PRELIMINARY ASSESSMENT OF VARIOUS SOURCES OF WATER IN KANO METROPOLIS, NIGERIA

BY

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A DISSERTATIONSUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIESAHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL MANAGEMENT

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NIGERIA

MAY, 2017

DECLARATION

I hereby declare that this dissertationtitled **"Preliminary Assessment of Various Sources of Water in Kano Metropolis"** was written by me and is a product of my research effort. It has not been presented in any previous application for any degree or diploma. All quotations are indicated and the sources of information are acknowledged by means of references.

…… ……

SamuelBoyi **Date**

CERTIFICATION

This dissertation titled**, "Preliminary Assessment of Various Sources of Water in Kano Metropolis"** by **BOYI, Samuel** meets the regulations that govern the award of Degree in Masters of Science (Environmental Management) of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated tothe memory of my late fatherMr M. Boyi.

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I am most grateful to the King of Kings and the Lord of Lords, God Almighty, the most gracious and merciful, to Him I owe my eternal gratitude for my life. My sincere appreciation goes to my supervisorsDr. Yusuf YakubuObadaki and Dr. B. A. Sawa fortheir immense and unreserved commitment and sacrifice to making sure that this work was accomplished. I am honestly grateful. I also appreciate the H.O.D and my lecturers in the Department of Geography for their support in the course of this study, I remain thankful to the R.A Adeniyi's, the Adeleye's, the Balogun's, the Otaru's, the Ado's, the Rimamdiya's, the Akinlose's, the Uzoukwu's, the Ocholi's, the Bello's, the Ailoge's the Poopola's, the Eze's, the Ukandu's, the Olopko's, the Omensa's, the Nwosu's, the Igonoh's, the Idakwoji's, the Oyetade'sand the Ehinlaye's.

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ABSTRACT

The effects of poor water quality in Nigeria and the world at large seems to be on the increase, yet, there have not been much significant efforts to combat the menace except the provision of cost effective alternative sources of clean water sources. This study was onthe preliminary assessment of the various sources of water in Kano Metropoliswhere ninety six (96) water samples were collected fromopen wells, boreholes, tap water and sachet water sources in study area using systematic sampling techniques. Laboratory analysis was carried out to determine the level of concentration on pH, colour, total hardness, conductivity, calcium, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese, zinc, lead and iron. The Water Quality Index for the study area was analysed and the quality from each source was compared with the acceptable drinking water quality standards.The study showed spatial variations and significant difference in level of concentration between the various sources within the Metropolis.Throughout the study, all parameters tested for sachet water were found to be within permissible limits, which shows excellentwater qualitieswith the exception of sachet water source in Dala Local Government Area where iron was found at 0.04mg/l to be slightly above the standards.Iron and Manganese had concentrations above World Health Organization and National Standard for Drinking Water Quality permissible limits for boreholes, wells and tap water which were between the range of 1.55mg/l and 2.95mg/l respectively.The Water Quality Indexshowed that wells, boreholes and tap water sources which is greaterthan 100 expect for Nasarawa and Taruni which is between 76-100 were unsuitable for human consumption in which frequent consumption will cause severe health risks, but tap water source in FaggeLocal Government Area just like sachet water source for the entire Metropolis which is between 0-25 showed that they were suitable for human consumption.The study recommends the need for government, communities and private individuals to work collectively in public enlightenment campaign on the dangers of poor water quality consumption, proper siting of wells and boreholes in residential areas, treatment and maintaining of existing water supply facilities.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Water, after air, is the most essential resource to the survival of life. Human life depends to a large extent, on water. It is used for an array of activities; chief among these being for drinking, food preparation, as well as for sanitation purposes. Since safe drinking water is essential to health, a community lacking good quality of this resource will be saddled with a lot of health problems which could otherwise be avoided (Miller, 1997).

Water is a resource that is both invaluable and vital to the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities. The value of water is linked to the provision and quality of ecosystems service. The importance of water to man cannot be over emphasized. Man can survive longer without food than without water. He requires it for his cooking, washing, sanitation, drinking and for growing his crops and running his factories. Therefore modern man like his primitive ancestors is heavily dependent on water for his sustenance. Apart from its industrial use water is a necessary social amenity. The provision of good quality water can help in eradicating water-borne diseases and in improving the general sanitation of Nigeria's towns and villages (Ayoade, 1975).

There is a growing concern everywhere that in the coming century, cities will suffer imbalances in quality water supply, consumption, and population. Many regions of the world are already

limited by the amount and quality of available water. According to WHO (2002), in the next thirty years alone, accessible water is unlikely to increase more than ten percent (10%), but the earth's population is projected to rise by approximately one-third. Unless the efficiency of water use rises, this imbalance will reduce the quality of water, reduce the conditions of health of people and deteriorate the environment and the world.

The growing demands for adequate quality water resources create an urgent need to link research with improved water management, better monitoring, assessment, and forecasting of water resources and sanitation issues with much emphasis on the roles of stakeholders (Yamaguchi and Wesselink, 2000). It must however be emphasized that adequate water quality needs seem to have improved greatly in some regions and countries especially in the developed world but for poor nations this is still a major issue (Stockholm International Water Institute, 2005). According to Sarpong (2002), the main source of water in these regions includes untreated rain water from roofs, polluted rivers and streams, unprotected wells and bore holes.

The quality of any body of surface or groundwater is a function of either or both natural influences and human activities. Without human influences, water quality would be determined by the weathering of bedrock minerals, atmospheric processes of evapotranspiration, and the deposition of dust and salt by wind. Others include, the natural leaching of organic matter and nutrients from soil, hydrological factors that lead to runoff, and by biological processes within the aquatic environment that can alter the physical and chemical composition of water (UNEP, 2006). Water quality assessment is a very complex subject, in part because water is a complex medium intrinsically tied to the ecology of the planet (Kolo, Dibal and Ndakawa, 2009). To

determine water quality therefore, several parameters must be examined. The complexity of water quality assessment as a subject is reflected in the many types of measurements of water quality. Among the key parameters listed by WHO (2011) for the determination of water quality for domestic use are Conductivity, dissolved oxygen (DO), pH, color of water, taste and odour, turbidity, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), micro-organisms such as faecal coliform bacteria (*Escherichia coli*), cryptosporidium and *Giardia lamblia*; nutrients (fertilizers), dissolved metals and metalloids (lead, mercury, arsenic, etc.) and dissolved organics.

Water related health problems are a growing human tragedy, and according to WHO (2002), it kills more than 5 million people a year with infants being the most affected. This figure seems to be the highest as compared to wars and disasters (UNESCO, 2003). The problems also prevent millions of people from leading healthy lives, and undermine developmental efforts by burdening the society with substantial socio-economic costs for treatment of water-borne diseases. This problem is of great significance in cities in developing countries, where polluted water, water shortages, and unsanitary living conditions prevail. Information from WHO (2002), WHO/UNICEF (2004) say although access to water has improved, access to safe water is still a major issue. The sources quoted that about some 1.1 billion people rely on unsafe drinking water sources in developing countries and the lowest drinking water coverage rates are in Sub Saharan Africa (58%) with a corresponding low sanitation coverage rates (36%) which leads to many deaths especially among children through diarrhea among other water-related diseases.

Sources of water available to mankind are: atmospheric water (precipitation), surface water (including rivers, streams and ponds), and groundwater. The potability of water from any of these sources is determined by the water quality (Miller, 1997). With 97% of all freshwater found on the earth being stored underground, accessing groundwater in the quest for potable water is a laudable venture. Groundwater is accessed by way of sinking wells and boreholes to reach the water table (Overseas Development Institute, 2009).

Drinking water has always been a major issue in many countries, especially in developing countries like Nigeria (Rajini, Roland, John, and Vincent, 2010). In Nigeria, majority of the rural populace do not have access to tap water and therefore, depend on well, stream and river water for domestic use (Shittu, Olaitan, and Amusa, 2008). The Population Reports (1998) mentioned Nigeria among the countries likely to face water shortages by the year 2025. The Drinking water availability ranking published in NationMaster.com, placed Nigeria at 116th position out of 147 countries. In the same report, the Nigeria's 62% availability was below the global weighted average of 79% (UNICEF/WHO 2000, cited in NationMaster.com 2008). The United Nations Children's Fund and World Health Organization also in a joint report raised an alarm over water contamination in Nigeria, noting that more than 70 per cent of water sources in Nigeria are contaminated and injurious to health (UNICEF/WHO, 2005). The situation in urban areas is also not cheerful. Less than 50% of the 85 million urban dwellers have "reasonable access to reliable water supply" (FMWR, 2000). Both rural and urban areas of Kano State experience water shortages.

The major causes of water pollution in most countries of the tropics can be linked to human activities such as sewage and refuse disposal, industrial effluents, agricultural activities, mining and quarrying activities. Etim and Adie (2012) observed that available sources of potable water for drinking and industrial uses in Nigeria are dwindling because of concomitant increase in population, urbanization and industrial activities.

In Nigeria, it is the duty of the government to protect the health of her citizens and the National Agency for Food and Drug Administration and Control (NAFDAC) is the agency saddled with this responsibility. Although there are conflicting reports, it is on record that less than thirty percent of Nigerians have access to safe drinking water with the rest obtaining their water from contaminated sources (Sule, 2009; Tina, 2010; Tokumbo, 2010; Ameto, 2011; Ndagi, 2011; Oyishi, 2011; Ameto, 2012). The providers of water supply services in Kano Metropolis are the Kano State Water Board, the Vendors, the private water supply operators and the hawkers. The Water Board functions include treatment, distribution and sale of water together with public enlightenment on water conservation. Vendors are the people that Water Board leases standby water taps to which they sell to individuals. The Private Water Supply Operators produce water (usually from boreholes equipped with electric submersible pumps) and sell to individuals and hawkers at the water source site. Water hawkers are individuals who use Jerry-cans (usually loaded on hand push carts) to buy water from the vendors or other sources and deliver water to households.

Today contaminated water kills more people than cancer, AIDS, wars, terrorism or accidents. It is pertinent that the water meant for human consumption be free of disease-causing germs and

toxic chemicals that pose a threat to public health according to Third World Academic of Sciences ([TWAS], 2002). It is therefore necessary to have an update on the quality of the water being supplied to the masses so as to create a consciousness for a need to treat water supplied to ensure healthy living. Also, it is pertinent that the water meant for human consumption be free of disease-causing germs and toxic chemicals that pose a threat to public health (TWAS, 2002). These provide the basis for physicochemical quality assessment of potable water in Kano Metropolis.

Water quality index (WQI) assesses the suitability of water quality for domestic purposes. It incorporates data from multiple water quality parameters into a mathematical equation that rates the nature of water bodies with numbers to determine their suitability for human consumption. According to Nives (1999), WQI is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts. WQI has been regarded as one of the most effective way to assess the quality of water (Tiwari and Mishra, 1985; Sinha and Ritesh, 2004).

1.2 STATEMENT OF THE RESEARCH PROBLEM

The inability of the Government to persistently provide adequate potable water for the growing population has tremendously contributed to the proliferation of the so-called ‘pure water’ producers in Nigeria (Akunyili, 2003). The provision of water that is not only safe, but tasteless, odorless and clean in appearance is top priority in any country that cares for good health, and poverty alleviation towards sustainable development. The private individuals purportedly treat

not-fit-for-drinking water, like well, borehole, and make them fit for drinking while consumers cannot by themselves ascertain the quality of drinking water. Naturally, water that appears murky, discolored, smelly or with unpleasant taste would be treated by these opportunists but not with grave suspicion from the consumers. Regulation of packaged water is therefore a government intervention in the private water sector for the sake of public health as it assures quality in the production and packaging of water. This is where NAFDAC comes in to safeguard the health of the nation by ensuring access to only safe and good quality packaged water supply to the public.

The need for safe water for mankind and to prevent water borne diseases, in order to safeguard human health led to the determination of the water quality of most water bodies for human use. The quality of water is the degree of its potability and is determined by the amount and level of physico-chemical, microbial and heavy metals found in it. Water for domestic purposes should be free from all these substances in order for it to be potable for human use vis-à-vis, prevent water borne diseases.

Gbadegesin and Olorunfemi (2007), Aderibigbe, Awoyemi and Osagbemi (2008), Maconachie (2008), and Adamu (2009) have corroborated the inadequacy of the country's water supply. Adamu (2009) provided evidence of this shortage of water in Kano and Kaduna respectively through their state-specific evidence in terms of quality. Gbadegesin and Olorunfemi (2007) while quoting figures from the National Millennium Developmental Goals Report of 2005, lamented that after almost sixty years of water supply in Nigeria. Previous studies in the Bompai

and Sharada industrial estates of Kano state have indicated that water contamination from heavy metals, such as Lead, Mercury, Chromium, and Cadmium is rife (Ahmed and Tanko, 2000).

Adamu and Adekiya (2010) carried out a study on assessment of water quality of boreholes around selected landfills in Kano Metropolis. The study considered pH, turbidity, conductivity, total solids (TS) suspended solids (SS), total dissolved solids (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved oxygen (DO), chloride, sulphate, nitrate, phosphate, Zinc, Lead, Nickel, Cadmium, Iron, Manganese, Copper, and chromium. The analysis revealed that some samples were acidic and some alkaline with a pH range of (6.80 – 7.75) and at the methogenic stage, samples have low BOD (28.5–46.0mg/dm3) and COD (55.00 – 89.25mg/dm3) values indicating active methogenesis process is taking place at the sites. The suspended solids, total dissolved solid and turbidity results varied significantly between sites, all samples contained low concentration of nitrate and sulphate with phosphate, chloride, lead and manganese in high ranges. Also when compared with the National Regulatory Standard, it showed that the pollution potentials of Gyadi-gyadi and Ubagama samples were higher than those of Hajj camp and Maimalari.

Bichi and Amatobi (2013) carried out a study on Assessment of the Quality of Water Supplied by Water Vendors to Households in Sabon-Gari Area of Kano, Northern Nigeria. The quality of the water was assessed at commercial sales points, water vendor's distribution Jeri-cans and household storage tanks. Ninety (90) water samples were collected at 10 locations spread across Sabon-Gari and analyzed for physicochemical and bacteriological parameters. The results obtained were compared with standards recommended by the World Health Organization

(WHO), the Nigerian Standard for Drinking Water Quality (NSDWQ) and the European Community (EC). Total Hardness (as $CaCO_3$), Conductivity and Free Chlorine values were not within acceptable limits in most of the samples. Colonies of microorganism were in excess amounts in 9 samples while coliform organism was detected in 19 samples. The percentage of colonies of microorganisms was 27%, 43% and 70% for commercial sales points, hawkers, Jerry-can, and household storage respectively. Also percentage of samples that tested positive to coliform organism was 10%, 20%, and 33% for commercial sales points, hawkers Jerry-can, and household storage respectively. Thus it was concluded that water quality was compromised at the private commercial supply, during hawker's distribution and in the household storage.

Also, a study carried out by Mohammed (2013) on quality assessment of potable water in Sabon-Gari, Kano State, the study compared the quality of some of the most patronized water considered consumable in Sabon Gari Area of Kano State with the World Health Organization (WHO, 2002) set standard which revealed a significant difference in the level of concentration of physicochemical parameters such as conductivity, color, total hardness, total dissolved solid, total alkalinity, turbidity, chlorides, calcium ions, (Fe) iron, and magnesium ions with higher concentrations in borehole water sources which are not within the WHO and EPA standards than in that of the sachet water.

Abdulbaki, Ahmad and Maina (2014) carried out a quality assessment of groundwater around open dumpsites in Kano Metropolis. The physicochemical and bacteriological quality of groundwater were assessed and samples from three areas located near the refuse dumpsites in the metropolis were collected to investigate the effect of pollutants to the quality of boreholes and well waters located within 50m, 100m and 150m from the pollution source. The water quality

indicating parameters were determined using standard procedures. SPSS was used to analyze the descriptive and correlation analysis of Alkalinity, Ca^{+2} Cl-, EC, Mg^{+2} pH, TDS and Temperature respectively. The bacteriological parameters analyzed were total coliforms and E-coli. All the results were compared with NSDWQ and WHO standards. The result revealed that waters samples from sites at Sorandinki received the highest mean values of the physicochemical parameters and the total coliforms, which could be attributed to the presence of larger volume of open dumps sites than those from sites at Bola and Court road respectively. The correlation between the alkalinity, TDS, pH and Cl is an indication of depositions of wastes of acidic nature at the dumpsites. The absence of E.coli. in all sampled waters rendered it useful for human consumptions when treated.

Sinha and Ritesh (2006) carried out Water Quality Index for drinking water in Hasanpur Nagar for 10 different sites, and concluded that the water was severely contaminated at almost all sampled sites. They proved WQI as an important tool for the assessment of water quality. Yisa and Jimoh (2010) conducted an analytical study on Water Quality Index of River Landzu in Bida Niger State, the results revealed a high value of WQI mainly from the higher concentrations of iron, chromium and manganese, COD and turbidity. It also indicated that the river was polluted and not safe for domestic use and would require further treatment.

Based on literature reviewed, though works have been done on the quality of potable water in Kano metropolis, but not much is done on water quality index and comparing water quality from various sources in the study area, therefore leaving a gap which this research intends to fill. A continuous periodical monitoring of water quality is necessary so that appropriate steps may be

taken for water resource management practices (Etim, Akpan, Andrew, and Edet, 2012). There is need to have an up-to-date quality status and water quality index for the water sources being exploited by the masses, this will create a consciousness for a need to treat water to ensure healthy living.

This research is on preliminary assessment of various sources of water in Kano Metropolis and its associated health implication to the public who may be at risk as well as proffering viable solutions towards eliminating such consequences in the study area. It is against this background that the study intends to answer the following questions:

1. What are the sources of water supply in the study area?
2. What are the levels of concentration of pH, colour, total hardness, conductivity, calcium, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese, zinc, lead and iron for the various sources of water supply in the study area?
3. What is the spatial variation in the level of concentration between open wells, boreholes, tap water and sachet water from the study area?
4. What is the difference in concentration between each source and the acceptable drinking water quality standard according to NSDWQ and WHO?
5. What are the water quality indices (WQI) of the area and its health implications?

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this research is to carry out a preliminary assessment of various sources of water in Kano Metropolis and its health implications to consumers. However the specific objectives are to:

i. identify the sources of water supply in the study area.
ii. determine the level of concentration of the physicochemical parameters such as pH, colour, total hardness, conductivity, calcium, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese, zinc, lead and iron in open wells, boreholes, tap water and sachet water.
iii. determine the spatial variation in the level of concentration between open wells, boreholes, tap water and sachet water.
iv. compare level of concentration from each source with the acceptable drinking water quality standard according to NSDWQ and WHO.
v. determine the water quality index (WQI) of the different sources of water.

1.4 HYPOTHESES

H_o There is no significant difference in level of concentration of physicochemical parameters between open wells, boreholes, tap water and sachet water in the study area.

H_o There is no significant difference in the level of concentration for physicochemical parameters for each source and the acceptable drinking water standard of NSDWQ and WHO.

1.5 SCOPE OF THE STUDY

This study focused on preliminary assessment of various sources of water in Kano Metropolis encompassing all the six local governments of Dala, Fagge, Gwale, Municipal, Nassarawa and Tarauni. The assessment covered possible sources of various water supply such as open wells, boreholes, tap water and sachet water (pure water), where the spatial variation in the level of concentration between the various sources, the water quality index (WQI) for the study area was determined and compared with the acceptable drinking water quality standard according to WHO and NSDWQ. Also samples from these sources was collected and analyzed within the months of July-August, 2015 at the peak of wet season.

1.6 SIGNIFICANCE OF THE STUDY

There are serious problems in Urban Water Sector (UWS) in Kano state as it is in several urban centers; this means high demand because of high populations and high water usage. Almost all cities exhaust, contaminate and vandalize most of their water sources such as rivers, lakes and in most case groundwater are inclusive. Water resources having misused, mismanaged and local sources are contaminated after incessant neglect the local water potential, all urban centers are continuously looking for another new alternative water sources to meet its populace demands (Kano State Environmental Planning and Protection Agency, 1990).

Kano metropolis is today one of the fastest growing cities in Nigeria and the largest in the whole of the Northern part of the country. Potable water supply in Kano metropolis is facing serious challenges because of rapid population growth, urbanization and imperatives of development.

The water supply does not satisfy the demand and the population has resorted to other sources of water supply regardless of their quality (Kazuare, 2005).

Though many works have been done on the water supply quality of the Metropolis, there is need to have a water quality index (WQI) and an update on the quality of the water being supplied to the masses, this will create a consciousness for a need to treat water supplied to ensure healthy living. Water has an important and undeniable influence on human health. In its pure state water helps the circulation of nutrients around the body whereas on the other hand, when water is impure it circulates disease pathogens through the body system.

CHAPTER TWO

LITERATURE REVIEW

2.1 GLOBAL POTABLE WATER SUPPLY

The 2009 World Water Development report revealed that nearly half of the global population will be living in regions of high water stress by 2030 (UN-World Water Development Report, 2009). This projection is particularly daunting considering that in 2000, 508 million people inhabited water-stressed or water-scarce regions indicating that the percentage of the world population affected by water-scarcity could balloon from 8% to 47% in a mere three decades (Population Reference Bureau, 2010). The amount of people living on less than $1.25 a day approximately corresponds with the amount of those unable to access safe drinking water (UN News Service, 2009).

The global population is expanding by 80 million people annually, increasing the demand for freshwater by about 64 billion m^3 a year (World Water Assessment Programme, 2009). In fact, water withdrawals tripled over the last 50 years due to population growth (Richard, Jean-Marc and Johan, 2009). This rapid growth rate also caused the potential global availability of water to decline from 12,900 m^3 per capita per year in 1970, to 9,000 m^3 in 1990, to about 7,000 m^3 in 2000 (United Nations Environment Programme, 2008).

Drinking water, or potable water, is defined as having acceptable quality in terms of its physical, chemical and bacteriological parameters so that it can be safely used for drinking and cooking (WHO, 2004). WHO defines drinking water to be safe if and only if no any significant health

risks during its lifespan of the scheme and when it is consumed. This thesis focuses on water quality for drinking and domestic uses.

Water of good drinking quality is of basic importance to human physiology and man's continued existence depends very much on its availability (FAO, 1997). Access to water is a prerequisite for health and livelihood, which is why the MDGs target is formulated in terms of sustainable access to affordable drinking water supply. The availability of improved and quality water supply and sanitation infrastructures are widely recognized as an essential component of human rights, social and economic development (African Development Fund, 2005). The poor and marginalized people living in rural and semi-urban settlements are most in need of improved and safe drinking water, appropriate forms of sanitation and access to water for other domestic purposes (Crow, 2001).

According to Federal Ministry of Health statistics, only about 30% of Nigerians have access to potable water while the United Nations estimated that about 1.2 billion people all over the world lack access to potable water (Oyeku, Omowumi, Kupoluyi and Toye, 2001; Ajewole, 2005). According to WHO (2006), basic access to water supply can be defined as the availability of drinking water at least 20 liters per day per person, a distance of not more than 1 km from the source to the house and a maximum time taken to collect round trip of 30 minutes. The UNDP (2008) says the minimum absolute daily water need per person per day is 50 liters (13.2 gallons) which include: 5 liters for drinking, 20 for sanitation and hygiene, 15 for bathing and 10 for preparing food. However because of scarcity of drinking water, millions of people try to exist on 10 liters (2.6 gallons) a day (ADF, 2005). In densely populated areas, a water hauling trip of 30 minutes or less, including queuing time would be a more appropriate indicator of access. As

indicated by ADF (2005), over one third of women in some of the regions spent more than two hours for each water collection trip. This will ultimately lead to household water insecurity (less water available than is needed for drinking, cooking, and sanitation) in rural areas, especially for those households for which the demand is higher due to large family size (Demeke, 2009). Because of these conditions, it is difficult to think about personal hygiene and sanitation especially for the rural communities. Despite the scarcity of water, many give priority for drinking and cooking purposes. Rural communities use unprotected springs and hand-dug wells commonly for cooking and drinking purposes. Whereas rivers besides their use for washing clothes are also used for drinking purposes.

The provision of potable water to the rural and urban population is necessary to prevent health hazards (Lemo, 2002). This results in not only sickness and death, but also economic crises. Therefore, safe drinking water is an essential component of primary health care and is vital for poverty alleviation. Introducing improved water supply sources at the household level enhance personal and community knowledge as well as awareness of the importance of other factors, such as hygiene and sanitation (Sobsey, 2002).

2.1.1 Perception of Drinking Water

In terms of drinking water quality, user perception is one of the most important things, sometimes exceeding actual quality of water especially when it concerns the quality of drinking water for the user communities (Sheat, 1992; Doria, 2010). There are different factors that influence the perception of drinking water quality, which includes the following:

i. Human sensory perceptions of taste, odor and color of water are related with mental factors and some extent taste, which is the more important because it may detect water contamination related to chemicals.

ii. People may perceive risks if they experience health problem caused by water.

iii. Experience with the previous water source status based on its taste, color and odor change. For example the change in the color of water from yellowish to bluish may feel that the water is perceived as not good water (Doria, 2010).

iv. Information plays a great role in changing people's perception on the water source behavior. It may be person to person or using media (like newspapers, brochures etc.) but in rural areas and poor urban residents interpersonal information is important.

2.2 WATER QUALITY

Water is one of the most important and abundant compounds of the ecosystem. All living organisms on earth need water for their survival and growth. As of now only earth is the planet having about 70 % of water. Due to increased human population, industrialization, use of fertilizers in agriculture and man-made activities water is highly polluted with different harmful contaminants. Therefore it is necessary that the quality of drinking water be checked at regular time intervals, because due to use of contaminated drinking water, human population suffers from varied of water borne diseases. It is difficult to understand the biological phenomenon fully because the chemistry of water reveals much about the metabolism of the ecosystem and explains the general hydro-biological relationship (Basavaraja, Hiremath, Anil and Puttiah, 2011).

The water supply data that do exist come mostly from state water agencies and other sources, such as the Federal Office of Statistics (MICS, 1999), the Federal Ministry of Water Resources and the UNICEF. While urban water supply agencies carry out routine water quality analyses at the treatment plants on a daily or weekly basis, there is usually no record kept of the results of such analyses. Rural water supply and sanitation agencies do not carry out routine water quality tests, but usually water quality test on every new borehole drilled to ascertain that it is suitable for human consumption. Also, the format for data gathering is not uniform across the Nigerian states that do keep records of their water quality data and there are no specific guidelines as to which parameters are to be tested (Ince, Bashir, Oni, Awe, Ogbechie, Korve, Adeyinka, Olufolabo, Ofordu and Kehinde, 2010).

