2011).

Some research have been conducted related to River Galma, some of which are: suitability assessment of surface water for irrigation in Galma floodplain, Zaria, Kaduna state north western, Nigeria, by Aliyu *et al.* (2016), temporal and spatial physico-chemical parameters of river Galma, Zaria, Kaduna state, Nigeria by Samuel *et al.* (2015), Udiba *et al.* (2014) studied the impact of industrial effluents from Dakace industrial area on the physico-chemical properties of river Galma, Zaria, Nigeria, industrial pollution and its implications for the water quality of river Galma: a case study of dakace industrial layout, Zaria, Nigeria by Udiba *et al.* (2014a), Butu and Bichi (2013) carried out research titled assessment of some heavy elements in Galma dam, Zaria, Nigeria. Udiba, *et al.* (2014), an assessment of the heavy metal status of river Galma around Dakace industrial layout, Zaria, Nigeria; effect of pollution on the physico-chemical parameters of water and sediments of river Galma, Zaria, Nigeria by Nnaji *et al.* (2011).

None of the researches cited above were on the impacts of human activities on water quality of River Galma. Considering all the aforementioned various point and non-point sources of pollution to the river caused by human activities, there is need to evaluate the quality of river Galma for safe use by the surrounding communities. This study helps to establish the effects associated with human activities around River Galma.

1.3 RESEARCH QUESTIONS

The research questions for this study are:

- i. What is the physico-chemical and biological value of parameters in the river?
- ii. How does the result compare to NSDWQ and WHO standards?
- iii. What is the temporal variation?
- iv. Which among the land use types/human activities has the most effect on the river?

1.4 AIM AND OBJECTIVES

The aim of the study is to assess the impact of human activities on the water quality of river Galma.

The aim was achieved through the following objectives: to

- i. Identify the value of some physico-chemical and biological parameters in the river
- ii. compare the water quality parameters with the Nigerian and WHO standards
- iii. Identify the temporal/seasonal variations of the water quality parameters over the two seasons
- iv. examine the impact of land use on the water quality parameters.

1.5 JUSTIFICATION

Access to safe drinking-water is essential to health. The importance of water, sanitation and hygiene to health and development has been reflected in the outcomes of a series of international policies, especially the Millennium Development Goals (MDGs) adopted by the General Assembly of the United Nations (UN) in 2000. There have been researches on river water quality around Nigeria and particularly in Kaduna such as: Aliyu, *et al.* (2016), who studied the suitability assessment of surface water for irrigation in Galma floodplain, Zaria, Kaduna state; Udiba, *et al.* (2014), an assessment of the heavy metal status of river Galma around Dakace

industrial layout, Zaria, Nigeria; Nnaji, *et al.* (2011), effect of pollution on the physico-chemical parameters of water and sediments of river Galma, Zaria, Nigeria; Butu, and Bichi, (2013), assessment of some heavy elements in Galma dam, Zaria, Nigeria; Abubakar, *et al.* (2015), heavy metals pollution on surface water sources in Kaduna metropolis, Nigeria; pollution indicators in River Kaduna by Mahre, *et al.* (2007); and Emigilati, *et al.* (2015), assessment of effluents discharged from textiles industries in selected villages in Kaduna. Although these studies were done on rivers in Kaduna, none of these are on the impact of human activities on River Galma.

1.6 SCOPE

This study involved the various human activities around River Galma, its effects on the river water quality, and was limited to stretches of downstream River Galma that passes through Zaria, from the Zaria dam through Dakace industrial area, down to the old Jos road and culminated at the new Jos road. The study concentrated on the determination of some physico-chemical parameters and coliform count which was chosen because it is a common biological parameter that indicates the presence of bacteria contaminants. The study was conducted between two seasons (wet and dry).

1.7 STUDY AREA

1.7.1 Location and Extent

The study area lies between latitude 7.7° to 7.8° , and longitude 11.07° to 11.14° , 128 km South-East of Kano and 64 km North-East of Kaduna City (figure 1). The Galma River extends over a distance of about 32Km – 35 Km at maximum flood water level. It has its headwaters near the north western edge of the Jos plateau and enters Kaduna River near Magami village. The main tributaries of river Galma are Shika river, Kinkiba river and Likarbu river. Other rivers include river Kubanni, Saye, Baki, Anchau, and Danwata. All the rivers with the exception of river

Galma are seasonal. The area consists of several settlements such as Bikaratu, Magami, Dakace, Fan Shanu, Likoro, GidanGayan, Amana, HausawanBugai, Burkonu, Rihogi, Bugai, Rikoka, Ashehu, Kafuri, Zaure, Among Others.

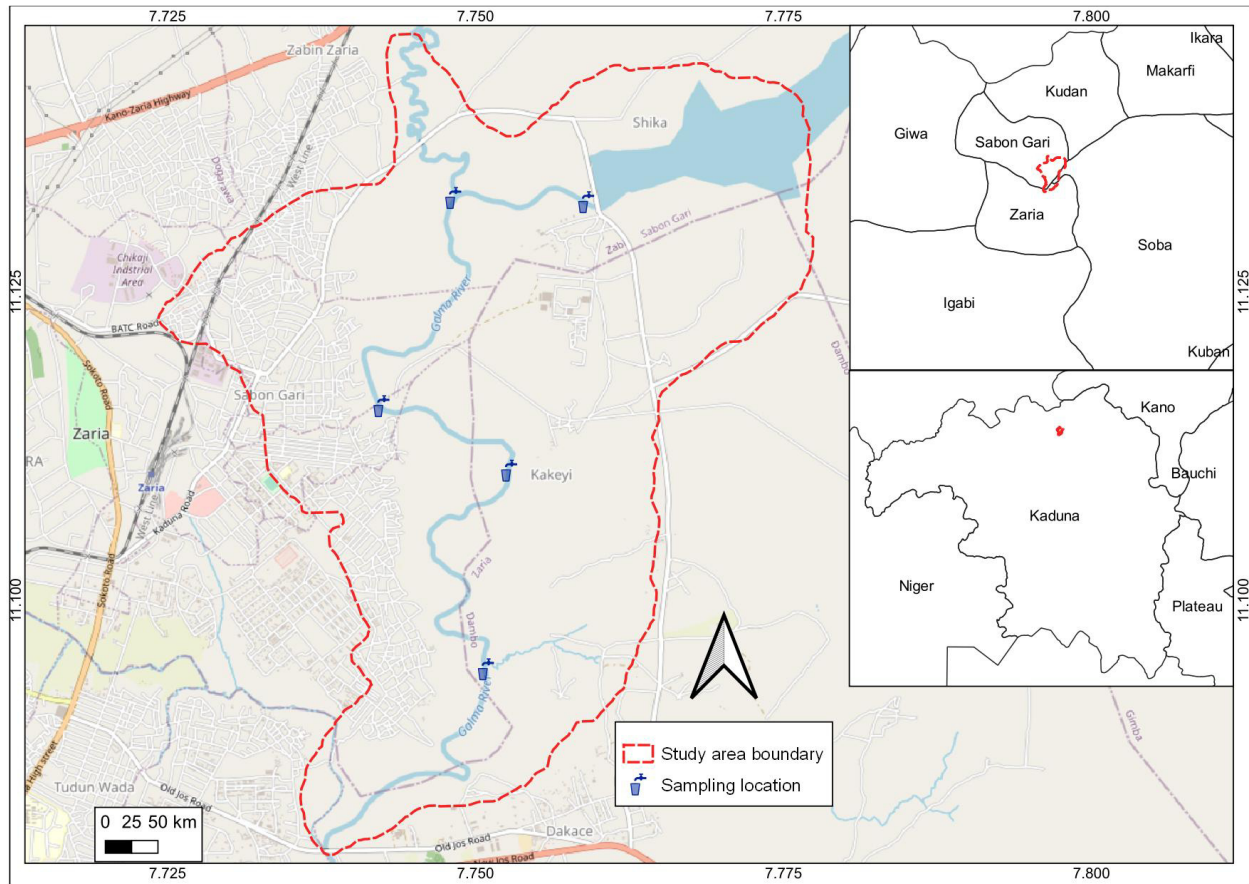


Figure 1. Map of the study area showing, Galma River and its surroundings.

1.7.2 Climate

The climate of the area consists broadly of wet and dry seasons. The climate is typical of Northern guinea savannah. Rainy season begins in May (or April) and lasts till October, with the highest rainfall occurring in September, while dry season lasts between November and April, which is because of the interplay of the two dominant air masses within the region i.e. the Tropical continental air masses (cT) and Tropical maritime air masses (mT) (Iguisi and Abubakar, 1998 in Yusuf and Shuaib, 2012).

Mean yearly temperature of the region is nearly 31°C with values that vary over the year from annual minimum of 25°C in July to a maximum temperature of 40°C in March. Mean yearly highest temperature is 36°C and the mean minimum is 22°C. The maximum diurnal maximum temperature is 41.1°C in March and 18°C in January. The mean monthly minimum and maximum temperatures in the basins are 37.3°C and 19.7°C, respectively, and the hottest months are February, March and April (Iguisi and Abubakar, 1998 in Yusuf and Shuaib, 2012).

The mean relative humidity fluctuates from 50 to 60% and has far reaching impact on evaporation and transpiration from large water bodies and adjacent vegetation. The monthly humidity varies from 36% to 46% during the four months of December to March and from 82% to 88% during the five months of June to October. Mean relative dampness swing with moderate, reaching its peak in the wet season (Iguisi and Abubakar, 1998 in Yusuf and Shuaib, 2012).

1.7.3 Soil and vegetation

The soil type is highly leached ferruginous tropical soils, developed on weathered regolith overlain by a thin deposit of windblown silt from the Sahara Desert during many decades of the propagation of the tropical continental air mass into the area. It is also rich in fine grain quartz and oligoclase (Wright and McCurry, 1970). Most of the soil is 30-40% rich in clay, which have the ability to retain moisture (Kowal and Omolokun, 1971). Also, most of its soil forms a hard surface cap under the impact of heavy rain. The scanty vegetation cover enhances surface run off due to low infiltration. This concurrently causes pollution of rivers and other environmental problems to the people. (Niniola, 1999).

The vegetation is basically savannah (northern Guinea Savannah zone) characterized by patches of woodland, herbs and grasses with few widely scattered deciduous trees, although continuous cultivation, bush burning and grazing activities have greatly modified the natural vegetation

cover and composition to mainly shrubs, stems and trees along with some tuft covers and some clusters of trees along river courses (Alkali, 2009). Trees species here include *Magnifera indica* dotting everywhere, *Parkia clappertoniana*, *Tamarindaindiana*, *Butyrispernum spp* and several others which are found to be useful to man. During the rainy season, the vegetation is thick and greenish but are dry and brownish during the dry season with little of these plants retaining their leaves. The dominant shrubs around the area is *Isobelinadoka* with an average height of 50 cm. Other less frequent shrub species include *Pilliosigma Spp* and *Terminacea avicennides*.

The common grass communities in the study area are mostly *Andropogon spp.* (Kwabe, 1987), the grasses sprout during rainy seasons, but are usually mostly absent during the dry season. Inclusively, there is the presence of *Isobelinadoka*, *tomentosa* and *Vapacatogoensis* with a well-developed grass layer (Nnaji *et al.*, 2011).

The vegetation is deciduous in nature because they shade their leaves in the cool dry season to prevent excessive loss of water through transpiration. They have long tap roots that go deep in search of water and broad trunks as in baobab to store water, along river banks, palms can be found. The vegetation cover changes seasonally, as such it is green and luxuriant during rainy season and yellowish- brown in the dry season.

1.6.4 Geology and relief

Zaria is underlain by three groups of rocks all of which belong to the Precambrian basement complex of Nigeria. These groups of rock include:

a. Gneiss of variable composition, which include granite rocks gneiss or schists, which have been thoroughly weathered at various depths and are found to form most of the superficial materials which are generally called drift.

b. Quartz, schist and quartzite which form a narrow bed of low rounded hill and valley topography. They are found in the north-south trending belt (forming ridges).

c. Gneiss or porphyritic granites are characterized by inselbergs of different shapes and sizes; these are often referred to as the older granite. They cover a small area with largest outcrop forming the Kufena group of inselbergs (Alkali,2009).

