PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY ASSESSMENT OF SOME SELECTED SACHET WATER BRANDS SOLD IN KANO METROPOLIS, NIGERIA

BY

HABIBA MUHAMMAD
SPS/10/MAB/00012

BEING A THESIS PRESENTED TO THE DEPARTMENT OF APPLIED BIOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN APPLIED BIOLOGY (HYDROBIOLOGY)

SUPERVISOR:
DR. I. I. INDABAWA

MARCH, 2014

CERTIFICATION

This is to certify that this research work entitled Physico-Chemical and Bacteriological Quality Assessment of some Selected Sachet Water Brands sold in Kano Metropolis was carried out by Habiba Muhammad (SPS/10/MAB/00012) under the Supervision of Dr. I. I. Indabawa of the Department of Biological Sciences Bayero University, Kano. No part of this dissertation has ever been presented for another degree or diploma.

…… ……..
Dr. I.I. Indabawa **Sign**
Supervisor

…… ……..
Dr. Abubakar Isma'il **Sign**
External Examiner

…… ……..
Dr. Bashir Muhammad **Sign**
Internal Examiner

…… ……..
K. M. Umar (Ph.D.) **Sign**
Dept'l PG Coordinator

…… ……
Dr. Zainab Tukur **Sign**
SPS Representative

…… ……..
Prof. (Dame) T. I. Oyeyi **Sign**
Head of Department & Chief Examiner

DEDICATION

I dedicated this work to the last and holy prophet, Muhammad Rasulillah (S.W.A). May I and those who believe in him be with him in the hereafter, Ameen.

ACKNOWLEDGEMENTS

I would first of all like to thank the almighty Allah, who made all things possible. May His peace and blessings be upon the last prophet Muhammad (S.W.A).

I am grateful to my supervisor, Dr. I.I. Indabawa who have guided and supplied me with some useful suggestions and encouragement during the research programme. Thanks to my H.O.D Dr. I. Lawal for his valuable input on all issues of concern at any time and place. Besides that, his contribution from the start of the programme to advising the draft of my research contributed to its final success. I am grateful to the unlimited assistance given to me by my level coordinator Dr. Sani Ibrahim. May God Almighty grand him good health. My thanks also goes to Dr. A.H. Kawo and to Mal. Yahya Mustapha in helping me in so many ways during the research programme. Thanks to Mal. Umar Sani Dorayi and Mal. Hassan Yahaya of Microbiology Department, B.U.K and also to Dr. Yahuza Muhammad and Mal. Muhammad Kamilu Ahmad. I must also thank Mal. Gambo Lab and Mal. Salisu Gambole of Microbiology laboratory Saadatu Rimi College of Education and also to Mal. Sabo Ado Abdullahi and Mal. Usman Zango for their assistance.

Very warm thanks to Hajiya Bilkisu Bello Abubakar and her entire family for their unlimited assistance, may God almighty reward them abundantly, Ameen. I am grateful to my brother Abdulhakeem and to my sisters Zainab and Jamila who provided great companionship during sample collection. My thanks goes to my parents, brothers, and sisters, and to Usman, Hashimu, Auwalu, Ahmad, shukura, Beby and her family for their valuable support. My acknowledgement also goes to the producers of the sachet waters under study for their co-operation. Lastly, my special thanks to my spouse Alh. Muhammad Bala Abdullahi and to my children Hilal, Salim, Yusrah, and Tasneem for their care, co-operation and support during the programme.

TABLE OF CONTENT

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

ABSTRACT

A total of 1080 samples of sixty (60) different brands of sachet water (30 NAFDAC registered and 30 non- NAFDAC registered) were purchased in triplicates from Kano Metropolis monthly for a period of six months (June-November, 2012) and analyzed to determine their physico-chemical and bacteriological quality. Results of the mean physico-chemical parameters of both the NAFDAC and the non-NAFDAC registered sachet water samples were found to be in conformity with the National Agency for Food, Drug Administration and Control (NAFDAC, 2004), Nigerian Industrial Standard (NIS, 2008), and World Health Organisation (WHO, 2003) except for pH values of <6 which were found in some sachet water samples and are below the recommended limit set by the regulatory bodies above. The mean results of the aerobic mesophilic bacterial count of the NAFDAC registered and the non-NAFDAC registered sachet water samples ranged between 0 cfu/ml - 2.68 x 10^2 cfu/ml and 0 cfu/ml - 2.92x10^2 cfu/ml respectively. This range falls within the limit set by the above regulatory bodies of <10^4cfu/ml. The total coliform count for the NAFDAC and the non-NAFDAC registered sachet water samples ranged from < 2 - 7 and < 2 - 9 respectively. There was no E. coli detected in all the water samples examined. The students distribution test (t-test) of all the physico-chemical parameters showed no significant difference at 0.01% between the NAFDAC registered and the non-NAFDAC registered sachet water samples(P<9.925). However, there is significant difference in aerobic mesophilic bacterial count between the NAFDAC registered and the non-NAFDAC registered water samples (P>2.326). Sachet water produced and sold in Kano Metropolis requires constant microbiological examination by the regulatory agencies so as to ensure public health safety of the population.

CHAPTER ONE

1.0 Introduction

1.1 Background of the Study

Water is one of most important factors in the development of any society. It is the second most important factor for all living organisms after air. Water makes up the world most abundant chemical compound covering three quarters of the earth surface. The importance of water cannot be over emphasized, as life cannot exist without it (Demming, 1975). Human beings in particular can survive longer periods without food but not without water. Water is needed by living organisms to enable them carryout various physiological functions and it also act as medium for all biochemical reactions within plants and animals. Water therefore, plays an essential role in supporting the lives of all living organisms. However, if contaminated with pathogenic micro-organisms has great potential risk for transmitting a wide variety of diseases and illness (Tebbutt, 1982, Jane, 1990). The availability of clean water in any society is therefore, directly related to the control or elimination of disease (George and Edward, 1985).

In the developed countries, water-related diseases are rare, essentially due to the presence of efficient water supply and waste water disposal systems. However, in the developing countries perhaps as many as 200 million people are without safe water supply and adequate sanitation (Tebbutt, 1982). As a result, the toll of water-related diseases in these areas is frightening in its extent.

A safe and potable water should conform to certain standard set by regulatory bodies such as World Health Organisation (Okedi, 1997). According to Cheesbrough (1994), water for human consumption is characterized by being potable (that is water free of pathogens and deleterious chemicals). Water is regarded potable, and fit or safe for consumption, if it is free from pathogenic and noxious substances such as pesticide, artificial fertilizer or heavy metal ions (Heritage, 1999) and should not have an unpleasant odour or taste, in other words potable water must be organo-leptically acceptable and aesthetically attractive ($Anon_1$, 2001).

The most popular commercial drinking water is the packaged drinking water sold in bottles and sachets. However, sachet water is a cheaper alternative to bottled water. The increased demand for these drinking water products is attributed largely to factors such as

inadequate or non-availability of reliable, safe municipal water in urban areas, impression that high quality natural spring water offers a healthy, refreshing and great tasting alternative to high calorie soft drinks and ordinary tap water, and convenience which has made the products meet the requirements of any lifestyle when needed (Gardner, 2004).
The production, marketing and consumption of sachet water have increased tremendously with several brands of different types of packaged water marketed in Nigeria and other developing countries.

Although, water in sachets is readily available and the price is affordable, there are still concerns about its safety. Also the integrity of the hygienic environment and conditions where the majority of the sachet water are produced has also been questioned (Dada, 2008). Concerns of vertical transmission of disease pathogens by vendors have also been raised, though, documented evidences are rare, there are claims of past outbreaks of water- borne illness that resulted from consumption of contaminated sachet water (Dada, 2008), most of which are of unknown origin.

1.2 Scope of the Research Work

This research work assessed the physico-chemical and bacteriological quality of some selected sachet water brands sold in Kano metropolis. The physico-chemical paramaters include temperature, pH, turbidity, conductivity, chloride and total hardness. While the bacteriological parameters are aerobic mesophilic bacterial count, enumeration of total coliform and characterization of *E.coli.*

1.3 Limitation of the Research Work

Although many parameters can be measured in assessing the physico-chemical and bacteriological quality of the sachet water brands selected in Kano metropolis. However, this research work was only limited to some of the physico-chemical and bacteriological parameters due to time factor. These parameters include:

a) Physical Parameters: - Temperature, pH, and turbidity.
b) Chemical Parameters: - Electrical conductivity, chloride and total hardness.
c) Bacteriological Parameters: - Aerobic mesophilic bacterial count, enumeration of total coliform, and isolation and characterization of *E.coli*

1.4 Justification of the Study

Water sold in sachets is the most readily available and affordable, especially among the poor and average income earners. However, there are concerns about its safety. The most important consideration about water for drinking is that it should be safe, clean and hygienic.

Although, these sachet water products in the markets are supposed to be registered, regularly supervised/monitored and assessed by regulatory agents/bodies such as NAFDAC to comply with certain minimum standard for human consumption, yet, there are several sachet waters in circulation which are produced and sold to the unsuspecting consumers in the public that may not necessary comply with the acceptable standard for quality drinking water. According to the World Health Organization (WHO, 2003) drinking water that has not been given proper attention have enormous potentials for spreading microbial diseases. Therefore, there is need to assess the quality/safety of sachet water sold in Kano metropolis.

1.5 Aim and Objectives

1.5.1 Aim

The study is aimed at assessing the physico-chemical and bacteriological qualities of some selected sachet water samples sold in Kano Metropolis with a view to determine its suitability for consumption in comparison with national and international standards.

1.5.2 Objectives

- To determine some physico-chemical parameters of the sachet water samples that includes temperature, pH, turbidity, conductivity, chloride and total hardness using standard methods.
- To enumerate aerobic mesophilic bacterial count using standard plates method.
- To enumerate Coliform bacterial count using MPN technique.
- To isolate and characterize *E. coli.*

CHAPTER TWO

2.0 Literature Review

2.1 Significance for Provision of Safe Drinking Water

Water has always been important and life sustaining to humans and is essential to the survival of all organisms (Greenhalgh, 2001). It is a crucial component of metabolic processes and serves as a solvent for many bodily solutes (Cleverland 2007; USEPA, 2005).

Adequate supply of fresh and clean drinking water is a basic need for all human beings. The availability of improved and good quality water supply and sanitation infrastructures are widely recognized as an essential component of human rights, social, and economic development (Third world water forum, 2003). The national water supply and sanitation (2000) policy makes the supply of adequate water supply and sanitation a right of all Nigerians (FRN, 2000). A reliable supply of clean water is highly essential in a bid to promoting healthy living among the inhabitants of a defined geographical region (Mustapha and Adamu, 1991). Accessibility and availability of fresh, clean water is the key to sustainable development and an essential element in health, food production and poverty reduction (Third world water forum, 2003). According to (WHO,2010), the quality of drinking water is a powerful environmental determinant of health. Drinking water quality management has been a key pillar of primary prevention for over one-and a half centuries and it continues to be the foundation for the prevention and control of water borne diseases (WHO, 2010). The provision of adequate supply of safe water has stimulated a reduction in the incidence of diseases in the developed nation. Even without medical intervention, the provision of safe drinking water and sanitation has greatly influenced a reduction in the transmission of many diseases, enhanced the efficiency of other health intervention and improved other non-health living condition.

However, Earnest *et al.* (2007) reported that a large segment of the population in the developing countries are drinking untreated or partially treated, unprotected surface water, from open wells, rivers and ponds that are often heavily contaminated by faeces and excretal matter, loaded with opportunistic pathogens comprising many diarrhoeal

causing organisms not only from man but also animals, such as donkeys, sheep, cattle, rats, birds, and so on.