Prior to the RADWQ project (2004), a rapid assessment of water quality was carried out nationwide in 2003. The goal was to examine the status of water quality management in the country and to discover any problem of water quality in the supply system. The assessment revealed that the iron content was high in virtually all groundwater-based water supplies, and that high turbidity was a common problem for supplies relying on surface water, especially in the rainy season when rivers carry a high sediment load. For some water supplies, public health was a real concern owing to the levels of chemicals that were either of natural geological origin (from rock-water interaction), or of anthropogenic origin (caused by human activities). Saltwater intrusion threatened water supplies in the coastal zones, which could put large populations at risk of water shortages and associated hazards. The groundwater in inland basins was contaminated by saline (e.g. in the Uju, Guma and Songo areas of Benue State) (Ince *et al*., 2010).

The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. Natural water contains different types of impurities which are introduced in to aquatic system by different ways such as weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal based materials (Adeyeye, 1994). The increased use of metal-based fertilizer in agricultural revolution of the government could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off. Also faecal pollution of drinking water causes water born disease which has led to the death of millions of people (Adefemi and Awokunmi, 2010).

In urban and peri urban settings across the country, there is a real threat that shallow groundwater and streams will become polluted from on-site sanitation systems, industrial effluent discharges and nonpoint pollution sources. Some of the major water supplies are drawn from rivers that are heavily polluted by chemical and biological industrial discharges, and by domestic septic tanks (Ince *et al.*, 2010).

Sources of water are many and varied, the level of contamination also vary, and consequently a high degree of public health hazard can be associated with drinking water. The implication therefore, is that any drinking water supplied to the public must be made wholesome and must meet WHO standards (Oyeku *et al*., 2001). Unfortunately, the quality of water supplied to the public in many places in Nigeria may not be said to be wholesome (Mendie, 2004). According to

the Institute of Public Health Analyst (IPAN), 50% of the "pure water" sold along the streets of Lagos may not be fit for human consumption (Osibanjo, Ajayi, Adebiyi and Akinyanju, 2000).

The quality of groundwater depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region. Industrial waste and the municipal solid waste have emerged as one of the leading cause of pollution of surface and groundwater. In many parts of the country available water is rendered non-potable because of the presence of heavy metal in excess. The situation gets worsened during the summer season due to water scarcity and rain water discharge. Contamination of water resources available for household and drinking purposes with heavy elements, metal ions and harmful microorganisms is one of the serious major health problems.

2.3 GROUNDWATER HYDROGEOCHEMISTRY

Groundwater contains a variety of chemical constituents at different concentrations. The greater part of the soluble constituents in groundwater comes from soluble minerals in soils and sedimentary rocks (Waterwatch, 2005). Groundwater chemistry changes, as the water flows in the underground environment, by the increase of dissolved solids and major ions. The longer the duration the groundwater staying in the ground, poorer will be the quality. The chemistry of the coastal aquifers is complex due to the threat of groundwater contamination by seawater (Radha, 1971; Lawrence, 1995). The quality of the groundwater mainly depends on the quality of cations and anions existing in it. The reasons for groundwater deteriorations are:

i. Discharge of industrial effluents,

ii. Discharge of sewage,
iii. Saline water intrusion along the coastal regions,
iv. Rock-water interaction in aquifer,
v. Microbial activities in bio-films underground,
vi. The hydrodynamic and dilution properties of aquifers and
vii. The intensity of pollution.

As the groundwater moves from the recharge area to the discharge area, the chemistry is affected by variety of geochemical processes. The dissolved components of water not only undergo changes during transport, but also react and redistribute the mass among various ions. With increase in the demands of groundwater in many coastal areas due to exponential growth of population and other needs, the base flow is decreased or even reversed, causing seawater intrusion. There are several other factors that contaminate groundwater and a few of them are:

i. Excess usage of fertilizer in agricultural activities,
ii. Extensive aquaculture in coastal environments and
iii. Salt pan industries.

Lawrence, Lloyd and Marsh (1976) demonstrated the mixing of different groundwater types in the limestone aquifer of England by detailed hydrochemistry studies. The distribution of ions in groundwater showed mixing of ancient connate water with the younger recharge water along an interface zone. Agro-chemicals are the main sources of nitrogen, and other organic and inorganic contaminants in the groundwater regime. Several authors have reported the presence of agro-chemicals in soils (Muir and Baker, 1978). Sage and Llyor (1978) demonstrated the application

of hydrochemistry to understand the sandstone aquifer of England. Freeze and Cherry (1979) studied water chemistry in combination with groundwater hydraulics. Stumn and Morgan (1981) introduced many innovative ideas on water chemistry and its relation to its geological environment.

The hydrologic cycle begins with the evaporation of water from the surface of water bodies. As moist air is lifted, it cools and water vapor condenses to form clouds. Moisture is transported around the globe until it returns to the surface as precipitation. Once the water reaches the ground, one of two processes may occur; (i) some of the water may evaporate back into the atmosphere or (ii) the water may penetrate the surface and become groundwater. Groundwater either seeps its way to into the oceans, rivers, and streams, or is released back into the atmosphere through transpiration. The balance of water that remains on the earth's surface is runoff, which empties into lakes, rivers and streams and is carried back to the oceans, where the cycle begins again (Johansson, Werner, Bosson, Berglund and Juston, 2005).

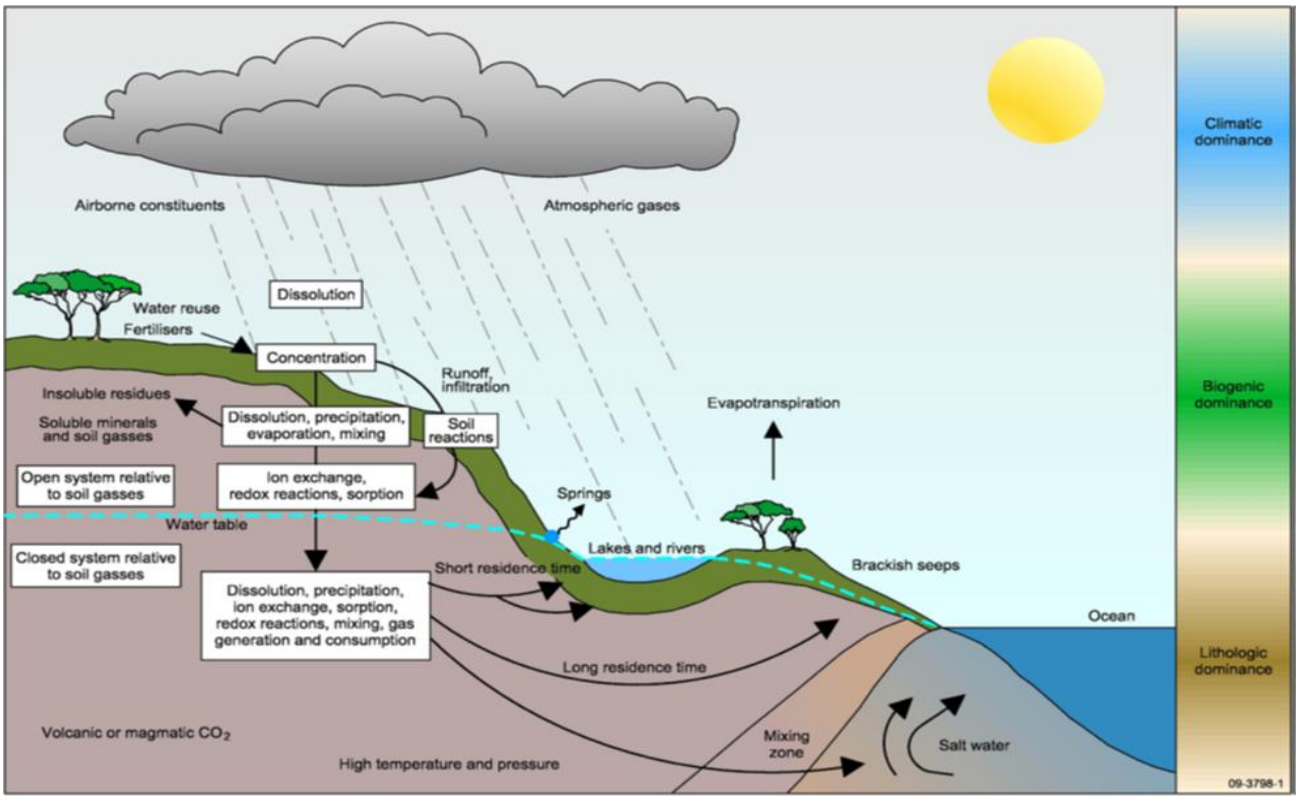


Figure 2.1: Conceptual Diagram of the Hydrogeochemical Cycle
Source: (Back and Hanshaw, 1993)

Ophori and Toth (1989) studied the patterns of groundwater chemistry in the unconfined aquifer of Ross Creek basin of Canada using all the major ion constituents and determined the flow directions. They further showed good correlation between groundwater flow and geochemical patterns. Hendry and Schwartz (1990) studied the chemical evolution of groundwater in the Milk river aquifer of Canada and observed well-defined ion composition trends in the groundwater. They determined a few geochemical processes, which altered the recharge water ionic concentrations. Elango (1992) had studied the hydro-geochemical nature of the multi-layered aquifer of North Chennai, and had brought out the relation of groundwater recharge to flow mechanisms.

Geochemical studies of waters have been utilized to help define the hydrology of an area. The contribution of groundwater to the chemical character of stream and river waters was studied using water chemistry (Williams, Kattelmann and Melack, 1990). Hudson and Golding (1997) reported that bicarbonate, silica, calcium and sodium are derived from the weathering of plagioclase, while magnesium and potassium are derived from the relatively less weatherable feldspars.

Scheytt (1997) investigated seasonal and temporal variation patterns of groundwater chemistry and depth-wise chemical composition of groundwater at various locations. Near the water table, groundwater was mainly influenced by recharge of rainfall. Elango, Kannan and Kumar, (2003) carried out extensive work on the hydrogeochemical nature of groundwater in an intensively irrigated region of Kancheepuram District of Tamil Nadu, South India. They also emphasised the need for regular monitoring of groundwater quality. Mohan, Singh, Tripathi and Chowdhary, (2000) attempted to assess the suitability and causes for deterioration of groundwater quality in Nainin industrial area of Allahabad District of Uttar Pradesh, by evaluating the hydro-geochemical nature of the groundwater. Subramani, Elango and Damodarasamy, (2005) studied the variation of groundwater quality and its suitability for drinking and agricultural use in Chithar River basin, Tamil Nadu, India. Reviews made in the journals and publications reveal that Hydrogeochemistry study on river basin will be helpful for monitoring the water quality in the basin. Udom, Ushie and Esu (2002), investigated the hydrogeochemistry of some groundwaters in parts of the Niger Delta.

2.4 WATER QUALITY INDICES

WQI was first seriously proposed and demonstrated beginning in the 1970s but were not widely utilized or accepted by agencies that monitor water quality (Cude, 2001). WQI, in common with many other index systems, relates to a group of water quality parameters to a common scale and combines them into a single number in accordance with a chosen method or model of computations (Mohsen, 2007). WQI has been regarded as one of the most effective way to assess the quality of water (Tiwari and Mishra 1985; Sinha and Ritesh, 2004).

Horton (1965) proposed the first water quality index (WQI). A number of indices have been developed to summarize water quality data in an easily expressible and easily understood format. According to Nives (1999), WQI is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts. Water quality of different sources has been communicated on the basis of calculated water quality indices (Pradhan, Patnaik and Rout, 2001).

Most countries practice the method which is similar to the existing Malaysian Department of Environment index that expresses quality of water via a single number by combining measurements of selected physical, chemical, biological and radioactive parameters (Cude *et al.*, 1997). Generally, a higher index value represents poor water quality. Therefore, a numerical index is used as a management tool in water quality assessment (Avvannavar and Shrihari, 2007).

WQI convert the bulk of water quality data into a single digit, cumulatively derived, numerical expression indicating the level of water quality. This, consecutively, is essential for evaluating the water quality of different sources and in observing the changes in the water quality of a given source as a function of time and other influencing factors (Sarkar and Abbasi, 2006). Sinha and Ritesh (2006) analyzed the WQI for drinking water at Hasanpur Nagar for 10 different sites, and concluded that the water is severely contaminated at almost all the sites of sampling. They proved WQI is an important tool for the assessment of water quality. Rita, Kumar and Nirmal, (2011) made a study on seasonal variation and WQI of Sabarmati River at Ahmedabad, Gujarat, India. The results of their study revealed that the quality of Sabarmati River was adversely affected by discharge of domestic, agricultural and industrial effluents as a result of extended urbanization. Review made in the journals and publications reveal that WQI study on river basin will be helpful for monitoring and prediction of the basin water quality. WQI has been developed to assess the suitability of water for a variety of uses. The index reflects the status of water quality in lakes, streams, rivers, and reservoirs. The concept of WQI is based on the comparison of the water quality parameter with respective regulatory standards (Khan, Husaini and Lumb, 2003).

Water quality index combines several important water quality parameters that give an overall index of the water quality for a specific use. Different pollutants and factors are required for the development of an index. The simplest WQI reflect on several simple water quality parameters such as dissolved oxygen, total suspended solid, pH, and possibly some nutrients. Measurements of each of these parameters are taken and compared to a classification table, where the water is identified as excellent, good, fair, poor or very poor (Davis and McCuen, 2005).

There are numerous water quality indices that have been developed to help water quality divisions in some parts of the U.S, Canada, and Malaysia. However, most of these indices are based on the WQI developed by the U.S. National Sanitation Foundation (NSF) (Said, Stevens and Sehlke, 2004). The present method used in Malaysia to calculate the WQI is based on opinion poll (Khuan, Noraliza and Rozita, 2002). Although WQI has the potential to summarize complex scientific information on water quality into a simpler form for assessment, communication and reporting purposes; there are merits and demerits of using WQI approach (UNEP, 2006). These are explained in Table 2.1.

Table 2.1 Advantages and Disadvantages of a Water Quality Index.

	Advantages	Disadvantages
1.	Measures general water quality	Does not measure water pollution
2.	Single number for overall water quality	Insensitive to individual problem parameters
3.	Good for communicating with the laymen	Poor for addressing particular technical problems
4.	Standardized so that different geographic areas can be directly compared	Does not take into acount local natural background water quality effects
5.	Many water experts' opinions taken into account when formulating WQI	Somewhat arbitrary and lack of a firm scientific basis

U.S. Council on Environmental Quality (1973)

2.5 HEALTH EFFECT OF WATER QUALITY PARAMETERS

2.5.1 Bacteriological Parameters

The diseases caused by water related microorganisms can be divided into four main categories:

i. Water-borne diseases: caused by water that has been contaminated by human, animal or chemical wastes. Examples include cholera, typhoid, meningitis, dysentery, hepatitis and diarrhea. Diarrhea is caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water (WHO, 2006). Poor nutrition resulting from frequent attacks of diarrhea is the primary cause for stunted growth for millions of children in the developing world (Gadgil, 1998).

ii. Water-related vector diseases: These are diseases transmitted by vectors, such as mosquitoes that breed or live near water. Examples include malaria, yellow fever, dengue fever and filariasis. Malaria causes over 1 million deaths a year (WHO, 2006). Stagnant and poorly managed waters provide the breeding grounds for malaria-carrying mosquitoes.

iii. Water-based diseases: These are caused by parasitic aquatic organisms referred to as helminthes and can be transmitted via skin penetration or contact. Examples include Guinea worm disease, filariasis, paragonimiasis, clonorchiasis and schistosomiasis.

iv. Water-scarce diseases: These diseases flourish in conditions where freshwater is scarce and sanitation is poor. Examples include trachoma and tuberculosis.

Testing the bacterial contaminants in water can be simplified by utilizing the presence of an indicator organism. An indicator organism may not necessarily pose a health risk but it can be

easily isolated and enumerated, is present in large numbers, is more resistant to disinfection than pathogens, and does not multiply in water and distribution systems (Gadgil, 1998). Traditionally, total coliform bacteria have been used to indicate the presence of fecal contamination; however, this organism has been found to exist and grow in soil and water environments and is therefore considered a poor parameter for measuring the presence of pathogens (Stevens, Ashbolt and Cunliffe, 2003). Studies also show that due to their ability to grow in drinking water distribution systems and their unpredictable presence in water supplies during outbreaks of waterborne disease, the sanitary significance or quality of water is difficult to interpret in the presence of total coliforms (Stevens, Ashbolt and Cunliffe 2003).

An exception is *Escherichia coli (E.coli),* a thermotolerant coliform, the most numerous of the total coliform group found in animal or human feces, rarely grows in the environment and is considered the most specific indicator of fecal contamination in drinking-water (WHO, 2004). The presence of E. coli provides strong evidence of recent fecal contamination (WHO, 2004, Stevens, Ashbolt and Cunliffe, 2003). The risk of coliform presence can depend on the health or sensitivity of the consumer. The risks of E. coli presence, slightly greater than WHO Guideline's zero count per 100ml may be of only low or intermediate risk. According to IRC, (2002) as cited by Michael (2006) about risk classification for thermotolerant coliforms or E. coli of rural water supplies shown below in Table 2.2.

Table 2.2: Water Quality Counts per 100mL and the Associated Risk

Count per 100ml	Risk Category
0	Inconformity with WHO guidelines
1-10	Low Risk
11-100	Intermediate Risk
101-1000	High Risk
>1000	Very High Risk

Source: IRC, (2002)

2.5.2 Chemical Parameters

Some of the main chemical parameters that are of a health concern according to WHO (2004) include the following:

i. Fluoride causes mottling of teeth and in severe cases can result in crippling skeletal fluorosis.
ii. The presence of arsenic implicates the risk of cancer and skin lesions.
iii. Nitrate and nitrite can cause methaemoglobinaemia. This arises from excess fertilizers or leaching of wastewater and other organic wastes into water surface.
iv. Lead can have adverse neurological effects, mainly in areas with acidic waters and the use of lead pipes, fittings and solder.

Secondary concern of the impact of chemical constituents is the effect on distribution and treatment systems that may be implemented to improve the access to a safe water supply. Corrosive properties of constituents can induce structural failure, which can also result in deterioration of the quality of the water and cause additional concerns for health and safety. Due

to these concerns, corrosion control is an important aspect of the management of a drinking water system. pH can control the solubility and reaction rates of most metal species involved in corrosion reactions (WHO, 2004). Iron, lead, copper, brass and nickel can also be used in construction of piping systems (WHO, 2004). Concrete is a composite material consisting of sand, gravel and cement, a binder consisting primarily of calcium silicates, aluminates and some lime (WHO, 2004). Structural deterioration or failure of cement may result from prolonged exposure to aggressive or highly corrosive waters which can result in leaching of metals from the cement into the water (WHO, 2004). When ferrous iron oxidizes to ferric iron, it can give a reddish-brown color to the water, which could be aesthetically displeasing (WHO, 2004). Manganese can cause an undesirable taste as well as staining laundry when levels exceed 0.1 mg/liter. The presence of manganese may also lead to the accumulation of deposits in the piping system (WHO, 2004).

2.5.3 Physical and Aesthetic Parameters

Consumer perception and acceptability of their drinking water quality depends on user sense of taste, odor and appearance (Sheat, 1992; Doria, 2010). That is why consumers have differing opinion about the aesthetic values of water quality. Relying on their own senses may lead to avoidance of highly turbid or colored but otherwise safe waters in favor of more aesthetically acceptable but potentially unsafe water sources (WHO, 2004).

Taste and odor can originate from various natural chemical contaminants, biological sources, microbial activity, from corrosion or as a result of water treatment (e.g. chlorination) (WHO, 2004). Color, cloudiness, particulate matter and visible organisms can also contribute to

unacceptability of water sources. These factors can vary for each community and are dependent on local conditions and characteristics. The following lists a number of primary aesthetic indicators that can cause water to be perceived as unacceptable:

i. True color (the color that remains after any suspended particles are removed).
ii. Turbidity (the cloudiness caused by particulate matter present in source water, suspension of sediment in the distribution system, the presence of inorganic particulate matter in some groundwater or sloughing of bio-film within the distribution system (WHO, 2004).
iii. unusual taste, odor and feel problems (usually due to total dissolved solids)

Turbidity is the most important problem for the aesthetic value of water quality. Although it doesn't necessarily adversely affect human health, it can protect microorganisms from disinfection effects, can stimulate bacterial growth, and indicate problems with treatment processes (WHO, 2004). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2004). An important operational water quality parameter is pH, although within typical ranges it has no direct impact on consumers. Low pH levels can enhance corrosive characteristics resulting in contamination of drinking-water and adverse effects on its taste and appearance (WHO, 2004). Higher pH levels can lead to calcium carbonate deposition. Careful consideration of pH is necessary to ensure satisfactory water disinfection with chlorine, which requires pH to be less than 8 (WHO, 2004). Total dissolved solids (TDS) and electrical conductivity (EC) are measures of the total ions in solution and ionic activity of a solution respectively. As TDS and EC increase, the corrosive nature of the water increases.

2.6 WATER QUALITY STANDARDS/GUIDELINES

The Guidelines describe reasonable minimum requirements of safe practice to protect the health of consumers and/or derive numerical "guideline values" for constituents of water or indicators of water quality. In order to define mandatory limits, it is preferable to consider the guidelines in the context of local or national environmental, social, economic and cultural conditions (WHO, 2008). By definition, a standard is "a rule or principle considered by an authority and by general consent as a basis of comparison. It is something normal or average in quality and the most common form of its kind". A proper standard for drinking water quality is thus the reference that will ensure that the water will not be harmful to human health. The framework against which a water sample can be considered good or "safe" is a drinking water quality standard. (Solsona, 2002). The primary purpose of the Guidelines for Drinking-water Quality is the protection of public health. Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all and improving access to safe drinking-water (WHO, 2008).

WHO divided drinking water guidelines according to; microbial, chemical, radiological and acceptability aspects.

2.6.1 Microbial Aspects

In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with human or animal (including bird) faeces. Faeces can be a source of pathogenic bacteria, viruses, protozoa and helminthes. Faecally derived pathogens are the principal concerns in setting health-based targets for microbial safety.

Drinking water outbreaks are particularly to be avoided because of their capacity to result in the simultaneous infection of a large number of persons and potentially a high proportion of the community.

2.6.2 Chemical Aspects

The health concerns associated with chemical constituents of drinking-water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure. There are few chemical constituents of water that can lead to health problems resulting from a single exposure, except through massive accidental contamination of a drinking-water supply. Moreover, experience shows that in many, but not all, such incidents, the water becomes undrinkable owing to unacceptable taste, odor and appearance.

2.6.3 Radiological Aspects

The contribution of drinking-water to total exposure to radionuclide is very small under normal circumstances. While finding levels of activity above screening values does not indicate any immediate risk to health, it should trigger further investigation into determining the radionuclide responsible and the possible risks, taking into account local circumstances.

2.6.4 Acceptability Aspects (Aesthetics Aspects):

Water should be free of tastes and odors that would be objectionable to the majority of consumers. In assessing the quality of drinking-water, consumers rely principally upon their senses. Microbial, chemical and physical water constituents may affect the appearance, odor or taste of the water and the consumer will evaluate the quality and acceptability of the water on the

basis of these criteria. Although these substances may have no direct health effects, water that is highly turbid, is highly colored or has an objectionable taste or odor may be regarded by consumers as unsafe and may be rejected (WHO, 2008).

2.7 WATER QUALITY SURVEILLANCE AND MONITORING IN NIGERIA

Details of the current water-quality monitoring and surveillance system are given in Table 2.3. Just prior to the RADWQ project, the Federal Ministry of Water Resources initiated the Water Quality Laboratories and Monitoring Network project, which plans to establish two reference laboratories in Lagos and Kano, and four regional laboratories in Akure, Enugu, Minna and Gombe. The laboratories are to monitor drinking-water quality for both rural and urban areas, and to carry out training for the State water agencies. Two laboratories, in Minna and Akure, had already been commissioned and were operational. The reference and regional laboratories intend to significantly improve the management and oversight of water quality throughout Nigeria.

Table 2.3 Structure of the Nigerian surveillance and monitoring system for drinking-water quality

ACTORS	ROLE AND REPRESENTATION
Federal Ministry of Health	Surveillance Activities
Federal Ministry of Water Resources	Monitoring and Surveillance Nationally and in Each State
National Water Resources Institute	Research Training and Monitoring
Federal Ministry of the Environment	Issuing Standards on Environmental Regulation and Surveillance
Universities and Polytechnics	Research and Training
International Donors	Capacity Development (Equipment, Funds, etc.)
National Bureau for Statistics	Collection, Collation and Issuing of Data
River Basin Development Authority	Monitoring Activities
State Water Agencies	Monitoring Activities
Rural Water-Supply/Sanitation Agencies	Monitoring Activities
Institute of Public Analytics of Nigeria	Monitoring and Quality Assurance
National Agency for Food and Drug Administration and control	Enforcement of Quality Standards for Packaged water
Standards Organization of Nigeria	Issuing Standards on water quality

Source; Ince *et al.,* (2010)

2.7.1 National Standards

Currently, there are two national standards for drinking-water in Nigeria, one was published by Federal Environmental Protection Agency in 1999, and the other by the Standard Organization of Nigeria, in 2003. Neither of the standards is widely accepted, however, and instead the WHO

guidelines and suggested values for drinking-water quality were used to analyze the RADWQ data for Nigeria (WHO, 2004).

2.7.2 Rapid Assessment of Drinking Water Quality Survey Design for Nigeria

The steering committee for Nigeria commissioned an initial assessment of the RADWQ survey design, based on the method of Howard, Ince and Smith 2003. The assessment used all available data on water supplies from the states of the Federation, as well as other sources of information, principally the Federal Office of Statistics (MICS, 1999), the Federal Ministry of Water Resources and UNICEF (Kehinde, 2003). In consultation with the committee, the preliminary design of the RADWQ survey was fine-tuned during the initial visit by the international consultant to ensure that site selection was random, but representative of technologies, and that water quality problems specific to Nigeria were addressed.

The major modifications to the RADWQ design for Nigeria were:

- The number of water systems for each technology type was not available. Primary stratification of the data was therefore by the proportion of households with access to water technology type in the 36 states of the Federation and the Federal Capital Territory of Abuja (FOS, 2003).
- Water supplied by vehicle or tanker truck covered <5% of the population nationally which would normally exclude this technology from a RADWQ survey, but in some urban areas this technology covered >5% of the population. It was therefore decided to assess water quality for this type of supply technology in one cluster, chosen to be in Hydrological Area as it had the highest population supplied by tanker truck technology.