The study area forms part of the dissected Zaria – Kano plains, which is an extensive peneplain developed on crystalline metamorphic rocks of the Nigerian basement complex. There is however, some inselbergs such as Kufena hill and some low quartzite ridges in the west that The plain on which the region is located varies in height from 620 meters to 6500 m, reflecting both a regional slope to the south and a local relative relief of 35 – 45 m. The causes of these differences according to Thorp (1970) may be associated with the type of landuse, vegetation cover, the cohesion and permeability of the regolith and varying intensity in erosion energy.

1.7.5 Drainage and hydrology

The drainage system is based on the river Galma, which is a major tributary of the River Kaduna. It has a drainage basin of over 6902 km² area. The River Galma has an average gradient over the plain of 1m per 3 km. It carries water throughout the year unlike many of its tributaries which dry up during January to May. There are numerous other streams covering the region, prominent among them are Shika river, Kinkiba river and Likarbu river. Other rivers include river Kubanni, Saye, Baki, Anchau, and Danwata.

1.7.6 Land use

Agriculture is the most prevalent land use in the study area. Farming system is mixed livestock and crop production. In the floodplain, land use is dominated by the cultivation of crops such as maize and rice in the rainy season while varieties of crops such as Cereal, sugarcane, roots and tuber are grown during the dry season. Fishing activities are also predominant around the rivers. Settlements and rock outcrops also form part of the land cover. A great portion of the land is also used for grazing by Fulani nomads as well as local herders. Agricultural activities and run-offs from settlements as well as feces from grazing animals are known to constitute contamination to water bodies.

Industrial activities in the study area are concentrated around Dakace industrial area. Notable industries operating around the study area are; Zaria industries limited (ZIL) which is a canvas tarpaulin manufacturing industry, Olam industries which is an animal feed production company, Diageo which produces food and beverage, Sunseed oil company, which produces vegetable oil, Mamu oil and gas, Nazamu oil and gas, as well as some concrete and block producing industries among others.

Commercial activities in the study area include a fish market along the new Jos road around the bridge and another close to the dam, a vegetable market where the sales of vegetables such as spinach, tomatoes, cucumber, carrot, garden eggs, cabbage, lettuce among others take place, a fruit market where the sales of such fruits as watermelon, mango, oranges etcetera are common, and an abattoir where animals are slaughtered and their meat sold around the study area.

The Zaria Dam also known as Galma multipurpose dam situated in the study area. Galma multipurpose dam is constructed on Galma river downstream with a reservoir capacity of

186,000,000m³. The main purpose of the dam is to supply water to the treatment plant for Zaria city water scheme, supply water for irrigation of about 2500 hectares of farmland and to also supply water to power a hydro-electric power generation of about 2.2 megawatts. The Zaria water treatment plant located in the study area has a capacity of 150 million liters of water a day.

A large percentage (over 30 percent) of the land use in the study area is covered by residential areas. Settlements such as Bikaratu, Magami, Dakace, Fan Shanu, Likoro, GidanGayan, Amana, HausawanBugai, Burkonu, Rihogi, Bugai, Rikoka, Ashehu, Kafuri, Zaure, and Dambo are found around the study area. Water from the river is used for domestic use in these settlements and the domestic activities taking place in these areas contribute to the quality of the river.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

Human activities that can cause contamination of water include release into the environment of man-made chemical and bacteriological contaminants. Major contamination sources are animal and human wastes, industry and mining activities, agriculture and accidental leaks such as oil spillage (SON, 2007).

2.1.1 Non-point source of pollution

Non-point source (NPS) pollution is typically caused by rainfall or snowmelt moving over or through the ground, picking up natural and human pollutants, and carrying those pollutants into surface waters. Pollutants include but are not limited to excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks; salt from irrigation practices and acid drainage from abandoned mines; and bacteria and nutrients from livestock, pet wastes, and faulty septic systems (EPA, 2005).

Non-point source pollution is a major problem for surface waters because in most cases, it is difficult to identify the source of the pollution. Therefore, control of non-point sources of pollution is problematic.

2.1.2 Effect of Agriculture on water quality

Agriculture and its resultant practices such as irrigation, use of chemical fertilizers as well as pest control using herbicides, insecticides, fungicides and bactericides, have resulted in negative effects on both ground and surface water. These effects include eutrophication (mainly nitrogen

and phosphorus), algal bloom, hypoxia and accumulation of toxic pesticides, which are essentially poisonous to plants and animals, including humans (FAO, 2010).

2.1.3 Temporal and Spatial Variation

For effective water-quality assessment and management a reflection of the temporal variation characteristics is very important (Huang and Xia, 2001). Temporal variation is the assessment of the effect of time on pollution such as the seasonal pattern and its effect on the constituent's relationship (Kannelet *et al.*, 2007). Variation in water quality is caused by natural process and anthropogenic sources (Li *et al.*, 2007).

The spatial extent of pollution is critical as the mixing of pollutants occurs over a given distance. From a water quality management perspective accurate assessment of spatial and temporal variation of pollutant loadings in streams within a watershed is essential (Elshorbagy *et al.*, 2006). The risk associated with pollution depends on both the extent of the temporal and spatial variation of the pollutant (Remesan and Panda, 2008).

2.1.4 Water Quality Standards

Drinking water quality standard ensures the safety of the drinking water supplies and the protection of public health (SON, 2007). Water quality standards are requirements, as regards suitability of water for industrial use, for drinking, for boilers and other uses. There are many sources of water quality criteria and standards, they may originate from international bodies (e.g. WHO standards), issued by regional bodies (e.g. EU standards) or individual countries (e.g. Nigerian standards). Various levels specified will consider the different uses for which water quality must be maintained and may differ. Standards are imposed in order to protect end uses, be these by humans, animals, agriculture or industry (EPA, 2001). In the present context, however, the main considerations are in regard to safeguarding public health.

2.1.5 Nigerian Standard for Drinking Water Quality

In 2005, the National Council on Water Resources (NCWR) recognized the need for the establishment of an acceptable Nigerian Standard for Drinking Water Quality due to the observation that the Nigerian Industrial Standard for Potable Water developed by Standards Organisation of Nigeria and the National Guidelines and Standards for Water Quality in Nigeria developed by the Nigerian Federal Ministry of Environment did not gain wide acceptance by stakeholders in the country. Therefore, the federal ministry of health in collaboration with standard organization of Nigeria, developed the present standard (SON, 2007).

2.1.5.1 Principles

The Nigerian Standards for drinking water quality has the following principles for effective protection of public health against water related diseases:

- a) The protection of drinking water from catchments and source to its use by consumers
- b) A collaborative multi-agency approach that involve all agencies with responsibilities in the management of water quality.
- c) Water quality standard that is comprehensive, realistic and implementable within the resources of the implementing agencies.
- d) The development of procedures and requirements that ensure good water quality management in order to meet the maximum allowable limits. These procedures also protect the environment
- e) An independent surveillance agency with strong enforcement authority and functions decentralized to local government level.
- f) An effective drinking water quality data management system to enable generation of data for the development of coherent public health-centered policies and practices.

The Nigerian standards for drinking water quality have a prepared table for Maximum concentration of microbiological, chemical and organic constituents / contamination allowed in

drinking water. These concentrations are based on WHO guideline value for which no adverse health effect is noticed.

2.1.6 Physico-Chemical Parameters

Water quality assessment is the overall process of evaluating the physical, chemical and biological nature of the water (Chapman, 1996). Physico-chemical variables have been well used for investigating, monitoring and assessment of rivers and streams (Downes *et al.*, 2002). The need of water quality assessment is to verify whether the observed water quality is suitable for intended uses, to determine trends in the quality of the aquatic environment and how that quality is affected by the release of contaminants due to anthropogenic activities, and/or by waste treatment operations (Chapman, 1996).

2.1.6.1 Temperature

Water bodies are characterized by temperature variations along with normal climatic fluctuations. Natural variations of the water temperature often are influenced by factors such as hydrological, climatological, spatial and temporal scale, geomorphic variations, and structural features of the region and catchment areas (Dallas and Rivers-Moore, 2011; Dallas, 2008; Chapman, 1996). At the river scale geomorphological variation, riparian vegetation cover and different type of habitat determine the temperature fluctuation longitudinally in the river. Headwaters covered by riparian vegetation usually present lower temperature than downstream where temperature is often high (Dallas, 2008). Temperature is important because it influences physical, chemical and biological processes in water bodies. Its degree of predictability in a stream provides an indication of the degree of structure and functional predictability of invertebrate communities (Vannote and Sweeney, 1980). The development of temperature criteria is important for the effective protection and management of aquatic ecosystems (Dallas and Rivers-Moore, 2011). For that reason, South African guidelines suggest that the water

temperature for aquatic ecosystems should not be allowed to vary from the background average daily water temperature considered to be normal for that specific site and time of day, by $> 2^{\circ}\text{C}$, or by $> 10\%$, whichever estimate is the more conservative.

Inter-basin transfer schemes also impact on water temperatures since many effluents increase flow volumes and may lead to ecosystem variability (Rivers- Moore *et al.*, 2008). Water temperature is recognized as an important abiotic driver of aquatic ecosystems (Dallas and Rivers-Moore, 2011). However, human activities constitute a main cause for temperature modification. Many human activities such as water abstraction, hot effluents from industrial processes, land-use change, returning irrigation waters, removal of riparian vegetation, increased storm water runoff, power generation, and climate change and global warming can cause temperature increases in the receiving water of 10°C or more (Dallas and Rivers- Moore, 2011; Dallas, 2008; Abel, 2002).

2.1.6.2 Effect of temperature on water quality

Rise in water temperature alter many physical and chemical characteristics of water including the solubility of oxygen and other gases, chemical reaction rates and toxicity, and microbial activity.

In freshwater the physical environment in terms of a reduction in density of water, a decrease in pH, a reduction in solubility of dissolved oxygen followed by an increase in BOD by stimulating organic decomposition by microorganisms are observed as temperature increases shows that the increasing water temperature decreases the dissolved oxygen concentration in water and therefore its availability to aquatic organisms (Dallas, 2008).

Higher temperature favors the growth of sewage fungus and also the growth of macrophyte and algal blooms when nutrient conditions are suitable (Dallas and Day, 2004). It leads also to rapid bacteria and phytoplankton growth (Chapman, 1996). These factors reduce the environmental

quality of the water; affect the suitability of drinking water and aesthetic values for recreation (Dallas and Day, 2004).

2.1.6.3 Turbidity

Turbidity is a measure of the cloudiness or murkiness of water due to suspended particles. Turbidity is measured in nephelometric turbidity units (NTU) using a turbidimeter. This instrument shines a beam of light at a water sample and measures the amount of light that passes through the water compared to the amount of light that reflects off particles in the water. Turbidity can range from less than 1 NTU to more than 1,000 NTU. At 5 NTU, water is visibly cloudy; at 25 NTU, it is murky.

Turbidity can be caused by organic particles, such as decomposed plant and animal matter, or living biological organisms such as algae and inorganic particles (silt, clay and natural chemical compounds like calcium carbonate).

Turbidity in surface water bodies usually has organic and inorganic matter. It can be caused by heavy rains, flooding and spring runoff landslides and bank erosion algae blooms people, animals or boats disturbing the waterbed human activities such as construction that disturb land storm water pollution from urban areas.

Since a wide variety of particles cause turbidity, it is difficult to determine the health risk. The health risk is usually not the particles themselves but the impact of the suspended particles on disinfection of the water. Also, changes in turbidity can flag a potential problem and may indicate new source of contamination of the water. Surface water or shallow wells tend to have higher levels of turbidity. Organic matter and micro-organism are often present. Micro-organisms attach themselves to the suspended particles in turbid water. This prevents the water

from being properly disinfected, and can increase the risk of gastrointestinal illnesses. Organic matter can contribute to the formation of harmful by-products, like trihalomethanes (THMs). Particles can also carry more substances into the body, including metals like lead.