According to the World Health Organisation (WHO, 2004), 1.1 billion people did not have access to an improved water supply in 2002, and 2.3 billion people suffered from diseases caused by contaminated water. Each year 1.8 million people die from diarrheal diseases, and 90% of these deaths are of children under five years (WHO, 2004).

2.2 Bacteria and Water Borne-Diseases

Water borne-diseases are defined as a group of diseases transmitted to humans by micro-organisms (bacteria, fungi, viruses and protozoans) through the medium (route) of water. They can also be transmitted by insects and other organisms that live and/or breed in water (Pelezer *et al*, 1989). Reports have shown that potable water supplies have become a route of transmitting bacteria to consumers (Mukhtar, 1998). There are many different types of bacterial water related diseases that include *Salmonelle, Shigella, Campylobacter, Vibrio cholerae,* and *Escherichia coli*.

a. Salmonellae

These are motile, aerobic or facultative anaerobic gram-negative rod shaped bacteria of the family enterobacteriaceae that live in the intestines of virtually all vertebrates, especially reptiles and are eliminated in faeces. According to Sleigh and Duguid, (2004), *salmonellae* are organisms that ferment glucose and mannose without producing gas but do not ferment lactose or sucrose; most of these produce hydrogen sulphide gas in triple sugar iron agar. They can be isolated using a number of low–selective media (Mackonkey agar, deoxychocolate agar), intermediate selective media (Salmonella-shigella (SS) agar, Hectoen agar (HE) agar), and selective media (Selenite agar with brilliant green). Individual isolate can then be distinguished by serotyping, bacteriophage typing, and genotyping (Micheal and David, 2005). As with closely related bacterium *E.coli*, salmonella are potentially enteric pathogens and are leading cause of bacterial food-borne illness. Humans acquire typhoid fever through the consumption of food or water contaminated with the faeces of carriers who may be asymptomatic. Patients typically experience gradually increasing fever, headaches, muscle pains, malaise and loss of appetite that may persist for a week or more. The organism may be released from the

gallbladder to re-infect the intestines, producing gastro enteritis and abdominal pains, followed by a recurrence of bacteremia. In some patients, the bacterium ulcerates and perforates the intestinal wall, allowing bacteria from the intestinal tract to enter the abdominal cavity causing peritonitis. Typhoid fever may last 4 weeks and 12 – 30% of patients die if not treated. Lost fluid and electrolytes can be replaced and typhoid fever treated with antibiotics such as ciprofloxacin or amphicillin (Robert, *et al*. 2009). Disease caused by *S. paratyphi* A and B are generally milder than typhoid. There is usually diarrhea and vomiting and the entire intestinal tract may be inflamed especially in B infections. *S. paratyphi* C has a limited distribution. It causes mainly bacteremia and occasionally abscesses, arthritis and inflammations of the gallbladder. (Cheesbrough, 2006). *S. typhi, E. coli, Shigella spp* and *Aeromonas hydrophilla* where isolated in Kainji Lake Atiribom *et al*, (2008).

The largest water borne outbreak of typhoid fever in Britain killed 43 people in Croydon in 1937 (Olabisi and Awonusi, 2008). Other outbreak of typhoid fever includes that of Dade county in Florida USA in 1973 involving 210 cases, Poiters in France 1974 involving 60 cases, all these incidences were attributed to water contamination and inefficient disinfection (Olabisi and Awonusi, 2008).

b. Shigella

Shigella are non-motile, gram-negative, non-sporing and non-capsulated rod bacteria and usually do not ferment lactose but ferment other carbohydrates with acid production but not gas, and they do not produce hydrogen sulphide gas (Cheesbrough, 1994). *Shigella* is the most common cause of bacillary dysentery worldwide (Walid and Ilyas, 2002). It is spread through faecal-oral transmissions primarily by food or water, fingers, faeces, and flies. There are four species that are closely related to *E.coli*, these include *Shigella flexineri, S.dysenteriae, S. boydi and S. sonneii*. Many share common antigens with one another and with other enteric bacteria (Sleigh and Duguid, 2004). *S. dysenteretiae* serotype 1 is the most virulent. It causes inflammation and ulceration of the intestinal tract, with severe dysentery, which often contains mucus and blood, marked dehydration and protein loss, abdominal cramps, rectal pain, taxaemia and high fever. Death can occur from circulatory collapse or kidney failure. Enterotoxin is produced but the virulence of *S.dysentereriae* 1 is thought to be due to its invasiveness. It is associated

with neutrophilia (Cheesbrough, 1994). Eradicating this disease can only be achieved through sanitary control of water, food and milk; sewage disposal and fly control, identification and treatment of patients carriers (Geo *et al*, 2002).

c. Campylobacter

Campylobacter infections are among the most common bacterial infections in human (Mahmud and Shadab, 2005). They produce both diarrhoeal and systemic illness. *Campylobacter* organisms are an important cause of traveler's diarrhea, especially in Thailand and surrounding areas of Southeast Asia. *Campylobacter*-like organisms can produce an enterocolitis/proctocolis syndrome in homosexual males. These organisms are related to *Helicobacter pylori* which were previously known as *Campylobacter pylori*. No reservoir other than the human gastric mucosa has been identified for *H.pylori* (Mahmud and Shadab, 2005).

Campylobacter jejuni is usually the most common cause of community-acquired inflammatory enteritis. It may also produce serious bacteraemic conditions in individuals with AIDS. *Campylobacter fetus* is an uncommon cause of bacteraemia in hosts who are immunocompromised. *Campylobacter lari*, which is found in healthy seagulls, has also been reported to produce recurrent diarrhoe in children. *Campylobacter upsaliensis* may cause diarrhea or bacteraemia, while *Campylobacter hyintestinalis* causes occasional bacteraemia in hosts who are immunocompromised (Mahmud and Shadab, 2005).

d. ***Vibrio cholerae***

Vibrio cholerae is a comma shaped, gram-negative aerobic bacillus whose size varies from 1µm to 3 µm in length and 0.5 µm to 0.8 µm in diameter. It's actively motile by means of polar flagellum (Geo *et al.*, 2002). *Vibrio cholerae* causes water borne disease known as cholera. The word "cholera" is derived from a Greek term that means "flow of bile". The genus vibrio is composed of species that occur naturally in estuarine and marine environment worldwide, preferring warm, salty and alkaline water. Most vibrio species are halotolerant and Nacl often stimulate their growth (Geo *et al.*, 2002). Cholera is the most feared epidemic diarrhoeal disease because of its severity. Two serogroups of 01 and 0139 causes outbreaks (Alexander and Kirscher, 2008). However majority of outbeaks was found to be caused by 01. Pathogenic *v. cholerae* can survive refrigeration

and freezing in food supplies (Reildl and Klome, 2002). Infective dose for healthy volunteers via oral route is greater than 1000 live organisms (Hartely *et al*., 2006). Dehydration and death can occur within a matter of hours of infection (Handa and Wood, 2006). Cholera epidemics occur particularly in crowded living condition e.g. refugee camps when water supplies are unsafe, and when food safety and hygiene are inadequate. Risk of cholera is high following manmade and natural disasters that results in flooding with fecal contamination of the environment and water supplies (Cheesbrough, 1994).

Cholera cases also tend to be clustered by location as well as season, with most infections occurring in children between 1-5 years (WHO, 2010). Infection is spread through ingestion of food or water contaminated with faecal material. After an incubation period of 2-5 days, diarrhea and abdominal pain begin suddenly. Vomiting sometimes occurs, but fever is rare. The diarrhea can be profuse, exceeding 5 litres during 24 hours, leading to loss of fluid and ions that is often fatal.

There is an estimated 3-5 million cases of cholera each year and resulted in 100,000-120,000 deaths. The short incubation period of two to five days enhance the potentially explosive patter of outbreak (Faruque and Nair, 2008 and WHO, 2010).

In 2005, 131,943 cholera cases with 2,272 deaths were recorded from 52 countries. Within the same year, 14 countries were affected in West Africa and they accounted for 58% of all cholera cases (WHO, 2010). In 2008, Nigeria recorded 6,330 cases of cholera with 429 deaths (WHO, 2010).

e. Escherichia coli (E.coli)

As other members of the enterobacteriaceae, they are gram-negative bacilli occurring singly or in pairs. They are facultative anaerobic with both a fermentative and respiratory type of metabolism and are either motile or non-motile. They are major facultative inhabitants of the large intestine (Chi Hiong and Burke 2006). Typically they produce positive tests for indole and methyl red but negative for lysine, citrate and voges Proskaeur tests. *E.coli* are positive for decarboxylase and mannitol fermentation, they produce gas from glucose as well as lactose with typical colonial morphology of an iridescent sheen on differential media such as Eosine methylene Blue agar. They form smooth, glossy translucent and rose pink colonies on MacConkey agar; they are impaired

or totally inhibited on desoxycholate citrate agar (DCA) (Edward and Ewing, 2002). They are distinguished from other coliforms by their ability to form gas from lactose at 44^0C (Sleigh and Duguid, 2004).

Escherichia coli is one of the most frequent causes of some of the many common bacterial infections such as traveller's diarrhea and other clinical infections like urinary tract infections (UTI) and cholecystitis. Diarrhea caused by toxin producing *E.coli* is the major cause of infant mortality in developing countries (Roger *et al*, 1988). Contaminated food and water are the major means by which the bacteria spread. As a cause of entric infections, six different mechanisms of action of six different varieties of *Escherichia coli* have been reported (Chi Hiong and Burke, 2006).

E. coli is very sensitive to disinfection; its presence in water sample is a sure sign of major deficiency in the treatment or integrity of the distribution system (Lechevallier *et al*., 2003). However its absence does not by itself provide sufficient assurance that the water is free from microbial pathogens.

2.3 The Burden of Water Borne-Diseases

The number of outbreaks of diseases that have been reported throughout the world demonstrates that transmission of pathogens by drinking water remains a significant cause of illness. Water related diseases continued to be one of the major health problems and accounted for one-third of intestinal infections globally (Oladipo *et al.*, 2009; Hunter, 1997). According to Edwin, (2009), the intake of unclean water could cause devastating microbial diseases with serious effects on human health. Idakwo and Abu (2004) reported that a wide variety of micro-organisms pathogenic to human beings are transmitted through contaminated water.

Mortality and morbidity from water borne diseases are very high. High prevalence of diarrhea amongst children and infants can be traced to the use of unsafe water and unhygienic practices. It is estimated that 150 000 to 200 000 children are lost to diarrhea related death in Nigeria (National Research Council, 1987). The World Health Organization (WHO, 1996) estimates total mortality from diarrheal diseases at over 3 million cases in 1995, with more than 80% among children under five years old. Diseases contracted through drinking water kills about 5 million children annually and make one-

sixth of world population sick (WHO,2004). Furthermore, WHO,(2007) reported that some 20,000 people die every day from water related diseases like typhoid and paratyphoid fever, cholera, bacillary dysentery and gastroenteritis.

Food- borne outbreaks of infectious diseases originate from food preparation with contaminated water. Low levels of pathogens in drinking water may rapidly multiply to infections doses when associated with food.

Besides causing death, water- related diseases also prevent people from working and leading active lives.

2.4 Some Drinking Water Quality Parameters

Water quality must be assess to prevent infections from water-borne diseases such as bacteria, protozoa, and many other organisms related to water, as well as any other undesirable substance that may affect the quality of the water.

Drinking water or potable water is water of sufficiently high quality that can be consumed or used with-out risk of immediate or long term harm (Greenhalgh, 2001). 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).