- Fluoride is a water-quality issue in some areas of Nigeria (e.g. Plateau State) and samples within one cluster were assessed for this water-quality parameter.
- Mining is a water quality issue in some areas of Nigeria (e.g. Plateau State) and samples within one cluster were assessed to determine its impact on water quality.

2.8 PHYSICOCHEMICAL WATER QUALITY AND WATER QUALITY INDEX STUDIES IN NIGERIA

Many researchers have stressed the importance of carrying out water quality assessments and establishing regional water quality index.

Matsuura (2003) reported that water demand in Nigeria far exceeds sustainable supply. Ibiam (2008) also reported that drinking water supply in Nigeria is grossly inadequate especially in the rural areas. In a survey conducted by the Federal Ministry of Health, only 15 per cent of villages have adequate and potable drinking water. The situation in urban areas is also not cheerful. Less than 50% of the 85 million urban dwellers have "reasonable access to reliable water supply" (FMWR, 2000). Both rural and urban areas of Kano State experience water shortages. According to Kazuare, (2005), less than 20% of the sixty wards in the six metropolitan local governments of the state have access to potable drinking water.

In carrying out assessment of the Physico-chemical and Escherichia coli assessment of selected sachet water produced in some areas of Minna, Ndamitso, Idris, Likita, Tijani, Ajai and Bala (2013) collected Ten brands of sachet water from the packaging factories (5 samples per brand) and were analyzed weekly for four weeks. Results obtained were compared with WHO and EPA standards for drinking and recreational water. Their pH values, except for Sabo Best (6.26 ±

0.02), were within the stated WHO/EPA standards (6.50 - 8.50). The coliform levels of FUTM is (75.00 ± 2.00), Happy Days (75.00 ± 2.00) and Carry More (23.33 ± 0.33), based on the most probable number (MPN), were unfit for potability since they could also contain other microorganisms implicated in gastro-intestinal water borne diseases. The respective 1.63 ± 0.10 and 1.54 ± 0.10 mg/dm3 for Evershine and Supreme waters were above the 0.3 mg/dm3 iron standard just as the respective copper and nitrate values of 1.19 ± 0.14, 1.27 ± 0.10, 1.48 ± 0.10 and 86.81 ± 0.62, 124.47 ± 1.36, 141.70 ± 0.00 mg/dm3 for Golden Age, Supreme and Sabo Best were higher than the respective 1 and 50 mg/dm3 standards for copper and nitrates. All other parameters were within the EPA and WHO values.

In a similar study in Sabon-Gari Area of Kano, Bichi and Amatobi (2013) assessed the Quality of Water Supplied by Water Vendors to Households, which was carried at commercial sales points, water vendor's distribution Jeri-cans and household storage tanks. Ninety (90) water samples were collected at 10 locations spread across Sabon-Gari and analyzed for physico-chemical and bacteriological parameters. The results obtained were compared with standards recommended by the World Health Organization (WHO), the Nigerian Standard for Drinking Water Quality (NSDWQ) and the European Community (EC). Total Hardness (as $CaCO_3$), Conductivity and Free Chlorine values were not within acceptable limits in most of the samples. Colonies of microorganism were in excess amounts in 9 samples while coliform organism was detected in 19 samples. The percentage of colonies of microorganisms was 27%, 43% and 70% for commercial sales points, hawkers' Jerry-can, and household storage respectively. Also percentage of samples that tested positive to coliform organism was 10%, 20%, and 33% for commercial sales points, hawkers' Jerry-can, and household storage respectively. Thus it was

concluded that water quality was compromised at the private commercial supply, during hawker's distribution and in the household storage.

In another instance, Adamu and Adekiya (2010) carried out a study on assessment of water quality of boreholes around selected landfills in Kano Metropolis which considered pH, turbidity, conductivity, total solids (TS) suspended solids (SS), total dissolved solids (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved oxygen (DO), chloride, sulphate, nitrate, phosphate, Zinc, Lead, Nickel, Cadmium, Iron, Manganese, Copper, and chromium. The analysis revealed that some samples were acidic and some alkaline with a pH range of (6.80 – 7.75) and at the methogenic stage, samples have low BOD (28.5 – 46.0mg/l) and COD (55.00 – 89.25mg/l) values indicating active methogenesis process is taking place at the sites used in industrial and agricultural purposes. The suspended solids, total dissolved solid and turbidity results varied significantly between sites, all samples contained low concentration of nitrate and sulphate with phosphate, chloride, lead and manganese in high ranges. Also when compared with the National Regulatory Standard, it showed that the pollution potentials of Gyadi-gyadi and Ubagama samples are higher than those of Hajj camp and Maimalari.

Similarly, a study carried out by Mohammed (2013) on quality assessment of potable water in Sabon-Gari Kano State, the study compared the quality of some of the most patronized water considered consumable in Sabon Gari Area of Kano State with the World Health Organization (WHO) set standard which revealed a significant difference in the level of concentration of physicochemical parameters such as conductivity, color, total hardness, total dissolved solid,

total alkalinity, turbidity, chlorides, calcium ions, (Fe) iron, and magnesium ions with higher concentrations in borehole water sources which are not within the WHO and EPA standards than in that of the sachet water.

Abdulbaki, Ahmad and Maina (2014) carried out a quality assessment of groundwater around open dumpsites in Kano Metropolis. The physicochemical and bacteriological quality of groundwater were assessed and samples from three areas located near the refuse dumpsites in the metropolis were collected to investigate the effect of pollutants to the quality of boreholes and wells waters located within 50m, 100m and 150m from the pollution source. The water quality indicating parameters were determined using standard procedures. SPSS was used to analyze the descriptive and correlation analysis of Alkalinity, Ca^{+2}, Cl^{-}, EC, Mg^{+2}, pH, TDS and Temperature respectively. The bacteriological analyzed were total coliforms and E-coli. All the results were compared with NSDWQ and WHO standards. The result revealed that waters samples from Sites at sorandinki received the highest mean values of the physicochemical parameters and the total coliforms, which could be attributed to the presence of larger volume of open dumps sites than those from sites at Bola and Court road respectively. The correlation between the alkalinity, TDS, pH and Cl is an indication of depositions of wastes of acidic nature at the dumpsites. The absence of E.coli in all sample waters rendered it useful for human consumptions when treated.

In applying water quality index in Nigeria, Ishaku (2011), carried out an assessment of groundwater quality index for Jimeta-Yola area. The study collected groundwater samples from hand-dug wells and boreholes in the dry season and rainy season periods and subjected same to physicochemical analysis. The results indicate that electrical conductivity (EC), chloride, nitrate and dissolved oxygen exceeded World Health Organization (WHO) standards in the dry season

and chloride, nitrate, dissolved oxygen, total hardness and chromium hexavalent exceeded WHO standards in the rainy season. Spatial distribution of EC, chloride, nitrate and chromium hexavalent in the dry and rainy season indicated that the sources of these contaminants result from point sources such as house hold solid wastes, sewage effluents and wastewater. The overall water quality index (WQI) value in the dry season was 96.4 which indicate good water quality. The overall WQI value in the rainy season was 138.5 which indicate poor water quality. The high value of WQI has been found to be mainly from chloride, nitrate, dissolved oxygen, chromium hexavalent and EC. The source of these contaminants is attributed to anthropogenic origin. The study revealed that the water quality is unfit for human consumption without treatment.

Similarly, Etim, Odoh, Itodo, Umoh and Lawal (2013), carried out water quality index for the assessment of water quality from different sources, in which streams, boreholes and pipe borne water in the Niger Delta region of Nigeria was evaluated. The investigations were carried out to compute the Water Quality Index (WQI) in order to assess the suitability of water from different sources collected from different areas within the Niger Delta region. WQI was determined on the basis of various physico-chemical parameters like pH, total alkalinity, chlorides, sulphate, nitrate, total hardness, calcium, magnesium, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids and total suspended solids. The results obtained for the WQI from the different sampling stations were found to be varied from 34.80 to 36.26 for pipe borne water, 38.52 to 48.67 for borehole water and 55.05 to 84.94 for stream water. Also the results indicated different water samples analysed from pipe born and borehole

water are safe for human consumption and for other domestic purposes while the samples analyzed from stream water are not safe for human consumption.

In another study by Odiba, Matthew, Raphael, Gary and Gideon (2014) on assessment of Water Quality Index in borehole and well water in Wukari town, Taraba State, where water samples collected from boreholes and hand dug wells located in two wards in Wukari town were assessed for some physico-chemical parameters on collection and after one week of storage using standard analytical methods. The parameters determined included temperature, turbidity, suspended solids, total dissolved solids, conductivity, pH, nitrate –nitrogen, phosphates, chlorides, alkalinity, COD and DO. The result showed that some parameters like turbidity, conductivity and suspended solids exhibited a marked drop in value following their storage for one week in both borehole and hand dug well water samples. Mean values of parameters like nitrate-nitrogen, phosphates and chlorides did not exhibit marked drop in concentration values in both water sources. Turbidity and suspended solid values in the well water samples was more than that of borehole waters however the mean conductivity values in borehole water is more than in well water. Water from both sources was found to exhibit hardness on collection and after one week of storage. The quality indices in borehole and well water on collection were found to be 26 and 136 respectively. After one week of storage the quality indices were determined and the values were found to be 15 and 89 respectively indicating improvement in the water quality after storage for one week. Borehole water in Wukari was found to possess better quality for drinking than well water. The study provides a baseline information on the quality of borehole and hand dug well waters in Wukari Town. In addition, the hardness of the water sources may be an indication of the presence of underlying minerals in the ground.

2.8.1 Summary of review

It is clear from the foregoing review that though works have been done on the quality of potable water, but not much was done on water quality index in Kano Metropolis. Owing to lack of potable water in most regions in Nigeria, people tend to depend on other sources of water for domestic use and other activities (Shittu, Olaitan and Amusa, 2008). The contamination of these water sources comes from different sources in the environment, they include effluents from sewages, household activities, industries, abattoir activities and pesticides (Iornumbe and Onah, 2008) and from animal faecal discharges into surface and groundwaters. One sure way by which information on the quality of water could be conveyed to those concerned is by using suitable indices (Dwivedi and Pathak, 2007).

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.1 THE STUDY AREA

3.1.1 Location and Size

Kano metropolis is located between Latitudes 11° 56' N - 12° 04' N and Longitudes 08° 26' E - 08° 39' E (Figure 3.1). It occupies an area of about 683km^2, with a crow fly distance of 19km from east to west and about 15km from north to south. Kano Metropolis is bordered by Minjibir LGA to the North East and Gezawa LGA to the East, while Dawakin Kudu LGA to the South East, Madobi and Tofa LGAs to the South West. It is the largest urban center in the Hausa land and most influential commercial town in the Sudan region. It is the third largest in the federation of Nigeria coming after Lagos and Ibadan. With a long standing sedentary population in an organized emirate, Kano's growth is phenomenal. McDonnell (2002) described it as a key area of modern Nigeria and one of the largest rural-urban complexes in Africa. Map of Kano showing the six LGAs are illustrated by Figure 3.1.

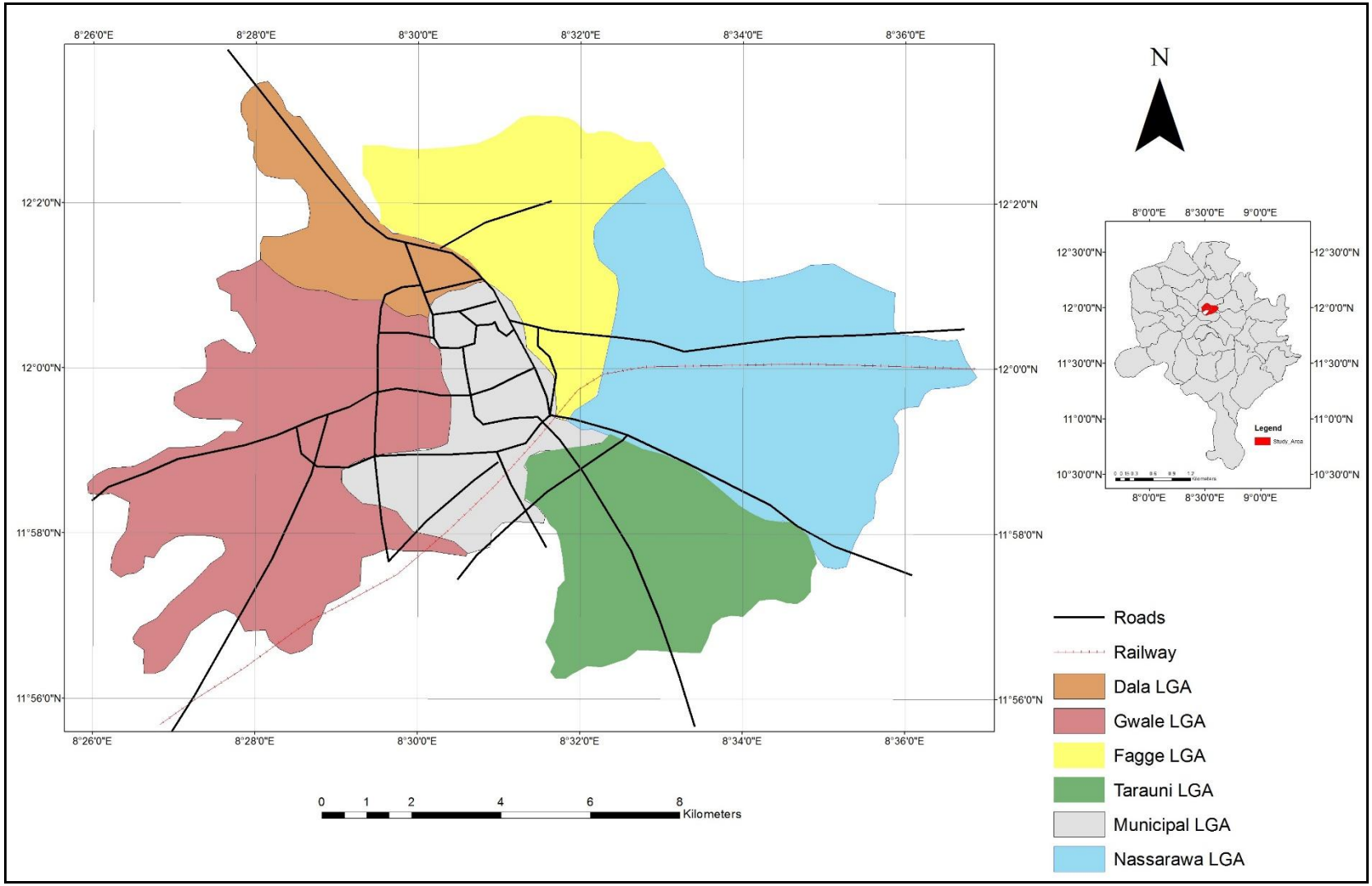


Figure. 3.1: Kano Metropolis
Source: Adapted from the Administrative Map of Kano State.

3.1.2 Climate

The climate is determined by the movement of two air masses, a moist rather cool southerly mass known as south-westerly and a hot and dry northern air called the north-easterlies. The moist southern air forms a wedge under the lighter dry air and the region where the two air masses meet is primarily an area of pronounced moisture gradient. The humidity gradient is called the Inter Tropical Discontinuity (ITD). The climate of the area is the tropical wet and dry type with wet season lasting for 4 - 5 months between May and September (Olofin and Tanko, 2002).

The ITD starts its southward movement in October and between March and May it has no considerable influence in the state and the weather is hot and dry during rainy season. The mean temperature is 28 to 30^0C while this is the period when the "false" start of the rain is recorded in May. A few rain fall is recorded in May (with an average of 3.9mm) and rainy days are separated by days of dry spell with less than 1% of the annual rainfall is recorded in May (Barau, 2007).

The ITD has by now made considerable advance northward and there is widespread rainfall in the state by June. Rainfall occurs mainly in the evenings for periods of one to three hours and considerable heavy rainfall (with an average of 866mm) is recorded in the first forty minutes of rainfall occurrences. Over 90% of the annual rainfall is recorded in this season. The average rainfall in 866mm in only about five months in the year, especially between July and October. This is the humid period when surface runoff is available for stream flow and soil moisture is sufficient for plant growth. Damina is the crop growing season when grains and legumes are grown. Temperature drops to an average of 24^0-29^0C while evaporation is lower because of the

higher relative humidity of the moist south westerlies air. This is why the runoff-coefficient is highest during this season (Barau, 2007).

The ITD reaches its southern limit during this season and the state is under the influence of the north easterly wind which brings a cool and dusty weather called 'Harmattan" between December and February, the dry air from the north brings no rainfall only the transported harmattan dust is deposited to replenish soil nutrient. The depth of the windrift material varies from an average of 1 to 2m. This is the cool season when temperature is 25 to 27^0C. Respiratory problems are experienced and asthma patients are particularly hard hit. The cool temperature makes the season suitable for wheat cultivation under irrigation. Wheat is an important crop in the Kano River Irrigation Project. Seasonality is an important aspect of the climate; it determines the length of the crop growing period. At another level, the variability of the annual rainfall during the rainy season (Damina) has important management implications (Barau, 2007).

The ITD is now in its southward retreat and only a few showers may be recorded in October accounting for less than 8% of the annual rainfall with an average of < 0.9mm. This is the harvest season between October and November when farmers are busy harvesting crops and traders are buying what is offered. Average temperature is 28-29^0C. During this season, as evaporation is in excess of rainfall. This is a season when soil moisture is depleted and stream flow recedes (Barau, 2007).

3.1.3 Geology, Relief and Hydrology

There is considerable relation between geology and drainage pattern. The small areas of Chad Sediments in Danbatta and Gaya Local Government Areas have groundwater potential with

limited channel development. The drainage systems are; Challawa, Watari, Jatau and Dudurun Gaya which joins the Hadejia River and empties into the chad basin, while Gari, Tomas and Jakara disappears into the sands of the Chad formation further east. Several manmade lakes such as Tiga, Challawa Gorge, Gari, Jakara, Watari, Guzuguzu, Kafin Chiri, Dudurun Gaya, Bagauda were constructed to improve portable water supply to towns and villages and to provide water for irrigation (Maiwada, 2000).

Groundwater potential is higher in the limited areas of sedimentary rock and it occurs in perched aquifers as well as in confined and semi confined aquifers. The potential is low in the basement complex area where the success ratio of boreholes is lower because of the limited depth of regolith, its clay content, and the localized occurrences of factures and joints. However, the basement area has higher surface runoff potential.

Kano is found on a relief plain of 472m above sea level on the northern high plains that are similar to the western plains and ranges. They are an extensive area in which basement complex igneous and metamorphic rocks have been eroded to form rolling, undulating and dissected plains and hills. The hills, which varied from isolated inselbergs and hill ranges to extensive areas of hilly terrain, are made up of more resistant granites, quartzite and quartz schists. While the general elevation is less than 500m, individual hills reach to nearly 1000m e.g. Gwauron Dutse and Dala hills (Maiwada, 2000).

3.1.4 Vegetation

Kano is mainly dominated by the Sudan and Guinea savannah. Savanna is simply described as closed grass or other predominantly herbaceous vegetation with scattered or widely spaced woody plants. The climatically defined vegetation type in the state are the northern Guinea savanna and Sudan savanna. Northern Guinea Savanna is an open woodland or bush land with grasses shorter than in the southern guinea where grasses are 1.5 to 3m tall. The Sudan Savanna has scattered trees in open grassland with grasses under 1.2m tall (Ahmed, 2006).

The vegetation has been largely cleared for cultivation to form cultivated parkland. Parkland has scattered protected trees at some distance apart in open cultivated land. Small trees and shrubs are more common on fallow land where regeneration may take place. About 75% of the land is cultivated parkland with average tree densities of less than 25 per hectare. Within the two broad types of vegetation identified, there are pockets of other structural types. Thick vegetation is found along large river channels and floodplains and it is described as impenetrable shrubby vegetation. Surviving savanna woodland is found as forest/game reserve such as the Falgore reserve (370km^2). Here the trees and limited number of shrubs form a light canopy. Where the woodland reserve is degraded due to uncontrolled exploitation it changes into scrub vegetation or bush which is made of shrubs and herb and it is not closed. Gazetted grazing reserves may be grassland where trees and shrubs do not exist. The grazing reserve is degraded, through uncontrolled exploitation, when woody vegetation encroaches (Badamasi, 2014).

Natural vegetation covers less than 5% of the land area and even then it is largely degraded, except for the Falgore reserve which also suffers from encroachment. The over-riding human influence means that most tree species are common to both northern Guinea and the Sudan

Savanna. Such common species include *Adansonia digitata* (kuka in Hausa) and *Vitex doniana* (Dinya) which provides edible fruits and leaves. *Diospyrosmes piliformis* (Kanya) and *Tamarindus indica* (Tsamiya) provide edible fruits while *Moringa oleifera* (zogale) provides edible leaves. Other species found in the two areas but more common in the Guinea zone include *Parkia Clappertoniana* (Doruwa) which has declined in the Sudan following the three dry decades, *Anogeissu leiocarpus* (Marke) and *Khaya senegalesnsis* (Madaci) are popular fuel wood species whose population has been decimated particularly in the Sudan. *K. senegalesnsis* is good timber, fuel wood, medicinal and provides fodder in the dry season but it has virtually disappeared (Barau, 2007).

3.1.5 Population, People and Ethics

Kano is the largest urban center in the Hausaland and the second largest in the country after Lagos. The most influential commercial town in the Sudan region, with a long standing sedentary population in the organized emirate, Kano's growth has been phenomenal. The population of Kano in 2006 was about 9,383,682 people, with six local governments. In the year 2000, Kano's population density ranged from 856per km^2 in peri-urban locations to 8000per km^2 in the metropolis (Maiwada, 2000). The 2006 census recorded an amazing increase to 2,163,225 in the city and 2,828,861 in the metropolis, while the current projected population of 2015 is 3,876,273 with a growth rate of 3.5% per annum. The population census for Kano has been comparatively high. Migration contributed a great deal due to the security afforded by the walls of the city and the economic prosperity. The majority of Kano's population is Hausa Fulani, there are also the Nupe and Kanuri "natives", Igbo, Yoruba and other ethnic groups from all over

the country as well as Lebanese, Asians and other foreigners (Kano State Investors Handbook, 2013). Four density zones are recognizable in the city (Barau, 2006);

1. High density areas including most of the old walled city (Birni), Fagge, Sabon Gari, Gwargwaruwa and the peripheral assimilated areas: Tudun Murtala, Kurna, Dakata, Unguwa Uku, Ginginya and Naibawa.

2. Medium density areas, largely the newly developed areas. Hausawa ,Tarauni, parts of Hotoro, Kawaji, Gadon Kaya, parts of Gwammaja, Kundila, Kabuga, Zoo Road, Tukuntawa and areas around Bayero University Road.

3. Low density areas are the G.R.A and institutional lands.

4. Commercial and industrial areas are high in the daytime and low densities at nighttime e.g. Kwari, Sabo-Gari, Wambai, Kwanar, Dawanau, Kurmi, Yan Kura, Bata Markets, and the Sharada, Challawa, Bompai industrial areas.

3.2 METHODOLOGY

3.2.1. Reconnaissance Survey

A reconnaissance survey of the area was carried out which includes visit to the location, in order to have an in-depth understanding of the settlement pattern and distribution of its population, and also investigating their various sources of water supply which was discovered to include sources such as open wells, boreholes, tap water and sachet water (pure water) as their major source of water supply. The purpose of this survey is to get the researcher acquainted with the study area.

3.2.2 Types of Data

The type of data required for this research includes data from GPS locations for each sampled point, data from laboratory analysis of water for the various sampled locations including pH, Colour, Total Hardness, Conductivity, Calcium, Magnesium, Chlorides, Sulphate, Sodium, Turbidity, Copper, Manganese, Zinc, Lead and Iron.

3.2.3 Sources of Data

3.2.3.1 Primary data

The primary source of data required for this study comprise data collected directly from the field using Hand-held Global Positioning System for location (Latitudes and Longitude) of various sources of potable water within the study area. It also includes laboratory results for each physicochemical water quality parameters (pH, Colour, Total Hardness, Conductivity, Calcium, Magnesium, Chlorides, Sulphate, Sodium, Turbidity, Copper, Manganese, Zinc, Lead and Iron) which was obtained directly from the collected water samples.

3.2.3.2 Secondary data

Secondary source of data comprise data from published World Health Organization and Nigerian Standard for Drinking Water Quality, while relevant literature were sourced from journals, newspapers, internet, annual reports and textbooks.

3.2.4 Water Sampling

In order to select sample points, a systematic sampling method was employed by drawing a list from all the wards within Kano Metropolis (Kano Municipal, Dala, Fagge, Gwale, Nassarawa,

and Tarauni) and arranging them in alphabetical order. Every fourth numbered ward from each LGA that make up the metropolis was selected to make the sample frame (See Tables 3.1 and 3.2).

Four (4) sample points were randomly selected within each of the sampled wards for the selected Local Government Areas (Table 3.2). Samples were taken for each of the water sources (open wells, boreholes, tap water and sachet water), with the exception of tap water source from Dala LGA which is unavailable. A total of Ninety six (96) water samples were collected from the study area.

The water samples were stored in 250ml plastic bottles pre-cleaned by washing with non-ionic detergents, rinsed with distilled water. Each sample was labelled and transported to the Centre for Energy Research and Training, Ahmadu Bello University Zaria, for the analysis.