2.1.6.4 pH

The concentration of proton (H^+), hydroxyl (OH^-), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions are some of the most important attributes determining the composition and quality of water. The concentration of hydrogen ions is an important factor. Its value varies from 0 to 14 with $pH = 7$ representing a neutral condition, $pH < 7$ indicating acid condition and $pH > 7$ as a basic condition. Acid waters ($pH < 7$) can have measurable alkalinity, and alkaline waters ($pH > 7$) can have measurable acidity (Chapman, 1996). The pH is principally controlled by the balance between carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds.

In natural freshwaters, pH varies from 3.0 to 11.0 and sometimes more. The values between 5.0 and 9.0 generally support a diverse assemblage of aquatic species (Abel, 2002). Abel (2002) reports that factors that influence pH include geology, biotic activities, type of vegetation, atmospheric influences, acid-neutralizing or buffering capacity, and cation exchange capacity. Diurnally change in pH can be influenced by the photosynthesis and respiration cycles of photoautotrophs in eutrophic waters and other effluents. The photosynthetic process may alter the balance between carbonate and bicarbonate by taking away CO_2 from surface water.

All-natural waters have some buffering capacity, which is the ability to absorb acid or alkaline inputs without undergoing a change in pH. Where the buffering capacity of water is exceeded by the input of an effluent, the pH of the water will change.

Human activities influence acidification of aquatic ecosystems by diverse point-source effluents. Alkaline pollution in rivers is less common than acid pollution. Many untreated effluents impact

water quality in term of pH which may be strongly acidic or alkaline. High biological activities due to alkaline effluents from certain industries increase pH values in the rivers under eutrophic conditions (Dallas and Day, 2004). A very common form of acid pollution involving extreme pH in many developing countries, including South Africa is acid mine drainage (Abel, 2002) which causes very considerable stream and river pollution problems (Ross, *et al.* 2007).

There are several factors which affect pH, these are biological activities, temperature, total dissolved salts, concentrations of organic and inorganic ions. Lower pH values often are related to higher conductivity.

In many aquatic ecosystems, the changes observed in the concentration of metallic complexes leading to increase in toxicity of most metal are attributed to small variations in pH. At low pH, streams and acid precipitation may liberate toxic heavy metals. The most probably heavy metal increases which result from a low pH include Ag, Al, Cd, Co, Cu, Hg, Mg, Ni, Pb and Zn (Kimmel *et al.*, 1985).

A non-metallic ion that can be similarly affected by changes in pH is the ammonium ion (NH_4^+). Lowering pH can also decrease the solubility of certain elements such as selenium. Leske and Buckley, (2003) reported that a very high or a low pH does not affect TDS concentration in water.

2.1.6.5 Nitrogen

In the environment, inorganic nitrogen occurs in a range of oxidation states as nitrate (NO_3^-) and nitrite (NO_2^-), the ammonium ion (NH_4^+) and molecular nitrogen (N_2) (Chapman, 1996). Studies have shown a strong relationship between agricultural land use and nitrogen concentrations in surface water. Cooke and Prepas (1998) showed that agricultural watersheds exported up to 50 times more nitrogen than forested watersheds. They also showed that agricultural practices also influenced the fractionation of nitrogen in runoff. Nitrate was the

predominant form of Nitrogen in runoff draining cropland, while ammonia was the dominant form of Nitrogen in mixed agricultural watershed. The dominant form of Nitrogen in municipal waste water is also ammonia. Excessive nitrate in drinking water can be harmful to young infants or livestock. Nitrate causes methaemoglobinaemia, which is also known as Blue Baby Syndrome, in young animals and human infants. This condition decreases the ability of the blood to carry oxygen (Chambers *et al.* 2001).

2.1.6.6 Ammonia

In aqueous solution, un-ionized ammonia exists in equilibrium with the ammonium ion. Total ammonia is the sum of these two forms (Chapman, 1996).

The ammonium ion (NH_4^+) is a reduced form of inorganic nitrogen derived mostly from aerobic and anaerobic decomposition of organic material. In rivers ammonia losses tend to be associated with surface runoff and erosion rather than subsurface flow (Heathwaite *et al.*, 1996). In wastewater treatment effluent the ammonium ion along with urea tends to prevail above other nitrogen compounds (Kannelet *et al.*, 2007).

2.1.6.7 Total Alkalinity

Alkalinity is the acid-neutralising capacity of water and is usually expressed in mg/l. When the water has no buffering capacity total alkalinity and acidity are inter-related with pH. However, as most natural waters contain weak acids alkalinity is usually determined as well as pH in water quality assessment (Chapman, 1996).

Total alkalinity, the concentration of bases in water is composed mainly of bicarbonate (HCO_3^-), carbonate (CO_3^{2-}) and hydroxyl (OH^-) ions and is expressed as mg/l of CaCO_3 . Total Alkalinity is affected by changes in flow regimes (Brydstenet *et al.*, 1990) and its natural variability is linked to the presence or absence of carbonate rock (Kney and Brandes, 2007). It can also be affected

by the denitrification process in water which increases alkalinity in river water (Kannelet *al.*, 2007).

2.1.6.8 Dissolved oxygen (DO)

To assess dissolved oxygen is fundamental for it influences almost all chemical and biological processes within water bodies (Chapman, 1996). Oxygen availability is recognized as a key factor in aquatic ecology influencing the composition of freshwater communities because its depletion in water bodies affects the distribution of many species, community structure and local richness (Jacobsen, 2008; Connolly *et al.*, 2004). Dissolved oxygen can be used to indicate the degree of pollution due to organic matter, the destruction of organic substances and the level of self-purification of the water. In natural freshwaters, dissolved oxygen ranges from 15 mg L⁻¹ at 0° C to 8 mg/L at 25° C (Chapman, 1996). In unpolluted water, dissolved oxygen concentrations range usually close to, but less than, 10 mg/L. Dissolved oxygen below 5 mg/L may negatively affect the functioning and survival of biological communities and below 2 mg L⁻¹ may have harmful effects on aquatic organisms (Chapman,1996). Oxygen enters the water by absorption directly from the atmosphere, by aquatic plant and algae photosynthesis and is removed from the water by respiration and decomposition of organic matter (Jacobsen, 2008). However, the level of dissolved oxygen concentrations may vary in water bodies.

Solubility of oxygen in water is inversely related to both temperature and salinity (Dallas, 2008). Higher temperatures and salinities reduce the solubility of dissolved oxygen in water, decreasing its concentration and thus its availability to aquatic organisms while low temperature and salinities increase the solubility of oxygen in water (Mason, 2002).

The structure of a stream or river may also affect dissolved oxygen contents. Turbulence of water, depth and degree of exposure of the substratum on surface water influence the re-aeration of water. In fast-moving streams, rushing water is aerated by bubbles as it churns over rocks and

falls down hundreds of tiny waterfalls. These streams, if unpolluted, are usually saturated with oxygen. In slow, stagnant waters, oxygen only enters the top layer of water, and deeper water is often low in DO concentration due to decomposition of organic matter by bacteria that live on or near the bottom (Dallas, 2008).

During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls. Whereas during dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases (Mason, 2002).

Oxygen depletion depends on total and nature of organic material load in the rivers, and the numbers and types of bacteria which degrade waste discharges into the river (Mason, 2002). The organic pollution such as municipal sewage treatment discharge, industry wastes, storm waters from urban areas, and farm effluents can lead to decreases in DO concentrations as a result of the increased microbial activity occurring during the degradation of the organic matter (Dallas and Day, 2004; Mason, 2002).

Waste streams also contain inorganic plant nutrients, namely nitrogen and phosphorus that stimulate primary productivity, indirectly affecting oxygen concentrations. Increased primary productivity results in increased dissolved oxygen during the day. In contrast, too many plants may reduce the DO levels, because of either night-time respiration by plants, algae, and decaying process by heterotrophic micro-organisms causing oxygen declines (Perry and Vanderklein, 1996). Dissolved oxygen is the amount of oxygen dissolved in water, measured in milligrams per litre (mg/ℓ). This component in water is critical to the survival of various aquatic lives in streams, such as fish. The ability of water to hold oxygen in solution is inversely proportional to the temperature of the water. For example, the cooler the water temperature, the more dissolved

oxygen it can hold. Dissolved Oxygen can vary seasonally or in 24 hours depending on the temperature and the biological activity (Chapman, 1996).

Dissolved oxygen is one of the parameters that influence the biodegradation rate in water bodies. Dissolved oxygen can either impair or support use for aquatic life depending on its concentration. Dissolved oxygen is affected by entry of organic matter into rivers especially from runoff during and after a rainfall event.

2.1.6.9 Biological Oxygen demand

Biological Oxygen Demand (BOD) is a measure of how much oxygen is used by microorganisms in aerobic oxidation, or the breakdown of organic matter. Usually, the higher the amount of organic material found in the stream; the more oxygen is used for aerobic oxidation. BOD depletes the amount of dissolved oxygen available to other aquatic life. This measurement is obtained over a period of five days, and is expressed in mg/ℓ. The levels of BOD in receiving waters is directly increased by the discharge of wastes high in organic matter, resulting in localized areas of Dissolved Oxygen depletion (Chapman, 1996). These organic wastes emanate from municipal sewage, industrial wastewater and non-point source pollutants and lead to problems of water access to downstream users (Poo *et al*, 2008).

2.1.7 Heavy Metals

Heavy metals are those metals and metalloids that are generally considered to be of sufficient distribution and abundance and are in some way environmentally or biologically significant as a toxic substance (Shirkanloo *et al.*, 2011). These toxic elements enter the body mainly through water, food and air, as well as cosmetics, dental products, and some drugs (Verma and Dwivedi, 2013).

Heavy metals occur naturally in the ecosystem with large differences in concentration. They also occur as a result of human activities such as mining and other industrial activities (Dupler,

2001). Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation is an increase in the concentration of a chemical in a biological organism over time, in comparison to the chemical's concentration in the environment. Compounds accumulate in living things any time they are ingested and stored faster than they are metabolized (broken down) or egested (Verma and Dwivedi, 2013).

According to Agency for Toxic Substances and Disease Registry [ATSDR] (as cited in Malik and Khan 2016), among heavy metals, Arsenic (As), Cadmium (Cd), Lead (Pb), Chromium (Cr), Copper (Cu), Mercury (Hg) and Nickel (Ni) are of more serious concern, mainly because of their presence at relatively high concentrations in drinking water and their effects on human health. The International Agency for Research on Cancer [IARC] (2016), have reported that inorganic As and Cd cause cancer in humans, As is related to cancer risk and skin damage, Cd is linked to kidney damage and cancer. Other effects such as Anemia from Pb, kidney and liver damage from Hg, and gastrointestinal disorder from Cu have also been reported. However, it has been reported that metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and Zinc (Zn) are essential nutrients that are needed for various biochemical and physiological functions whose inadequate supply may lead to a variety of deficiency diseases or syndromes (Tchounwou et al., 2012).

2.1.7.1 Chromium and Chromium Contamination

Chromium is widely distributed in the earth's crust. Soils and rocks may contain small amounts of chromium, almost always in the trivalent state. chromium is a toxin typically originating from anthropogenic activity. However, chromium occurs naturally at high concentration in ultramafic rocks and is a common contaminant in surface and ground water.

Chromium and its salts are used in the leather tanning industry, the manufacture of catalysts, pigments and paints, fungicides, the ceramic and glass industry, and in photography, and for chrome alloy and chromium metal production, chrome plating, and corrosion control.

Chromium is an essential metal, and can also be carcinogenic. Chromium (VI) compounds are toxins and known human carcinogens, whereas Chromium (III) is an essential nutrient (Goyer, 2004; Martin and Griswold, 2009). Excessive intake of chromium results in severe acute effects such as gastrointestinal disorders, haemorrhagic diathesis, and convulsions cardiovascular shock which may lead to death, chromosomal aberrations and chromatid exchange, as well as lung cancer (Tchounwou et al., 2012).

2.7.2 Cadmium and cadmium contamination

Cadmium is a soft, bluish-white metallic element occurring primarily in Zinc, Copper and Lead ores, that is easily cut with a knife and is used in low-friction, fatigue resistant alloys, solders, dental amalgams, Nickel-cadmium storage batteries, nuclear reactor shields, and in rustproof electroplating (WHO, 2011b) other uses include pigments, metal coatings, and plastics (Gautam et al., 2014). Cadmium is soluble in acids but not in alkalis. It is similar in many respects to zinc. (WHO, 2011b). Cadmium is a very toxic metal. All soils and rocks, including coal and mineral fertilizers, contain some cadmium.