All physico-chemical parameters have been documented as National Secondary Drinking Water Regulation (NSDWR), and they are non-enforceable guidelines regulating contaminants that may cause serious effect in drinking water (EPA, 2002). However, the presence of bacteria (total coliform, faecal coliform, and *E. coli*) have been documented as National Primary Drinking Water Regulations (NPDWRs) or primary standards which protect public health by limiting the levels of contaminants in drinking water (EPA, 2002). Physical, chemical, and bacteriological parameters are therefore the main measures in assessing water quality. The physical characteristics of drinking water by themselves could sometime be indicators of the chemical and microbiological quality of the water (Denloye, 2004). Physical parameters include temperature, PH, turbidity, etc, chemical parameters include conductivity, chloride, total hardness to mention but a few while bacteriological parameters include total coliform bacteria, and specific pathogenic species of bacteria such as *E. coli.* Physico-chemical parameters affect the aesthetics and

taste of the drinking water and may complicate the removal of microbiological pathogens, however, they are not as sensitive as the bacterial parameters which are of greater concern because of their immediate health risk (EPA, 2010).

2.4.1 Temperature and Potable Water

Temperature is basically important for its effect on other properties, for example, speeding up chemical reactions, reduction in solubility of gases, amplification of taste and odour etc (Tebutt, 1982). It is widely recognized as an important controlling factor in influencing bacterial growth. According to WHO (1996), the microbiological characteristics of water are related to temperature through its effects on both growth and survival of micro-organisms. Consequently, growth of nuisance microorganisms is enhanced by warm water conditions and could lead to the development of unpleasant taste and odours. Prescott *et al.* (1999), reported 20 – 45^0C as optimal growth temperature for mesophilic microorganisms.

2.4.2 pH and Potable Water

The pH of a solution describes its hydrogen-ion concentration (Lehr *et al.*, 1980). pH is one of the parameters that addresses the aesthetic quality of water such as taste, which has no serious health significance (WHO, 1996). Practically every phase of water treatment such as softening, precipitation, coagulation, disinfection and corrosion controls are pH depended (APHA, 1985).

A pH of 7 is neutral, pH of less than 7 indicates acidity, and a pH higher than 7 indicates alkalinity. 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).

2.4.3 Turbidity and potable water

Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye (Encarta, 2009). In other words, turbidity is the measure of the relative clarity of a liquid. Turbidity is caused by suspended matter or impurities that interfere with the clarity of the water. Typical sources

of turbidity in water include; high ion concentrations which give water a rust-red coloration (mainly ground water and ground water under the direct influence of surface water, air bubbles and particles from the treatment process e.g. hydroxides, lime softening etc. Turbidity in drinking water may also increases as a result of decreased in effectiveness of the coagulation-filtration process or as a result of placing filters back into service without being back washed. Clarity is important when producing water for consumption and in many manufacturing uses. Turbidity is mostly an aesthetic characteristic of drinking water, significant evidence exists that controlling turbidity is a competent safeguard against pathogens in drinking water.

WHO, (2003) established that the turbidity of drinking water should not be more than 5 NTU, and should be below 1 NTU. High turbidity is often associated with higher levels of disease causing microorganisms such as bacteria and other parasites (Shitu *et al.,* 2008). In drinking water, the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases.

2.4.4 Conductivity and potable water

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminium cations. Conductivity increases as the concentration of ions increases. Solutions of most inorganic compounds and more abundant ions have higher conductivity (APHA, 1985).

Water conducts electricity because it contains dissolved solids that carry electrical charges. This dissolved solid affects the water's ability to conduct electricity. Therefore, measuring the conductivity of the water indirectly indicates the amount of total dissolved solids (TDS) in the water. Significant changes in conductivity can be an indicator that a discharge or some other source of pollution has entered the water.

Conductivity is also affected by temperature, the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25^{o}C (EPA, 2002).

2.4.5 Chloride and Potable Water

Chloride ions are non-cumulative toxins, however, if an excess amount is taken over a period of time, can constitute a health hazard (Oyelude and Ahenkorah, 2012). Chloride has been used in the past as an indicator of water pollution, in as much as a sudden increase in cl^- is an indication of possible sewage introduction into the water supply. It is recommended that water supply should contain <250 mg/L of cl^-, however, people who are acclimatized to it can use water with even higher concentrations (APHA, 1985).

2.4.6 Total Hardness and Potable Water

The total water hardness is the sum of the molar concentrations of Ca^{2+} and mg^{2+}, in mol/L or mmol/L units. WHO (2003), says that there is no convincing evidence that water hardness causes adverse health effects in human. In fact, the National Research Council (1987) has found that hard water can actually serve as a dietary supplement for calcium and magnesium. It has been suggested that moderately hard water containing sufficient calcium is essential for normal growth and health. However, high values of hardness arising from elevated levels of magnesium sulphate are undesirerable (Dodoo *et al*., 2006).

2.5 Bacteriological Quality of Drinking Water

The investigation of the bacterial quality of water is designed to assess the total coliform content which has been used as the primary indicator bacteria for the presence of disease causing organisms (PHLS, 2000; APHA, 1992, PHLS/SCA, 1981). It is impracticable to monitor drinking water for every possible microbial pathogen (Sunday *et al.*, 2011). Therefore a more logical approach is the detection of organisms normally present in the faeces of man and other animals as indicators of faecal pollution, as well as indicators of the efficiency of water treatment and disinfection. The term “indicator organisms” refers to the organisms, whose presence in water is evidence that the water is polluted with, among other things, faecal material from human or other warm-blooded animals (Pelezar *et al.*, 1989). The term has also been variously defined as those bacterial groups or species whose presence in water above certain numerical limits, indicates exposure to conditions that might introduce hazardous organisms and/ or allow the proliferation of pathogenic or toxigenic species (APHA, 1985, Food and Agricultural Organization, FAO,

1979; Refai, 1979). Some of the important characteristics of an indicator organism are as follows:

a) It is present in polluted waters and absent from unpolluted (potable) waters.

b) It is present in waters when pathogens are present.

c) The quality of indicator organism correlates with degree of pollution.

d) It survive better and longer than the pathogens.

e) It has uniform and stable properties.

f) It is generally harmless to humans and other animals (Pelezar *et al.*, 1989).

The occurrence of pollution indicator bacteria (PIB), i.e. total and faecal coliforms is used as a sanitary parameter for evaluating the quality of drinking water (WHO, 1996; Jazrawi and Hindawi, 2011). It is also known that these indicators are associated with disease causing genera of importance to public health (Armstrong *et al.*, 1981). The following groups have been used as bacterial indicator organisms in microbiological evaluation of the quality of drinking water.

2.5.1 Aerobic Mesophilic Bacteria

The aerobic mesophilic bacterial plate count is one of the most useful tools for determining the microbiological status of waters. A high bacteria count often indicates contamination of water from faecal sources. Frequent examinations for faecal indicator organisms remain the most sensitive and specific way of assessing the hygienic quality of waters (WHO, 1993). The standard plate count provides a means of determining the density of aerobic and facultatively an aerobic heterotropic bacteria in water and it is the best available measure of water treatment plant efficiency (APHA, 1985).

The plate count is also of value in indicating whether a particular supply is suitable for use in the preparation of food and drinks, where a high bacterial content may lead to food spoilage. The advantage of the plate counts for this purpose, however, is that it gives a direct assessment of the number of viable bacteria in the supply (APHA, 1985). A high aerobic mesophilic count does not in itself present a risk to human health (WHO, 2002) nevertheless; they are used as good indicators of the overall quality of production (Oyedeji *et al*., 2010).

According to WHO, (1985) drinking water sample would be regarded as likely to be contaminated if it contains total viable counts up to 10^4cfu/ml.

2.5.2 Total Coliform

Total coliform bacteria are commonly found in the environment such as soil or vegetation and are generally harmless. A negative total coliform bacteria results means the water is safe for human consumption from a bacteriological standpoint. Although total coliforms detected in water samples indicates unsanitary conditions and do not necessary mean that the water is contaminated but an indication of danger to the health of consumers of the water. If only total coliform bacteria are detected in drinking water, the source is probably environmental, and fecal contamination is not likely. However, if environmental contamination can enter the system, there may be a way for other pathogens to enter the system. It is important to determine the source and resolve the problem (Washington State Department Of Health, 2006).

2.5.3 Fecal Coliform

Fecal coliform bacteria are a sub-group of the total coliform group. They appear in great quantities in the intestines and feaces of people and animals. The presence of fecal coliform in a drinking water sample often indicates recent fecal contamination meaning that there is a greater risk that pathogens are present than if only total coliform bacteria are detected (Washington State Department Of Health, 2006).

2.5.4 *E.coli*

Most *E.coli* are harmless and are found in great quantities in the intestines of human and warm blooded animals. Some strains, however, may cause illness. The presence of *E.coli* in a drinking water sample almost always indicates recent fecal contamination meaning that there is a greater risk that pathogens are present. Treated water should therefore not contain this organism because it is an indicator microorganism for other pathogens that may be present in faeces (USEPA, 2006). Most outbreaks have been related to food contamination, covered by a specific strain of *E.coli* known as *E.coli* O157:H7 which can cause serious illness and death.

2.6 Contamination of Water

Increasing population has placed ever greater burden on water supplies, both in terms of quantity, quality, demand, as well as contamination potential due to increased human activity on watersheds and chemical waste disposal into waters, forcing use of less

desirable supplemental raw water sources, which stress existing treatment effectiveness (Edwin, 2000). Waste water, feedlots, storm water, runoff and other human activities often discharge to a water source or sources for public supply, even the most pristine watershed can be potentially contaminated by animals with human pathogens (Edwin, 2000). Consequently, contamination of water is an important mode of transmission of various diseases.

2.6.1 Some Possible Sources of Sachet Water Contamination

Several studies have been carried out to analyze the sources of sachet water contamination. Sachet water contamination could be influenced by many factors such as the raw water source, inadequate treatment process such as improper use of filters, hygienic practices observed during production, improper storage and handling of the sachet water, among others. Adekunkle *et al*., (2004) and Dada (2008), have questioned the quality of sachet waters, unhygienic, environments where they are produced and also non adherence to NAFDAC guidelines. Nwosu and Ogueke (2004), reported that the sources of contamination of sachet water could be the main water source because some unscrupulous producers just packaged and seal pipe-borne water without any form of treatment. The bacterial quality of sachet water was investigated at point of sale in South-Western Nigeria using standard microbial procedures; the results showed that 87% of the packaged water samples were untreated or produced under unhygienic conditions. The study also showed that about 65% of the polythene sachets used was not food-grade quality. High aerobic colony counts on the order of 10^6 were recorded from 93% of sample examined. Poorly maintained filter systems are also a possible source of contamination because bacteria can grow on filters if they are not changed regularly, and thereafter enter the water supply. Onifade and Ilori, (2008); Dada, (2008) and Adewaje *et al.*, (2011), reported that sachet water were contaminated as a result of poor handling of the products by the producers and vendors. Al-Lahham *et al*., (1990); Bonner *et al.*, (2001), Daniel *et al*., (2002), and Michael *et al*., (2002) have identified improper handling as the source of infection in food and water borne diseases in several countries and for different types of micro-organisms. In a study carried out in Lagos, enteric pathogens and *E.coli* were not isolated from any samples and brands of sachet water but formed a significant part of the isolates on the sachet surfaces of samples collected from the cooling receptacles (pail, wheel barrow, and refrigerator) (Egwari *et al.*, 2005).