Table 3.1: Wards by LGAs in Kano Metropolis

Kano Municipal	Dala	Fagge	Nassarawa	Gwale	Tarauni
Chedi	Adakawa	Fagge A	Dakata	Dandago	Babban Giji
Dan Agundi	Bakin Ruwa	Fagge B	Gama	Diso	Darmanawa
Gandun Albasa	Dala	Fagge C	Gawuna	Dorayi	Daurawa
Jakara	Dogon Nama	Fagge D	Gwagwarwa	Galadanchi	Gyadi-Gyadi Arewa
Kankarofi	Gobirawa	Fagge E	Giginyu	Goron Dutse	Gyadi-Gyadi Kudu
Shahuchi	Mmaja	Kwachiri	Hotoro North	Gwale	Hoatoro (NNPC)
Sharada	Kabuwaya	Rijiyar Lemo	Hotoro South	Gyaranya	Kauyen Alu
Sheshe	Kantudu	Sabon Gari East	Kawaji	Kubuga	Tarauni
Tudun Nufawa	Kofar Mazugal	Sabon Gari West	Kaura Goje	Mandawari	Ungowar Gano
Tudun Wazirchi	Kofar Ruwa	Yammata	Tudun Murtala	Sani Maingagge	Unguwa Uku
Yakasai	Madigawa		Tudun Wada		
Zaitawa	Yalwa				
Zango					

Source: Modified from (INEC, 2015)

Table 3.2: Sampled Wards in Kano Metropolis by LGA

Kano Municipal	Dala	Fagge	Nassarawa	Gwale	Tarauni
Chedi	Adakawa	Fagge A	Dakata	Dandago	Babban Giji
Kankarofi	Gobirawa	Fagge E	Giginyu	Goron Dutse	Gyadi-Gyadi Kudu
Tudun Nufawa	Kofar Mazugal	Sabon Gari West	Kaura Goje	Mandawari	Ungowar Gano
Zango	Yalwa	Yammata	Tudun Wada	Sani Maingagge	Unguwa Uku

Source: Modified from (INEC, 2015)

3.2.5 Laboratory analysis

The collected water samples from the various sources were analyzed using standard procedures as indicated in Table 3.3.

Table 3.3: Analytical methods adopted for physicochemical analysis

No.	Parameter	Method of Analysis
1	pH	Digital pH meter (APHA, 1992)
2	Colour	Alpha Platinum-Cobalt Standard Range (APHA, 1992)
3	Total Hardness	EDTA-Titrimetry (APHA, 1992)
4	Conductivity	Digital conductivity meter (Hem, 1985)
5	Calcium	Flame Photometric (APHA, 1992)
6	Magnesium	Spectrophotometry (APHA, 1992)
7	Chlorides	Mohr'sTitrimetry (APHA, 1992)
8	Sulphate	Turbidimetric Method (APHA-AWWA-WEF, 1998)
9	Sodium	Flame Photometric (APHA, 1992)
10	Turbidity	Nephelometric Method (APHA, 1992)
11	Copper	Spectrophotometry (APHA, 1992)
12	Manganese	Spectrophotometry (APHA, 1992)
13	Zinc	Spectrophotometry (APHA, 1992)
14	Lead	Spectrophotometry (APHA, 1992)
15	Iron (Fe)	Spectrophotometry (APHA, 1992)

Source: Compiled by the Author (2015)

3.2.6 Data Analysis

The procedure adopted in this research work forms the basis for physicochemical quality assessment of potable water in Kano Metropolis, Nigeria.

Objective (i) the identification of the sources of potable water supply was achieved by carrying out a reconnaissance survey of the study area in order to understand the various source of potable

water supply available within the study area. They are open wells, boreholes, tap water and sachet water (pure water), and GPS coordinate for each source point.

Objective (ii) the determination of the level of concentration of the physicochemical parameters such as pH, colour, total hardness, conductivity, calcium, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese, zinc, lead and iron in open wells, boreholes, tap water and sachet water (pure water) was achieved by collecting water samples from the various sources and carrying out laboratory analysis using standard laboratory equipment where the concentrations were tested for the following; pH, colour, total hardness, conductivity, calcium, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese, zinc, lead and iron as indicated in Table 3.3.

Objective (iii) the determination of the spatial variation in the level of concentration of the various parameters between open wells, boreholes, tap water and sachet water (pure water) was achieved by using Analysis of Variance (ANOVA) test at 95 % confidence limit to test hypothesis one for significant difference in level of concentration for physicochemical parameters between open wells, boreholes, tap water and sachet water in the study area using Statistical Package for Social Science.

Objective (iv) the comparison of concentration levels of each parameter from each source with the acceptable drinking water quality standard was achieved using t-test at 95 % confidence level to test hypothesis two for significant difference in the level of concentration for physicochemical

parameters for each source and the acceptable drinking water standards (NSDWQ, 2007; WHO, 2010) using Statistical Package for Social Science.

Objective (v) assessment of the water quality using water quality index (WQI) was achieved by calculating the water quality index WQI for each of the Local Government Areas within the metropolis. WQI was computed to reduce the large amount of water quality data to a single numerical value. The WQI reflects the composite influence of different water quality parameters on the overall quality of water. Once the WQI scores were known, it was then compared against a scale (Table 3.4) to determine how healthy the water is for different Local Government Areas that make up the Metropolis (Asuquo and Etim, 2012).

water quality index was computed by adopting the method of Tiwari and Mishra (1985) who used the Weighted Arithmetic Index method, expressed by equation (3.2)

$$WQI = \left(\sum_{I=1}^{i=n} W_i \, q_i \right)$$ .....(3.2)

The quality rating scale for each parameter qi was calculated using this expression:

$$qi = (Ci/Si) \times 100$$

Where WQI = Water Quality Index
Qi = Quality Rating Scale
Ci = Concentration in Each Water Sample
Si = Respective Standards
Wi = Relative weight

The quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100.

Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter using equation (3.3):

$$Wi = 1/Si \quad \ldots\ldots (3.3)$$

The overall Water Quality Index (WQI) was then calculated by aggregating the quality rating (qi) with unit weight (Wi) linearly using equation (3.4) :

$$\text{Overall WQI} = \frac{\sum q_i w_i}{\sum w_i} \quad \ldots\ldots (3.4)$$

Table 3.4. Status of Water Quality based on Arithmetic WQI Method

No.	Water Quality Index Level	Water Quality Status
1	0-25	Excellent water quality
2	25-50	Good water quality
3	51-75	Poor water quality
4	76-100	Very poor water quality
5	>100	Unsuitable for drinking

Source: (Brown *et al*., 1972; Asuquo and Etim, 2012)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents and discusses the findings of the research based on the level of physicochemical water quality and water quality index of the various sources of potable water supply in Kano Metropolis.

4.2 SOURCES OF POTABLE WATER SUPPLY IN THE STUDY AREA

The various sources of water in the study area include; open wells (WW), boreholes water (BW), tap water (TW) and sachet water (SW), with the exception of tap water source in Dala LGA which is unavailable. The various sources, their locations and coordinates are shown in Tables 4.1 to 4.6 respectively, which are summarized and presented in Fig 4.1.

Table 4.1 Distribution of Water Samples in Kano Municipal LGA

S/no	Water Sources	Name of Location	Latitude	Longitude
1	BW	Korner Freedom Sharada 1.	11°58'07.77"N	8°30'45.69"E
2	SW	Al- Qamar Sachet Water	11°57'58.15"N	8°30'25.75"E
3	TW	Salanta Primary School	11°57'59.51"N	8°30'21.01"E
4	WW	Inuwa Phase 1	11°57'57.64"N	8°29'53.36"E
5	BW	Gandun Albasa Phase	11°58'28.24"N	8°31'26.86"E
6	SW	Akarma Sachet water	11°57'10.04"N	8°31'42.91"E
7	TW	Jamb Training Centre	11°58'46.38"N	8°31'26.48"E
8	WW	Gandu Kofar Giji	11°58'21.56"N	8°31'38.84"E
9	BW	Kofar Dan Agundi	11°58'54.29"N	8°31'22.27"E
10	SW	FFF King Sachet water	11°59'11.52"N	8°31'15.73"E
11	TW	Emir Palace Road	11°59'19.64"N	8°31'14.07"E
12	WW	Dan Adabawa	11°58'55.13"N	8°31'20.55"E
13	BW	Rimishahua Yakasai	11°59'51.09"N	8°31'19.22"E
14	SW	Anushuwa Sachet water	11°59'27.60"N	8°31'45.06"E
15	TW	Shakara GGSS Yakasai	11°59'38.57"N	8°31'40.06"E
16	WW	Rimi Market Yakasai	11°59'46.66"N	8°31'26.17"E

Source: Field Survey, 2015

Table 4.2 Distribution of Water Samples in Dala LGA

S/no	Water Sources	Name of Location	Latitude	Longitude
1	BW	Kaigama Yarkwadi	12°03'03.73"N	8°30'0.74"E
2	SW	Mai Haduha Sachet Water	11°59'57.88"N	8°29'53.92"E
3	WW	Kabuga Aisan	11°59'45.11"N	8°29'58.17"E
4	BW	ABY Service Station Aminu Kano way	11°59'41.96"N	8°29'58.87"E
5	SW	Madigawa Sachet Water	12°00'39.52"N	8°29'56.77"E
6	WW	Goron Dutse	12°00'39.23"N	8°29'55.56"E
7	BW	Kofar Ruwa	12°00'46.27"N	8°30'00.28"E
8	SW	A.D.O Sachet Water	12°00'37.02"N	8°29'57.99"E
9	WW	Kofar Dawanu	12°00'56.08"N	8°29'49.33"E
10	BW	Jakara Goron Dutse Road	12°00'58.09"N	8°29'26.32"E
11	SW	A.A Sachet Water	12°00'58.36"N	8°29'49.66"E
12	WW	Sani Buhari Road	12°00'59.45"N	8°29'47.62"E

Source: Field Survey, 2015

Table 4.3 Distribution of Water Samples in Fagge LGA

S/no	Water Sources	Name of Location	Latitude	Longitude
1	BW	Bura Street	12°00'40.00"N	8°31'31.54"E
2	SW	Dutsawa Sachet Water	12°00'36.04"N	8°31'38.87"E
3	TW	Layin Saimaila Maizuga	12°00'39.32"N	8°31'30.37"E
4	WW	Layin Bashir Fashi	12°00'40.46"N	8°31'27.11"E
5	BW	Police Barracks Kastina Road	12°01'03.55"N	8°31'29.92"E
6	SW	Ashton Road by Airport	12°02'21.51"N	8°31'25.91"E
7	TW	Nitel Training Centre Katsina Road	12°01'42.43"N	8°31'05.06"E
8	WW	Ashton Road by Airport	12°02'00.47"N	8°31'12.89"E
9	BW	Nomansland 1 Living faith	12°01'58.58"N	8°32'09.75"E
10	SW	J-Zee Sachet Water	12°01'55.31"N	8°32'09.96"E
11	TW	Fanisau	12°02'53.06"N	8°32'21.74"E
12	WW	GJSS Natsugune	12°02'47.65"N	8°32'23.24"E
13	BW	Ibo Road by Market	12°00'41.94"N	8°32'22.18"E
14	SW	A.V Ventures Sachet Water	12°01'35.17"N	8°32'08.07"E
15	TW	Ijebu Road Sabon-Gari	12°01'31.46"N	8°32'22.03"E
16	WW	Zungeru Road	12°01'36.57"N	8°31'54.38"E

Source: Field Survey, 2015

Table 4.4 Distribution of Water Samples in Nassarawa LGA

S/no	Water Sources	Name of Location	Latitude	Longitude
1	BW	Asibitn Nassarawa	11°59'52.48"N	8°32'54.36"E
2	SW	Iceberg Sachet Water	12°00'26.86"N	8°32'57.28"E
3	TW	State Road	11°59'06.33"N	8°33'08.96"E
4	WW	Audu Bako way	12°00'13.04"N	8°32'35.12"E
5	BW	Nassarawa Secretariat	12°02'16.73"N	8°32'51.29"E
6	SW	Hadaya Sachet Water	12°00'43.01"N	8°33'13.73"E
7	TW	Club Road	12°01'08.00"N	8°33'05.03"E
8	WW	Dantata Road bompoi	12°01'01.37"N	8°34'04.42"E
9	BW	Dantata B	12°01'16.82"N	8°34'47.96"E
10	SW	G.B.S Table Water	12°00'39.96"N	8°35'08.72"E
11	TW	NTSI	12°00'27.21"N	8°35'10.79"E
12	WW	Dakata Police station	12°00'57.42"N	8°34'37.03"E
13	BW	Mai riaga street badawa Layout	11°59'30.02"N	8°34'26.25"E
14	SW	UGIL Sachet Water	11°59'16.03"N	8°34'30.09"E
15	TW	SSS Office Sardauna Crescent	11°59'34.91"N	8°34'40.37"E
16	WW	Layin Tifa Badawa	12°00'09.07"N	8°34'53.97"E

Source: Field Survey, 2015

Table 4.5 Distribution of Water Samples in Gwale LGA

S/no	Water Sources	Name of Location	Latitude	Longitude
1	BW	Bayan Kofa	12°00'40.27"N	8°29'07.15"E
2	SW	Dansanka Sachet Water	12°00'51.51"N	8°28'43.37"E
3	TW	Layin Alhasan Master	12°00'53.11"N	8°28'35.19"E
4	WW	Ungwar Daba	12°00'51.29"N	8°28'43.38"E
5	BW	North West University Road	12°02'26.02"N	8°29'15.80"E
6	SW	Dish Pure Water	12°00'32.06"N	8°29'29.78"E
7	TW	Alh. Iinbawa Street	12°00'27.39"N	8°29'34.44"E
8	WW	Kofar Waika	12°00'32.15"N	8°29'19.18"E
9	BW	Layin Malami	12°00'34.85"N	8°29'39.13"E
10	SW	Akaram Sachet Water	12°00'42.57"N	8°29'17.36"E
11	TW	Layin Motar Soldier	12°00'44.19"N	8°29'44.02"E
12	WW	Doran Dutse	12°00'47.09"N	8°29'45.11"E
13	BW	Kayin Baria	12°00'46.86"N	8°29'43.86"E
14	SW	Nar Khair Sachet Water	12°00'46.78"N	8°29'40.94"E
15	TW	Motar Soldier 1	12°00'52.99"N	8°30'19.82"E
16	WW	Motar Soldier 2	12°00'48.37"N	8°29'37.08"E

Source: Field Survey, 2015

Table 4.6 Distribution of Water Samples in Tarauni LGA

S/no	Water Sources	Name of Location	Latitude	Longitude
1	BW	Hausawa Murtala road	11°57'48.61"N	8°52'06.46"E
2	SW	FASCO Sachet Water	11°57'52.33"N	8°32'29.26"E
3	TW	Aminu Kano Teaching Hospital	11°57'59.11"N	8°32'52.52"E
4	WW	Hayin Danfulani	11°57'52.56"N	8°32'09.48"E
5	BW	Tarauni LGA	11°58'26.87"N	8°33'40.39"E
6	SW	Sky Care Sachet Water	11°56'36.56"N	8°33'56.03"E
7	TW	U-turn, Naibawa	11°56'16.37"N	8°33'38.26"E
8	WW	FGC, Kano	11°57'00.44"N	8°33'53.48"E
9	BW	Kundila Housing Estate	11°57'54.02"N	8°33'28.44"E
10	SW	Trisco Sachet Water	11°58'30.92"N	8°33'33.83"E
11	TW	Daurawa Maiduguri Road	11°58'12.55"N	8°33'34.02"E
12	WW	Layin Baba Impossible	11°57'52.76"N	8°33'35.76"E
13	BW	Usani Guaduwawa Street	11°58'38.93"N	8°33'37.09"E
14	SW	Al-Nana Sachet Water	11°58'42.68"N	8°33'40.82"E
15	TW	Tarauni Primary School	11°58'43.87"N	8°33'47.82"E
16	WW	Konar Masalaci	11°58'44.54"N	8°33'41.99"E

Source: Field Survey, 2015

4.2.1 Spatial Distribution of Sampled Points

This section shows the spatial distribution for the various sampled points within Kano Metropolis encompassing the six LGAs (Dala, Fagge, Gwale, Municipal, Nassarawa and Tarauni). Figure 4.1 depicts the actual location of the sampled potable water sources collected for the study which includes open wells, boreholes, tap water and sachet water sources in Kano metropolis.

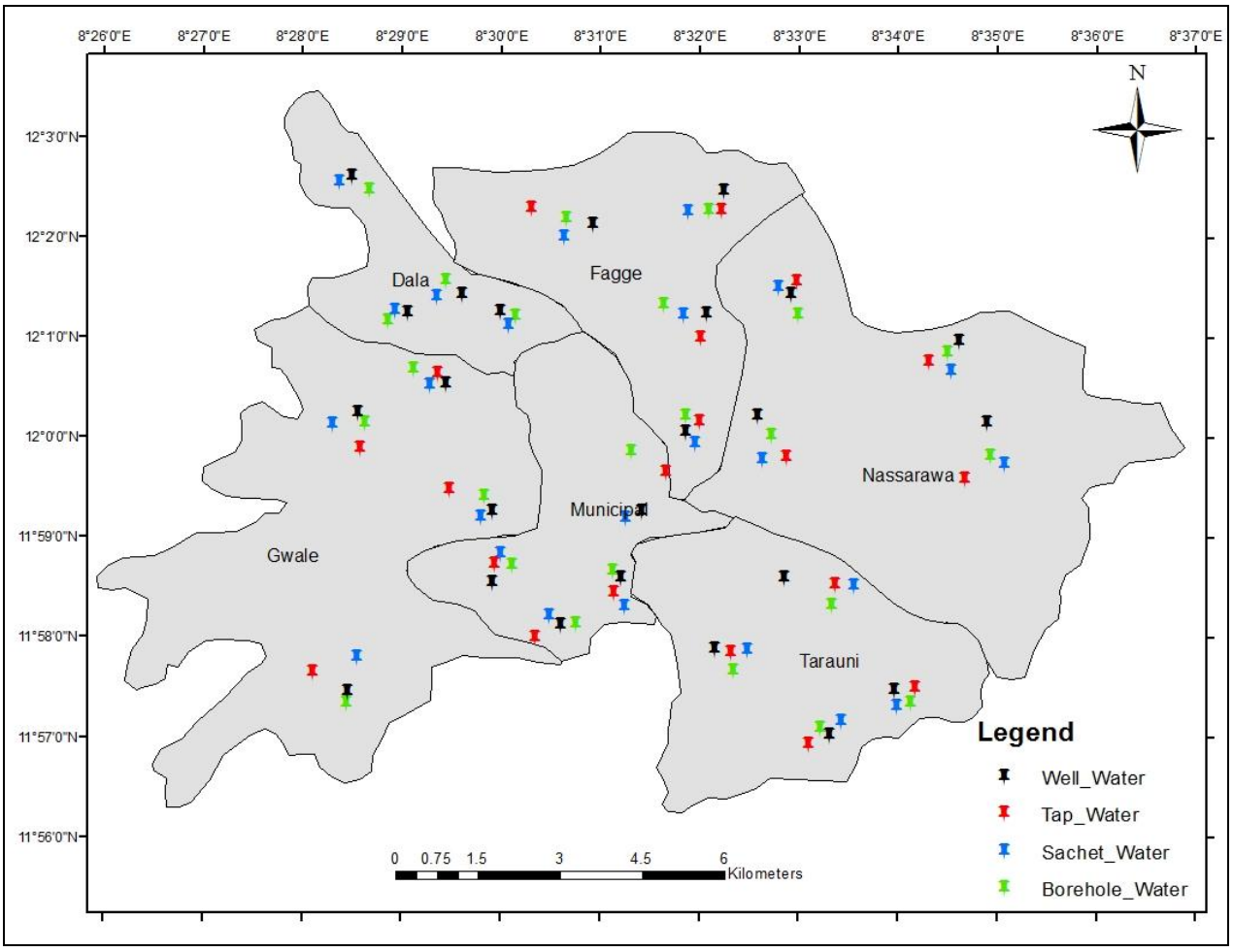


Figure 4.1: Spatial Distribution of Sampled Potable Water Sources
Source: Author's Fieldwork, 2015

It was observed from the study that the water board, communities and individuals produce water from both surface and groundwater deposits. Kano State Water Board is responsible for the water supply to Kano metropolis, while Kano State Rural Water Supply and Sanitation Agency (RUWASA) is responsible for water provision to rural areas. Most areas such as Dala Local Government Area do not have tap water supply.

The Local Government Areas within the metropolis have boreholes and wells constructed by individuals and non-governmental organizations for water supply which are over-exploited. Since the tap water supply is deficient, sachet water sources are multiplying and generate profits for their private operators. An example of these sources within the study area are shown in Plates I to V.



Plate I. Tap Water Source in Kano Municipal LGA
Source: Author's Fieldwork, 2015



Plate II. Well Water Source along a Drainage in Dala LGA
Source: Author's Fieldwork, 2015



Plate III. Well Water Source in a Residence in Tarauni LGA
Source: Author's Fieldwork, 2015



Plate IV. Borehole Water Source in a Residential Area in Fagge LGA
Source: Author's Fieldwork, 2015



Plate V. Sachet Water Industry in Nassarawa LGA
Source: Author's Fieldwork, 2015

4.3 LEVEL OF CONCENTRATION OF PHYSICOCHEMICAL PARAMETERS

Tables 4.7 - 4.10 presented in this section show the summarized laboratory results of water quality from the study area. The mean of each quality parameter was calculated for the sources and each LGA that constitutes the metropolis.

Table 4.7 Mean Concentration of Physicochemical Parameters for Tap Water

Physicochemical Parameters	KANO METROPOLIS				
	Kano Municipal	Fagge	Nassarawa	Gwale	Tarauni
pH	7.29	6.43	7.26	6.90	7.26
Colour (tcu)	3.75	4.00	4.30	4.25	4.63
Total hardness (mg/l)	12.23	12.03	11.96	12.09	11.98
Conductivity (µS/cm)	7.58	4.82	6.60	7.59	6.04
Calcium (mg/l)	4.78	4.94	3.49	4.38	5.11
Magnesium (mg/l)	1.00	1.37	1.58	1.43	0.67
Chlorides (mg/l)	0.86	1.38	1.32	1.42	1.36
Sulphate (mg/l)	2.18	2.42	1.76	1.38	1.93
Sodium (mg/l)	5.38	5.18	4.50	3.93	4.95
Turbidity (ntu)	12.96	13.5	13.24	11.4	7.71
Copper (mg/l)	0.36	0.03	0.67	0.35	0.31
Manganese (mg/l)	0.05	0.07	0.04	0.08	0.03
Zinc (mg/l)	0.26	0.44	0.22	0.27	0.18
Lead (mg/l)	0.02	0.00	0.01	0.03	0.01
Iron (mg/l)	0.45	0.28	0.32	0.54	0.48

Source: Laboratory Analysis, 2015

From Table 4.7, the mean concentration for pH showed higher values in Kano Municipal, Nassarawa and Tarauni while lower values were found in Fagge and Gwale. Colour showed similar values for the Metropolis but a lower value in Kano Municipal. The concentration for total hardness higher values in Kano Municipal, Fagge and Gwale, while Nassarawa and Tarauni recorded lower values. Conductivity concentration showed higher values within the Metropolis with the exception of Fagge with considerably lower values. The concentration for turbidity showed much higher values within the Metropolis with the exception of Tarauni with lower concentration. Lead concentration for tap water showed considerably lower values across the Metropolis while no trace was recorded for Fagge LGA.

Table 4.8 Mean Concentration of Physicochemical Parameters for Borehole Water

Physicochemical Parameters	KANO METROPOLIS					
	Kano municipal	Dala	Fagge	Nassarawa	Gwale	Tarauni
pH	6.71	6.28	6.24	6.50	6.48	6.80
Colour (tcu)	5.00	5.00	5.00	5.00	5.00	5.00
Total hardness (mg/l)	87.68	65.35	52.6	93.90	72.78	102.00
Conductivity (µS/cm)	530.00	312.25	378.25	388.25	316.00	375.00
Calcium (mg/l)	13.43	15.06	15.35	16.64	16.74	12.98
Magnesium (mg/l)	15.73	15.58	13.40	17.03	15.03	15.35
Chlorides (mg/l)	72.18	48.29	64.23	62.86	48.78	52.16
Sulphate (mg/l)	7.63	4.01	2.91	2.71	5.08	2.75
Sodium (mg/l)	12.72	12.90	9.68	12.05	12.64	7.17
Turbidity (ntu)	2.70	3.25	2.69	2.68	3.24	3.13
Copper (mg/l)	0.27	0.25	0.50	0.33	0.18	0.46
Manganese (mg/l)	0.02	0.03	0.01	0.04	0.02	0.08
Zinc (mg/l)	1.46	1.55	1.56	1.50	1.65	1.09
Lead (mg/l)	0.03	0.01	0.01	0.01	0.03	0.01
Iron (mg/l)	2.17	2.33	3.20	2.36	2.06	2.05

Source: Laboratory Analysis, 2015

From Table 4.8, the concentration for pH showed similar values within the Metropolis. The values for colour showed same values for all the LGAs within the Metropolis. Conductivity recorded significantly higher values Dala, Fagge, Nassarawa, Gwale and Tarauni LGAs with the exception of Kano municipal with much lower values. The result for chlorides showed higher values for Kano Munucipal, Fagge and Nassarawa LGAs, while lower values were recorded for Tarauni, Gwale and Dala LGAs.

Table 4.9 Mean Concentration of Physicochemical Parameters for Sachet Water

Physicochemical Parameters	KANO METROPOLIS					
	Kano municipal	Dala	Fagge	Nassarawa	Gwale	Tarauni
pH	7.52	7.31	7.27	7.37	6.77	7.15
Colour (tcu)	5.00	5.00	5.00	5.00	5.00	5.00
Total hardness (mg/l)	4.32	8.15	6.56	7.85	8.51	5.72
Conductivity (µS/cm)	4.59	2.28	2.36	2.20	3.87	1.81
Calcium (mg/l)	4.29	3.68	4.03	3.55	4.23	4.12
Magnesium (mg/l)	0.69	0.35	0.52	0.66	3.09	0.21
Chlorides (mg/l)	0.55	1.01	0.93	0.86	0.32	1.10
Sulphate (mg/l)	1.34	1.20	1.42	1.31	1.40	1.33
Sodium (mg/l)	0.59	2.16	0.39	1.40	0.37	1.14
Turbidity (ntu)	0.30	0.39	0.15	0.48	0.27	0.40
Copper (mg/l)	0.02	0.01	0.02	0.03	0.02	0.02
Manganese (mg/l)	0.02	0.02	0.01	0.02	0.02	0.02
Zinc (mg/l)	0.15	0.18	0.15	0.16	0.13	0.16
Lead (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Iron (mg/l)	0.04	0.04	0.03	0.06	0.01	0.02

Source: Laboratory Analysis, 2015

Table 4.9 showed much lower values for sachet water within the entire metropolis then other water sources. Dala and Gwale LGAs showed relatively higher concentrations for total hardness in sachet water within the Metropolis. The sachet water source from the entire LGA within the Metropolis revealed no trace in lead concentration.