Cadmium is the most toxic element, even at its low concentration in the food chain and has been found to be the cause of itai-itai disease in Japan. Unlike other heavy metals, cadmium is not essential for biological systems. Hence it has no benefit to the ecosystem and only harmful effects have been reported (Gautam et al., 2014)

According to Davison et al., 1988 as cited in (Goyer, 2004), acute effects from oral cadmium exposure are uncommon, but high exposure to cadmium fumes (which can occur in some occupational settings) can cause acute bronchitis or even chronic disease, such as emphysema or

pulmonary fibrosis and lung cancer. Chronic exposure over several years to low doses of cadmium which might, for example, occur through cigarette smoking or daily ingestion of rice contaminated by cadmium can cause kidney tubular dysfunction and osteoporosis in susceptible populations (Goyer, 2004).

Cadmium and cadmium compounds are known human carcinogens. Smokers get exposed to significantly higher cadmium levels than non-smokers. Severe damage to the lungs may occur through breathing high levels of cadmium. Ingesting very high levels severely irritates the stomach, leading to vomiting and diarrhea. Long-term exposure to lower levels leads to a buildup in the kidneys and possible kidney disease, lung damage, and fragile bones (Martin and Griswold, 2009).

Cadmium may cause renal injuries and may interfere with the renal regulation of the calcium and phosphate balance. Cadmium concentrations in urine reflect long term exposure and the quantity of cadmium stored in the body, particularly in the kidney and liver (Shirkanloo et al., 2011).

2.1.7.3 Nickel and Nickel Contamination

Nickel is a lustrous white, hard, ferromagnetic metal. Nickel may be present in water as a result of dissolution from nickel ore-bearing rocks. Nickel is used principally in its metallic form combined with other metals and non-metals as alloys. Nickel alloys are characterized by their hardness, strength, and resistance to corrosion and heat. Nickel is mainly used for producing stainless steels, non-ferrous alloys, and super alloys. Nickel and nickel salts are also used in electroplating, as catalysts, in nickel–cadmium batteries, in coins, in welding products, cigarettes, cosmetics, spark plugs and in certain pigments and it is estimated that 8% of nickel is used for household appliances (WHO, 2005a; Gautam et al., 2014). Nickel is also used in production of some food supplements, which sometimes contain several micrograms of nickel per tablet/capsule (EU, 2004).

Nickel helps in the synthesis of the red blood cell, but when the concentration is high, it becomes toxic. Some health effects associated with intake of nickel in high quantities over a long period are damage to cells, damage the liver, and heart as well as decrease in body weight. Nickel poisoning can also cause cancer, nervous system damage, as well as reduction in cell growth (WHO, 2005a Wuana and Okieimen, 2011).

2.1.7.4 Zinc and Zinc Contamination

Zinc is a transition metal which occurs naturally in soil (Davies and Jones, 1988 in Wuana and Okieimen, 2011). It is released to the environment from both natural and anthropogenic sources, but Zn concentrations are rising unnaturally rapidly, due to anthropogenic additions. Most Zn is added during industrial activities, such as mining, coal, and waste combustion and steel processing. Many foodstuffs contain certain concentrations of Zn. Drinking water also contains certain amounts of Zn, which may be higher when it is stored in metal tanks. The world's Zn production is still on the rise which means that more and more Zn ends up in the environment. Water is polluted with Zn, due to the presence of large quantities present in the wastewater of industrial plants. A consequence is that Zn polluted sludge is continually being deposited by rivers on their banks. Zinc may also increase the acidity of waters. Zinc causes damage in aquatic fauna and flora, some fish can accumulate Zn in their bodies, when they live in Zn-contaminated waterways. When Zn enters the bodies of these fish, it is able to biomagnify up the food chain. Water-soluble zinc that is located in soils can contaminate groundwater. Plants often have a Zn uptake that their systems cannot handle, due to the accumulation of Zn in soils (Wuana and Okieimen, 2011). Industrial sources or toxic waste sites may cause the concentrations of Zn in drinking water to reach levels that can cause health problems. Although zinc is essential for human health, its shortage can cause birth defects. Zinc has been linked to some health

conditions in humans such as anemia, lack of muscular coordination and abdominal pain (Gautam et al., 2014).

2.1.7.5 Copper and Copper Contamination

Copper is a transition metal, it is the third most used metal in the world. Copper is an essential micronutrient required in the growth of both plants and animals. In humans, it helps in the production of blood haemoglobin. In plants, copper is especially important in seed production, disease resistance, and regulation of water. It is present in munitions, alloys (brass, bronze) and coatings. Copper compounds are used as or in fungicides, algicides, insecticides and wood preservatives and in electroplating, azo dye manufacture, engraving, lithography, petroleum refining and pyrotechnics. Copper compounds can be added to fertilizers and animal feeds as a nutrient to support the growth of plants and animals (ATSDR, 2002; Wuana and Okieimen, 2011). Copper compounds are also used as food additives (e.g., nutrient and/or colouring agent). Copper can be found in surface water, groundwater, sea water and drinking water. Its concentrations vary as a result of differences in some characteristics of water such as Ph and hardness (WHO, 2004). Copper normally occurs in water from additives that are meant to control algal growth. Although interaction of copper with the environment is complex, research shows that most Copper introduced into the environment are stable, or rapidly become stable and results in a form which does not pose a risk to the environment. In fact, unlike some man-made materials, Copper is not magnified in the body or bioaccumulated in the food chain. In the soil, the solubility of Copper is increases drastically at pH 5.5 (Martinez and Motto, 2000), which is very close to the recommended ideal agricultural soil pH of 6.0–6.5.

Copper is also an essential nutrient, but it's consumption in high doses can lead to health effects such as gastro-intestinal bleeding, headache, nausea, vomiting, diarrhea, anaemia, liver and kidney damage, stomach and intestinal irritation, haematuria, intravascular haemolysis, oliguria,

acute renal failure and hepatocellular toxicity (Agarwal et al., 1993, Wuana and Okieimen, 2011).

2.1.8 Pathogens

Pathogens are disease-causing microorganisms, such as bacteria and viruses that come from the fecal waste of humans and animals (Cabral, 2010). Polluted surface waters can contain a large number and variety of pathogenic microorganisms which includes bacteria, viruses and protozoa. The main origin of these pathogenic microorganisms is human feces and the feces of warm-blooded animals, which are introduced to the aquatic environments through the release of wastewater effluents, surface runoff and soil leaching (Ouattara et al, 2011). Exposure to pathogens, either from direct contact with contaminated water or through eating contaminated shellfish can cause a number of health problems such as cholera, typhoid fever, dysentery, among others. Children under five in Asian and African countries are the most affected by microbial diseases that are transmitted through ingestion of contaminated water (Cabral, 2010).

2.1.8.1 Total coliforms

Total coliform (coliform organisms) have been recognized as a suitable microbial indicator of drinking water quality for a very long time, because they are easy to detect and enumerate in water. The term “coliform organisms” refers to Gram-negative, rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties and able to ferment lactose at 35–37°C to produce acid, gas, and aldehyde within 24–48 hours. They are also oxidase-negative and non-spore-forming and display β-galactosidase activity (WHO, 2005). Coliform are useful indicators of the possibility of presence of enteric pathogenic bacteria and virus. They are usually present in water containing enteric pathogens, and survive longer than the disease-producing organisms, therefore water that is free of total coliforms is generally considered free of disease-forming bacteria (Scott, 1995).

2.2 LITERATURE REVIEW

2.2.1 Studies on River Water Quality and it's Suitability for drinking

Haritash, Gaur and Garg (2016) collected water samples from River Ganga in Rishikesh, India to assess its suitability for drinking, irrigation, and industrial usages using various indices. The samples collected were analysed for physico-chemical and biological parameters. Based on the values obtained, it was found that water in upper segment of the river can be used for drinking but after treatment; organized outdoor bathing in the middle segment; and can be used as drinking water source as well as in the lower segment. All the parameters were within the specified limits for drinking water quality except E. coli. The indices of suitability for irrigation and industrial application were also evaluated. The irrigation quality ranged from good to excellent at almost all places with the exception of percent sodium. Heavy metals (lead, Copper, Zinc, Nickel) were found either absent or within the limits specified. There was no specific industrial input of pollutants, it was therefore suggested that Industrial applications of the river water should be limited since the water was found to be aggressive, with the problem of heavy to intolerable corrosion. Water quality of Ganga in Rishikesh was concluded to be good with few exceptions but needs regular monitoring and some control measures.

Oribhabet *et al.* (2013) conducted a study on the ecological impact of human settlement on the water quality of Lower Cross River, Nigeria, where they evaluated the physical and chemical conditions of the river water from January to August, 2011. Areas with intense human activities and those without human activities were sampled. It was found that only water level and COD were significantly different between the sites. Results were compared between some parameters with Standard Organization of Nigeria, and World Health Organization maximum permissible limits for drinking water, which indicated that the water was not polluted and therefore suitable for drinking. However, the BOD and COD concentrations of greater than 2mg/L and 20mg/L

respectively were indicative of pollution. It was concluded that physical and chemical parameters investigated indicated that human settlement in the study area did not have any significant impact on the Lower Cross River water quality; However, the study could serve as a baseline for the study area, since there is absence of industrial activities in the area at present. It was recommended that since BOD and COD values are highly above recommended maximum permissible limits, further investigation of the water quality of the river is required, particularly upstream of the study area and that the study should be followed by assessment of the biological characteristics of the present study area of the river.

Alsaqqar, Khudair and Hasan (2013) assessed water quality of the Euphrates River within Al-Anbar province, Iraq and its suitability for drinking. Ten stations were identified and water samples collected from these station for a period of six years (2004-2010) and subjected to physic-chemical analysis for ten parameters. Water quality index was employed in analyzing the obtained results. Some of the parameters were found to have high concentrations and were attributed to the various human activities taking place around the river, particularly domestic and industrial activities. It was concluded that the quality of the Euphrates River is poor and unsuitable for drinking.

Joshi, Kumar and Agrawal (2009) carried out a study to assess the water quality of river Ganga in Haridwar district for drinking purposes. Five sampling stations were identified and ninety water samples were collected over three seasons in two years, and then analysed for physico-chemical parameters. The results were compared with set standards and it was found that pH, electrical conductivity total dissolved solids, total suspended solids, turbidity and sodium are above the prescribed limits in some areas. Water quality index value indicated that water samples

in some stations are unfit for drinking, due to the high concentrations of dissolved solids and sodium. Temporal variations were also observed.

Alam, *et al.* (2007) conducted research on parts of Surma River in Bangladesh. Ten sampling stations were selected based on industrial, municipal and agricultural activities taking place, from where water samples were collected and analyzed for various water quality parameters during two seasons (dry and monsoon). The analyses involved physical, chemical and biological parameters, and the water was found to be more turbid in the monsoon season, but biological oxygen demand (BOD) and fecal coliform concentrations were found to be higher during the dry season. It was therefore concluded that the water is unfit for drinking except treated, but could be used for other purposes.

2.2.2 Effect of Human Activities on Surface Water Quality in Different Parts of the World.

Johannessen, *et al.* (2015) conducted a study on diverse land use and the impact on irrigation water quality, in the Norwegian river of Lier, where they summarized data on fecal indicators and selected bacterial pathogens to assess level of fecal contamination in five (5) river points, between two seasons, for eight (8) years. The research concluded that there has been increase in fecal contamination in the river, which was attributed to increase in population and change in land use practices.

Ontumbeet *al.* (2015) carried out research on the influence of agricultural activities on water quality of River Sosiani in Uasia Gishu county, Kenya. The study identified agricultural activities within the catchment area, using landsat images, and sampling points were identified from these areas. Samples were collected for two seasons (wet and dry). Parameters tested for include pH, TSS, turbidity, EC, temperature, nitrates and total phosphorous. It was found that the

river is stressed by nutrients originating from agricultural activities and actions are needed to check further degradation.