CHAPTER THREE

3.0 Materials and Methods

3.1 Description of Study Area

Kano state has a population density of nine million, four hundred and one thousand two hundred and eighty eight people National Population Commission (NPC), 2006. It covers an area extending between latitude $12^0$40' and $10^0$30' and longitude $7^0$40' and $9^0$40'. The state is characterized by two seasons: the rainy season, which last from May to September, and the dry season that lasts from October to April. The mean annual temperature is between 16 – 47^0C and the mean annual rainfall ranges from 700 to 1160mm Alhassan *et al.*, (2008). Climate variations result in four distinct periods:

i) **Hot and Dry period**: This period run between February to May.

ii) **Warm and Wet Period**: This is a humid period during which soil moisture becomes sufficient for plant growth, grains and legumes are favoured, and it falls around June to September.

iii) **Warm and Dry Period**: Few showers are recorded during this period which sets in around October and ends in December. Farmers are usually busy harvesting crops during this season. During this period, soil moisture is depleted and stream flow recedes.

iv) **Cold and Dry Period**: This period results in cool and dusty weather commonly referred to as "harmattan" and is between December and February.

3.1.1 Description of the Sampling Sites

Sachet water samples were randomly purchased from different sachet water factories in six local government areas of Kano metropolis. The local government areas include: Gwale, Tarauni, Fagge, Dala, Nassarawa and Kano Municipal. The sampling sites were chosen based on the population density of the state.

Site 1 (Gwale Local Government Area)

Gwale local government area lies between latitude 11.977473^0 and longitude 8.406540 and is located to the South-west of Kumbotso, west of Ungoggo local government area and east of Municipal local government area of the State.

Site 11 (Tarauni Local Government Area)

Tarauni local government lies between latitude 11.965353^0 and longitude 8.566175 . Tarauni local government area was carved out of the former Municipal local government area of Kano State. It shares boundary with Nassarawa local government area to the north- East, Kumbotso to the South-east and Municipal to the West.

Site 111 (Fagge Local Government Area)

Fagge local government area lies between latitude 12.037976^0 and longitude 8.523243 and shares boundary with Dala local government area to the north-west, Kano Municipal to the South and Nassarawa local government to the north-East.

Site 1V (Dala Local Government Area)

Dala L.G.A lies between latitude 12.004720^0 and longitude 8.498337 and is situated at the North West of Ungoggo local government area. It shares boundary with Gwale local government to the South-west and Fagge local government to the north-east.

Site V (Nassarawa Local Government Area)

Nasarawa local government lies between latitude 12.001453^0 and longitude 8.567122. It is situated to the north of Kano Municipal. It shares boundary with Tarauni local government area to the South-east, and Fagge to the north.

Site V1 (Kano Municipal Local Government Area)

Kano Municipal lies between latitude 11.986288^0 and longitude 8.523439 and is located at the south-east of Tarauni local government area. It shares boundary with Kumbotso to the south-west and Fagge to the north East (Figure1).

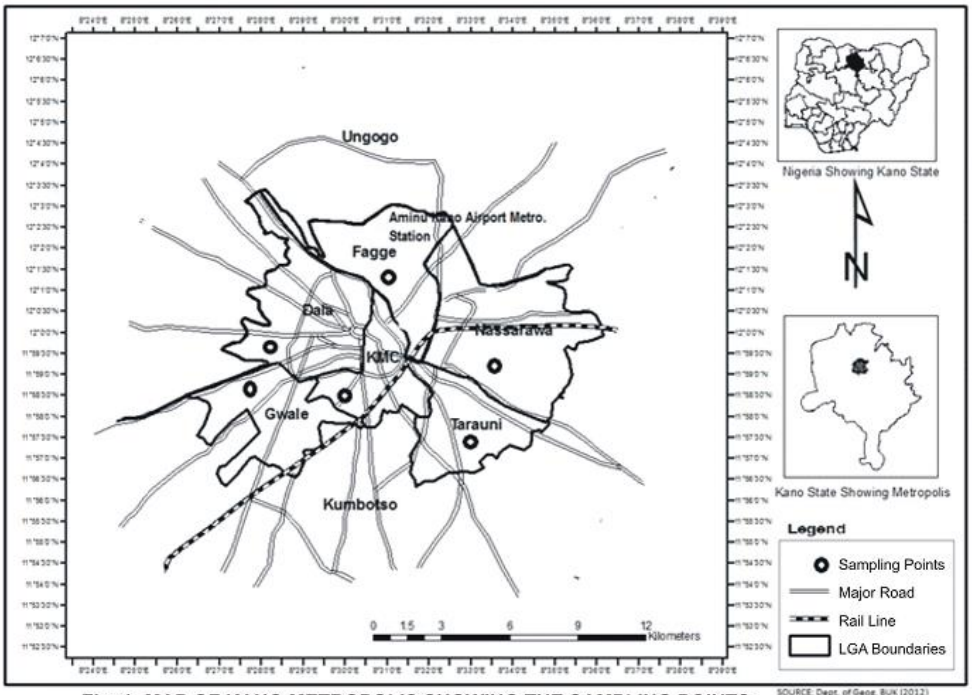

Fig. 1: MAP OF KANO METROPOLIS SHOWING THE SAMPLING POINTS

Adopted from the Department of Geography, B.U.K 2012

3.2 Sample Collection

A total of 1080 samples of sachet water were purchased from sixty different brands of sachet water factories (i.e. 30 NAFDAC registered and 30 non-NAFDAC registered) for a period of six months (June-November, 2012) from six local government areas in Kano metropolis. The samples were purchased immediately after production of the sachet water and were labeled appropriately and taken to the laboratory in insulated containers with ice packs. Analysis was carried out within 4 hours after sampling, where immediate microbiological evaluation was delayed; the samples were refrigerated at 4^0C and analyzed within 24 hours of collection as prescribed by Lisle, (1993).

3.3 Determination of Physical Parameters

3.3.1 Temperature

The temperature of the water samples were measured as described by (APHA, 1998). The temperatures were measured in the storage room immediately after production of the sachet water with a pH meter model 8681. This instrument was supplied with a fully integrated pH/temperature electrode with pH accuracy of ± 0.2. The electrode of the pH

meter was rinsed in distilled water and blot dried. It was then immersed into the water sample for 30 seconds until the reading was maintained, and the temperature reading recorded from the meter scale.

3.3.2 Hydrogen Ion Concentration (pH)

The pH of the water samples were measured in the storage room with a pH meter model 8681. This instrument was supplied with a fully integrated pH/temperature electrode with pH accuracy of ± 0.2. The electrode of the pH meter was rinsed in distilled water and blot dried. It was then immersed into the water sample for 30 seconds until the reading was maintained, and the pH reading recorded from the meter scale (APHA, 1998).

3.3.3 Turbidity

This was determined in the laboratory using a turbidity meter model LP 2000. This instrument was supplied with a small glass tube that has a lid inserted inside a hole on the meter. The tube was removed from the hole and filled with distilled water; the lid was replaced tightly on the tube. The tube was then inserted into the hole on the meter. The reading button was pressed, and the reading was taken after it was maintained on the meter scale. The tube was removed from the hole and the distilled water was poured out. The water sample was poured into the tube, the lid was replaced and the tube was inserted into the hole on the meter. The reading button was pressed and the reading was subtracted from the initial reading of the distilled water (Hanna Instruments, 2004).

3.4 Determination of Chemical Parameters

3.4.1 Total Hardness

Total hardness was determined by ethylenediamine tetra acetic acid (EDTA) titrimetric method as described by APHA, (1998). In this method, fifty milliliters of each water sample in a 250 ml flask was mixed with 1 ml of NH_4 Cl – NH_4OH buffer and 2 ml of Solochrome black "T" indicator and titrated with 0.02N EDTA to a blue end point. Total hardness was calculated with the expression:

$$\text{Total hardness (mg/L)} = \frac{A \times 100}{50}$$

Where A = Titre value.

3.4.2 Chloride

This was determined by titration method as described by AOAC, (2000), where 100ml of the water sample was measured and poured into a conical flask. Two drops of potassium chromate indicator was added and then shaken. It was then titrated against 0.025M silver Nitrate ($AgN0_3$). The end-point of the titration was given by a red colour of the silver chloride precipitate. Titration was repeated on a further two 100ml water samples and the average of the mean volume of silver nitrate used was calculated and recorded.

$$\text{Chloride } cl^- \text{ in mglL} = \frac{A \times M \times 35.45 \times 1000}{\text{Sample Volume}}$$

Where A = Titre value

M = Molarity of titrant ($AgNO_3$)

3.4.3 Electrical Conductivity (EC)

This was measured in the laboratory by following the protocol of APHA, (1998). In this method, a conductivity meter Hatch model (0150) was used. This metre measured the current passing through a solution between two electrodes in the probe. The electrodes were standardized in distilled water and placed into the water samples for 20 seconds and the reading was recorded in microsiemens per centimeter (µs/cm).

3.5 Determination of bacteriological parameters

3.5.1 Enumeration of Aerobic Mesophilic Bacterial Count

This was carried out according to the protocol of Refai, (1979). In this method, one end of each sample of the sachet water was cleansed with 70% ethanol. A sterile pair of scissors was used to cut opened the water sample at the sterilized end. One milliliter (1ml) of the sample was aseptically dispensed into a test tube containing 9.0ml of sterile distilled water and labeled 1:10. From this tube, 1.0ml was dispensed after agitation into another tube containing 9.0ml of sterile distilled water and labeled 1:100. This was also agitated and from it 1.0ml was dispensed into another tube containing 9.0ml of sterile distilled water and labeled 1:1000 and the procedure was repeated up to $1:10^5$. Using sterile pipette 1.0ml of inoculum was transferred from the dilution tubes into duplicate Petri dishes. This was followed by pouring of a warm molten nutrient agar (Oxoid). The plates were then gently rocked on a flat surface and allowed to solidify, and finally

incubated at 37^0C for 24 hours. Following 24 hours incubation plates containing 30 – 300 colonies were selected and counted and the number multiplied by the inverse of dilution factor to get the number of colony forming unit per ml (cfu/ml).

3.5.2 Enumeration of Total Coliform

The multiple tube fermentation technique was used for the enumeration of total coliform bacteria, as recommended by Refai, (1979). Each sample was inoculated into 3 sets of tubes as follows; 10ml of each sample inoculated into five tubes containing 10ml of sterile double strength lactose broth with inverted Durham tubes. Then, one ml of each sample inoculated into five tubes each containing 5ml of sterile single strength lactose broth with inverted Durham tubes. Then 0.1ml inoculated into five tubes each containing 5ml of sterile single strength lactose broth with inverted Durham tubes. The tubes were incubated at 37^0C for 24 hours. Following incubation, tubes showing gas production were counted and compared to MPN table adapted from APHA, (1992) for the determination of most probable number (MPN) of coliforms.

3.5.2.1 Confirmation of Coliform Bacteria

For the confirmation of coliform bacteria, the protocol of Refai, (1979) was also adopted, in this method a loopful of broth from gas positive tubes was streaked onto eosin methylene blue (EMB Antc UK) agar plate and incubated at 37^0C for 24 hours. The plates were observed after 24 hours for the presence of bluish black colonies with green metallic sheen which confirms the presence of coliform bacteria. Colonies that formed green metallic sheen on EMB were bio-chemically characterized to be E.*coli* using indole, methyl red, vogers proskauer and citrate tests.

3.5.2.2 Isolation and Characterization of *E.coli*

Imvic Reactions: (1 = Indole, M = methyl red, vi = vogers = proskauer and C = citrate). This is a test where E.*coli* can be differentiated from other coliform group such as Enterobacter aerogenes.

Indole Test

This was carried out according to the protocol of Bankole and Shuaibu, (2008). In this method, 5ml of peptone water was inoculated with a loopful of the test sample and incubated for 24 hours. After 24 hours, 3 drops of Kovacs indole reagent was added and shaken gently. A positive reaction is indicated by the development of a red colour in the reagent layer above the broth within 1 minute. In a negative reaction, the indole reagent retains its yellow colour.