Table 4.10 Mean Concentration of Physicochemical Parameters for Well Water

Physicochemical Parameters	KANO METROPOLIS					
	Kano Municipal	Dala	Fagge	Nassarawa	Gwale	Tarauni
pH	7.34	7.05	7.39	7.29	6.97	7.29
Colour (tcu)	5.00	5.00	5.00	5.00	5.00	5.00
Total hardness (mg/l)	74.25	34.03	24.10	77.53	75.30	65.10
Conductivity (µS/cm)	400.95	648	512.50	519.65	140.38	394.65
Calcium (mg/l)	3.75	9.05	10.41	10.68	11.01	5.95
Magnesium (mg/l)	14.98	15.23	13.86	14.15	13.20	13.83
Chlorides (mg/l)	19.28	25.85	18.66	27.08	21.08	17.08
Sulphate (mg/l)	3.19	5.53	2.04	5.54	1.94	4.72
Sodium (mg/l)	16.01	23.85	22.20	15.68	16.10	14.06
Turbidity (ntu)	3.48	5.03	4.45	4.29	2.77	3.53
Copper (mg/l)	1.18	0.41	0.27	0.54	0.13	0.71
Manganese (mg/l)	0.92	0.32	0.44	0.19	0.56	0.78
Zinc (mg/l)	1.91	2.39	0.59	1.55	1.72	2.01
Lead (mg/l)	0.01	0.01	0.03	0.02	0.01	0.02
Iron (mg/l)	3.26	2.68	1.87	2.20	1.24	2.95

Source: Laboratory Analysis, 2015

From the Table 4.10 above, the mean concentration for pH showed similar higher values within the Metropolis while lower value was found in Gwale. Colour revealed uniform values for the throughout the Metropolis. The concentration for conductivity showed significant higher values in Kano Municipal, Dala, Fagge, Nassarawa and Tarauni while Gwale recorded lower value. The concentration for copper showed lower values within the Metropolis with the exception of Kano Municipal with significantly higher value. Lead concentration in tap water revealed considerably lower values across the Metropolis.

4.4 SPATIAL VARIATION IN LEVEL OF PHYSICOCHEMICAL QUALITY BETWEEN THE VARIOUS SOURCES OF POTABLE WATER

Figures 4.2 – 4.16 present the spatial variation of physicochemical quality between various sources of potable water supply in Kano Metropolis.

4.4.1 Variations in pH of Water in the Study Area

Figure 4.2 shows the variation in concentration of pH for tap, borehole, sachet and well water sources within the metropolis.

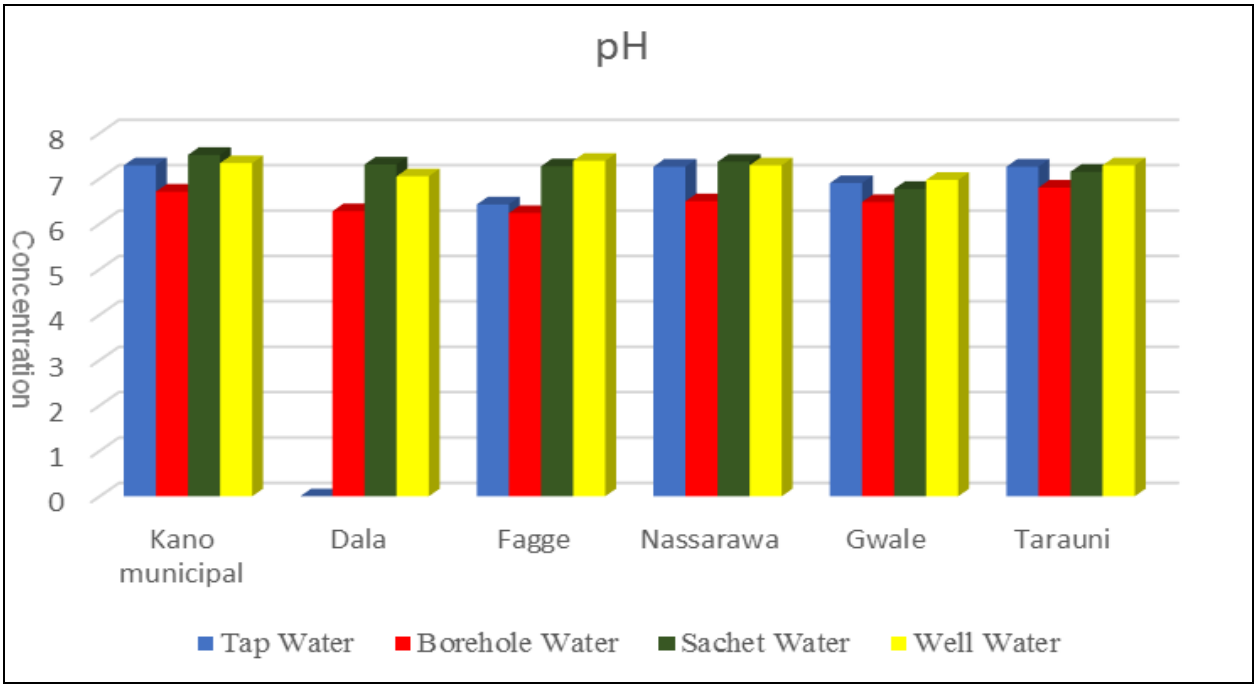


Figure 4.2: Variation in pH for Different Water Sources
Source: Author's Analysis, 2015

The result for pH in Kano metropolis shows Fagge LGA with the lowest pH value of 6.24 in borehole water sources, while the highest value is found in sachet water source in Kano municipal area of Kano state.

4.4.2 Variations in Colour of Water in the Study Area

Figure 4.3 shows the variation in concentration of colour for tap, borehole, sachet and well water sources within the metropolis.

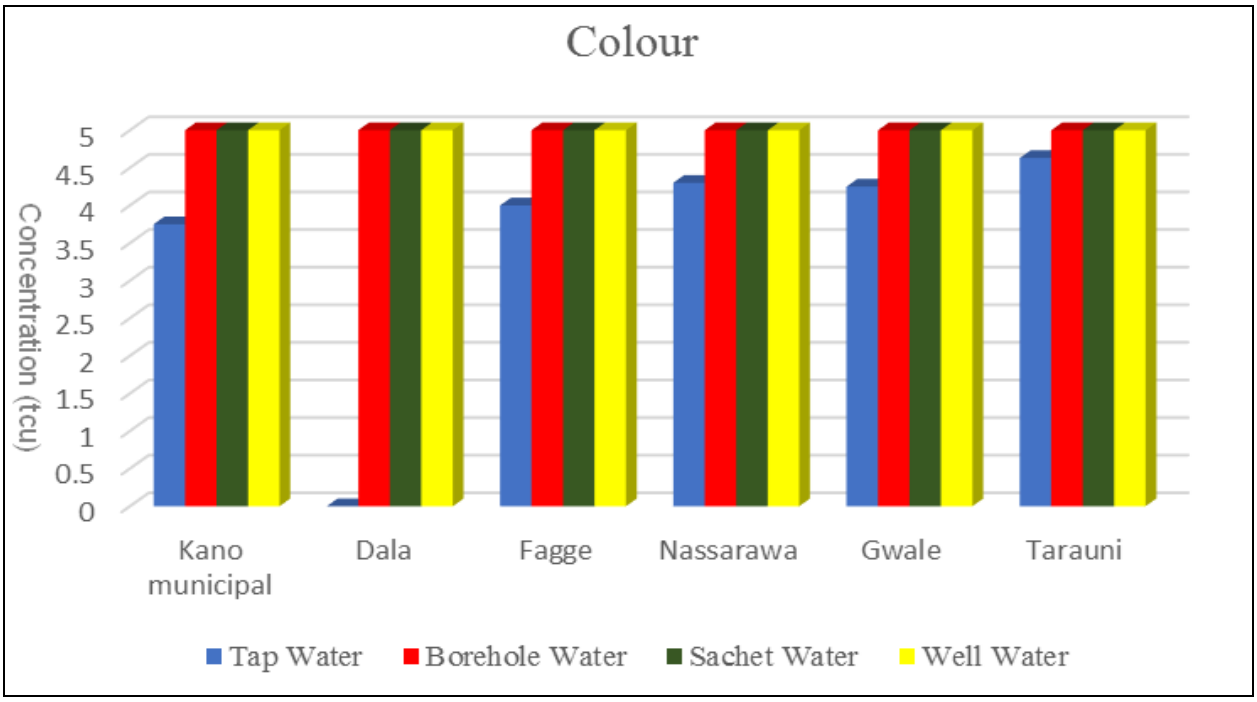


Figure 4.3: Variation in Colour for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.3 shows the level of colour in water samples collected, the values indicated a constant value of 5.0TCU across the LGA that constitute the metropolis in all water sources, with the exception of tap water with the highest value of 4.5 TCU recorded in Tarauni LGA and lowest value of 3.5 TCU in Kano municipal area of Kano state.

4.4.3 Variations in Total Hardness of Water in the Study Area

Figure 4.4 shows the variation in concentration of total hardness for tap, borehole, sachet and well water sources within the metropolis.

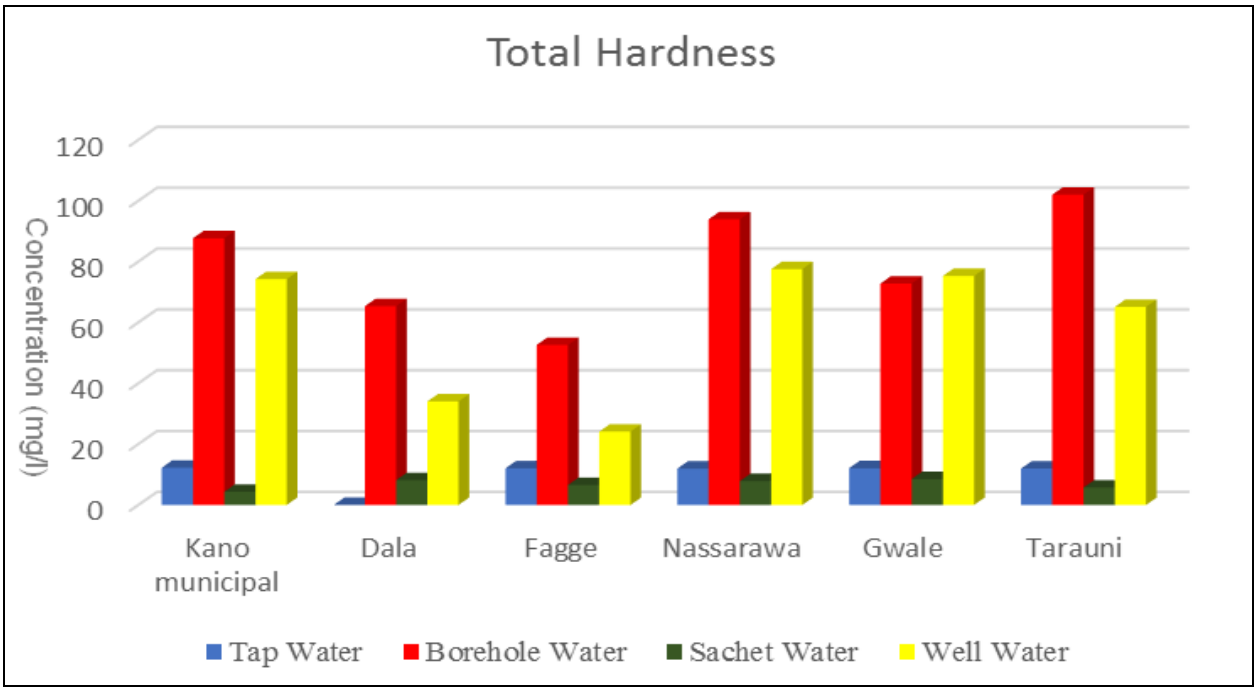


Figure 4.4: Variation in Total Hardness for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.4 shows variations in levels of total hardness in water sources across the Metropolis. Tarauni and Nassarawa recorded the highest values of 100Mg/L and 90Mg/L respectively in borehole water sources, while lowest values are recorded in sachet and tap water across the Metropolis.

4.4.4 Variations in Conductivity of Water in the Study Area

Figure 4.5 shows the variation in concentration of conductivity for tap, borehole, sachet and well water sources within the metropolis.

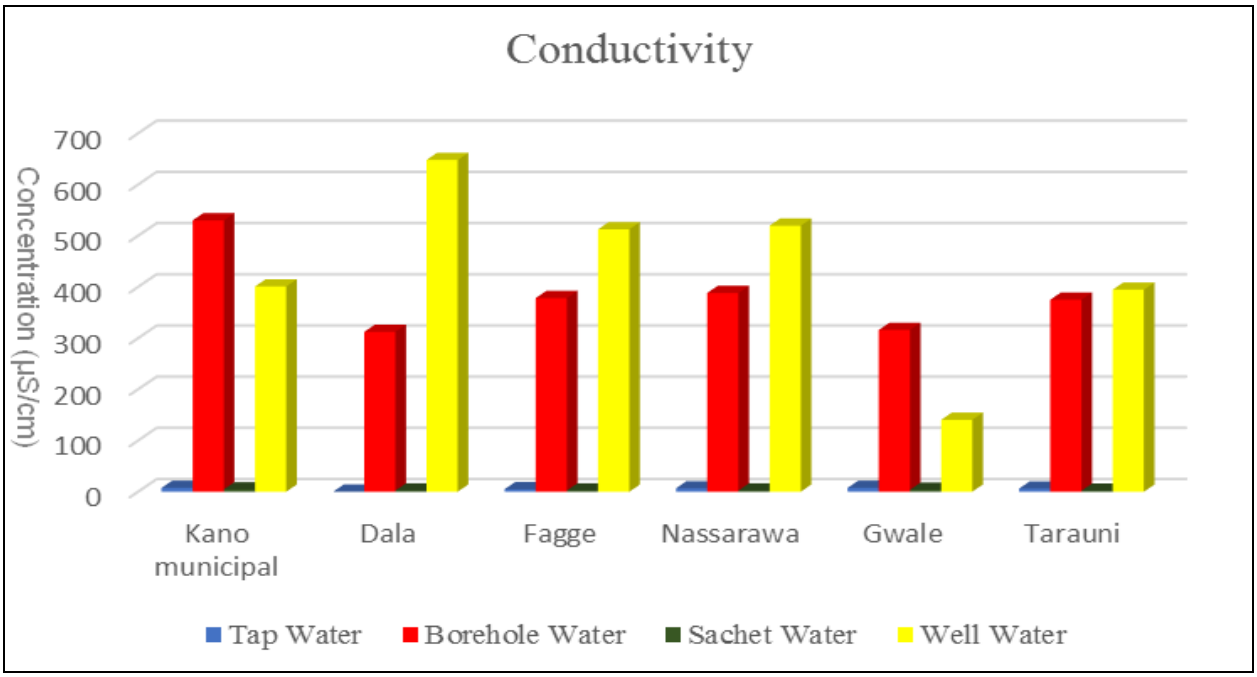


Figure 4.5: Variation in Conductivity for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.5 shows variations in levels of conductivity in water sources across the Metropolis. Well and borehole water sources in the metropolis records significantly high values across the metropolis, where Dala LGA recorded the highest value of 648µS/cm for well water and Kano municipal with highest value of 530µS/cm for borehole water source. Values less than 10µS/cm are found in tap and well water sources across the Metropolis.

4.4.5 Variations in Calcium of Water in the Study Area

Figure 4.6 shows the variation in concentration of calcium for tap, borehole, sachet and well water sources within the metropolis.

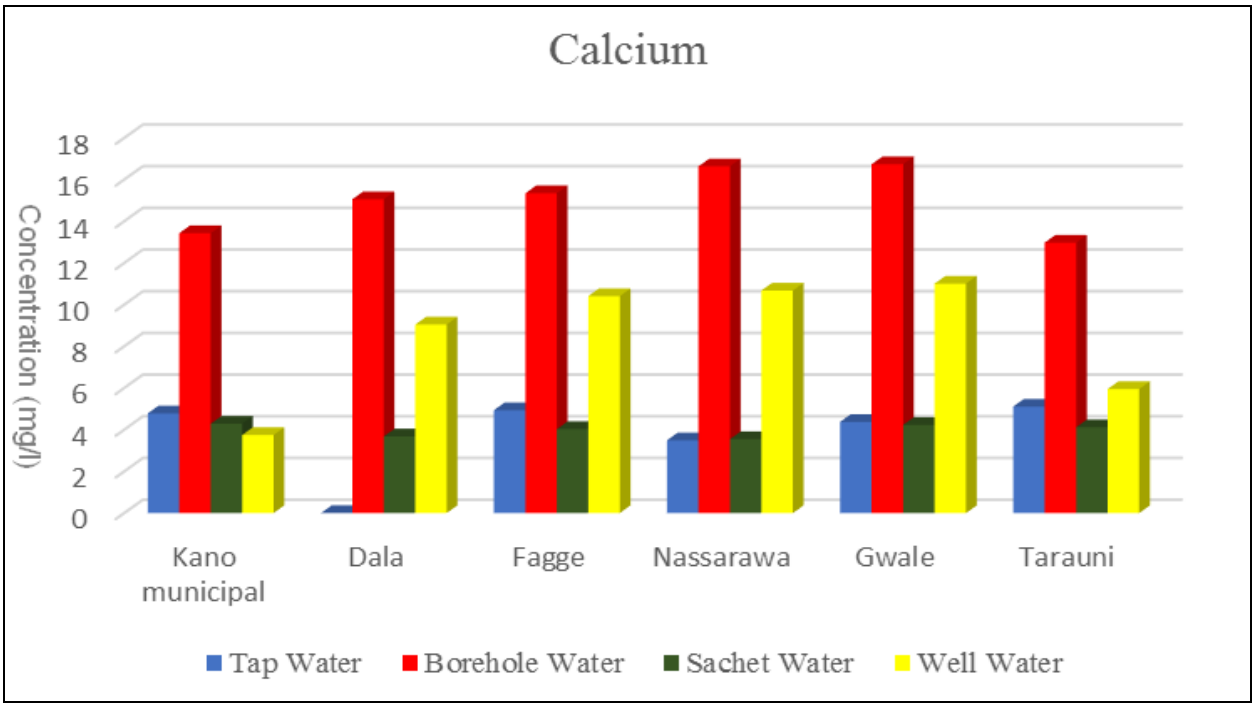


Figure 4.6: Variation in Calcium for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.6 shows higher concentration of calcium in borehole water sources across the Metropolis, with the highest concentration of 16.64Mg/L and 16.74Mg/L in Nassarawa and Gwale LGA respectively.

4.4.6 Variations in Magnesium of Water in the Study Area

Figure 4.7 shows the variation in concentration of magnesium for tap, borehole, sachet and well water sources within the metropolis.

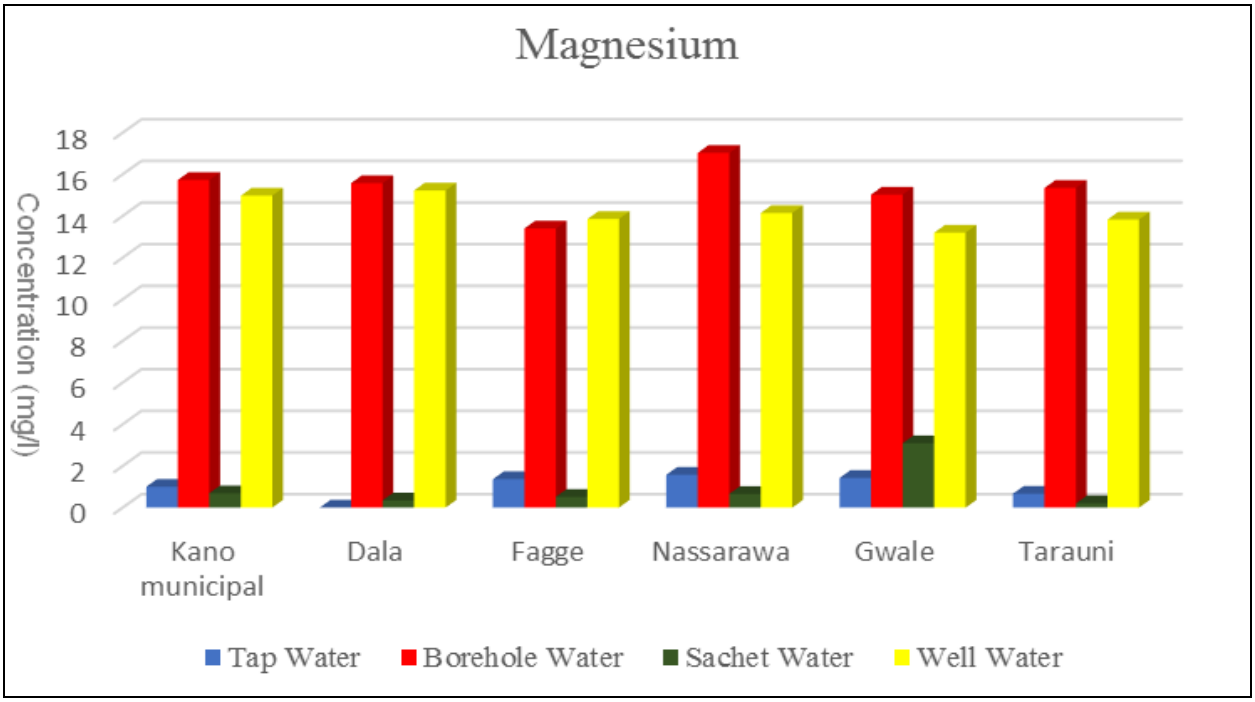


Figure 4.7: Variation in Magnesium for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.7 shows higher concentration of magnesium in borehole and well water sources across the Metropolis, with the highest concentration of 17.03Mg/L for borehole water source in Nassarawa LGA. Tap and sachet water sources records lowest concentration of less than 3.0Mg/L across the Metropolis.

4.4.7 Variations in Chlorides of Water in the Study Area

Figure 4.8 shows the variation in concentration of chlorides for tap, borehole, sachet and well water sources within the metropolis.

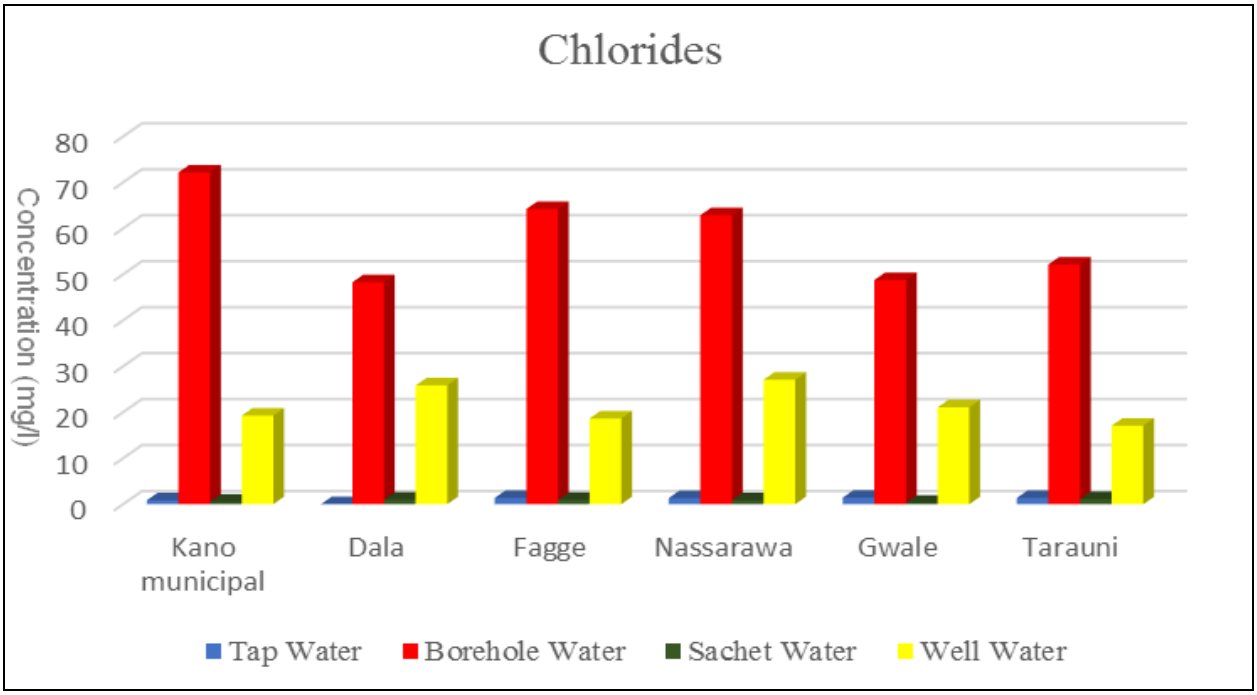


Figure 4.8: Variation in Chlorides for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.8 shows higher concentration of chlorides in borehole water source across the Metropolis, with the highest concentration of 72.18Mg/L for borehole water source in Kano municipal area of Kano state. Well water sources in the Metropolis records highest value of 27.08Mg/L in Nassarawa LGA and lowest value of 17.08Mg/L in Tarauni LGA, while tap and sachet water sources records lowest concentration of less than 1.5Mg/L across the Metropolis.

4.4.8 Variations in Sulphate of Water in the Study Area

Figure 4.9 shows the variation in concentration of sulphate for tap, borehole, sachet and well water sources within the metropolis.