Bu et al. (2014) in determining the relationship between land use patterns and river water quality in the Taizi River basin, China used land use types and land use metrics. Samples were collected along the river during the dry and rainy seasons and they were analysed for different water quality parameters. It was discovered that vegetated areas had a positive effect on river water quality, built up areas had higher nitrogen and phosphorous, agricultural land use produced results that were high for most physicochemical variables and nitrogen during the rainy season. It was concluded that the river generally suffered organic, phosphorous and nitrogen pollution. Furthermore, agricultural land use and built up areas had the worst water quality than other areas, suggesting that human activities impact negatively on water quality.

Gandaseca, *et al.* (2014) investigated the effects of land use on river water quality of AwatLawas mangrove forest Limbang Sarawak, Malaysia. Water samples were collected from fifty-two (52) different sampling points selected from upstream, midstream and downstream of the river, between two seasons (wet and dry seasons) from November 2012 to May 2014. Results of the study were compared with the Malaysian water quality index and found to be of moderate water quality status.

Alam, *et al.* (2007) conducted research on parts of Surma River in Bangladesh. Ten sampling stations were selected based on industrial, municipal and agricultural activities taking place, from where water samples were collected and analyzed for various water quality parameters during two seasons (dry and monsoon). The analyses involved physical, chemical and biological parameters, and the water was found to be more turbid in the monsoon season, but biological

oxygen demand (BOD) and fecal coliform concentrations were found to be higher during the dry season. It was therefore concluded that the water is unfit for drinking except treated, but could be used for other purposes.

Ciobataru (2015) conducted a research on rivers Buzau and Danube and groundwater in Braila county, south-eastern Romania. The article analysed the effects produced by anthropogenic pollution via irrigation and chemical processing, to water quality. Concentration of nitrates, phosphates, dissolved oxygen among others were determined. It was discovered that the main sources of water pollution in Braila County, are the population which discharge untreated wastewater, a series of public and private companies as well as pig complexes. The quality of the water and environment in Braila County improved significantly after the enterprises and pollutant sections and the pig complexes were closed.

2.2.3 Surface Water Quality of Africa

Garaet *al.* (2017) conducted a study titled health safety of drinking water supplied in Africa: a closer look using applicable water-quality standards as a measure. They investigated 21 water quality parameters of 18 selected African countries, to assess if they have significant differences across countries. These were compared to standards set by WHO, EU, US and China. They found that there were significant statistical differences among twenty of the twenty-one studied parameters and concluded that the mean quality standards of Africa were generally higher (weaker) than those of WHO, EU and China but compared well with those of US. It was recommended that nations should frequently update without delays, their standards as new information become available, as there are emerging novel pollutants that are of health concern. The African Union or regional groups like the Economic Community of West African States

(ECOWAS) and Southern African Development Community (SADC) were advised to develop regional water-quality standards and benefit from knowledge and technological sharing, leading to improved supply of high-quality water in their individual countries.

Nienie et al. (2017) conducted a research on the seasonal variability of water quality by physiochemical indexes and traceable metals in suburban area Kikwiti, Democratic Republic of Congo. Water samples were collected from wells and rivers in Kikwit for two seasons (wet and dry seasons) and tested for some physico-chemical and heavy metal parameters. It was found that values for parameters vary between seasons. Comparisons were made with WHO guidelines and the water was deemed fit for consumption and other domestic activities.

Anyonaet al. (2014) in their research on the effect of anthropogenic activities on physico-chemical parameters and benthic macroinvertebrates of Mara River tributaries, Kenya, tested for dissolved oxygen, conductivity, total phosphorous and total dissolved solids in areas of anthropogenic activities, and found all parameters to be higher in these areas than in areas of less anthropogenic activities.

In a study conducted by Kibenaet al. (2014) which assessed the relationship between water quality parameters and changes in land use patterns in the upper Manyame river of Zimbabwe, Land cover data for the year 1984, 1995, 2003 and 2011 were acquired from landsat image and historical water quality data for year 1996, 2000/2001, 2008/2009 were also acquired from the relevant agency. Then water quality of 15 sites was monitored for 25 water quality parameters for six (6) months. Parameters such as total nitrogen and phosphorous showed significant increase over the years, there was noticeable decrease in forested areas, grassland and bareland while urban areas and agricultural land increases. It was concluded from results of buffer analysis that agricultural activities and settlements are the main sources of pollution to the water,

and a combined programme of point source control and land use modification was recommended.

Masere, Munodawafa and Chitata (2012) conducted a study along Manyame River to assess human impact on water quality of the river. Thirty-five (35) sites were selected for sampling and were further grouped into five (A, B, C, D and E) with A representing upstream and E downstream. Eight (8) water quality parameters (nitrates, phosphates, copper, iron, biochemical oxygen demand BOD, dissolved oxygen DO, pH, turbidity) were analyzed. The results were compared against the Zimbabwe National Water Authority (ZINWA) standards, four of the parameters, namely; nitrate, phosphate, turbidity and dissolved oxygen were greater than the maximum permissible limits set by ZINWA, and the quality of the water was found to be decreasing downstream.

2.2.5 Effects of Human Activities on Water Quality in Nigeria

Fashaeet *al.* (2017) examined land use dynamics and surface water quality in a typical urban centre of south-western Nigeria, where they studied the differences between the qualities of surface water traversing the various land use types within Ibadan metropolis, South-Western, Nigeria. They identified the pattern of distribution and compared the concentration of some of the chemical and physical components of the surface water in order to determine the impact of human activities on the concentration of the physical and chemical components of water within the study area. Topographical map and Google Earth satellite images as well as fieldwork were

used in determining the sampling sites. Four rivers that traversed the metropolis were selected, from where a total of twenty samples was collected with five samples from each stream that traverse the various land use types. Samples were then subjected to laboratory analysis and data collected was analyzed using descriptive statistics, analysis of variance and simple linear regression analysis. They found that there was a significant relationship between residential and commercial land use and surface water quality change and concluded that commercial and residential effluents has strong negative impact on the surface water quality change compared to industrial and agricultural land use in the study area.

Omotayo *et al.* (2017) evaluated water quality parameters in rivers from five locations in Yobe state, Nigeria. Water samples were collected from the five locations and analysed for physicochemical and bacteriological parameters. Results obtained were compared to WHO standards. It was found that most of the samples had results of physical and chemical parameters falling below standards set by WHO. The bacteriological parameters as well fell below standards, which shows bacteriological contamination. They suggested that water from these areas should be treated before consumption and other domestic use.

Abubakar *et al.* (2015) conducted a study titled heavy metals pollution on surface water sources in Kaduna metropolis, where they examined the effects of heavy metal pollutants to aquatic ecosystems and the environment by considering the role of urban, municipal, agricultural, industrial and other anthropogenic processes as sources of heavy metal pollution in surface water sources of Kaduna metropolis. Samples of water were collected from River Kaduna and along the Kakuri – Makera drains. The X – Ray florescence (XR F) was used as an analytical technique for the detection of heavy metals. Heavy metals such as Lead {Pb}, Arsenic {As}, Iron {Fe}, Chromium {Cr}, Copper {Cu} and Zinc {Zn} were tested for and compared to WHO guidelines.

The results showed the concentration of most of the heavy metals were higher than acceptable limits by WHO. It was then concluded that the water from the river is polluted and may cause serious ecological and health hazards. They recommended among other things that there should be proper monitoring of effluents into receiving water as an integral part of water management in the rivers so that whether or not imposed standards and regulations are met can be verified.

Obeta, Ocheje and Nwokocha (2015) examined the effects of land use on the quality of Imabolo stream in Ankpa urban area of Kogi state. Seven land use types were identified as forested, agricultural, residential, commercial, educational, industrial and transportation. Water samples were collected from each of these land use types for both dry and rainy seasons using standard procedures. These samples were tested for some physico-chemical as well as bacteriological parameters. The results were compared to standards set by the WHO and NSDWQ. Water quality index (WQI) was also used for analysis of quality rating among the land use types. It was discovered that commercial land use had the highest negative effect on the quality of the stream, followed by industrial, residential, transportation and finally agricultural land use. The pollution of the stream varies with seasons, with the rainy season producing more pollution. The water quality of the stream generally is poor. They recommended improved land use optimization, water source protection water pollution control and creation of awareness among the populace.

Uzairuet *al.* (2014) carried out a study titled bioavailability studies of metals in surface water of river Challawa, Nigeria. They assessed the bio-available fractions of the metals zinc (Zn), lead (Pb), copper (Cu), chromium (Cr) and cadmium (Cd) in surface water of river Challawa, Kano, Nigeria, across seasons as a result of industrial activities. They found that the concentrations of most metals increased significantly during the dry seasons. Concentrations of Cu and Zn are within the standard limits of EPA and WHO for these metals in drinking water while Pb, Cr, and

Cd had their concentrations higher than EPA and WHO standard limits. The results showed that metals concentrations in the mobile and dissolved fractions which are easily bio-available were high. It was concluded that the metal could leach during changes in environmental conditions and pose threat to the surrounding groundwater quality. Also, with elevated levels of some metals in control point, sources other than industrial effluents could be responsible. With the continuous discharge of waste and waste water, especially with Cr, Pb, and Cd, the study area is likely to be severely affected.

Dimowo (2013) in his assessment of some physico-chemical parameters of River Ogun (Abeokuta, Ogun State, Southwestern Nigeria), which he compared with National and International standards, selected four (4) locations along the River, in consideration of all possible human activities that could affect water quality of the river. Water samples from the selected points were collected monthly for seven (7) consecutive months from December to June 2012. Using the Hanna combo pH and EC multimeter and mercury in glass thermometer, pH, conductivity, air temperature and water temperature parameters were determined on site. While dissolved oxygen, Nitrate, alkalinity, hardness and phosphate were determined in the laboratory. The results were then compared with National permissible limits of national administration for food, drugs and control (NAFDAC), federal environmental protection agency (FEPA) and standard organization of Nigeria (SON). As well as international standards of world health organization (WHO), united states environmental protection agency (USEPA) and European union standards for drinking water. The findings were that most of the parameters measured were above maximum permissible limits of all the standards and the water is therefore unfit for domestic uses, drinking and aquaculture. It was recommended that water should be treated if it must be used.

Oribhabet *et al.* (2013) conducted a study on the ecological impact of human settlement on the water quality of Lower Cross River, Nigeria, where they evaluated the physical and chemical conditions of the river water from January to August, 2011. Areas with intense human activities and those without human activities were sampled. It was found that only water level and COD were significantly different between the sites. Results were compared between some parameters with Standard Organization of Nigeria, and World Health Organization maximum permissible limits for drinking water, which indicated that the water was not polluted and therefore suitable for drinking. However, the BOD and COD concentrations of greater than 2mg/L and 20mg/L respectively were indicative of pollution. It was concluded that physical and chemical parameters investigated indicated that human settlement in the study area did not have any significant impact on the Lower Cross River water quality; However, the study could serve as a baseline for the study area, since there is absence of industrial activities in the area at present. It was recommended that since BOD and COD values are highly above recommended maximum permissible limits, further investigation of the water quality of the river is required, particularly upstream of the study area and that the study should be followed by assessment of the biological characteristics of the present study area of the river.

Nnaji, *et al.* (2011) in their research on the effect of pollution on physico-chemical parameters of water and sediments of river Galma, Zaria, Nigeria, collected samples from upstream and downstream of the river in twenty sampling points. These samples were analysed for thirteen physico-chemical parameters for water and ten parameters for sediments. It was concluded that the river was suitable for aquaculture as well as municipal water supply.

Longe and Omole (2008) in their analysis of pollution status of River Illo, Ota, Nigeria, considered the human activity of abattoir operations, from sales point, grazing field,

slaughtering, to waste dump associated with the abattoir, in selecting sampling points. Seven sampling points were selected in this regard including one control point. The samples were collected during the dry season and tested for biological oxygen demand (BOD), dissolved oxygen (DO), chemical oxygen demand (COD), total dissolved solids (TDS) and total solids (TS). The findings indicated that re-aeration of the river body was slow while full recovery from pollution was not attained even at 100m downstream. Sanitation program from remediation was recommended to improve quality of water in the river.