Methyl Red Vogers Proskauer Test

This was carried out as recommended by (Mackie and McCartney, 2004, Bankole and Shuaibu, 2008). In this method, 5ml of MR-VP broth culture of 2 days incubation was inoculated and incubated for 48 – 72 hours at 35^0C. One ml of the broth was transferred to a small serological tube, 2 – 3 drops of methyl red was added to the broth. A red colour indicates high acidity (pH 4.4) showing E. *coli* ,a yellow colour indicated much less acidity. To the remaining 4ml of the broth in the original tube, 5 drops of 40% potassium hydroxide (KOH) was added, followed by the addition of 15 drops of 5% Naphthol in ethanol. It was shaken and the cap of the tube was loosen and placed in a slopping position. The development of a red colour in about 2-5 minutes indicated a positive reaction. Vogers-proskauer negative test showed no colour change.

Citrate Utilization Test

This was carried out according to the method described by Matsen and Sherris, (1999), Longmore *et al*., (2002), Cowan and Steal, (2008). In this method, Sterile Simmon's citrate medium slant/broth was inoculated with a loopful of the test sample and incubated at 37^0C for 24 hours and sometimes to 96 hours to clear doubts. Positive test showed growth with intense blue colour on the slant. Negative result showed no growth with no change in colour.

3.6 Data Analysis

The physico-chemical parameters, Aerobic mesophilic bacterial count, and total coliform count of both the NAFDAC and the non- NAFDAC registered sachet water samples were evaluated with the statistical program for the social sciences (SPSS), version 15.0 for windows 2003. The mean, standard deviation (S.D) and t- test were used to summarize the physico-chemical and bacteriological qualities of the sachet waters under study.

CHAPTER FOUR

4.0 Results and Statistical Analyses

4.1 Physico-Chemical Analysis of the NAFDAC Registered Sachet Water Samples

Table 1 shows the mean values of physico – chemical parameters of the NAFDAC registered sachet water samples. The mean temperature ranged was lowest (25.5^0C) in samples 28x and 30x, and the highest (29.1^0C) was recorded in samples 14x. The mean PH value ranged between (5.7) in sample 27x and the highest (8.1) in sample 2x.

Sample x have the lowest turbidity of (0.1 NTU) and the highest (2.6 NTU) was recorded in sample 12x. The lowest conductivity (11.0µ/cm) was recorded in sample x with the highest (154.6µ/cm) in sample 2x. The lowest chloride content (23.0mg/L) was found in sample 2x with the highest (58.0mg/L) in sample x. Total hardness falls between the range of (2.0mg/L) in sample x and (45.3mg/L) in sample 2x (Table 1).

4.2 Physico-Chemical Analysis of the non- NAFDAC Registered Sachet Water Samples.

Table 2 shows the mean values of physico – chemical parameters of the non-NAFDAC registered sachet water samples. The temperature range falls between the range of (24.5^0C) in samples 6y and (30.6^oC) in sample 16y. The PH range recorded was (5.0) in sample 17y with the highest (8.6) in sample 2y. Sample 20y has the lowest turbidity (0.1NTU) while sample 4y (3.8 NTU) has the highest turbidity. The lowest conductivity recorded was found in sample 20y (70.3 µs/cm) with highest (207.3 µs/cm) in sample 22y. The lowest chloride content of (15.0mg/L) was recorded in samples 4y, 13y, 22y, and 28y with the highest (47.9 mg/L) in sample 20y. The mean total hardness of the water samples ranged between (4.5.mg/L) in sample 20y and the highest (46.1mg/L) in sample 22y.

4.3 Bacteriological Analysis of the NAFDAC Registered Sachet Water Samples

The mean Aerobic mesophilic bacterial count of the NAFDAC Registered Sachet Water Sample ranged between (0cfu/ml) in samples x, 15x, 16x, 19x and 21x to (2.68 X 10^2 cfu/ml) in samples 2x and 10x. While the coliform count from the MPN index ranged between < 2 in samples x, 13x, 15x, 16x, 19x, and 21x to 7 in samples 5x, 10x, 11x, 12x, 22x, 24x, and 25x (Table 3).

4.4 Bacteriological Analysis of the non- NAFDAC Registered Sachet Water Samples

The mean Aerobic mesophilic bacterial count of the non - NAFDAC Registered Sachet Water Samples however reveals the ranged of (0cfu/ml) in sample 20y to (2.92 X10^2 cfu/ml) in sample 6y. The coliform count from the MPN index of the non - NAFDAC registered water samples range between <2 in sample 20y to 9 in samples 3y, 5y, and 6y (Table 4).

4.5 Table 5 indicates the level of significance of the physico-chemical parameters of the NAFDAC registered sachet water and the non-NAFDAC registered sachet water when subjected to student distribution Test (t-test). The calculated values of temperature, pH, turbidity, conductivity, chloride and total hardness (-0.687, -0.815, -4.400, -4.778, -10.182 and -3.204) respectively are less than the critical value (9.925). Therefore, there is no significant difference between all the physico-chemical parameters at 0.01% (P<0.01).

Table 5: The Level of Significance of the Physico-Chemical Parameters of the NAFDAC and the non-NAFDAC Registered Sachet Water Samples in Kano Metropolis, 2012

Water parameter	Status	N	Mean	STD	Df	Tcal.	Tcri	Level of Significance
Temperature	NAFDAC Registered Water	30	26.577	0.789	2	-0.687	9.925	NS
	non-NAFDAC ssRegistered Water	30	26.370	1.446		-0.687		
pH	NAFDAC Registered Water	30	7.233	3.678	2	-0.815	9.925	NS
	non-NAFDAC Registered Water	30	6.667	0.993		-0.815		
Turbidity	NAFDAC Registered Water	30	0.900	0.560	2	-4.400	9.925	NS
	non-NAFDAC Registered Water	30	1.603	0.673		-4.400		
Conductivity	NAFDAC Registered Water	30	81.290	32.614	2	-4.778	9.925	NS
	non-NAFDAC Registered Water	30	1.249	37.866		-4.778		
Chloride	NAFDAC Registered Water	30	27.693	5.062	2	-10.182	9.925	NS
	non-NAFDAC Registered Water	30	46.893	9.000		-10.182		
Total Hardness	NAFDAC Registered Water	30	21.897	10.405	2	-3.204	9.925	NS
	non-NAFDAC Registered Water	30	30.000	9.143		-3.204		

Key: STD – Standard deviation, NS – No significant difference
Tcal – Calculated value, Tcri – Critical value

4.6 Table 6 indicates the level of significance of aerobic mesophilic bacterial count of both the NAFDAC and the non-NAFDAC registered sachet water samples. The calculated value (4.578) is greater than the critical value (2.326). Therefore there is significant difference between the NAFDAC and the non-NAFDAC registered sachet water samples.

Table 6: Aerobic Mesophilic Bacterial Count of the NAFDAC and the non-NAFDAC REGD Sachet Water Samples in Kano Metropolis, 2012

Test	Status of water labeled	N	Mean	STD	Df	Tcal.	Tcri	Level of Significance
Aerobic Mesophilic Bacterial Count (cfu/ml)	NAFDAC REGD Water	30	2.327	0.490	58	4.578	2.326	SD
	non-NAFDAC REGD Water	30	1.560	0.777		4.578	2.326	

Key: STD – Standard deviation, SD – There is significant difference
Tcal – Calculated value, Tcri – Critical value

4.7 Table 7 indicates the level of significance of coliform count of both the NAFDAC and the non-NAFDAC registered sachet water samples. The calculated value (2.051) is less than the critical value (2.326). Therefore there is no significant difference between the NAFDAC and the non-NAFDAC registered sachet water.

Table 7: Coliform Counts of the NAFDAC REGD and the non-NAFDAC REGD Sachet Water Sampled in Kano Metropolis, 2012.

Test	Status of water labeled	N	Mean	STD	Df	Tcal.	Tcri	Level of Significance
Coliform Count	NAFDAC Registered Water	30	3.033	1.066	58	2.051	2.326	NS
	non-NAFDAC Registered Water	30	2.467	1.074		2.051	2.326	

Key: STD – Standard deviation, NS – No significant difference
Tcal – Calculated value, Tcri – Critical value

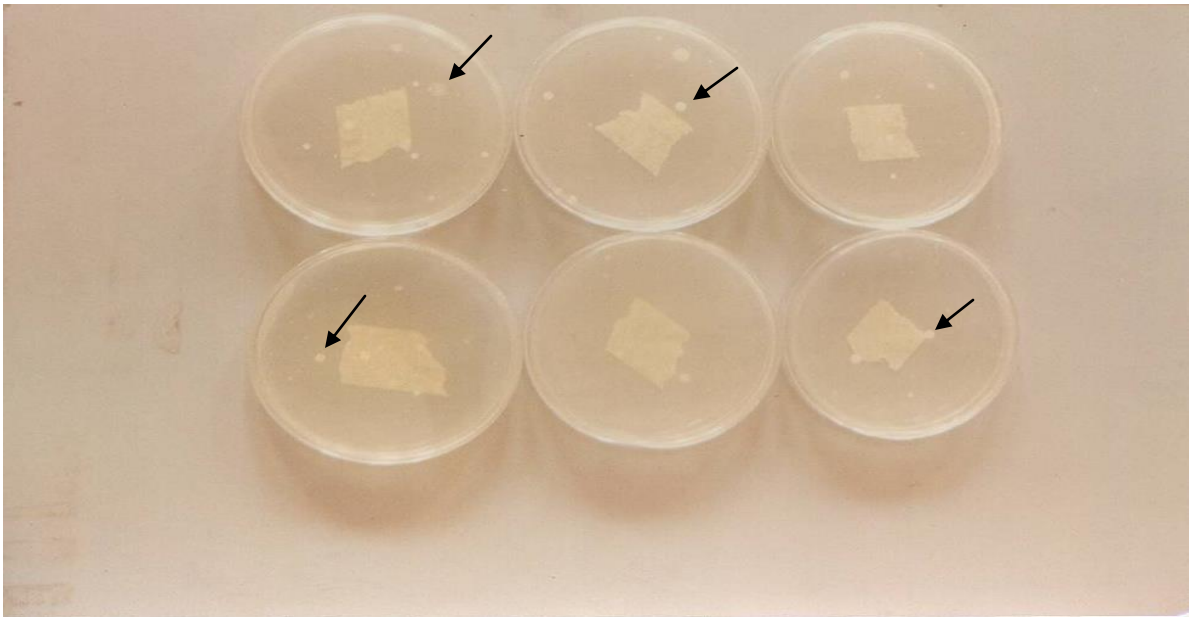

Plate 1: Aerobic Mesophilic Bacterial Plate Count of the NAFDAC Registered Sachet Water Sample showing positive result in Fagge Local Government Area, 2012.