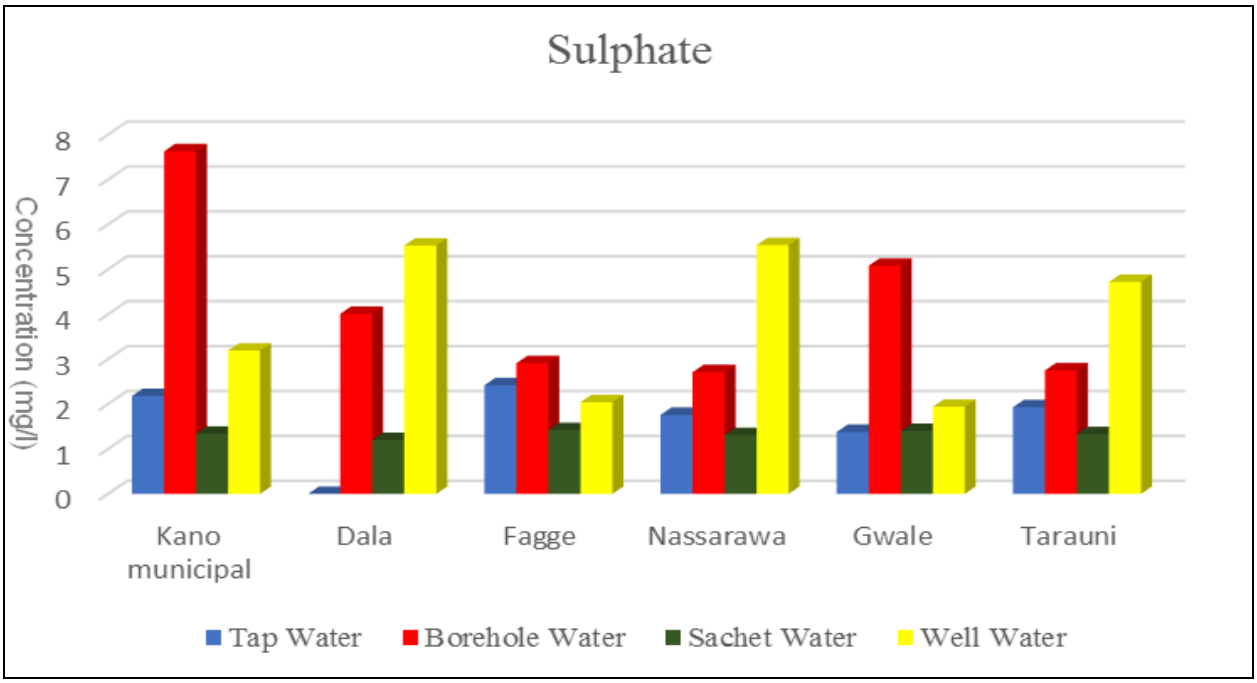


Figure 4.9: Variation in Sulphate for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.9 shows higher concentration of sulphate in borehole and well water sources across the Metropolis, with the highest concentration of 7.63Mg/L for borehole water source in Kano municipal LGA. Tap and sachet water sources records lowest concentration of less than 2.42Mg/L across the Metropolis.

4.4.9 Variations in Sodium of Water in the Study Area

Figure 4.10 shows the variation in concentration of sodium for tap, borehole, sachet and well water sources within the metropolis.

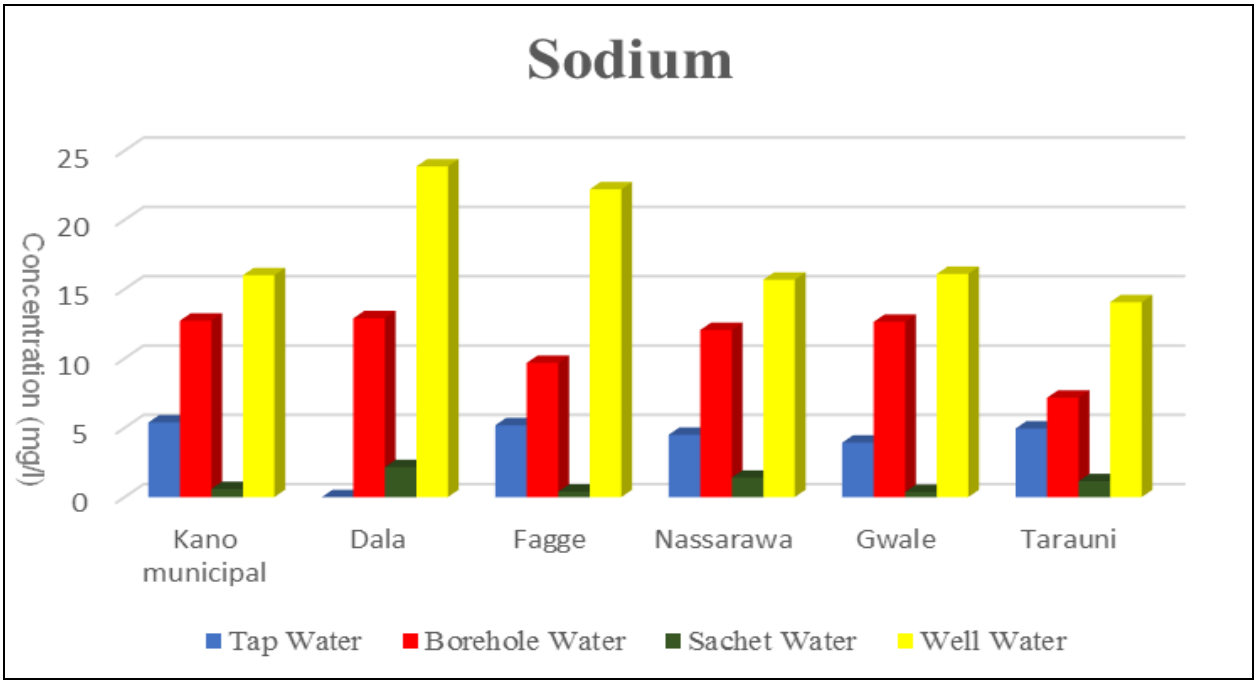


Figure 4.10: Variation in Sodium for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.10 shows higher concentration of sodium in well and borehole water sources across the Metropolis, with the highest concentration of 23.85Mg/L for well water source in Dala LGA. The concentration of sodium in borehole water source across the Metropolis ranges between 12.90Mg/L in Dala LGA and 7.17Mg/L in Tarauni LGA. Tap and sachet water sources records lowest concentration of below 5.38Mg/L across the Metropolis.

4.4.10 Variations in Turbidity of Water in the Study Area

Figure 4.11 shows the variation in concentration of turbidity for tap, borehole, sachet and well water sources within the metropolis.

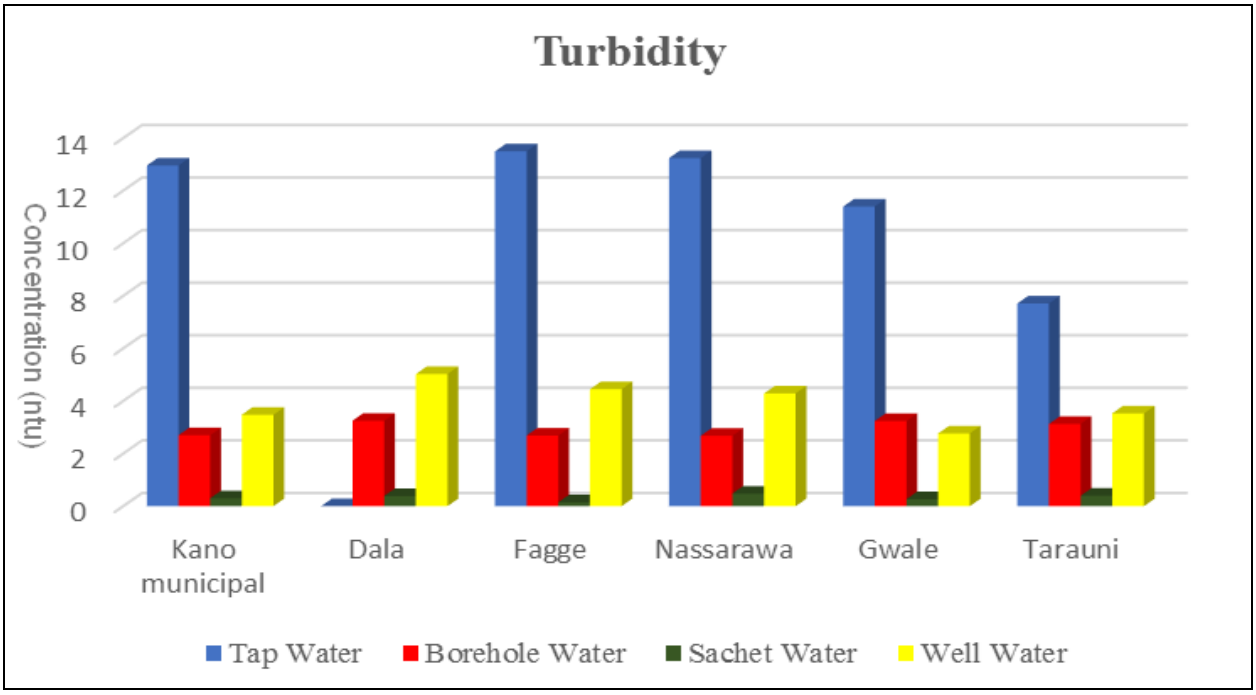


Figure 4.11: Variation in Turbidity for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.11 shows that borehole water source has the highest turbidity across the Metropolis, with a maximum value of 13.5NTU in Fagge LGA and a minimum value of 7.71NTU in Tarauni LGA. Borehole and well water sources has values ranging from 5.03NTU in Dala LGA to 2.77NTU in Gwale LGA, while sachet water source shows the lowest values across the Metropolis with values less than 0.48NTU in Nassarawa LGA.

4.4.11 Variations in Copper of Water in the Study Area

Figure 4.12 shows the variation in concentration of copper for tap, borehole, sachet and well water sources within the metropolis.

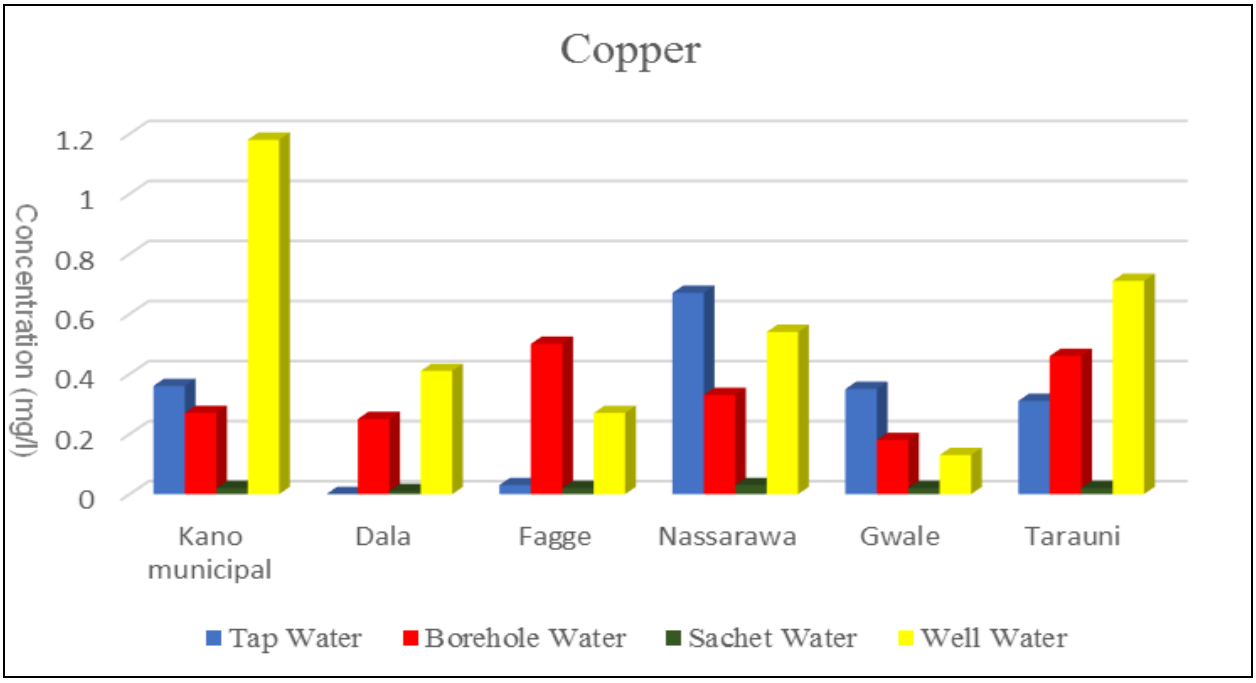


Figure 4.12: Variation in Copper for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.12 shows that well water source in Kano municipal has the highest level of copper (1.18Mg/L). Significant variation exist between tap water and borehole water sources within the Metropolis with values ranging between 0.67Mg/L and 0.03Mg/L respectively. While sachet water source shows the lowest values across the Metropolis with values less than 0.03Mg/L.

4.4.12 Variations in Manganese of Water in the Study Area

Figure 4.13 shows the variation in concentration of manganese for tap, borehole, sachet and well water sources within the metropolis.

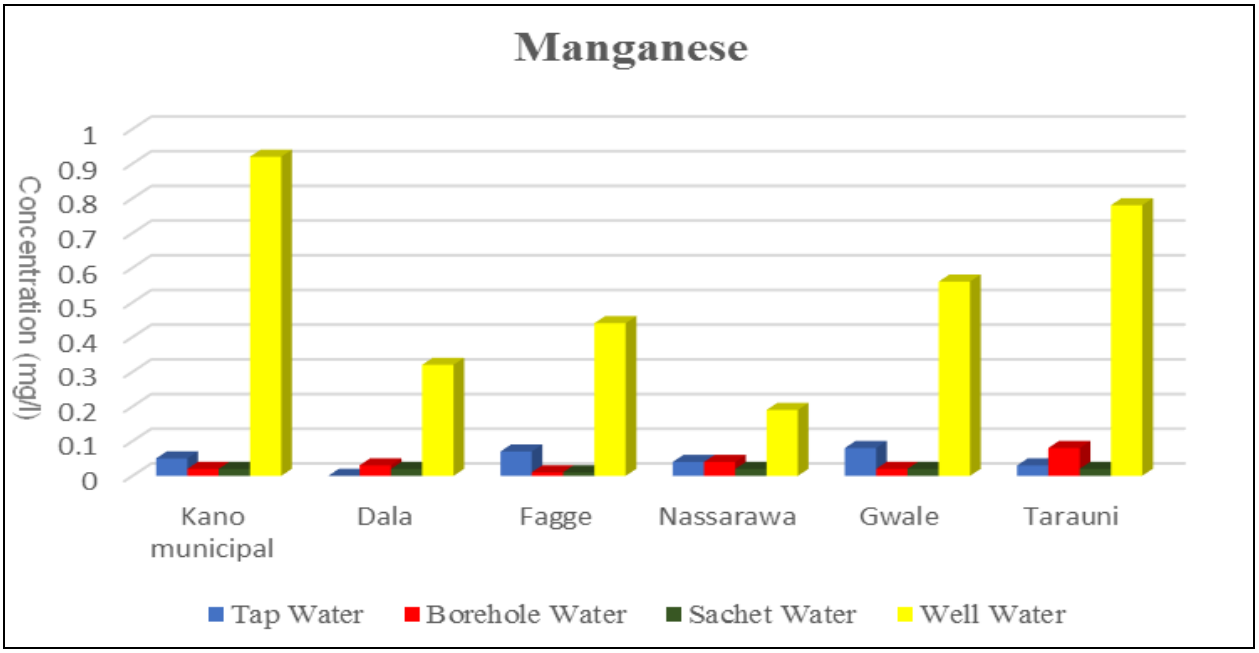


Figure 4.13: Variation in Manganese for Different Water Sources
Source: Author's Analysis, 2015

The concentration of manganese as shown in figure 4.13 shows that well water source has the highest concentration across the Metropolis, with a maximum value of 0.92Mg/L in Kano municipal LGA and a minimum value of 0.32Mg/L in Dala LGA. Tap water, borehole water and sachet water sources have significantly lower values across the Metropolis with values less than 0.08Mg/L.

4.4.13 Variations in Zinc of Water in the Study Area

Figure 4.14 shows the variation in concentration of zinc for tap, borehole, sachet and well water sources within the metropolis.

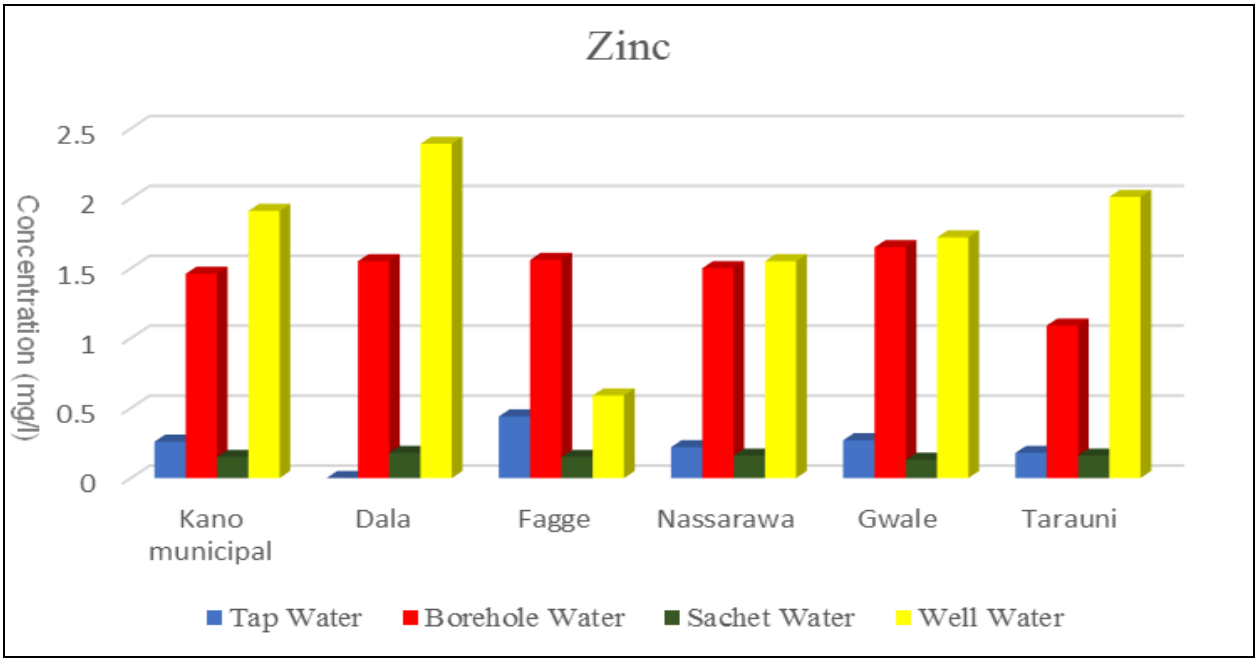


Figure 4.14: Variation in Zinc for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.14 shows higher concentration of zinc in borehole and well water sources across the Metropolis, with the highest concentration of 2.39Mg/L for well water source in Dala LGA and 1.65Mg/L for borehole water in Gwale LGA. Tap and sachet water sources records lowest concentration of less than 0.44Mg/L across the Metropolis.

4.4.14 Variations in lead of Water in the Study Area

Figure 4.15 shows the variation in concentration of lead for tap, borehole, sachet and well water sources within the metropolis.

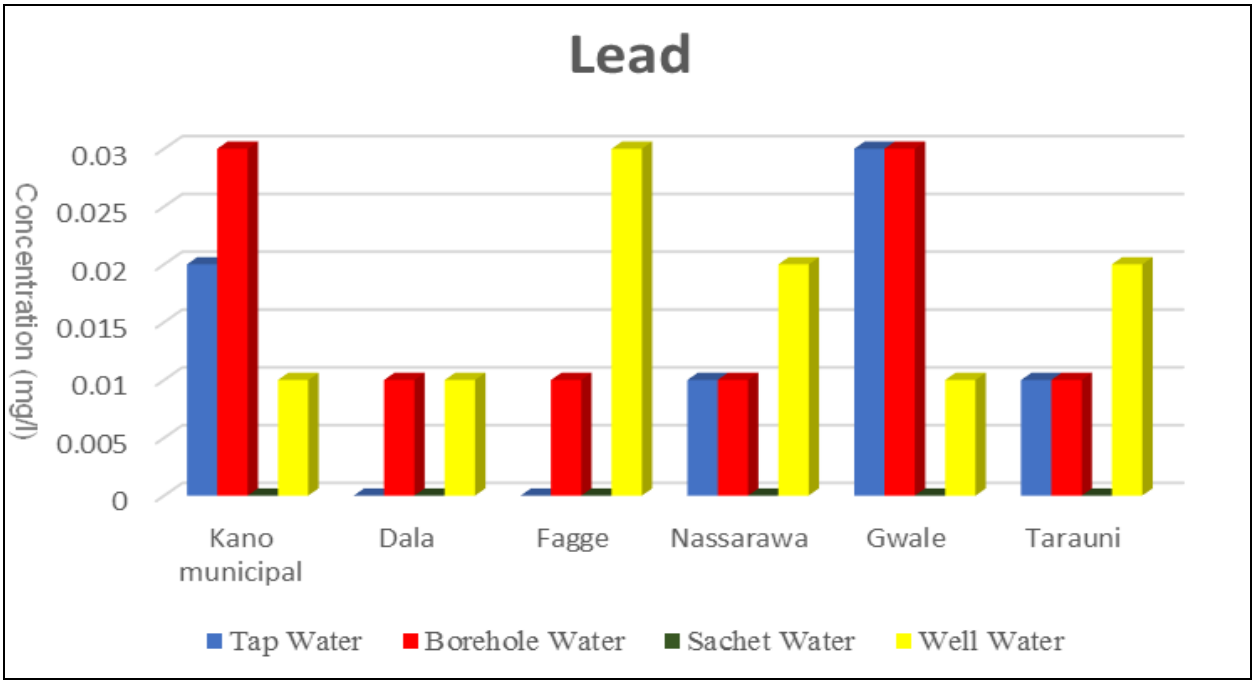


Figure 4.15: Variation in Lead for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.15 shows variations in levels of lead concentration in water sources across the Metropolis. The highest values lead (0.03Mg/L) are found in borehole and well water sources in Kano municipal and Fagge LGA respectively, and Gwale LGA in tap water and borehole water sources. Across the metropolis the presence of lead are found not to be existent in sachet water sources.

4.4.15 Variations in Iron of Water in the Study Area

Figure 4.16 shows the variation in concentration of iron for tap, borehole, sachet and well water sources within the metropolis.

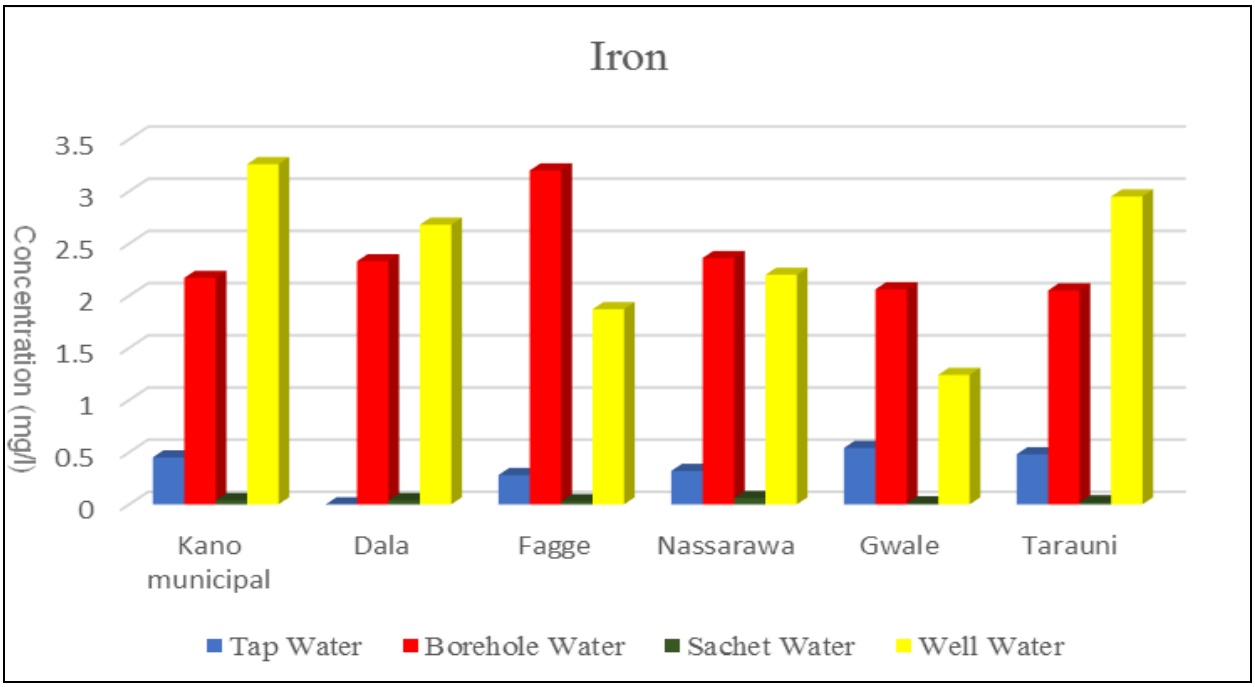


Figure 4.16: Variation in Iron for Different Water Sources
Source: Author's Analysis, 2015

Figure 4.16 shows higher concentration of iron in borehole and well water sources across the Metropolis, with the highest concentration of 3.26Mg/L for well water in Kano municipal and 3.20Mg/L for borehole water source in Fagge LGA. Tap and sachet water sources records lowest concentration where sachet water source has values less than 0.06Mg/L across the Metropolis.

4.5 SIGNIFICANCE OF VARIATION IN LEVEL OF PHYSICOCHEMICAL QUALITY BETWEEN THE VARIOUS SOURCES OF POTABLE WATER

Result of the ANOVA is presented in Table 4.11.

Table 4.11. Variation in Level of Water Quality between Sources across the Metropolis

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	11265.515	3	375.505	6.334	0.01
Within Groups	20235.464	341	593.092		
Total	31500.979	344			

P Value = 0.00

** Significant difference exit at P≤ 0.05 level

This test of hypothesis that there is no significant difference in level of concentration for physicochemical parameters between open wells, boreholes, tap water and sachet water in the study area. The result from Table 4.11, shows a significant difference in physicochemical properties between the various sources of water across the Metropolis. Reason being that the P Value 0.00 was found to be lower than 0.05 level of significance therefore the Null hypothesis is rejected and implies that there is a significant difference in level of concentration between open wells, boreholes, tap water and sachet water (pure water) in the study area.

The levels of the physicochemical pollutants in the study revealed a wide range of variations all through the different sampling locations. This is similar to the study of Nduka and Orisakwe (2009) which attributed this observation to the differential derivations of inorganic pollutants from source rocks and discharge from domestic sewage. The elevated levels of some of these

pollutants could also be greatly linked to chronic contaminations from toxic waste dump sites. Effluent seepages from these waste dumpsites could be infiltrating into the groundwater zones (especially into the shallow aquifers) over the years.

4.6 DIFFERENCE IN LEVEL OF CONCENTRATION OF PARAMETERS FOR EACH SOURCE AND THE ACCEPTABLE DRINKING WATER STANDARD

4.6.1 Level of Concentration of Water Sources and Acceptable Drinking Water Standard for Kano Municipal LGA

This section shows the difference between the physicochemical concentrations for the different sources of potable water within Kano Municipal LGA and the drinking water standards (Nigerian Standard for Drinking Water Quality (2007) and World Health Organization (2010)). The results for each source are shown in Tables 4.12 to 4.15 respectively.