2.2.6 Recent Studies on Human Activities and River Water Quality

Wang *et al.* (2020) studied the relationship between land use types, water and sediment parameters, and macrobenthos community structures in the upper middle course of the Fenhe river and urbanization intensity. Four land uses viz: cropland, grassland, forest, wetland and construction land were identified and samples were collected from twenty three sampling sites and tested for physico-chemical, heavy metals and biological parameters, as well as macrobenthos community compositions. It was concluded that intensification of urbanization has strong effects on the water, sediments and macrobenthos in the river.

Baluch and Hashmi (2019) investigated the impact of anthropogenic and natural sources of pollution on water quality of upper Indus basin by using multivariate statistical analysis. Some physico-chemical parameters were tested from sixty-four sampling sites cutting across six regions. The results indicated that anthropogenic activities as well as run-off and erosion were the major sources of pollution and that parameters influenced by anthropogenic activities were dissolved oxygen, electrical conductivity, total dissolved solids and lead.

Camara *et al.* (2019) studied the impact of land uses on water quality in Malaysia. They studied land use changes in urbanization, industrialization and agricultural processes and its effect on water quality by evaluating the significance of both land use and water quality attributes in other studies. The results indicated that agricultural and forest-related activities had more effect on water quality through significant positive correlation with physical and chemical parameters, while urban development activities had greater impact on water quality through alteration of hydrological processes.

Chetty and Pillay (2019) assessed the influence of human activities on river health, using two South African rivers (Palmiet and Sezela) in KwaZulu-natal with differing pollutant sources as case study. The human activities were classified viz: industrial, residential, agricultural, informal settlements. Samples were collected from both rivers and tested for some heavy metal parameters. Palmiet river which comprises industrial activities, residential and informal settlements was found to have significantly elevated levels of metal concentrations while the Sezela river which comprises agricultural activities and informal settlements showed metal concentrations that pose little to no threat to human health. It was concluded that both rivers show deterioration, with industrial activities have the major effect on Palmiet river water quality and agricultural activities having more effect on Sezela river.

Fashaet *al.* (2019) studied land use and its impacts on surface water quality in an emerging urban city. Land use types were classified into residential, vegetated and commercial, water samples were collected and tested for different parameters, variations in water quality across the different land use types were examined and comparisons were made with WHO standards. Total dissolved solids, bacterial load and total solids were found to be above the limit recommended by

WHO and it was recommended that continual intensive water quality monitoring programme for surface waters across the area to ensure safety of health.

Yadav *et al.* (2019) in their study assessed the influence of different land uses on some water quality parameters on the Mun River, in Thailand. Water samples were collected at different points both seasonally and annually to determine spatial and temporal variations. The result showed that urban land use adds tremendously to nutrient concentrations, followed closely by agricultural land use. Higher concentrations of parameters were observed during the dry seasons except for fecal coliform, suspended solids and total phosphorus which has higher readings in the wet seasons. It was therefore recommended that there is need for multi-scale interventions and effective pollution control measures especially on nutrient, pathogenic bacteria and solids pollution, in order to improve the river water quality.

Fagbayide and Abulude (2018) assessed the effects of human activities on the water quality parameters of Ala River in Akure, Ondo State, Southwest Nigeria. Three sampling sites were selected along the course of the river to reflect a consideration of all possible human activities that are capable of affecting the quality of the river water. They collected water samples monthly for three months (February to April 2015) at the three sampling sites and then analysed for some physico-chemical parameters (pH, total dissolved solids, dissolved oxygen, biochemical oxygen demand, total hardness, phosphate, temperature, calcium, magnesium, chlorine, nitrate, iron and zinc), then their environmental effects on the river were investigated. The results indicated variations in the quality of the sampled water when compared with the World Health Organization standards for domestic and commercial water for the selected parameters. They observed that traces of some hazardous physical and chemical impurities in the river were above the acceptable limits, and thereby pose a health risk to several rural communities who rely on the

river as their source of domestic water. They suggested that the law should be enforced to discourage unnecessary waste dumping and discharging of other forms of pollutants into surface water in Nigeria.

CHAPTER THREE MATERIALS AND METHODS

3.1 MATERIALS USED IN THE STUDY

The research was conducted using a number of materials, these are:

Geographic positioning system (GPS) for taking co-ordinates of sampling sites, plastic bottles for collection of water samples from the river, sterilized hand gloves for wearing to prevent contamination of samples, cooler and ice for preserving the samples during transportation,

conical flasks, beakers, pH meter, pipette, glass-stoppered bottle, burette, Atomic absorption spectrophotometry (AAS) machine and chemical reagents for use in the laboratory.

3.2 RECONNAISSANCE SURVEY

Reconnaissance survey was conducted to familiarize with the study area terrain especially the land use pattern and to identify the sources of pollution into the River Galma based on the predominant land use types which are; residential, agricultural, commercial and reservoir,

3.3 TYPES AND SOURCES OF DATA

3.4 DATA COLLECTION

The data used for this research was primarily water samples collected from the field which were taken to the laboratory and was subjected for analysis, for the following parameters: temperature, turbidity, pH, electrical conductivity, total dissolved solids, dissolved oxygen, biological oxygen demand and heavy metals. Other dataset includes Satellite Image (Landsat) and topo maps. Detail of dataset used for the study is described below.

3.4.1 Field data

The samples were collected on 18th August and 19th September 2018 (wet season) and 19th November and 18th December 2018 (dry season). A total of 20 water samples were collected from the five-land use location (Reservoir/River Channel, Industrial area/Farmland, Residential area/Farmland, Treatment plant/Farmland and Commercial/Farmland). The samples were collected during the wet and dry season, ten samples each; and they were subjected to 10 physico-chemical analysis namely: Temperature, pH, Cadmium, Chromium, Dissolved Oxygen, Biological Oxygen Demand, Zinc, Copper, Coliform, Total Dissolved Solid, Chemical Oxygen Demand, Electrical Conductivity, Color and Odour. The absolute locations were recorded against each of the samples using a Garmin GPS.

3.4.2 Secondary data

Secondary data for the study includes Landsat satellite images which was sourced from (<https://earthexplorer.usgs.gov/>) and topographic maps.

3.5 SAMPLING AND SAMPLING TECHNIQUE

Cluster sampling was used for the study. The rationale behind choosing the cluster sampling technique was because of the homogeneity of pollution discharge by each of the five identified cluster (reservoir, treatment plant, industrial area, residential area, commercial area and farmland) type in the study area. A total of 20 samples were collected for the period (dry & wet season) of samples collection. Four samples each were collected from the five sampling sites for the two seasons.

3.6 METHOD OF DATA COLLECTION

Samples were collected using sterilized plastic containers (75CL) for collection of sample waters for physico-chemical analysis, biological analysis and heavy metals analysis. For collection of samples for physico-chemical parameters, bottles were washed with detergent and rinsed severally. They were then rinsed with distilled water, before taken to the field for water sampling. On the field, bottles were rinsed using the sample water before filling the bottles with the sample water, the cap of the bottles are then replaced tightly, and the bottles labeled for identification purpose. The grab sampling method was employed for collection of water samples. Cooler and ice were used for storage of samples after collection and during transportation to the laboratory. This is in order to preserve the samples. This procedure is in accordance with the method recommended by the American public health association (APHA) guidelines for water sampling.

3.6 LABORATORY ANALYSIS

The water samples collected was analyzed in the laboratory for different physical, chemical and biological parameters. These include temperature, turbidity, pH, electrical conductivity, total dissolved solids, dissolved oxygen, biological oxygen demand and heavy metals. Maximum permissible limits of Nigerian standards for domestic water quality (NSDWQ) and world health organization (WHO) were used as measures in the study.

3.6.1 pH

Apparatus such as 50ml beaker, pH metre, buffer 4 and 7, as well as measuring cylinder were used in determining the pH of the samples. The pH metre is calibrated using buffer 4 and buffer 7. 40ml of each sample is now measured and placed in the 50ml beaker. The readings are then taken for each sample and recorded (international centre for agricultural research in the dry areas ICARDA, 2013).

3.6.2 Dissolved oxygen (DO)

Portions of the sample were placed in a glass-stoppered bottle. Bottle was carefully filled to the brim to avoid trapping air bubbles. 2cm^3 of manganese chloride solution and 2cm^3 of alkaline iodine were added to the sample using pipettes, whose tip was placed in the bottom of the sample bottle. 2cm^3 of concentrated hydrochloric acid was added and the bottle closed. 50cm^3 of this solution was removed and placed in a conical flask. This was titrated with 0.01M sodium thiosulphate solution from the burette. This was done in drops while shaking the flask until colour became pale. 3 drops of starch solution was added and the titration continued until the blue-black colouration of the starch disappeared. The volume of thiosulphate used was recorded. This was repeated with two other 50cm^3 samples of water and the mean volume was obtained.

Using this solution, 1cm³ of 0.01M thiosulphate solution corresponds to 0.056cm³ of oxygen at standard temperature and pressure (STP) (Taylor *et al.*, 1997).

The final dissolved oxygen was calculated using the formular: Oxygen in cm³/dm³ = 0.056 × x × 1000/50 at STP. Where x = mean volume of 0.0125M thiosulphate solution required for titration of 50cm³ of sample.

3.6.3 Biological Oxygen Demand (BOD)

Values for biological oxygen demand are gotten, using the dissolved oxygen values. The initial values for dissolved oxygen were taken, samples were then stored in a dark incubator at 20⁰C for five (5) days. After five days, the measurements are taken for the final dissolved oxygen. The final dissolved oxygen is subtracted from the initial dissolved oxygen to arrive at the BOD reading.

3.6.4 Heavy Metals

The heavy metals analyzed are Cadmium (Cd), Chromium (Cr), Zinc (Zn), Copper (Cu) and Nickel (Ni). They were analyzed using the atomic absorption spectrophotometry (AAS) machine. A portion of the sample water was digested using the nitric acid (HNO₃). The instrument is then calibrated in accordance with the metal to be investigated. The hollow cathode lamp for the metal of interest is inserted, the digested sample is then applied and the atomization is taken from the readout screen and recorded.

3.7 DATA ANALYSIS

The data was discussed and presented using tables, charts and figures. This section presents and analyses the data acquired from the field for ease of understanding.

3.6 Statistical Analysis

Descriptive statistics was used to describe the data collected. The seasonal variations between the wet and dry seasons were described using the descriptive statistic. Seasonal variations were also analyzed using Analysis of variance (ANOVA) to determine the relationship within and between groups. The Pearson Correlation Coefficient was used to determine the impact of different landuse types on water quality parameters.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 LEVEL OF PHYSICO-CHEMICAL PARAMETERS

The ranges of physiochemical parameters measured at all the sampling sites and for the period of the samples collection are reported in Table 4. The collected samples were subjected to laboratory analysis and the results were also analyzed using the descriptive statistics, which includes: mean, coefficient of variation as well as standard deviation.

Descriptions for the water quality are displayed in Table 1.

Table 1: Descriptive statistics of water quality parameters of dry and wet seasons

Parameter	pH	T	EC	D.O	BOD	CO	TDS	Ni	Cr	Cd	Zn	Cu
Dry season												
Mean	6.3	28	49.1	10.4	2.4	30.4	721.0	0.2	0.0074	0.0357	1.9	0.050
Standard Deviation	0.032	1.5	0.9	15.0	0.8	12.7	75.2	0.0188	0.0073	0.0226	0.9	0.010
CV	0.5	14.6	1.8	143.6	30.8	41.7	10.4	10.9	97.7	63.4	46.3	19.9
Wet Season												
Mean	6.4	32	55.4	7.1	3.1	53.6	772.0	0.3	0.0285	0.0622	3.7	0.4
Standard Deviation	0.3	4.7	20.0	0.5	0.6	71.1	250.6	0.4	0.0264	0.0172	1.4	0.5
CV	4.1	25.2	36.1	6.6	18.9	132.7	32.5	113.3	92.8	27.7	37.2	125.2

Units: Temperature (⁰C); Conductivity (mS/cm); DO, BOD, COD, TDS, Nickel, Chromium, Cadmium, Zinc and Copper (mg/L)

The results indicated that there was a wide variation between the mean values of all water quality parameters under investigation between the two seasons (wet and dry) except pH. This is because the temperature did not vary much between the two seasons and it is well documented in Dallas, (2008) that pH decreases with increase in temperature. These findings agreed with the findings of Tian *et al.*, (2019), who found that water quality parameters are likely to vary with season. On the other hand, there were no much variations for the samples collected within the

same season as indicated by coefficient of variation of less than 30% in most of the parameters during dry season except for COD (41%), Nickel (Chromium (97%). Similarly, during the wet season, coefficient of variation is less than 30% except for EC (36%), COD (132%), TDS (32%), Nickel (113%), Chromium (92%) Copper (125%) (Table 1). These findings are similar to that of Abubakaret *al.*, (2015) and Nienieet *al.*, (2017) whose studies were conducted in River Kaduna, Nigeria and RiverKikwit,Congo respectively.