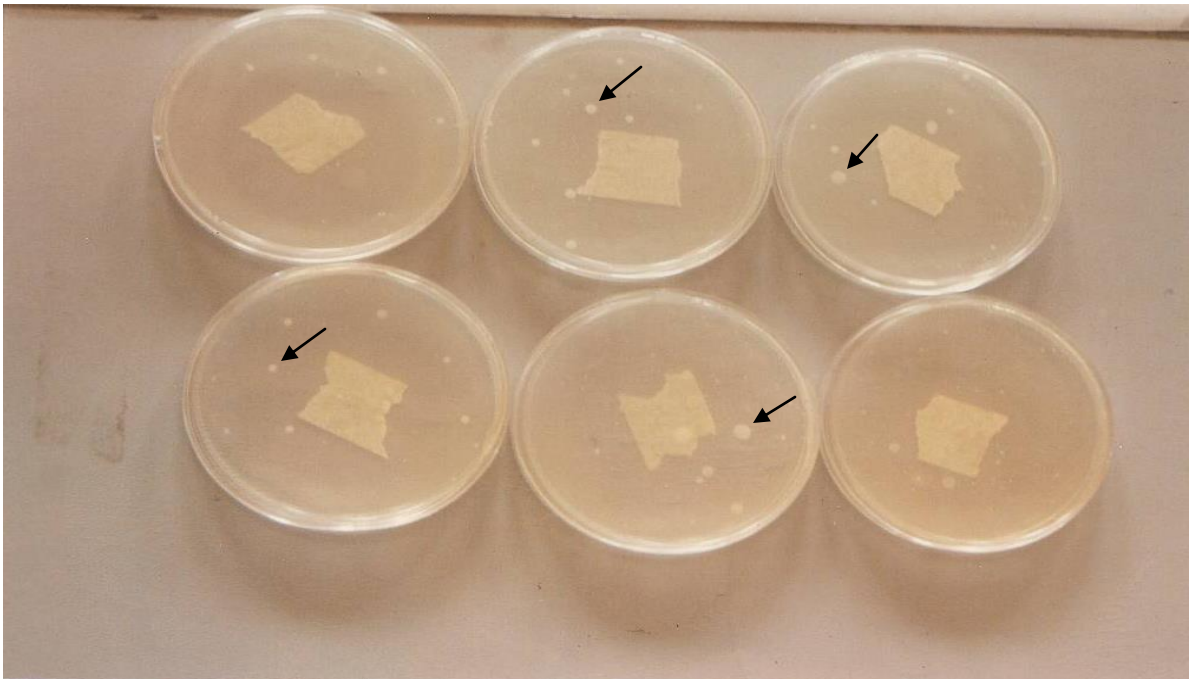

Plate 2: Aerobic Mesophilic Bacterial Plate Count of the non- NAFDAC Register Sachet Water Sample showing positive result in Fagge Local Government Area 2012.

CHAPTER FIVE

5.0 Discussion, Conclusion and Recommendations

5.1 Discussion

5.1.1 Analyses of Physico-Chemical Parameters of the NAFDAC and the non-NAFDAC registered Sachet Water Samples.

The mean temperature range of the NAFDAC registered sachet water samples falls within the range of 25.5^0C in samples 28x and 30x to 29.1^0C in sample 14x. While that for the non-NAFDAC registered sachet water samples falls within the range of 24.5^0C – 30.6^0C in samples 16y and 6y respectively. The temperature values obtained for both the NAFDAC and the non-NAFDAC registered sachet water samples in this study fall within the optimal growth range for mesophilic bacteria including human pathogens.

The range of this finding is slightly higher than that of Taiwo *et al*. (2012) of 25.10^0C – 27.70^0C reported in Abeokuta metropolis. The findings is also higher than that of Emmanual and Solomon,(2012) whom reported temperature range of 26.0 – 27.5^0C.

The pH range of the NAFDAC registered sachet water samples falls within the range of 5.7 in sample 27x and 8.1 in sample 2x. While the range of 5.0– 8.6 were recorded in samples 17y and 2y respectively for the non-NAFDAC registered sachet water samples. The highest pH recorded (8.6) in sample 2y is slightly basic, while the lowest value of 5.7 recorded is acidic and does not fall within the limit set by NAFDAC, (2004), NIS, (2008), and WHO, (2003). The pH range of this finding is similar to the findings of Alhassan *et al.* (2008) whom recorded mean pH range of 4.68 – 8.8 in his study. Dodoo *et al.* (2006) recorded pH range of 6.25 – 7.93 in their findings. Furthermore, Emmanuel and Solomon, (2012) reported pH range of 8.32 – 7.52 in their findings of quality of sachet and bottled water in Bolgatanga Municipality of Ghana.

The turbidity range of the NAFDAC registered sachet water samples falls within the range of 0.1 – 2.6 NTU in samples x and 12x respectively and for the non-NAFDAC registered sachet water samples the range is within 0.1– 3.8 NTU in samples 20y and 4y respectively. All the values above falls within the limit set by all the regulatory bodies mentioned earlier of 5 Nephelometric Turbidity Unit (NTU).

The result of this finding is lower than the range recorded by (Taiwo *et al*., 2012) of 0.30–4.13 NTU. However, the turbidity of this finding is higher than the findings reported by Oyeku *et al. (*2001); Nwosu and Ogueke, (2004) in their study of physical characteristics of sachet water sold in Lagos and Owerri respectively. Furthermore, (Onweluzo and Akuagbazie, 2010) revealed zero (0) turbidity in bottled and sachet water sold in Nsukka town. And also (Dodoo *et al.*, 2006) recorded the range of 0.45 – 1.72 NTU in Cape coast municipality of Ghana.

The result of the mean conductivity range of the NAFDAC registered sachet water were within11.0 µs/cm– 154.6 µs/cm in samples x and 2x respectively. While the mean conductivity range of the non-NAFDAC registered sachet water samples were within the range of 70.3 µs/cm in sample 20y and 207.3 µs/cm in sample 22y. All these values fall within the limit set by the aforementioned regulatory bodies of 0 – 1000 µs/cm. Onweluzo and Akuagbazi, (2010) recorded conductivity range of 1.37 – 7.18 µs/cm which was less than the value found in this study. In addition, Oyeku *et al*. (2001); Nwosu and Ogueke, (2004) made similar observations of conductivity with Onweluzo and Akuagbazi, (2010).

The mean range of chloride for the NAFDAC registered sachet water samples falls within the range of 23.1 – 58.8 mg/L in samples 2x and x respectively. However, for the Non-NAFDAC registered sachet water samples, the range is within 15.0 mg/L in samples 4y, 13y, 22y, and 28y and 47.9 mg/L in sample 20y. All these range are in accordance with the range set by all the regulatory bodies mentioned earlier. Alhassan *et al*. (2008) reported the range of 123 – 166 mg/L of chloride which is higher than the range found in this study. Dodoo *et al*. (2006) reported the range of 1.57 – 37.7 mg/L of chloride in sachet water.

The mean range of total hardness falls within the range of 2.0 – 45.3 mg/L in samples x and 2x respectively for the NAFDAC registered sachet water samples. While that for the non-NAFDAC registered sachet water was found to be in the range of 4.5 – 46.1 mg/L in samples 20y and 22y respectively. All these range are in conformity with the range set by all the regulatory bodies mentioned earlier of 100mg/L.

The finding of this study is less than that reported by Dodoo *et al*. (2006) of 88 – 126 mg/L for total hardness. Alhassan *et al*. (2008) reported 0.00 – 66.8 mg/L of total

hardness, while Onweluzo and Akuagbazie, (2010) recorded 2.0 – 6.60 mg/L of total hardness in sachet water.

All the physico-chemical parameters analyzed for both the NAFDAC and the non-NAFDAC registered sachet water falls within the limit set by (NAFDAC, 2004), (NIS, 2008), and (WHO, 2003). This may be as a result of using ion exchange resins to regulate the amount of ions in the water. However, samples 17y (5.0), 16y (5.2), 14y (5.4), 13y (5.3), 12y (5.3), 9y (5.9), 30x (5.9), 27x (5.7), and 14x (5.8) have pH values of <6 and these values are below the recommended limit set by the above regulatory bodies of 6.5-9.5. The low pH found in these sachet water samples may be as a result of unqualified personnel in the sachet water factories.

5.1.2 Bacteriological Analysis of the NAFDAC and the non-NAFDAC Registered Sachet Water Samples

Values of the Aerobic mesophilic bacterial count and coliform count range of the water samples were presented in table 3 and 4 for the NAFDAC registered and the non-NAFDAC registered sachet water respectively. For the mean aerobic mesophilic bacteria count of the NAFDAC registered sachet water samples, it was found that 16.7% of the samples had bacteria count ranged between < 30 cfu/ml in samples 1x, 14x, 15x, 19x and 21x and 53.3% had bacteria count of ($1.13x10^2$-$1.94x10^2$ cfu/ml) in samples 4x, 6x, 7x, 8x, 9x, 13x, 14x, 17x, 18x, 20x, 23x, 25x, 26x, 27x, 28x, and 30x while 30% of the samples had bacteria count range of ($2.09x10^2$ - $2.68x10^2$ cfu/ml) in samples 2x, 3x, 5x, 10x, 11x, 12x, 22x, 24x, and 29x. For the coliform count range, 40% of the NAFDAC registered sachet water samples had the range of <2/100ml, 36.7% had the range of 2-4/100ml and 23.3% had coliform count range of 2-7/100ml.

For the non-NAFDAC registered sachet water samples, 3.3% had < 30 cfu/ml in sample 20y and 96.7% had bacteria count range of ($2.03x10^2$ - 2.92 x 10^2 cfu/ml) in samples 1y, 2y, 3y, 4y, 5y, 6y, 7y, 8y, 9y, 10y, 11y, 12y, 13y, 14y, 15y, 16y, 17y, 18y, 19y, 21y, 22y, 23y, 24y, 25y, 26y, 27y, 28y, 29y and 30y. For the coliform count range of the non-NAFDAC registered sachet water samples, 13.3% had coliform count range of <2/100ml, 30% had the range of 2-4/100ml, 46.6% had the range of 4-7/100ml while 10% had the range of 2-9/100ml. Coliform count higher than 30 exceed the limits set by the regulatory bodies such as NAFDAC, (2004), NIS, (2008), and WHO, (2003). These

showed that most of the NAFDAC and the non-NAFDAC registered sachet water were contaminated with bacteria. However, the NAFDAC registered sachet water samples were less contaminated with bacteria, this could be attributed to better hygienic practices such as well tiled rooms, use of disinfectant, use of adequate filters and UV light observed in the NAFDAC registered factories compared to the non-NAFDAC registered factories. Relatively, high aerobic colony counts are indicative of poor, unhygienic handling and processing, resistance of the pathogens to disinfectants and other water treatment agents.

Abdullahi and Indabawa, (2004) reported the ranges of 0/100ml, 1-2/100ml, and 4/100ml of coliform count in their studies of Microbiological Analysis of some packaged water sold in Kano Metropolis. Furthermore, Indabawa and Wudil, (2001) reported 30% of sachet water samples to have coliform count of <1/100ml, 40% had the range between 1-3/100ml, and 30% of the samples showed coliform count ranging from 4-6/100ml. Waziri, (2010) reported that 55.5% of sachet water analyzed in Damaturu, Yobe state, Nigeria showed coliform count ranging from 0-1/100ml. Total coliform counts of 1 – 7 cfu/ml was reported by Onweluzo and Akuagbazie (2010). A similar study in Osogbo metropolis, compared the MPN values of sachet water, tap water, and well water recorded 0 – 1 cfu/100ml for sachet water which was of good quality (Olowe *et al.*, 2005). Also Ajayi *et al.*, (2008) in their study of packaged drinking waters in Ibadan, reported positive coliform counts in most of the sachet water under study. Total coliforms above the WHO standards were also reported from Port-Harcourt, a study that investigated five different brands of sachet water (Ifeanyi *et al.*, 2006). Banwart, (2004), Edema *et al*., (2001) similarly observed that many brands of water sold in Abeokuta did not meet WHO bacterial standards. Furthermore, in 81 samples of bottled and sachet waters hawked in Ilorin metropolis, 40% failed to meet microbial quality standard (Olayemi, 1999).

The findings compares with a similar study done in Cape coast, which reported that various brands of sachet water produced in the municipality of Ghana were contaminated with coliforms (Dodoo *et* al., 2006).

E.coli was not detected in both the NAFDAC registered and the non-NAFDAC registered sachet water samples. This may be as a result of using UV lights in the sachet water factories.