Table 4.12 Difference between Concentration of Tap Water and Acceptable Drinking Water Standard for Kano Municipal LGA

Physicochemical parameters	Tap Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.29	6.5-8.5	0.06	NS	8.5	0.06	NS
Colour (tcu)	3.75	15	0.02	S	15	0.02	S
Total hardness(mg/l)	12.23	500	0.01	S	150	0.00	S
Conductivity(μS/cm)	7.58	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	4.78	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	1.00	50	0.00	S	0.20	0.09	NS
Chlorides (mg/l)	0.86	250	0.01	S	250	0.01	S
Sulphate (mg/l)	2.18	250	0.00	S	100	0.01	S
Sodium (mg/l)	5.38	50	0.00	S	200	0.00	S
Turbidity (ntu)	12.89	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.36	2.0	0.13	NS	1.0	0.12	NS
Manganese (mg/l)	1.00	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	0.26	3.0	0.00	S	3.0	0.00	S
Lead (mg/l)	0.02	0.01	0.06	NS	0.01	0.06	NS
Iron (mg/l)	0.45	0.3	0.07	NS	0.3	0.07	NS

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The comparison between tap water from Kano Municipal and the standards (WHO and NSDWQ) shows no significant difference in levels of concentration for pH, copper, lead and iron. The concentration for pH and copper were found to be within the standards, though the concentrations for lead and iron were found to be slightly above WHO and NSDWQ.

While the remaining parameters were found to have significant difference in levels of concentration and within the permissible limit, with the exception of manganese found to be above the WHO and NSDWQ permissible limits. Also magnesium was found to be within the WHO permissible limits and above NSDWQ permissible limits. This shows that tap water from Kano municipal is safe for consumption. The concentrations for iron and manganese do not

cause health problems, but do form a reddish-brown (iron) or brownish-black (manganese) slime in toilet tanks and can clog water systems. Also, frequent consumption overtime may result in toxicity and pose health effects to the population due to the concentration of lead. The result is in contrast with the study of Shalom, Obinna, Adetayo and Eze (2011) investigating the chemical characteristics of potable water in Ota and environs which showed absence of lead, iron and manganese concentration in tap water.

Table 4.13 Difference between Concentration of Borehole Water and Acceptable Drinking Water Standard for Kano Municipal LGA

Physicochemical parameters	Borehole Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.71	6.5-8.5	0.21	NS	8.5	0.21	NS
Colour (tcu)	5.00	15	0.01	S	15	0.01	S
Total hardness(mg/l)	87.68	500	0.01	S	150	0.06	NS
Conductivity(μS/cm)	530	NA	NA	NA	1000	0.03	S
Calcium (mg/l)	13.43	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	15.73	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	72.18	250	0.06	NS	250	0.06	NS
Sulphate (mg/l)	72.18	250	0.00	S	100	0.07	NS
Sodium (mg/l)	12.73	50	0.01	S	200	0.00	S
Turbidity (ntu)	2.70	5.0	0.16	NS	5.0	0.16	NS
Copper (mg/l)	0.27	2.0	0.00	S	1.0	0.01	S
Manganese (mg/l)	15.73	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	1.46	3.0	0.06	NS	3.0	0.06	NS
Lead (mg/l)	0.03	0.01	0.06	NS	0.01	0.06	NS
Iron (mg/l)	2.17	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the analysis shows no significant difference in levels of concentration for the values of pH, chlorides, turbidity and zinc, all within the quality standards, with exception of lead which was found to be slightly above WHO and NSDWQ. While colour, total hardness,

magnesium, sodium, copper, manganese and iron were found to have significant difference in levels of concentration and are within the permissible limit, with iron found to be above the NSDWQ permissible limit and magnesium within WHO permissible limits and above NSDWQ permissible limits. Sulphate was found to have significant difference in level of concentration and within WHO permissible limits while no significant difference in level of concentration and within the NSDWQ permissible limits.

The result shows that borehole water from Kano municipal is safe for domestic use but frequent consumption overtime may result in toxicity and pose adverse health effects to the population due to the concentration of lead. The results is in contrast with the study carried out by Njar, Iwara, Offiong and Deekor (2012) on assessment of heavy metal status of boreholes in Calabar South Local Government Area.

Table 4.14 Difference between Concentration of Sachet Water and Acceptable Drinking Water Standard for Kano Municipal LGA

Physicochemical parameters	Sachet Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.52	6.5-8.5	0.09	NS	8.5	0.09	NS
Colour (tcu)	5.00	15	0.01	S	15	0.01	S
Total hardness(mg/l)	4.32	500	0.00	S	150	0.01	S
Conductivity(μS/cm)	4.59	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	4.29	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	0.69	50	0.00	S	0.20	0.07	NS
Chlorides (mg/l)	0.55	250	0.00	S	250	0.00	S
Sulphate (mg/l)	1.34	250	0.00	S	100	0.00	S
Sodium (mg/l)	0.59	50	0.00	S	200	0.00	S
Turbidity (ntu)	0.30	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.02	2.0	0.00	S	1.0	0.02	S
Manganese (mg/l)	0.69	0.1	0.06	NS	0.2	0.07	NS
Zinc (mg/l)	0.15	3.0	0.07	NS	3.0	0.07	NS
Lead (mg/l)	0.00	0.01	0.21	NS	0.01	0.21	NS
Iron (mg/l)	0.04	0.3	0.08	NS	0.3	0.08	NS

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the table above shows values of pH, manganese, zinc, lead and iron which were found to have no significant difference in levels of concentration and within permissible limits of WHO and NSDWQ. While colour, total hardness, conductivity, chlorides, sulphate, sodium and copper were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ permissible limit. Magnesium have significant difference in level of concentration and within WHO permissible limits while no significant difference in level of concentration in NSDWQ and slightly above permissible limits. The result shows that sachet water from Kano municipal is safe for domestic use and do not pose health effects to the population. This result is in agreement with the study carried out by David, Awoh

and Essa, (2013) who concluded that the concentrations levels of physicochemical parameter are of low values in comparison with the standard levels of the World Health Organization standard.

Table 4.15 Difference between Concentration of Well Water and Acceptable Drinking Water Standard for Kano Municipal LGA

Physicochemical parameters	Well Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.34	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	5.00	15	0.01	S	15	0.01	S
Total hardness(mg/l)	74.25	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	400.95	NA	NA	NA	1000	0.02	S
Calcium (mg/l)	3.75	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	14.98	150	0.00	S	0.20	0.00	S
Chlorides (mg/l)	19.28	250	0.00	S	250	0.00	S
Sulphate (mg/l)	3.19	250	0.00	S	100	0.00	S
Sodium (mg/l)	16.01	50	0.00	S	200	0.00	S
Turbidity (ntu)	3.48	5.0	0.11	NS	5.0	0.11	NS
Copper (mg/l)	1.18	2.0	0.15	NS	1.0	0.12	NS
Manganese (mg/l)	14.98	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	1.91	3.0	0.08	NS	3.0	0.08	NS
Lead (mg/l)	0.01	0.01	1.04	NS	0.01	1.04	NS
Iron (mg/l)	3.26	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result showed that the values of pH, turbidity and copper were found to have no significant difference in levels of concentration and within permissible limits. Copper was also found to be slightly above the NSDWQ permissible limit. While colour, total hardness, conductivity, magnesium, chlorides, sulphate, sodium, manganese and iron were found to have significant difference in levels of concentration and within the permissible limit, with the exception of manganese and iron found to be above the WHO and NSDWQ permissible limit and magnesium

within the WHO limits but above the NSDWQ permissible limits. This shows that well water from Kano municipal is safe for domestic use. The concentrations for manganese and iron may cause health problems such as damage to internal organs and may increase the risk of diabetes, heart attack and cancer, particularly in older people. The result is similar to the findings of Adewara and Akinlolu (2008) who confirmed significant concentrations in metals like manganese and iron in well water sources of Ibadan metropolis.

4.6.2 Level of Concentration of Water Sources and Acceptable Drinking Water Standard for Dala LGA

This section shows the difference between the physicochemical concentrations for the different sources of potable water within Dala LGA and the drinking water standards (Nigerian Standard for Drinking Water Quality (2007) and World Health Organization (2010)), with the exception of tap water source. The results for each source are shown in Tables 4.16 to 4.18 respectively.

Table 4.16 Difference between Concentration of Borehole Water and Acceptable Drinking Water Standard for Dala LGA

Physicochemical parameters	Borehole Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.28	6.5-8.5	0.10	NS	8.5	0.10	NS
Colour (tcu)	5.00	15	0.10	NS	15	0.10	NS
Total hardness(mg/l)	65.35	500	0.10	NS	150	0.10	NS
Conductivity(μS/cm)	312.25	NA	NA	NA	1000	0.02	S
Calcium (mg/l)	15.06	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	15.58	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	48.29	250	0.00	S	250	0.00	S
Sulphate (mg/l)	4.01	250	0.00	S	100	0.00	S
Sodium (mg/l)	12.9	50	0.00	S	200	0.00	S
Turbidity (ntu)	3.25	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.03	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	1.48	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	1.55	3.0	0.08	NS	3.0	0.08	NS
Lead (mg/l)	0.01	0.01	1.04	NS	0.01	1.04	NS
Iron (mg/l)	2.33	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

It can be deduced from the result that the values of pH, colour, total hardness, zinc and lead were found to have no significant difference in levels of concentration and within permissible limits, with exception of pH which was found to be slightly below the WHO and NSDWQ permissible limits. While conductivity, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese and iron were found to have significant difference in levels of concentration and within the permissible limit, with the exception of manganese and iron found to be above the WHO and NSDWQ permissible limit and magnesium within the WHO limits but above the NSDWQ permissible limits. From the result lower concentration of pH recorded makes borehole water from Dala LGA slightly acidic, soft and corrosive, which is why iron and manganese were found to have higher concentrations and can cause premature damage to metal piping and can be toxic to the human body when consumed over time. This findings is similar to the study of

Sarauta and Sabo (2014) who revealed that iron and manganese in groundwater recorded values above the permissible limits of World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) in Bauchi Metropolis.

Table 4.17 Difference between Concentration of Sachet Water and Acceptable Drinking Water Standard for Dala LGA

Physicochemical parameters	Sachet Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.31	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	8.15	500	0.00	S	150	0.00	S
Conductivity(µS/cm)	2.28	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	3.68	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	0.35	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	1.01	250	0.00	S	250	0.00	S
Sulphate (mg/l)	1.20	250	0.00	S	100	0.00	S
Sodium (mg/l)	2.16	50	0.00	S	200	0.00	S
Turbidity (ntu)	0.39	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.02	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	0.03	0.1	0.11	NS	0.2	0.11	NS
Zinc (mg/l)	0.18	3.0	0.00	S	3.0	0.00	S
Lead (mg/l)	0.00	0.01	1.04	NS	0.01	1.04	NS
Iron (mg/l)	0.04	0.3	0.06	NS	0.3	0.06	NS

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result revealed that the values of pH, manganese, lead and iron were found to have no significant difference in levels of concentration and within permissible limits, with exception of iron which was found to be slightly above the WHO and NSDWQ permissible limits. Colour, total hardness, conductivity, magnesium, chlorides, sulphate, sodium, turbidity, copper and zinc were found to have significant difference in levels of concentration and within the permissible limits, with the exception of magnesium which was found to be within the WHO limits but slightly above the NSDWQ permissible limits. Iron and manganese percolates through soil and

rock in the earth crust and into groundwater. The groundwater being used for producing sachet water are not properly filtered and treated as they still contain higher levels of iron and manganese concentration. The effect of this is that the iron concentration may affect the aesthetic quality of potable water such as taste, color and sometimes odour. Also the high level of manganese in has the possibility of causing Neurological disorder if consumed frequently. This result is not in agreement with the study of Sheshe and Magashi (2014) who concluded that sachet water produced from borehole and tap water in Kano metropolis conformed to the requirements of WHO standards. But the result agrees with the findings of Uduma and Uduma (2014) in a study carried out on physicochemical analysis of the quality of sachet water consumed in Kano metropolis.

Table 4.18 Difference between Concentration of Well Water and Acceptable Drinking Water Standard for Dala LGA

Physicochemical parameters	Well Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.05	6.5-8.5	0.07	NS	8.5	0.07	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	34.03	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	648	NA	NA	NA	1000	0.04	S
Calcium (mg/l)	9.05	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	15.23	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	25.85	250	0.01	S	250	0.00	S
Sulphate (mg/l)	5.53	250	0.00	S	100	0.00	S
Sodium (mg/l)	23.85	50	0.00	S	200	0.00	S
Turbidity (ntu)	5.03	5.0	1.03	NS	5.0	1.03	NS
Copper (mg/l)	0.32	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	1.51	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	2.39	3.0	0.09	NS	3.0	0.09	NS
Lead (mg/l)	0.01	0.01	1.05	NS	0.01	1.05	NS
Iron (mg/l)	2.68	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH, turbidity, zinc and lead were found to have no significant difference in levels of concentration and within permissible limits, with exception of turbidity which was found to be slightly above the WHO and NSDWQ permissible limits. Colour, total hardness, conductivity, magnesium, chlorides, sulphate, sodium, copper, manganese and iron were found to have significant difference in levels of concentration and within the permissible limits, with the exception of manganese and iron which were found to be above the permissible limits, while magnesium which was found to be within the WHO limits but above the NSDWQ permissible limits. This shows that well water from Dala LGA shows higher values of turbidity indicating presence of suspended particles present in well water and not safe for consumption and the concentrations for manganese and iron may cause health problems when consumed frequently such as damage to internal organs and may increase the risk of diabetes, heart attack and cancer, particularly in older people. This result agrees with previous works of Ugya, Umar and Yusuf (2015) where iron and manganese were reported to occur in high concentrations in well water sources.

4.6.3 Level of Concentration of Water Sources and Acceptable Drinking Water Standard for Nasarawa LGA

Tables 4.19 to 4.22 in this section shows the difference between the physicochemical concentrations for the various sources of potable water within Nasarawa LGA and the drinking water standards (Nigerian Standard for Drinking Water Quality (2007) and World Health Organization (2010)).

Table 4.19 Difference between Concentration of Tap Water and Acceptable Drinking for Nasarawa LGA

Physicochemical parameters	Tap Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.26	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	4.30	15	0.00	S	15	0.00	S
Total hardness(mg/l)	11.96	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	6.60	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	3.49	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	1.58	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	1.32	250	0.00	S	250	0.00	S
Sulphate (mg/l)	1.76	250	0.00	S	100	0.00	S
Sodium (mg/l)	4.50	50	0.00	S	200	0.00	S
Turbidity (ntu)	13.24	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.67	2.0	0.06	NS	1.0	0.06	NS
Manganese (mg/l)	0.04	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	0.22	3.0	0.02	S	3.0	0.02	S
Lead (mg/l)	0.01	0.01	1.05	NS	0.01	0.06	NS
Iron (mg/l)	0.32	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH, copper and lead were found to have no significant difference in levels of concentration and within permissible limits. Colour, total hardness, conductivity, magnesium, chlorides, sulphate, sodium, turbidity, manganese, zinc and iron were found to have significant difference in levels of concentration and within the permissible limits, with the exception of iron which was found to be slightly above the permissible limits, while magnesium was found to be within the WHO limits but above the NSDWQ permissible limits. This result shows that tap water from Nasarawa LGA is safe for domestic. This result is similar to the findings of Abdullahi and Indabawa (2012) who concluded that iron slightly exceeds the permissible limits of drinking water recommended by WHO for tap water in Dutse, Jigawa State.

Table 4.20 Difference between Concentration of Borehole Water and Acceptable Drinking Water Standard for Nasarawa LGA

Physicochemical parameters	Borehole Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.5	6.5-8.5	0.06	NS	8.5	0.06	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	93.9	500	0.00	S	150	0.00	S
Conductivity(µS/cm)	388.25	NA	NA	NA	1000	0.01	S
Calcium (mg/l)	16.64	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	17.03	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	62.86	250	0.00	S	250	0.00	S
Sulphate (mg/l)	2.71	250	0.00	S	100	0.00	S
Sodium (mg/l)	12.05	50	0.00	S	200	0.00	S
Turbidity (ntu)	2.68	5.0	0.01	S	5.0	0.00	S
Copper (mg/l)	0.33	2.0	0.00	S	1.0	0.03	S
Manganese (mg/l)	0.04	0.1	0.03	S	0.2	0.00	S
Zinc (mg/l)	1.50	3.0	0.00	S	3.0	0.00	S
Lead (mg/l)	0.01	0.01	0.08	NS	0.01	0.08	NS
Iron (mg/l)	2.36	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH and lead were found to have no significant difference in levels of concentration and within permissible limits. Other parameters were found to have significant difference in levels of concentration and within the permissible limits, with the exception of iron which was found to be above the permissible limits, while magnesium was found to be within the WHO limits but above the NSDWQ permissible limits. This result shows that borehole water from Nasarawa LGA is not safe for domestic use because the concentration of iron which may cause health problems such as damage to internal organs and may increase the risk of diabetes, heart attack and cancer, particularly in older people when consumed frequently. This agrees with previous works of Akoto and Adiyiah (2007) and Shalom, Obinna, Adetayo and Eze (2011) where iron was reported to occur in high concentrations in groundwater sources.

Table 4.21 Difference between Concentration of Sachet Water and Acceptable Drinking Water Standard for Nasarawa LGA

Physicochemical parameters	Sachet Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.37	6.5-8.5	0.09	NS	8.5	0.09	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	7.85	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	2.20	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	3.55	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	0.66	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	0.86	250	0.00	S	250	0.00	S
Sulphate (mg/l)	1.31	250	0.00	S	100	0.00	S
Sodium (mg/l)	1.40	50	0.00	S	200	0.00	S
Turbidity (ntu)	0.48	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.03	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	0.02	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	0.16	3.0	0.00	S	3.0	0.00	S
Lead (mg/l)	0.00	0.01	1.04	NS	0.01	1.04	NS
Iron (mg/l)	0.06	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

Result from the table above shows the comparison between sachet water in Nasarawa LGA and the standards (WHO and NSDWQ). It shows that the values of pH and lead were found to have no significant difference in levels of concentration and within permissible limits. Other parameters were also found to have significant difference in levels of concentration and within the permissible limits, with the exception of magnesium was found to be within the WHO limits but above the NSDWQ permissible limits. The result shows that sachet water from Nasarawa LGA is safe for consumption. This result is in agreement with Sheshe and Magashi (2014) in a study conducted on sachet water in Kano metropolis.

Table 4.22 Difference between Concentration of Well water and Acceptable Drinking Water Standard for Nasarawa LGA

Physicochemical parameters	Well water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.29	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	77.53	500	0.00		150	0.01	S
Conductivity(μS/cm)	519.65	NA	NA	NA	1000	0.03	S
Calcium (mg/l)	10.68	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	14.15	50	0.01	S	0.20	0.00	S
Chlorides (mg/l)	27.08	250	0.01	S	250	0.01	S
Sulphate (mg/l)	5.54	250	0.00	S	100	0.01	S
Sodium (mg/l)	15.68	50	0.01	S	200	0.00	S
Turbidity (ntu)	4.29	5.0	0.07	NS	5.0	0.07	S
Copper (mg/l)	0.54	2.0	0.02	S	1.0	0.04	S
Manganese (mg/l)	0.19	0.1	0.09	NS	0.2	0.06	NS
Zinc (mg/l)	1.55	3.0	0.03	S	3.0	0.03	S
Lead (mg/l)	0.02	0.01	1.06	NS	0.01	1.06	NS
Iron (mg/l)	2.20	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the table above shows that the values of pH, manganese and lead were found to have no significant difference in levels of concentration and within permissible limits with the exception of manganese which was found within WHO permissible limits but higher than NSDWQ permissible limits and lead which was found to be slightly above both standards. Other parameters were found to have significant difference in levels of concentration and within the permissible limits, with the exception of magnesium which was found to be within the WHO limits but above the NSDWQ permissible limits. The higher values of manganese and lead in well water source in Nassarawa LGA are similar to the studies of Muhammad and Fanan (2012). It shows that well water from Nasarawa LGA is safe for domestic use but frequent consumption

overtime may result in toxicity and pose adverse health effects to the population due to the concentration of lead.

4.6.4 Level of Concentration of Water Sources and Acceptable Drinking Water Standard for Tarauni LGA

This section shows the difference between the physicochemical concentrations for the various sources of potable water within Tarauni LGA and the drinking water standards (Nigerian Standard for Drinking Water Quality (2007) and World Health Organization (2010)). The results for each source are shown in Tables 4.23 to 4.26 respectively.

Table 4.23 Difference between Concentration of Tap Water and Acceptable Drinking Water Standard for Tarauni LGA

Physicochemical parameters	Tap Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.26	6.5-8.5	0.08	NS	8.5	0.08	NS
olour (tcu)	4.63	15	0.00	S	15	0.00	S
Total hardness(mg/l)	11.98	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	6.04	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	5.11	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	0.67	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	1.36	250	0.00	S	250	0.01	S
Sulphate (mg/l)	1.93	250	0.00	S	100	0.00	S
Sodium (mg/l)	4.95	50	0.00	S	200	0.00	S
Turbidity (ntu)	7.71	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.31	2.0	0.00	S	1.0	0.02	S
Manganese (mg/l)	0.03	0.1	0.01	S	0.2	0.00	S
Zinc (mg/l)	0.18	3.0	0.01	S	3.0	0.00	S
Lead (mg/l)	0.01	0.01	1.05	NS	0.01	1.05	NS
Iron (mg/l)	0.48	0.3	0.10	NS	0.3	0.102	NS

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH, lead and iron were found to have no significant difference in levels of concentration and within permissible limits with the exception of iron which was found above both standards. Other parameters were found to have significant

difference in levels of concentration and within the permissible limits, with the exception of turbidity was found to be above WHO and NSDWQ permissible limits and magnesium above NSDWQ limit. The result shows that tap water from Tarauni LGA is not safe for consumption because frequent consumption overtime may result in toxicity from iron and the level of turbidity is as a result of suspend solids present in the water making it less attractive for drinking because of its murkiness. This result is in agreement with the study of Odafivwotu (2014) on the impact of pipe distribution network on the quality of tap water in Ojota, Lagos State where the turbidity levels and iron concentration are reportedly higher than the recommended standard.

Table 4.24 Difference between Concentration of Borehole Water and Acceptable Drinking Water Standard for Tarauni LGA

Physicochemical parameters	Borehole Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.8	6.5-8.5	0.07	NS	8.5	0.07	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	NS
Total hardness(mg/l)	102	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	375	NA	NA	NA	1000	NA	NA
Calcium (mg/l)	12.98	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	15.35	50	0.01	S	0.20	0.00	S
Chlorides (mg/l)	52.16	250	0.00	S	250	0.00	S
Sulphate (mg/l)	2.75	250	0.00	S	100	0.00	S
Sodium (mg/l)	7.17	50	0.00	S	200	0.00	S
Turbidity (ntu)	3.13	5.0	0.03	S	5.0	0.03	S
Copper (mg/l)	0.46	2.0	0.01	S	1.0	0.01	S
Manganese (mg/l)	0.08	0.1	0.06	NS	0.2	0.06	NS
Zinc (mg/l)	1.09	3.0	0.03	S	3.0	0.03	S
Lead (mg/l)	0.01	0.01	1.05	NS	0.01	1.05	NS
Iron (mg/l)	2.05	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the analysis shows that the values of pH, colour, manganese and lead were found to have no significant difference in levels of concentration and within permissible limits of both standards. Other parameters were found to have significant difference in levels of concentration and within the permissible limits, with the exception of iron which was found to be above WHO and NSDWQ permissible limits, and magnesium which was found to be within WHO limits but above NSDWQ permissible limits. The result shows that borehole water from Tarauni LGA is not safe for consumption because frequent consumption overtime may result in toxicity from iron concentration similar to the works of Akoto and Adiyiah (2007) where iron was reported to occur in high concentrations in groundwater sources.

Table 4.25 Difference between Concentration of Sachet Water and Acceptable Drinking Water Standard for Tarauni LGA

Physicochemical parameters	Sachet Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.15	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	5.72	500	0.00	S	150	0.00	S
Conductivity(µS/cm)	1.81	NA	0.01	NA	1000	0.00	S
Calcium (mg/l)	4.12	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	0.21	50	0.00	S	0.20	1.01	NS
Chlorides (mg/l)	1.10	250	0.01	S	250	0.00	S
Sulphate (mg/l)	1.33	250	0.01	S	100	0.00	S
Sodium (mg/l)	1.14	50	0.01	S	200	0.00	S
Turbidity (ntu)	0.40	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.02	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	0.02	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	0.16	3.0	0.00	S	3.0	0.00	S
Lead (mg/l)	0.00	0.01	1.04	NS	0.01	1.04	NS
Iron (mg/l)	0.02	0.3	0.01	S	0.3	0.01	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the table above shows that the values of pH and lead were found to have no significant difference in levels of concentration and within permissible limits of both standards,

while magnesium was found to have no significant difference and slightly above the NSDWQ limits and significant difference in level of concentration within the permissible limits of WHO. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ. The shows that sachet water from Tarauni LGA is safe for consumption. This result is in agreement with Sheshe and Magashi (2014) in a study conducted on sachet water in Kano metropolis. It also similar to the study carried out by David, Awoh and Essa, (2013) who concluded that the concentrations levels of physicochemical parameter are of low values in comparison with the standard levels of the World Health Organization standard.

Table 4.26 Difference between Concentration of Well water and Acceptable Drinking Water Standard for Tarauni LGA

Physicochemical parameters	Well water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.29	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	65.1	500	0.00	S	150	0.01	S
Conductivity(μS/cm)	394.7	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	5.95	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	13.83	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	17.08	250	0.01	S	250	0.00	S
Sulphate (mg/l)	4.72	250	0.00	S	100	0.00	S
Sodium (mg/l)	14.06	50	0.02	S	200	0.00	S
Turbidity (ntu)	3.53	5.0	0.06	NS	5.0	0.06	NS
Copper (mg/l)	0.71	2.0	0.01	S	1.0	0.01	S
Manganese (mg/l)	0.76	0.1	0.06	NS	0.2	0.06	NS
Zinc (mg/l)	2.01	3.0	0.04	S	3.0	0.04	S
Lead (mg/l)	0.02	0.01	1.06	NS	0.01	1.06	NS
Iron (mg/l)	2.95	0.3	0.01	S	0.3	0.01	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the analysis shows that the values of pH, turbidity, manganese and lead were found to have no significant difference in levels of concentration and within permissible limits of both standards, with the exception of manganese and lead which were found to be above the permissible limits of WHO and NSDWQ. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ, with the exception of iron which was found to be above WHO and NSDWQ permissible limits, while magnesium which was found to be within WHO limits but above NSDWQ permissible limits. This result shows that well water from Tarauni LGA is not safe for consumption and consumption overtime may result in toxicity and pose adverse health effects to the population due to the concentration of lead. This is similar to the study of Yakubu (2013) on assessment of Water Quality of hand-dug wells in Zaria.