4.3 VARIATION OF WATER QUALITY PARAMETERS WITH SEASONS

Besides the spatial variation, water quality also varies with seasonal changes, especially with streamflow and temperature variability. Thus, streamflow and temperature are also important

Table 2 shows ANOVA values with a significant difference between the water quality parameters between both dry and rainy seasons and within the seasons at 0.05 level of significance (P values are less than F values)

Table 2: Summary Statistics of Analysis of Variance

Dry season						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	4657067	11	423369.8	840.5	3.329E-99	1.88
Within Groups	54398	108	503.7			
Total	4711466	119				
Wet season						
Between Groups	5253842	10	525384.2	84.6	6.1877E-44	1.93
Within Groups	614691	99	6209.0			
Total	5868533	109				

Source: Author's analysis

predictors that explain some of the variation in water quality parameters. The findings of this study showed that although difference was observed between means temperature values of the two seasons there was no remarkable difference. Increase in water temperature alters many physical and chemical characteristics of water including the solubility of oxygen and other gases,

chemical reaction rates and toxicity, and microbial activity. In freshwater the physical environment in terms of a reduction in density of water, a decrease in pH, a reduction in solubility of dissolved oxygen followed by an increase in BOD by stimulating organic decomposition by microorganisms are observed as temperature increases shows that the increasing water temperature decreases the dissolved oxygen concentration in water and therefore its availability to aquatic organisms (Dallas, 2008).

Cadmium metal is used in the steel industry and in plastics. Cadmium compounds are widely used in batteries. Cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. The mean values of cadmium for both dry and wet season were found to be 0.0357 and 0.0622 mg/L respectively. This can be attributed to contaminations within surface runoff from agricultural and domestic sources. This agreed with the findings of Abubakar, *et al.* (2015), Ikotun *e tal.* (2012).

The mean values of chromium for dry and wet seasons were found to be 0.0074 and 0.0285mg/L respectively. Nickel was found to be 0.2 and 0.3mg/L for dry and wet season respectively.

Dissolved oxygen is the most important parameter for assessing water quality as it affects aquatic life and their distribution (Rabeeet *al.*, 2011; Naubiet *al.*, 2016). In this study, the mean DO for dry and wet season were respectively found to be 10.4 and 7.2 mg/L. Therefore, the aquatic life is severely affected because there is no sufficient dissolved oxygen for respiration

There was no much difference between the two seasons under study in terms of TDS levels. The mean TDS levels for dry season and wet season was 721 and 772 mg/L respectively. This is palatable as drinking water because it contains less than 1000mg/L).

The mean values of electrical conductivity were 49.1 and 55.4 mS/cm for dry and wet season respectively. The findings indicated that there was no great difference between the two seasons under study. BOD is the amount of oxygen utilized by the microorganisms to break down organic compounds during five days in the laboratory (Smitha and Shivashankar, 2013). The mean values of BOD were 2.4 and 3.1mg/L for both dry and wet season respectively.

Changes in the normal appearance, odour or taste of a drinking-water supply may signal changes in the quality of the raw water source or deficiencies in the treatment process and should be investigated. Water should be free of tastes and odours that would be objectionable to the majority of consumers. The findings of this study showed that all the water samples were brownish and odorless in both wet and dry seasons. Microbial, chemical and physical water constituents may affect the appearance, odour or taste of the water. Therefore, brown colour of the samples signal the changes in the quality of the water. This can only be proven after examining the chemical properties of the samples.

4.2 WATER QUALITY PARAMETERS COMPARISON WITH NSDWQ AND WHO STANDARDS

The standard for drinking water as given by NSDWQ (NSDWQ, 2007) and World Health Organization (WHO) (WHO, 2012) is shown in Table 3. The results obtained from laboratory analysis were compared with the Standard Guidelines by NSDWQ and WHO for drinking water. The mean value of each parameter for the two seasons was computed in the river and was compared with the standard guideline values. The comparison determined the safety level of the river using the set standard.

The mean value of pH for water samples collected in the dry season and rainy season is 6.31. However, the recommended value according to WHO guidelines for drinking water quality and

Nigerian standards for drinking water quality is within 6.5-8.5 (Table 3). Therefore, this indicates that the pH value is slightly below the permissible range by 0.187. Hence, this indicate that the water is slightly acidic, but by a negligible figure. pH is the concentration of hydrogen ions. pH determines the acidity or alkalinity of water (Chapman,1996).

Table 3. Maximum permissible limits of drinking water by NSDWQ and WHO

S/N	Water Quality Parameter	Study result	NSDWQ	WHO	REMARKS
1	pH	6.313	6.5-8.5	6.5-8.5	Ideally not permissible, however a difference of 0.187 is negligible.
2	Temperature	30	Ambient	-	Permissible
3	Conductivity	52.25	100µs/cm	-	Permissible
4	D.O	8.79	>5	-	Permissible
5	BODs	2.7645	5	-	Permissible
6	COD	42	NS	-	N/A
7	TDS	746.5	500	2000	Not permissible according to NSDWQ, but permissible by WHO standards.
8	Coliform	Too numerous to count	10	00	Not permissible
9	Nickel	0.25	0.02	0.07	Not permissible
10	Chromium	0.012	0.05	0.05	Permissible
11	Cadmium	0.049	0.003	0.003	Not permissible
12	Zinc	2.80	3.0	-	Permissible
13	Copper	0.210925	1.0	2.0	Permissible

Units: Temperature (°C); Conductivity (mS/cm); DO, BOD, COD, TDS, Nickel, Chromium, Cadmium, Zinc and Copper (mg/L)

Source: Laboratory analysis 2019

Human activities influence acidification of aquatic environment due to effluents, and acidic pollution is more common than alkaline pollution (Dallas and Day, 2004). However, there is no certainty as to a direct relationship between pH and human health, due to its close association with other aspects of water quality.

The mean value for temperature in the study area for both seasons is 14.62⁰C (Table 3). An ambient temperature is ideal for drinking water. High water temperature may change physical

and chemical characteristics of water (Dallas, 2008). Furthermore, high temperature enhances growth of micro-organisms, and may cause problems related to taste, odour, colour and corrosion (WHO, 2017). In terms of the conductivity, the mean value observed for both seasons was 52.25. The NSDWQ recommends a limit of 1000 micro siemens for drinking water. Conductivity is used in measuring the concentration of dissolved solids in water (Yilmac and Koc, 2014). It is the ability of a solution, metal or gas, invariably all materials to pass electric current. In solution the current is carried by cations and anions. In aqueous solution, the level of ionic strength varies. The purer the water, the lower its conductivity, and the more concentrations of chemical found in water, the higher its conductivity. As shown in Table 3., the dissolved oxygen has a mean value of 8.79 mg/l in the study area for the period of the study. According to NSDWQ, dissolved oxygen in water should be more than 5mg/l. Therefore, the value in the study area is within the desirable level. Dissolved oxygen is the level of free, non-compound oxygen present in water. Because of its influence on the organisms living within a body of water, oxygen gets into water by diffusion from surrounding air, by rapid movement otherwise known as aeration and as a waste product of photosynthesis (Kumar and Puri, 2012).

The mean BOD observed value in the study area was 2.7645 mg/l (Table 3). Although, there is no limit recommended by WHO, however, NSDWQ recommends a limit of 5mg/l. the observed mean for both seasons fall within the recommended limit. BOD measures the amount of oxygen used by micro-organisms in aerobic oxidation, or the breakdown of organic matter (Chapman, 1996). The levels of BOD in water is increased by discharge of waste that are high in organic matter, from municipal sewage, industrial wastewater, and other non-point source pollutants (Poo *et al.*, 2008).

There is no stated limit for COD by both WHO and NSDWQ. However, the mean value was 42 mg/l (Table 3). The chemical oxygen demand is a measure of water and wastewater quality. COD values suggests level of organic matter content of water. It is the amount of oxygen necessary to oxidize all of the organic carbon completely to carbon dioxide (CO₂) water (H₂O). When result of chemical oxygen demand is more than twice that of biological oxygen demand, then it is suspected that most of the organic material in the sample is not biodegradable by ordinary micro-organisms (Woodward and Amp, 2006).

Whereas, the mean value of TDS observed for both dry and wet season was 746.5 mg/l. However, no health-based guideline has been proposed by the WHO on TDS. However, it is of the opinion that palatability of water when TDS is less than 600mg/l is good and that it becomes increasingly unpalatable when TDS levels is greater than 1000mg/l. on the other hand, NSDWQ fixed 500mg/l as limit for TDS in drinking water. In view of this, the TDS for both dry and rainy season in the study area is above the recommended standards for NSDWQ. TDS refers to the inorganic salts and little amounts of organic matter present in solution in water. These constituents are usually nitrate anions, potassium cations and carbonate, magnesium, hydrogen carbonate, calcium, chloride and sulfate. Sources of TDS in water can be natural, sewage, urban run-off, agricultural run-off and industrial waste water.

According to WHO, coliform should not be found at all in drinking water. While NSDWQ recommends a limit of 10cfu. The results for both dry and rainy season indicates a high presence of coliform, in many cases too numerous to count, with the lowest result observed being 95cfu. The observed values are way above recommended guidelines for both WHO and NSDWQ. Total coliform includes a wide range of organisms that can survive and grow in water. Total coliforms occur in natural water and sewage. Some of the bacteria which comprises total coliform get to

the water through human and animal faeces. The presence of coliform in water indicates contamination (WHO, 2017).

The recommendation on nickel in drinking water is 0.07mg/l by WHO, while that of NSDWQ is 0.02mg/l. However, the mean value for the study is 0.25mg/l. Consequently, this shows that the result for the study area is above the recommended limits for both WHO and NSDWQ. Nickel in its pure form is said to be a hard, silvery-white metal and has properties that make it useful for making alloys, in combination with other metals. It is used for nickel plating, ceramics colouring, battery making and as catalyst to increase rate of chemical reactions. Nickel occurs naturally, can be found in soil, can be emitted from volcanoes and can be found in ocean floors. It can be released from industrial wastes, power plants and trash incinerators (ATSDR, 2005). Health effects from exposure to Nickel are cancer of the lung, reduced lung function, *bronchitis* and *nasal sinus* (ATSDR, 2005; WHO, 2017). The mean value of chromium observed in the study area for the period of study was 0.012mg/l (Table 3). The chromium value limit recommended by both WHO and NSDWQ is 0.05mg/l. Therefore, the result is below the limit recommended by both WHO and NSDWQ. Chromium is said to be an odourless and tasteless metallic element found naturally in rocks, plants, animals, volcanic dust and soil. Trivalent (chromium-3) and hexavalent (chromium-6) are the most common forms of chromium found in natural waters (EPA, 2017) Health effect associated with chromium is lung cancer through inhalation of chromium-6. Consequently, chromium-6 has been classified in group I (human carcinogen) and chromium-3 in group III (not classifiable as to its ability for causing cancer to humans) (WHO, 2017).

The maximum cadmium limit recommended by both WHO and NSDWQ is 0.003mg/l. However, 0.049 mg/l mean value was found in the study (Table 3) which is above the

recommended standards for drinking water by both WHO and NSDWQ. Cadmium is an element found naturally in soils and on the earth crust. It is used as a constituent in making batteries, cheap jewelries, paints, steel and plastics, pigments and coatings. It is a contaminant that has been found in water that are used for drinking, and too much cadmium in drinking water may not be good for the health (MDH, 2014). It is released to the environment in waste water, fertilisers or impurities in zinc of galvanized pipes, solders and some metal fittings. Cadmium affects the kidney when in high doses (WHO, 2017). The WHO has concluded that Zinc is of no health concern. Therefore, it has no limit fixed for zinc in drinking water. However, NSDWQ recommended 3.0mg/l as the limit for zinc in drinking water. Taking this into consideration, the value for zinc concentration (2.8mg/l) in the study area is within the set limit by NSDWQ. Zinc is said to be essential. It is a trace element found in about all food and potable water as salts or organic complexes. Levels of zinc in surface water and groundwater are usually not above 0.01mg/l and 0.05mg/l respectively (WHO, 2017).