The finding of this study conforms to the result of Dada, (2008). However, (Ifeanyi *et al*, 2006) reported the presence of *E.coli* from sachet water in Port-Harcourt. Ezeugwanne *et al*. (2009) also reported the presence of *E.coli* in 36% of the water samples analyzed in Nnewi, South-East, Nigeria. NAFDAC, (2004) NIS, (2008), and WHO (2003) stated that no *E.coli* should be detected in any drinking water as its presence in any drinking water poses a serious threat to the health of individual. Dada, (2008) stated that the absence of *E.coli* in the sachet water samples may however be insufficient to justify the purity to the analyzed packaged water.

5.2 Conclusion

From the findings of this research, it can be concluded that all the physico-chemical parameters of the sachet water samples under study met the standards set by NAFDAC, (2004), NIS,(2008) and WHO,(2003) except some samples that have pH of less than 6, and this value is below the recommended unit set by the aforementioned regulatory bodies. The aerobic mesophilic bacteria count of the NAFDAC and the non- NAFDAC registered sachet water samples ranged between <30- $2.92x10^2$cfu/ml. This range falls within the limit set by all the regulatory bodies above of $<10^4$cfu/ml. However, 40% of the NAFDAC registered sachet water samples had coliform count range of <2/100ml which is in conformity with the above regulatory bodies, while 60% of the samples did not conform with the standard sets by the above regulatory bodies and hence not safe for human consumption. While for the non- NAFDAC registered sachet water samples, 0nly 13.3% had coliform count range of <2/100ml and conforms to the standard set by NAFDAC, (2004), NIS,(2008) and WHO,(2003) and 86.7% of the sachet water samples did not conform to the standard set by the above regulatory bodies. This outcome is indeed worrying because of the public health consequences. Therefore, there is need for NAFDAC and other regulatory bodies to intensify efforts in routine monitoring of activities in the sachet water industry.

5.3 Recommendations

From the findings of this research the following recommendations can be made;

1. NAFDAC should ensure strict adherence to good manufacturing practices by all sachet water manufactures.
2. NAFDAC should intensify their efforts on the assessment of water quality of all sachet water in Kano, conduct routine tests on these products and publish regularly the list of producers who have registered their products, and then alert consumers about those with the good quality/safe products.
3. Producers who did not register with NAFDAC should be punished accordingly.
4. Public should make use of only NAFDAC registered sachet water.
5. Producers of sachet water should pay more attention to environmental hygiene and of their personnel.
6. The producers should also provide qualified personnel who can treat and monitor the product to ensure production of safe potable water.

REFERENCES

Abdullahi, B. A. and Indabawa, I. I. (2004): Microbiological Analysis of Some Package Water Sold in Kano Metropolis. *Best Journal* 1(2): 62 – 65

Adekunle, L. V., Sridhar, M.K.C, Ajayi, A.A., Oluwade, P. A. and Olawuyi, J.F. (2004): *An* Assessment of the Health and Socio Economic Implications of Sachet Water in Ibadan *Nigeria*: A Public Health Challenge. *African Journal of Biomedical Research* Vol. 7, pp. 5

Adewaje, S.O., Ogundiran, M.A. and Adebayo, E.A. (2011): Physico-Chemical and Bacteriological Quality of Some Vended Sachet Water Samples in Ilorin, Nigeria. *Journal of Research in Biology* Vol.2, pp. 122 – 128

Ajayi, A. A, Sridhar MKC, Adekunle, L. V, Oluwande, P. A, (2008): *Quality of Packaged Waters Sold in Ibadan Nigeria* 11(3): 251 – 258.

Alexander, K. and Kirscher (2008): Rapid Growth of Planktonic *Vibrio cholera* No. 1 and non 0139 Strains in Large Alkaline in Australia: Dissolve Organic Carbon Quality. *Applied Environmental Microbiology*. 74: 2004 – 2015.

Alhassan, A. J., Imam, A. A. and Yakasai, H. M. (2008): Quality Assessment of Sachet Water Packed Around Kano Metropolis. *Bajopas* 1(1): 83 – 87.

Al-Lahham A. B., Abu-Saud, M., Shehabi, A. A. (1990): Prevalence of *Salmonella, Shigella* and intestinal parasites in food handlers in Irbid, Jordan. J. Diarrhoeal Dis. Res. 8(4):160-162

American Public Health Association, (1998): S*tandard Methods for the examination of water and waste water.* 20th ed. APHA, Washington, DC.

American Public Health Association (APHA) (1992): Standard Methods for the Examination of Water and Wastewater. *Water Pollution Control Federation* 18th edition, Washington, D.C.

American Public Health Association (1985): *Standard Methods for the Examination of Water and Waste*. 16th edition American Public Health Association Inc. New York. P. 526, 67, 157.

Anon$_1$ (2001): *Good Health. Weekly Tuesday Newspaper.* June 26, 2001, page1.

AOAC (2000): *Official Methods of Analysis*. Association of Analytical Chemistry Washington D.C, 547 – 567

Armstrong, J. L., Shigeno, D. S., Colmiris, J. J., and Ceider, R. J., (1981): *Standard Bacterial Count in Water*. Applied and Environmental Microbiology 42; 277

Atiribom,, R. Y., Yakubu, S. E. and Okuofu, C. A. (2008): Bacteriological Quality of Kainji Lake Water and the Effect of Human Activities on the Lake. *Biological and Environmental Sciences Journal for the Tropics* 5(4): 12 – 16.

Bankole, O.S. and Shu'aibu, M.B. (2008): *Essentials of laboratory practical in microbiology*. 1st edition. Tobest publisher, S.W. 225 Hospital Road Minna – Niger state, Nigeria.

Banwart, G. J. (2004): *Basic Food Microbiology*, 2nd ed. Chapman and Hall Inc., New York. Pp 751.

Bonner, C., Foley, B. Wall, P. and Fitzgerald, M. (2001): *Analysis of Outbreaks of Infectious Intestinal Disease* in Ireland: 1998 and 1999. Irish Med. J. 94(5):140-144

Cheesbrough, M. O. (2006): *District Laboratory Manual for Tropical Countries*, Cambridge Press, UK p. 177 – 182, 190, 195.

Cheesbrough M.O. (1994). *Medical laboratory manual of tropical countries*. Vol. II. Microb. *Bustler* Worth and Companies Publishers.

Chi Hiong, J. G., and Burke, J. P., (2006): *Enterobacteriaceae*. Microbiological Identification Manual. 13th Edition p.910 Churchill Longman Group, United Kingdom.

Cleverland, C. (2007): *The Benefits of Water* Achieved from the Origin on 2007 – 01 – 10.

Cowan, S.T., and Steal, K.J. (2008): *Manual for the identification of medical bacteria*. Cambridge University Press London. P. 150.

Dada, A. C. (2008): Sachet Water Phenomenon in Nigeria: Assessment of the Potential Health Impacts *African Journal of Microbiology Research* Vol.3(1) pp.015 – 021

Daniel, N.A, MacKinnon L, Rowe SM, Bean NH, Griffin PM, Mead PS (2002). *Food-borne disease outbreaks in United States schools*. Pediatric Infect. Dis. J. 21 (7): 623-628

Demning, H.C. (1975). *Water the fountain of opportunity*. Onp Press University. P. 4 – 5

Denloye, S. A. (2004): *Quality Parameters for Packaged Water*. NAFDAC Laboratory Experience, IPAN News.

Dodoo, D. K., Quagraine, E. K., Okai-sam, F., Dorsa, J., Ranabo, A., and Headley, J. V. (2006): Quality of Sachet Waters in the Cape Cost Municipality of Ghana. *Journal of Environmental Science and Health,* Vol. 41(3).

Earnest, H., Jawetz, C., Joseph, L., Melnik, N. and Edward, A. (2007): *The Family Enterobacteriaceae*, Review of Medical Microbiology 17th Edition Applestone and Lange Medical Publisher Norwalk. Pp 232-45.

Edema M. O., Omemu A. M., and Fapetu O. M. (2001): *Microbiology and Physico-chemical Analysis of Different Sources of Drinking Water in Abeokuta*, Nigeria. Nig. J. Microbiol, 15(1), 57 – 61

Edward, P. R., and Ewing, W. H. (2002). (Eds): *Identification of Enterobacterianceae*. Minneapolis; Burges Publishing Company. New York. Pp. 245 – 300

Edwin, E. G., (2009): *Control of Microorganisms in Water*, Environmental Protection Agency, Cincinnati, Ohio.

Edwin, E. G., (2000): *Control of Microorganisms in Water*, Environmental Protection Agency, Cincinnati, Ohio.

Egwari, L. O., Iwuanyanwa, S., Ojelabi, C. I., Uzochukwu, O., and Effiok, W. W., (2005): Bacteriology of Sachet Water Sold in Lagos, Nigeria. *East African Medial Journal*. 82(5): 235 – 40.

Emmanuel, O. O, and Solomon, A. (2012): Quality of sachet and Bottled Water in Bolgatanga Municipality of Ghana. *Research Journal of Applied Science, Engineering Technology*. 4(9):1094-1098.

Encarta (2009): *Microsoft Encarta* DVD.

Environmental Protection Agency (2010): *National Recommended Water Quality Criteria*. http://www.epa.gov/waterscience/pe/revcom

Environmental Protection Agency (2002): US Environmental Protection Agency, Safe Drinking Water Act Amendment http://www.epa.gov/safewater/mcl.Html

Ezeuigwunne, I. P., Agbakoba, N. R., Nnamah, N. K. & Anhalu, I. C, (2009): The Prevalence Bacteria in Packaged Sachet Water Sold in Nnewi, south-east, Nigeria. *World Journal of Dairy and Food Science* 4(10): 19 – 21.

Faruque, S. M. and Nair, G. B. (2008): *Vibro Cholerae Genomics and Molecular Biology*, Casier Academic Press.

Federal Republic of Nigeria (2000): *Water Supply and Sanitation Interim Strategy* Note. Q://Personal/Word/Nigeria Water Sector/Nigeria WSS Strategy.

Food and Agriculture Organization of United Nations. (1979): *Manuals of Food Quality Controls Microbial Analysis*. Rome. Pp. A18 – 23.

Gardner, V. T., (2004): *Bottled Water*; Frequently Asked Questions. International Bottled Water Association, IBWA New, 12(5):3.

Geo, F. B., Janet, S. B., Stephen, A. M., (2002): *Medical Microbiology* 22nd edition McGraw Hill Education U.S.A.

George, T. and Edward D.S. (1985): *Water quality*. Addison Wesley Publishing Company p. 124 - 128

Greenhalgh, A., (2001): *Health Living Water*: BBC Health.

Handa, L. T., and Wood, G. K. (2006): *Investigation on Bacteriological Quality of Potable Water,* Sources of Tropical Countries Appleston Medical Publication. New York p.543-546.

HANNA Instruments (2004): *Instruction Manual: HI 146 Portable water proof microprocessor Dissolved Oxygen, ph/EC/TDS meters. Hanna instruments, Canada. www.hanna.com*

Hartely, M. D., Glee, M. J. and David, I. S. (2006): *Hyper Infectivity*: A Critical Element in the Ability of *V. cholerae* to Cause Epidemics? *PLOS MEDICINE* 363 – 369.

Heritage, J. (1999): *Microbiology in Action.* Cambridge University Press. p82 – 84. http://www.climatetemp.info/nigeria/kano

Hunter, P. R., (1997): *Water-borne Diseases Epidemiology*. Chichster, UK p.112

Idakwo P. Y. and Abu, G. O. (2004): Distribution and Statistical Analysis of Bacteria in Lake Alau in the Arid Northern Nigeria. *Nigerian Journal of Appl. Sci. Env. Mgt*. 8(1): 5 - 9

Ifeanyi V. O., Obiekezie S. O, Udebuani A. C. and Abara P. N. (2006): *Quality Evaluation of Sachet Water Sold in Port-Harcourt,* Nigeria. *International Journal of Natural and Applied Sciences* 2(4): 332 – 335

Indabawa, I. I. and Wudi, M. A. (2001): Microbiological Screening of Pure Water Sold in Kano Metropolis. *NISEB Journal* Vol. 1 No. 1

Jane, T. (1990): *Microorganisms and Biotechnology* Ford Press Limited. 1st Edition, London. P. 35 – 40.