4.6.5 Level of Concentration of Water Sources and Acceptable Drinking Water Standard for Gwale LGA

Tables 4.27 to 4.30 shows the difference between the physicochemical concentrations for the various sources of potable water within Gwale LGA and the drinking water standards (Nigerian Standard for Drinking Water Quality (2007) and World Health Organization (2010))

Table 4.27 Difference between Concentration of Tap Water and Acceptable Drinking Water Standard for Gwale LGA

Physicochemical parameters	Tap Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.43	6.5-8.5	0.06	NS	8.5	0.06	NS
Colour (tcu)	4.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	12.03	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	4.82	NA	0.00	NA	1000	0.00	S
Calcium (mg/l)	4.94	NA	0.01	NA	NA	0.01	NA
Magnesium(mg/l)	1.37	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	1.38	250	0.00	S	250	0.00	S
Sulphate (mg/l)	2.42	250	0.00	S	100	0.00	S
Sodium (mg/l)	5.18	50	0.00	S	200	0.00	S
Turbidity (ntu)	13.5	5.0	0.02	S	5.0	0.02	S
Copper (mg/l)	0.03	2.0	0.01	S	1.0	0.01	S
Manganese (mg/l)	0.08	0.1	0.06	NS	0.2	0.06	NS
Zinc (mg/l)	0.44	3.0	0.02	S	3.0	0.02	S
Lead (mg/l)	0.03	0.01	0.06	NS	0.01	0.06	NS
Iron (mg/l)	0.28	0.3	0.07	NS	0.3	0.07	NS

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the analysis shows that the values of pH, manganese, lead and iron were found to have no significant difference in levels of concentration and within permissible limits of both standards, with the exception of lead which found to be above the permissible limits of WHO and NSDWQ. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ, with the exception of magnesium which was found to be within WHO limits but above NSDWQ permissible limits. This shows that tap water from Gwale LGA is not safe for consumption and may pose adverse health effects to the population if consumed frequently due to the concentration of lead. This result is in agreement with the study of Odafivwotu (2014) on the impact of pipe distribution network on the quality of tap water in Ojota, Lagos State.

Table 4.28 Difference between Concentration of Borehole Water and Acceptable Drinking Water Standard for Gwale LGA

Physicochemical parameters	Borehole Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.5	6.5-8.5	0.07	NS	8.5	0.07	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	93.9	500	0.02	S	150	0.00	S
Conductivity(μS/cm)	388.25	NA	0.00	NA	1000	0.01	S
Calcium (mg/l)	16.64	NA	0.01	NA	NA	0.01	NA
Magnesium(mg/l)	17.03	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	62.86	250	0.00	S	250	0.00	S
Sulphate (mg/l)	2.71	250	0.00	S	100	0.00	S
Sodium (mg/l)	12.05	50	0.03	S	200	0.00	S
Turbidity (ntu)	2.68	5.0	0.03	S	5.0	0.03	S
Copper (mg/l)	0.33	2.0	0.01	S	1.0	0.03	S
Manganese (mg/l)	0.02	0.1	0.01	S	0.2	0.01	S
Zinc (mg/l)	1.50	3.0	0.06	NS	3.0	0.06	NS
Lead (mg/l)	0.03	0.01	0.06	NS	0.01	0.06	NS
Iron (mg/l)	2.36	0.3	0.01	S	0.3	0.01	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the analysis shows that the values of pH, zinc and lead were found to have no significant difference in levels of concentration and within permissible limits of both standards, with the exception of lead which found to be above the permissible limits of WHO and NSDWQ. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ, with the exception of iron found to be above both standards, while magnesium was found to be within WHO limits but above NSDWQ permissible limits. This shows that borehole water from Gwale LGA is not safe for consumption and may pose adverse health effects to the population if consumed frequently due to the concentration of lead. The results is in contrast with the study carried out by Njar, Iwara, Offiong and Deekor

(2012) on assessment of heavy metal status of boreholes in Calabar South Local Government Area.

Table 4.29 Difference between Concentration of Sachet Water and Acceptable Drinking Water Standard for Gwale LGA

Physicochemical parameters	Sachet Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.37	6.5-8.5	0.08	NS	8.5	0.07	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	7.85	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	2.20	NA	0.01	NA	1000	0.00	S
Calcium (mg/l)	3.55	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	0.66	50	0.00	S	0.20	0.07	NS
Chlorides (mg/l)	0.86	250	0.00	S	250	0.00	S
Sulphate (mg/l)	1.31	250	0.00	S	100	0.00	S
Sodium (mg/l)	1.40	50	0.00	S	200	0.00	S
Turbidity (ntu)	0.48	5.0	0.01	S	5.0	0.01	S
Copper (mg/l)	0.03	2.0	0.02	S	1.0	0.02	S
Manganese (mg/l)	0.02	0.1	1.04	Ns	0.2	1.03	NS
Zinc (mg/l)	0.16	3.0	0.01	S	3.0	0.01	S
Lead (mg/l)	0.00	0.01	0.06	NS	0.01	0.06	NS
Iron (mg/l)	0.06	0.3	0.07	NS	0.3	0.07	NS

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the analysis shows that the values of pH, manganese, iron and lead were found to have no significant difference in levels of concentration and within permissible limits of both standards. Magnesium was found to have no significant difference for NSDWQ and above permissible limits, while significant difference for WHO and within permissible limits. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ. This shows that sachet water from Gwale LGA is safe for consumption. This result is in agreement with Sheshe and Magashi (2014) in a study conducted on sachet water in Kano metropolis.

Table 4.30 Difference between Concentration of Well water and Acceptable Drinking Water Standard for Gwale LGA

Physicochemical parameters	Well water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	7.29	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	5.00	15	0.00	S	15	0.00	S
Total hardness(mg/l)	77.53	500	0.00	S	150	0.00	S
Conductivity(µS/cm)	519.65	NA	NA	NA	1000	0.02	S
Calcium (mg/l)	10.68	NA	NA	NA	NA	NA	S
Magnesium(mg/l)	14.15	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	27.08	250	0.00	S	250	0.00	S
Sulphate (mg/l)	5.54	250	0.00	S	100	0.00	S
Sodium (mg/l)	15.68	50	0.00	S	200	0.00	S
Turbidity (ntu)	4.29	5.0	1.20	NS	5.0	1.20	NS
Copper (mg/l)	0.54	2.0	0.01	S	1.0	0.01	S
Manganese (mg/l)	0.56	0.1	0.01	S	0.2	0.01	S
Zinc (mg/l)	1.55	3.0	0.02	S	3.0	0.02	S
Lead (mg/l)	0.01	0.01	1.05	NS	0.01	1.05	NS
Iron (mg/l)	2.20	0.3	0.02	S	0.3	0.02	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result from the analysis shows that the values of pH, turbidity and lead were found to have no significant difference in levels of concentration and within permissible limits of both standards. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ with the exception of manganese and iron which were found above the both standards, while magnesium was found to be above NSDWQ permissible limits and within WHO limits. This shows that well water from Gwale LGA is safe for domestic use but not safe for consumption and may pose adverse health effects to the population if consumed frequently. This result agrees with previous works of Ugya, Umar and Yusuf (2015) where iron and manganese were reported to occur in high concentrations in well water sources.

4.6.6 Level of Concentration of Water Sources and Acceptable Drinking Water Standard for Fagge LGA

This section shows the difference between the physicochemical concentrations for the various sources of potable water within Fagge LGA and the drinking water standards (Nigerian Standard for Drinking Water Quality (2007) and World Health Organization (2010)). The results for each source are shown in Tables 4.31 to 4.34 respectively.

Table 4.31 Difference between Concentration of Tap Water and Acceptable Drinking Water Standard for Fagge LGA

Physicochemical parameters	Tap Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.90	6.5-8.5	0.07	NS	8.5	0.07	NS
Colour (tcu)	4.25	15	0.00	S	15	0.00	S
Total hardness(mg/l)	12.09	500	0.01	S	150	0.01	S
Conductivity(µS/cm)	7.59	NA	0.01	S	1000	0.00	S
Calcium (mg/l)	4.38	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	1.43	50	0.01	S	0.20	0.01	S
Chlorides (mg/l)	1.42	250	0.01	S	250	0.01	S
Sulphate (mg/l)	1.38	250	0.01	S	100	0.01	S
Sodium (mg/l)	3.93	50	0.01	S	200	0.01	S
Turbidity (ntu)	11.4	5.0	0.01	S	5.0	0.01	S
Copper (mg/l)	0.35	2.0	0.01	S	1.0	0.01	S
Manganese (mg/l)	0.28	0.1	0.06	NS	0.2	0.06	NS
Zinc (mg/l)	0.27	3.0	0.00	S	3.0	0.00	S
Lead (mg/l)	0.00	0.01	1.05	NS	0.01	1.04	NS
Iron (mg/l)	0.54	0.3	0.06	NS	0.3	0.06	NS

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH, manganese lead and iron were found to have no significant difference in levels of concentration and within permissible limits of both standards with exception of manganese and iron. Other parameters were found to have significant

difference in levels of concentration and within the permissible limits of WHO and NSDWQ with the exception of magnesium which was found to be above NSDWQ permissible limits and within WHO limits. This shows that tap water from Fagge LGA is not safe for consumption and may pose adverse health effects to the population if consumed frequently. This result is in agreement with the study of Odafivwotu (2014) on the impact of pipe distribution network on the quality of tap water in Ojota, Lagos State where manganese and iron concentration are reportedly higher than the recommended standard.

Table 4.32 Difference between Concentration of Borehole Water and Acceptable Drinking Water Standard for Fagge LGA

Physicochemical parameters	Borehole Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.48	6.5-8.5	0.08	NS	8.5	0.08	NS
Colour (tcu)	5.00	15	0.01	S	15	0.01	S
Total hardness(mg/l)	72.78	500	0.01	S	150	0.01	S
Conductivity(μS/cm)	316	NA	0.01	NA	1000	0.03	S
Calcium (mg/l)	16.74	NA	0.00	NA	NA	NA	NA
Magnesium(mg/l)	15.03	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	48.78	250	0.00	S	250	0.00	S
Sulphate (mg/l)	5.08	250	0.00	S	100	0.00	S
Sodium (mg/l)	12.64	50	0.00	S	200	0.00	S
Turbidity (ntu)	3.24	5.0	0.04	S	5.0	0.04	S
Copper (mg/l)	0.18	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	1.72	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	1.65	3.0	0.00	S	3.0	0.02	S
Lead (mg/l)	0.01	0.01	1.05	NS	0.01	1.05	NS
Iron (mg/l)	2.06	0.3	0.07	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH and lead were found to have no significant difference in levels of concentration where pH was found slightly below the lower limits of both standards of

6.5 and lead to be within permissible limits. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ with the exception of manganese and iron above permissible limits of both standards, while magnesium was found to be above NSDWQ permissible limits and within WHO limits. This shows that borehole water from Fagge LGA is not safe for consumption and may pose adverse health effects to the population if consumed frequently. The findings agrees with previous work of Shalom, Obinna, Adetayo and Eze (2011) where iron and manganese were reported to occur in high concentrations in groundwater sources.

Table 4.33 Difference between Concentration of Sachet Water and Acceptable Drinking Water Standard for Fagge LGA

Physicochemical parameters	Sachet Water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.77	6.5-8.5	0.09	NS	8.5	0.09	NS
Colour (tcu)	5.00	15	0.01	S	15	0.01	S
Total hardness(mg/l)	8.51	500	0.01	S	150	0.01	S
Conductivity(µS/cm)	3.87	NA	0.00	S	1000	0.00	S
Calcium (mg/l)	4.23	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	3.09	50	0.00	S	0.20	0.00	S
Chlorides (mg/l)	0.32	250	0.00	S	250	0.00	S
Sulphate (mg/l)	1.40	250	0.00	S	100	0.00	S
Sodium (mg/l)	0.37	50	0.00	S	200	0.00	S
Turbidity (ntu)	0.27	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.02	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	0.03	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	0.13	3.0	0.02	S	3.0	0.02	S
Lead (mg/l)	0.00	0.01	1.02	NS	0.01	1.02	NS
Iron (mg/l)	0.01	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH and lead were found to have no significant difference in levels of concentration and within permissible limits. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ with the exception of magnesium which was found to be above NSDWQ permissible limits and within WHO limits. This shows that sachet water from Fagge LGA is safe for consumption. This result is in agreement with Sheshe and Magashi (2014) in a study conducted on sachet water in Kano metropolis.

Table 4.34 Difference between Concentration of Well water and Acceptable Drinking Water Standard for Fagge LGA

Physicochemical parameters	Well water	WHO Standard (2010)	P-value	Remarks	NSDWQ Standard (2007)	P-value	Remarks
pH	6.97	6.5-8.5	0.09	NS	8.5	0.09	NS
Colour (tcu)	5.00	15	0.01	S	15	0.01	S
Total hardness(mg/l)	75.3	500	0.00	S	150	0.00	S
Conductivity(μS/cm)	140.38	NA	NA	NA	1000	0.00	S
Calcium (mg/l)	11.01	NA	NA	NA	NA	NA	NA
Magnesium(mg/l)	13.20	50	0.01	S	0.20	0.01	S
Chlorides (mg/l)	21.08	250	0.01	S	250	0.01	S
Sulphate (mg/l)	1.94	250	0.00	S	100	0.00	S
Sodium (mg/l)	16.1	50	0.00	S	200	0.00	S
Turbidity (ntu)	2.77	5.0	0.00	S	5.0	0.00	S
Copper (mg/l)	0.13	2.0	0.00	S	1.0	0.00	S
Manganese (mg/l)	3.03	0.1	0.00	S	0.2	0.00	S
Zinc (mg/l)	1.72	3.0	0.00	S	3.0	0.00	S
Lead (mg/l)	0.03	0.01	0.06	NS	0.01	0.06	NS
Iron (mg/l)	1.24	0.3	0.00	S	0.3	0.00	S

Source: Laboratory Analysis, 2015
NA - Not Available
S – Statistically Significant
NS- Not Statistically Significant

The result shows that the values of pH and lead were found to have no significant difference in levels of concentration and within permissible limits while lead was found to be above the

permissible limits. Other parameters were found to have significant difference in levels of concentration and within the permissible limits of WHO and NSDWQ with the exception of manganese and iron found to be above the standards. Magnesium was found to be above NSDWQ permissible limits and within WHO limits. The higher concentrations on lead, manganese and iron. This shows that well water from Fagge LGA is not safe for consumption and may pose adverse health effects to the population if consumed frequently due to higher concentrations on lead. The result buttressed the findings of Adewara and Akinlolu (2008) that confirmed significant concentrations of metals like lead, manganese and iron in well water sources.

4.7 ASSESSMENT OF WATER QUALITY BASED ON WATER QUALITY INDEX

The uses to which water can be put depend on its chemical quality. The water quality index indicates the quality of water in terms of index number which represents overall quality of water for any intended use (Etim, Akpan and Andrew, 2012). In this section, the WQI is established from important physicochemical parameters such as pH, colour, total hardness, conductivity, calcium, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese, zinc, lead and iron. The results of the WQI for physicochemical parameters of the different sources of potable water supply in Kano metropolis analyzed are presented in Tables 4.35. The result are discussed based on the water quality ratings presented in Table 3.4.

Table 4.35 Water Quality Index for Kano Metropolis

Kano Metropolis	WQI for Water Sources			
	Tap Water	**Borehole Water**	**Sachet Water**	**Well Water**
Kano Municipal	183.88	284.93	2.20	199.79
Dala	- -	112.80	2.20	141.72
Fagge	9.34	119.51	1.22	318.68
Nassarawa	94.53	113.97	2.40	212.93
Gwale	274.56	283.87	1.88	148.49
Tarauni	94.93	114.47	2.00	270.00

Source: Laboratory Analysis, 2015

Tap Water Quality Index

From Table 4.35 above, the WQI rating for tap water source varies from one metropolis to another within the metropolis where tap water from Kano municipal and Gwale LGA are unsuitable for drinking (WQI >100). Tap water from Nassarawa LGA and Tarauni LGA have very poor water quality rating (76-100), while Fagge LGA has values similar to those of sachet water excellent water quality (0-25) which makes it suitable for domestic use and human consumption. The result for Kano Municipal, Gwale, Nassarawa and Tarauni LGA is in contrast with the findings of Etim Odoh, Itodo, Umoh and Lawal (2013) but similar when compared with results from Fagge LGA. Etim *et al.*, (2013) reported the WQI from the different sampling stations for pipe borne water and falls under the good water quality status.

Borehole Water Quality Index

From Table 4.35 above, the water quality index (WQI) for borehole water in Kano municipal, Dala, Fagge, Nassarawa, Gwale and Tarauni LGA shows that the WQI exceeds 100 which makes it unsuitable for drinking. These result for borehole water is in contrast with the study of Olowe Oluyege and Famurewa (2016) who reported poor water quality ratings for borehole water WQI 54.16. But in agreement with the study of Oko, Aremu, Odoh, Yebpella and Shenge (2014) who reported unsuitable for drinking ratings for borehole water WQI 136 in Wukari Town, Taraba State.

Sachet Water Quality Index

Table 4.35 above shows the results of the water quality index (WQI) for sachet water source in Kano municipal, Dala, Fagge, Nassarawa, Gwale and Tarauni LGA falls within the excellent water quality ratings of between 0 and 25 which makes it suitable for domestic use and human consumption. This result is similar to the study of Olowe, Oluyege and Famurewa (2016) who reported good water quality ratings WQI 49.59 for sachet water in Ado-Ekiti and Environs, Nigeria.

Well Water Quality Index

The water quality index (WQI) for well water source in Kano municipal, Dala, Fagge, Nassarawa, Gwale and Tarauni LGA in Table 4.35 shows that the WQI exceeds 100 which makes it unsuitable for drinking. The result for well water source is similar to the findings of Oko, Aremu, Odoh, Yebpella and Shenge (2014) who reported unsuitable for drinking ratings for well water WQI 136 in Wukari Town, Taraba State. It is also similar to the study of Ishaku

(2011) on assessment of groundwater quality index for Jimeta Yola area, Northeastern Nigeria who reported WQI of 138.5 as unfit for human consumption without treatment. But not in line with the study of Chandaluri, Rao, Hariharan and Bharathi (2010) in Guntur District Andhra Pradesh India, where results obtained from wells were found to vary from WQI of 38.3 to 42.6.

4.7.1 Water Quality Index Comparison between Water Sources

This section compares the results from Table 4.35 where the water quality index for each of the potable water source (tap, borehole, sachet and well water) was compared for each LGA (Kano Municipal, Dala, Fagge, Nassarawa, Gwale and Tarauni) within the Kano Metropolis. This comparison was made to indicate which potable water source is suitable for consumption within each LGA in the Metropolis.

The result of the water quality index for Kano Municipal LGA revealed that tap water, borehole water and well water exceeded the water quality index rating of 100 indicating water unsuitable for drinking. While the result for sachet water quality index shows that the sachet water source falls within the excellent water quality ratings of between 0 and 25 which makes it suitable for domestic use and human consumption.

The water quality index for Dala LGA indicated that tap water source was not available for the analysis but borehole water and well water sources exceeds the water quality index rating of 100 which makes it unsuitable for drinking. While the result for sachet water quality index shows that

an excellent water quality ratings of between 0 and 25 which makes it suitable for human consumption.

Result from Fagge LGA showed that water quality index for borehole and well water source exceeds the water quality index rating of 100 which makes it unsuitable for drinking. However, the result for tap and sachet water quality index shows an excellent water quality ratings of between 0 and 25 which makes it suitable for human consumption.

The result of the water quality index for Nassarawa LGA revealed that borehole water and well water far exceeds the water quality index rating of 100 which makes it unsuitable for drinking. While the result for tap water quality index shows a very poor water quality rating 76-100 which makes it suitable for domestic use but not for human consumption. Sachet water quality index from the analysis shows that the sachet water source falls within the excellent water quality ratings of between 0 and 25 which makes it suitable for human consumption.

The result from Gwale LGA revealed that the water quality index for tap, borehole and well water sources far exceeds the water quality index rating of 100 which makes it unsuitable for drinking. However, the result for sachet water quality index shows that it falls within the excellent water quality ratings of between 0 and 25 which makes it suitable for human consumption.

The result from Tarauni LGA, similar to the result from Nassarawa LGA revealed that the water quality index for borehole water and well water far exceeds the water quality index rating of 100 which makes it unsuitable for drinking. However, the result for tap water quality index shows a very poor water quality rating 76-100 which makes it less suitable for domestic use and not for human consumption. Sachet water quality index shows that the sachet water source falls within the excellent water quality ratings of between 0 and 25 which makes it suitable for human consumption.

Finally, it can be deduced from the result of the water quality index analyzed for Kano Metropolis, that wells, boreholes and tap water sources are unsuitable for human consumption in which frequent consumption will cause severe health risk. But tap water source in Fagge Local Government Area just like sachet water source for the entire Metropolis showed suitability for human consumption.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the summary of this work, conclusion derived from the findings as well as recommendations.

5.2 SUMMARY OF FINDINGS

Preliminary assessment of various sources of water in Kano Metropolis was carried out using laboratory techniques to determine the level of concentration of parameters such as pH, colour, total hardness, conductivity, calcium, magnesium, chlorides, sulphate, sodium, turbidity, copper, manganese, zinc, lead and iron in open wells, boreholes, tap water and sachet water sources. The spatial variation that exist between sources was determined, the water quality index (WQI) for the study area was analyzed and the quality from each source was compared with the acceptable drinking water quality standard according to (NSDWQ, 2007; WHO, 2010) and found out that:

i. The study showed spatial variations in physicochemical parameters between various sources of potable water supply in Kano Metropolis and also showed significant difference in level of concentration between open wells, boreholes, tap water and sachet water.

ii. Water sources in Kano Municipal LGA showed that lead and iron were found to be slightly above WHO and NSDWQ for tap water. Lead and iron were also found to be

slightly above the quality standards for borehole water. While manganese and iron were found to be slightly above the quality standard for well water.

iii. Results from Dala LGA showed that pH, manganese and iron were found to be above the WHO and NSDWQ permissible limit for borehole water. While iron was found to be slightly above the quality standards for sachet water. Turbidity, manganese and iron were found to be above the permissible limit for well water.

iv. The results obtained from Nasarawa LGA showed that iron was found to be slightly above WHO and NSDWQ permissible limits for tap and borehole water. All parameters in sachet water were found to be within the quality standards. Also manganese and magnesium were found to be within WHO limits and above NSDWQ permissible limits for well water.

v. Results obtained from Tarauni LGA showed that iron was found to be above WHO and NSDWQ permissible limits for tap water, borehole and well water. All parameters for sachet water were found to be within the standards.

vi. The results obtained from Gwale LGA showed that lead and iron were found to be above WHO and NSDWQ permissible limits for tap and borehole water. All parameters analyzed in sachet water were found to be within the standards. While manganese and iron were found to be above WHO and NSDWQ permissible limits for well water.

vii. The results obtained from Fagge LGA showed that manganese and iron were found to be above WHO and NSDWQ permissible limits for tap water and well water, while pH was found to be above the standard for borehole water and parameters analyzed for sachet water were found to be within the quality standards.

viii. The water quality index for Kano Municipal and Gwale LGA revealed that tap, borehole and well water are unsuitable for drinking. While the result for sachet water quality index shows that the sachet water falls within the excellent water quality ratings. Dala and Fagge LGA borehole and well water are unsuitable for drinking, while the result for sachet water quality index in Dala and tap water quality index in Fagge LGA shows that an excellent water quality rating suitable for human consumption.

ix. The water quality index for Tarauni LGA similar to the result from Nassarawa LGA revealed that borehole water and well water far exceeds the water quality index rating indicating water unsuitable for drinking. While the result for tap water quality index shows a very poor water quality rating less suitable for domestic use and not for human consumption, but sachet water quality index shows that it is suitable for human consumption.

5.3 CONCLUSION

Most people do not fully understand the real dangers of physicochemical pollution of water and just how common they are in our modern world. This study revealed that:

i. All the sachet water from the study area are suitable for consumption except for sachet water in Dala LGA where iron was found to be slightly above WHO and NSDWQ standards.

ii. Poor water qualities was witnessed in tap, wells and borehole water within the metropolis. This high levels would accumulate in the body after long term consumption and could be fatal to health of the population.

iii. The accurate interpretation of water quality data is of utmost importance in water quality investigation. Thus, the WQI criteria approach to interpretation is desirable, essentially due to its simplicity. Using water quality indices for particular consumption is considered a simple method for the primary recognition of water quality. The use of water quality index will not only allow assessment of changes in water quality over time and space but also evaluate successes and shortcomings of domestic policy and inter-national treaties designed to protect aquatic resources. From the study, sachet water source was found to be suitable for human consumption and should be patronized more than other sources of water due to its level of purity.

5.4 RECOMMENDATIONS

According to Kulkarni (1997), it is more economical to maintain the quality of water through source protection. In Kano metropolis, the nature of pollutants generation and the attitude of residents to sanitary, environmental ethics, are not very encouraging. To address problems

associated with quality of potable water supply in Kano metropolis, there are needs for government, community and private individuals to work collectively in achieving the following:

i. The local authorities and individuals should provide waste management disposal systems that would take care of waste and refuse dumps within the metropolis.
ii. The government should allocate more funds to water resources sector in order to improve water supply and replacing corrosive and coagulated pipes.
iii. All contaminated sources be subjected to further treatments by the government agencies so as to reduce drastically, the concentration of these identified physicochemical parameters which are capable of posing adverse threat to health of consumers and the society.
iv. Individuals are advised to take responsibility of their well-being by testing their drinking water sources periodically and treatment of water before they can be used for drinking and other domestic purposes.
v. There should be proper orientation and re-orientation of all communities within the metropolis by government and non-governmental organizations on the impacts of indiscriminate waste discharge on water quality, health and environment, proper siting of wells and boreholes in residential areas, treatment and maintaining of existing water supply facilities.
vi. The water treatment plants should be well equipped by the government with state of the art facilities that will ensure proper removal of pollutants from water so as to keep it within WHO and NSDWQ safe drinking water standards.

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