The mean value of copper observed in the study area was 0.21 mg/l. The maximum limit for copper recommended by WHO is 2.0mg/l and that of NSDWQ is 1.0mg/l. the mean value for both dry season and wet season in the study area falls within the limit set by both WHO and NSDWQ. Copper compounds are used in fungicides, algicides, insecticides and wood preservatives, in electroplating, dye manufacture, engraving, lithography, petroleum refining, pyrotechnics and is added to fertilizer and animal feeds as a nutrient to support plant and animal growth (ATSDR, 2002).

4.4 IMPACTS OF LAND USE/HUMAN ACTIVITIES ON WATER QUALITY

Land use primarily influences aquatic conditions through both point source (PS) and non-point source (NPS) pollution, particularly urban and agricultural land use. Land use patterns reflect the influence of human activities on natural environment, having dramatic effects on aquatic

ecosystems. In other words, land use has strong effects on the water quality of adjacent water bodies. In view of the aforementioned assertion, the study was classified into five classes (Figure 2).

Table 4: Land use land cover classification of study Area

Land use	Area(sq.km)	Percentage
Reservoir/River channel	1.40	6.12
Industrial area/Farmland	4.69	20.50
Residential area/Farmland	6.95	30.38
Treatment plant/Farmland	4.63	20.22
Commercial/Farmland	5.21	22.78
Totals	22.88	100

Source: Author's analysis, 2018

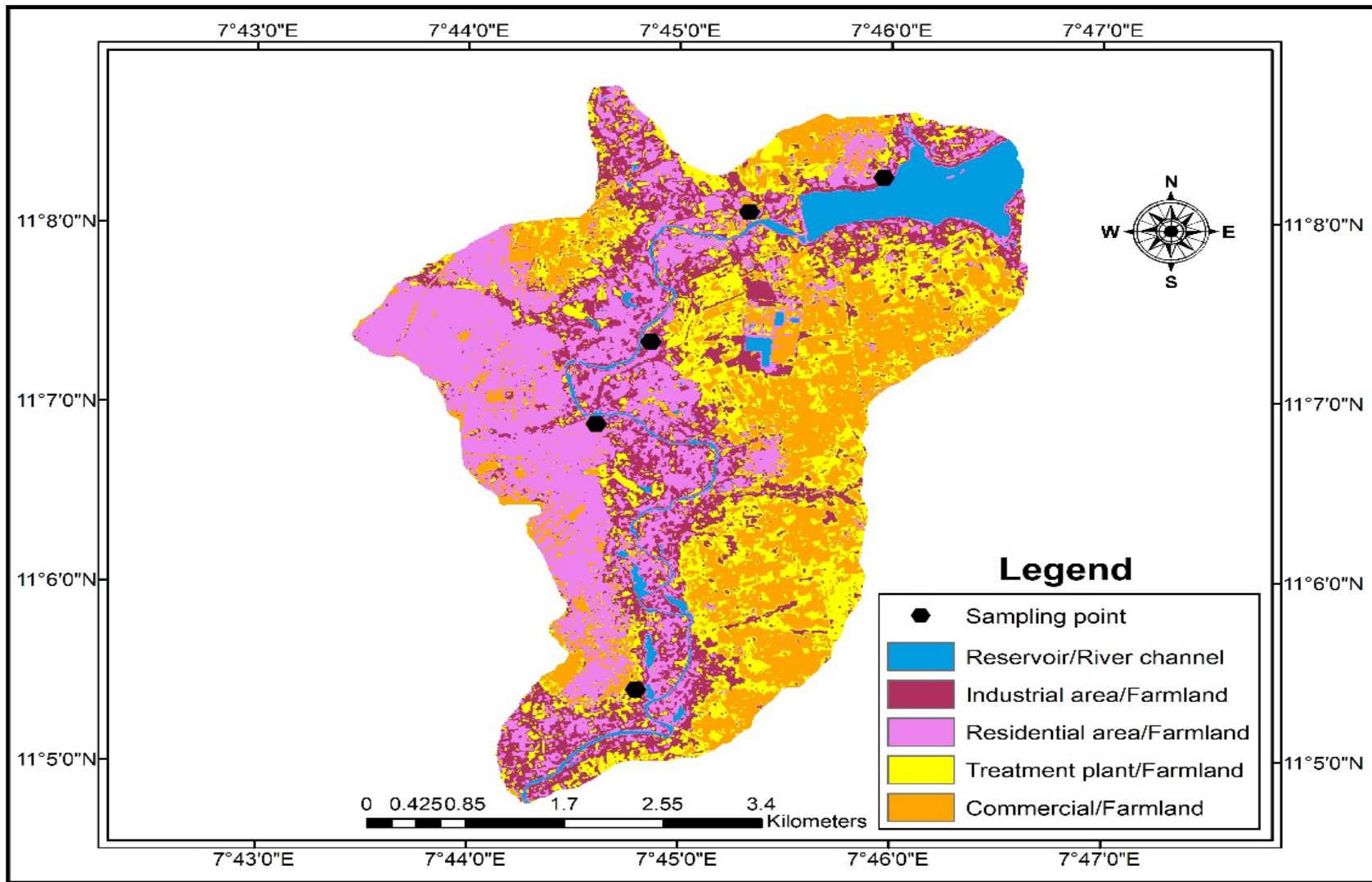


Figure 2. Land use types in the study area.

Table 4 shows that residential/farmland area constitutes greatest part 30.38% (6.95 km²) of the total area of the study site while reservoir/farmland occupies the least area 6.12% (1.4 km²).

Table 5. Pearson correlation coefficients between different land use and water quality parameters (wet season)

Land use (%)	D.O	BODs	COD	TDS	Col
Reservoir/River channel	-.170	-.627	.050	.542	.074
Industrial area/Farmland	-.084	-.084	.401	-.095	.164
Residential area/Farmland	.401	-.677	-.677	-.904*	.547
Treatment plant/Farmland	-.095	-.904*	.783	.783	-.812
Commercial/Farmland	.164	.547	-.812	-.782	-.782

Source: Author's analysis

Table 6. Pearson correlation coefficients between different land use and water quality parameters (wet season)

Land use (%)	Ni	Cr	Cd	Zn	Cu
Reservoir/River channel	-.644	-.242	.755	-.282	.161
Industrial area/Farmland	.553	.553	-.572	.368	.468
Residential area/Farmland	-.572	.129	.129	-.105	.510
Treatment plant/Farmland	.368	-.105	-.799	-.799	-.157
Commercial/Farmland	.468	.510	-.157	.589	.589

Source: Author's analysis

There was a positive relationship between the reservoir/river channel land use (%) and the concentration of TDS (0.542), see Table 5, during the wet season. This is mainly due to the reservoir siltation in the Basin resulting from the exposure of soil surface carried by runoff. However, the concentrations of D.O, BODs, are negatively correlated, while COD and Coliform are weakly correlated with the Reservoir River channel land use. However, looking at the result in Table 6 (dry season) TDS is weakly correlated (0.373) as compared to the wet season on the

Reservoir land use type. This is as a result of cessation of rainfall which is the main agent that generates runoff and subsequently depositing sediments into the reservoir.

As shown in Tables 7 and 8, there is a positive relationship between Industrial area/Farmland land use type and Zinc (0.638). This is as a result of industrial effluents which releases their waste without treatment through point sources directly into the Galma River see Figure 1 As such this has been confirmed by the strong correlation. Heavy metal contamination which are affected by industrial activities in the area, for example, Cr, Cu and Cd are common materials in textile, dyes, electroplating, galvanizing battery manufacturer and plastic fabrication industry (Wong, 2005), these are popular types of industry in the study area.

Table 7 Pearson correlation coefficients between different land use and water quality parameters (dry season)

Land use (%)	D.O	BODs	COD	TDS	Col
Reservoir/River channel	-.038	-.966**	-.737	.373	-.227
Industrial area/Farmland	.048	.048	-.531	-.695	.023
Residential area/Farmland	-.531	.695	.695	-.481	.096
Treatment plant/Farmland	-.695	-.481	.295	.295	-.142
Commercial/Farmland	.023	.096	-.142	-.276	-.276

Source: Author's analysis

Table 8 Pearson correlation coefficients between different land use and water quality parameters (dry season)

Land use (%)	Ni	Cr	Cd	Zn	Cu
Reservoir/River channel	.756	.135	.102	.843	.030
Industrial area/Farmland	-.360	-.360	.278	.638	.449
Residential area/Farmland	.278	.198	.198	-.035	.071
Treatment plant/Farmland	.638	-.035	.334	.334	.612
Commercial/Farmland	.449	.071	.612	-.154	-.154

Source: Author's analysis

As indicated in Table 5 and 6, most of the relationship that exist between land use and water quality parameter were negative. However, this is as a result of the nature/complexity of the land use in the study area. As seen in Table 4 it is almost impossible to separate each of the land use type from farmlands. In line with this, the farmlands have the ability to absorb, retain the pollutants. As a result, the farmlands play a complicated role in influencing the water quality in the study area especially during the wet season, although dry season farming is predominant along the river bank.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

In this study, the effects of human activities were assessed on water quality in River Galma for two seasons (wet and dry). A total of 20 water quality parameters were collected from five sampling sites consisting of different human activities in form of land use types which were categorized into reservoir/river channel, industrial area/farmland, residential area/farmland, treatment plant/farmland and commercial area/farmland. The physiochemical parameters namely, pH, Temperature, Total Dissolved Solid (TDS), Conductivity (EC), Coliform, Cadmium (Cd), Chromium (Cr), Oxygen Demand (DO), Zinc (Zn) and Copper (Cu) were measured during the dry season and wet season. These parameters were considered primary, especially when assessing for water in terms of drinking water and the level at which different land use types could influence their concentration. The parameters have shown little variations from dry to wet season. The standards used for the comparative assessment were NSDWQ and WHO. Furthermore, five land use types were determined from a Sentinel Image and were correlated with these parameters. However, most of the water quality parameters conform with these standards with exception of few parameters such as Coliform, Nickel Chromium and Cadmium.

5.2 CONCLUSION

The land use types in the study area have indicated impacts on the water quality within the watershed, but it is still necessary to add some other ecological indicators and analyze their influence on the water quality. In particular, we should expand the method of analyzing the relationship between land use and water quality but not the simple Pearson correlation. Our study focuses on the effect of land use types on water quality in the study area.

There is a relatively high level of concentration of physico-chemical parameters in the study area and very high concentrations of biological parameters, considering the high levels of coliform count in the study area.

However, there is no variation within the same seasons but little variation was observed between seasons. There are higher concentrations of some parameters during the wet season and lower concentrations during the dry season, which could be attributed to the run off which washes down more contaminants to the river during the wet seasons. Although in the case of heavy metals, it is observed to have a higher concentration during the dry seasons.

Heavy metal concentration has positive relationship with industrial/farmland land use type as well as reservoir land use, which indicates that industrial areas produce heavy metal. TDS and COD concentrations on the other hand have positive relationship with the treatment plant/farmland land use. However, most of the relationship between the land use and water quality parameters is negative or insignificant. It is therefore concluded that the human activities/land use type has some effects on water quality of the river.

A number of parameters do not conform to the standards recommended by both NSDWQ and WHO. In light of this, and especially considering the high level of coliform counts found in the water samples, the water from River Galma is therefore recommended to be properly treated before consumption.

5.3 RECOMMENDATIONS

The study recommends as follows:

- i. Non-point pollution should be managed by protecting and enhancing riparian zones such as ecological buffer zones.
- ii. There is the need to minimize industrial activities very close to the river as industrial land use is the major source of pollution to the river.
- iii. There is need to treat the water for coliform, nickel, chromium and zinc, which have high concentrations in the river.
- iv. Further research should encompass other ecological indicators to analyze their influence on water quality of the River.

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