Jazrawi, J. K and Hindawi, A. K., (2011): Pollution Indicator Bacteria (PIB). *Journal of Biological Science Research.* 17:31 – 40.

Lechevallier, M. W., (2003): *Conditions Favouring Coliform and HPC Bacterial Grow in Drinking Water and on Water Contact Surfaces*.

Lehr, J. H., Tyler, E. G., Wayne, A. P., and Jack, D., (1980): *Domestic Water Treatment*. The Book Press.

Lisle, J. (1993). *Bacterial Indication of Drinking Water Portability* in: An Operator's Guide to Bacteriological Testing, American Water Works Association.

Longmore, G. Wilkinson, R. and Rajagopalan, S. (2002): *Oxford Handbook of Clinical Medicine*. 6th edition. Oxford University Press. United Kingdom.

Mahmud, J and Shadab, A. (2005): *Campylobacter e-medicine Specialities*, 134:1-7.

Matsen, J. M. and Sherris, J. C. (1999): Comparative Study of the Efficiency of Seven (7) Paper-Reagent Strips and Conventional Biochemical Test in Identifying Gram-negative Organisms. *Journal of Applied Microbiology* 18:452 – 459

Michael, J., Pelezar, J.R, Chan, E.C., Noel, R. K., (2002): *General Microbiology*, 5th Edition.

Michael, Z. and David, P. D. (2005): *Salmonellosis, E-medicine Specialities*, 134:211-246.

Mukhtar, M. D. (1998): Microbiological and Physico-chemical studies on Salanta River. *Journal of Aquatic Sciences*. 46:89 – 94

Mustapha, S., and Adamu, E. P., (1991): *Discussion on Water Problems in Nigeria*: Focus on Bauchi State. National Res, Inst.

National Agency for Food and Drug Administration and Control (NAFDAC) (2004): *Guidelines for production and registration* of *packaged water*. New guidelines and regulations. NAFDAC, Abuja, Nigeria. Pp. 1 – 10.

National Population Commission of Nigeria (NPC) (2006): *Provisional Figures for Census 2006*. Vol.1, pp.22

National Research Council (1987) *Drinking Water and Health.* Washington, DC.

Nigerian Industrial Standard (2008): *Standard for Potable Water* NIS 306: 2008. Standard Organization of Nigeria.

Nwosu J. N., and Ogueke, C. C. (2004): Evaluation of Sachet Water Samples in Owerri Metropolis. *Nigerian Food Journal.* 22:164 – 170.

Okedi, S., (1997): *Training guide for water quality testing and control* (New York books).

Olabisi, O. and Awonusi, A. (2008): *Water and Pollution Agents in the 21st Century*. Nature and Science. 6(4) p. 16 - 24

Oladipo, I. C., Onyenike, I. C. and A. O. Adebiyi (2009): Microbiological Analysis of Some Vended Sachet Water in Ogbomoso. *African Journal of Food Science* Vol.3 (12), pp.406 – 412

Olayemi A. B. (1999): Microbial Potability of Bottled and Packaged Drinking Waters Hawked in Ilorin Metropolis. *International Journal of Environmental Health Research* 9 (3), 245 – 248

Olowe, O. A, Ojurongbe, O., Opaleye O. O., Adedosu O. T, Olowe R. A. and Eniola K. (2005): Bacteriological Quality of Water Samples in Osogbo Metropolis. *African Journal of Clinical and Experimental Microbiology* 6(3): 219 – 222

Onifade, A. K and Ilori, R. M., (2008): Microbiological Analysis of Sachet Water Vended in Ondo State Nigeria. *Environmental Research Journal* Vol. 2, No3, pp.107 – 110.

Onweluzo, J. C and Akuagbazie, C. A. (2010): Assessment of the Quality of Bottled and Sachet Water Sold in Nsukka Town. *Journal of Tropical Agriculture, Food, Environment and Extension* Vol. (9); No.1 pp. 104 – 110.

Osuinde, M. I., and Eneuzie, N. R., (1999): Bacteriological Analysis of Ground Water. *Nigeria Journal of Microbiology* Vol. 13:47 – 54.

Oyedeji, O., Olutiola, P. O. and Monimuola, M. A. (2010): Microbiological Quality of Packaged Drinking Water Brands Marketed in Ibadan Metropolis and Ile-Ife City in South Western Nigeria. *African Journal of Microbiology Research* Vol. 4(1) pp. 096 – 102.

Oyeku, O.M.; Omowumi, O.T.; Kupoluyi, C.F. and Toye, E.O. (2001). Wholesomeness Studies of Water Produced and Sold in Plastic Sachets (Pure Water) in Lagos Metropolis. *Nigerian Food Journal*, 19: 63– 69.

Oyelude, O. O, and Ahenkorah, S. (2012): Quality of Sachet Water and Bottled Water in Bolgatanga Municipality of Ghana. *Research Journal of Applied Sciences, Engineering and Technology* 4(9): 1094 – 1098.

Pelezar, J. R., Michael, M., and Roger, D. R., (1989): *Introduction to General Microbiology*. 5th Edition pp. 427 – 429.

Prescott, L. M., Harley, J. P. and Klein, D. A., (1999): *Microbiology* 4th Edition Mchrawhill Publishing Company, New York pp. 127 – 919

Public Health Laboratory Service (PHLS) (2000): *Guidelines for the Bacteriological Quality of Ready to Eat Foods Sampled at Point of Sale, Communicable Disease and Public Health* Vol.3, No. 3

Public Health Laboratory Service/Standing Committee of Analysis (PHLS/SCA) (1981): *A Comparison of Confirmatory Media for Coliform Organisms and Escherichia coli* in Water, by a Joint Committee of the Public Health Laboratory Service/Standing Committee of Analysis. Journal of Hygiene Vol. 87, pp. 369

Refai, M.K., (1979): Methods of microbiological analysis of food and water. Manual of food and agricultural organization of the United Nations (FAO). EC/Microbiol/75/Report/annex.Sciences.

Reildl,, H. and Klome, K. E. (2002): *Vibrio Cholerae* and Cholera: Out of the Water and Into the Host. *FEMS Microbiology Review* 26: 125 – 139.

Robert, W. B. (2009): *Microbiology with Diseases by Body System* (2nd edition) Pearson Education Inc. 1301 Sansome St. San Francisco CA 94111 USA p. 702, 706, 707, 732.

Roger, Y. S., John, L. I., L. W. and Page, R. P. (1988): *General* Microbiology, 5th edition by Prentice Hall Inc. Englewood Cliffs New Jersy USA p. 445, 624.

Shittu, O. B., Olaitan, J. O., and Amusa, T. S., (2008): Physico-chemical and Bacteriological Analysis of Water used for Drinking and Swimming Purposes in Abeokuta, Nigeria. *African Journal of Biomedical Research*, Vol. 11, p.285 – 290.

Sleigh, J. D. and Duguid, J. P. (2004): Enterobacteriaceae, In; Mackey and McCartney (1999): *Practical Microbiology*. 13th Edition, Longman Group Publishers, United Kingdom.

Sunday, B. A, Micheal, I. N, and Adidy S. O. (2011): Storage Effects on the Quality of Sachet Water Produced within Port Harcourt Metropolis, Nigeria. *Jordan Journal of Biological Sciences* Vol. 4(3). Pp.157 – 164.

Taiwo, A. A., Idowu .., Lanre-Iyanda, Y. A,, Jolaosa, A. A., Jiboku, O. O., and Taiwo, A. G. (2012): Physico-chemical and Bacteriological Analyses of Sachet Water Samples in Abeokuta Metropolis. *Global Advanced Research Journal of Agriculture Science* Vol. 1(1) pp. 001 – 006.

Tebbutt, T.H.Y, (1982): *Principles of Water Quality Control.* 3rd ed. (Revised & Enlarged) Pergamon Press, New York.

Third World Water Forum (2003): *Blockade, Myth, Illusions in Development and Cooperation*. Volume 30, No.1

U.S. Environmental Protection Agency (2006): *Ground Water and Drinking Water* – E. *coli* 015:H7 in Drinking water,

USEPA, Dallos, T., X. (2005): *Exposure Scenario Selection*. Chapter 3: http://www.epa.goo/earth/rb/bpd/rca_c/Pd-D/chap3: Retrieval 2007 – 02 – 19. RCRA Delisting Technical Support Document p.8

Walid, A. and Ilyas, B., (2002): *Shigella, E-medicine Specialities*, 23:2 – 10.

Washington State Dept. of Health, (2006): Retrieved on 6/26/2006 at 6:30pm: file//g/coliform.mdrinkingwaterwashintongstatedept.ofhealth.html

Waziri, M. (2010): Assessment of the Microbial Quality of Sachet Water in Damaturu – Yobe State, Nigeria. *Journal of Asian Scientific Research*, Vol. 2, No. 2, pp. 76 – 80.

WHO, (2010): *Bacteriology of Drinking Water*. The International Standards for Drinking Waters, Geneva.

WHO, (2007): *Antimicrobial Resistance*. WHO, Scientific Working Group Geneva. Communicable Diseases 1211:27 Switzerland.

WHO, (2005): *Guidelines for the Control of Shigellosi, including Epidermis Due to Shigella Dysenteriae Type 1*.

WHO, (2004): *Guidelines for Drinking Water Quality*. 3rd ed. Incorporating First and Second Agenda Vol. 1, World Heath Organization, Geneva.

WHO, (2003): *Guidelines for Examination of Drinking Water*. Drinking Water Quality Control in Small Community Suppliers, Geneva, (3), 19 – 34

WHO, (2002): Heteroprohic Plate Count Measure in Drinking Water Safety Management. *WHO Public Health Expert Report*, Geneva. Switzerland.

WHO, (1996): *Fighting Disease – Fostering Development. Geneva*: World Health Organization.

WHO, (1993): *Guidelines for Drinking Water Quality*. 2nd ed. Vol. 1: Recommendations. Geneva – World Health Organization.

WHO, (1985): *Guidelines for Drinking Water Quality* Vol. EFP 82: 39

www.bbchealth.org

www.wellcarehotline.org (2007)

Appendix I: Some Guidelines for Drinking Water Quality

Parameter		NAFDAC Maximum allowed limits (2004)	NIS Standards (2008)	WHO Standards (2003)	
				Highest Desirable	maximum permissible
1.	Temperature (^{0}C)	NS	Ambient	NS	NS
2.	pH	6.5-8.5	6.5-8.5	7.0 - 8.9	6.9 – 9.5
3.	Turbidity (NTU)	5.0	5.0	5.0	5.0
4.	Conductivity (µs/cm)	1000	1000	900	1200
5.	Chloride (mg/L)	100	100	200	250
6.	Total hardness (mg/L)	100	100	100	500
7.	Bacterial Count(cfu/ml)	$<10^4$	$<10^4$	$<10^4$	$<10^4$
8.	Total Coliform	-	-	-	-
9.	E. *coli*	-	-	-	-

Sources: NAFDAC (2004), NIS (2008) and WHO (2003)

Appendix II: Monthly Temperature (^{o}C) of the NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1x	27.0	26.2	26.6	26.8	26.9	26.6	26.7
2x	26.4	26.6	26.0	27.0	27.9	25.6	26.8
3x	26.0	26.1	25.8	26.6	26.7	26.6	26.6
4x	25.5	26.0	25.8	26.3	25.6	25.7	25.8
5x	26.4	26.8	26.0	25.9	25.9	26.2	26.2
6x	27.0	27.0	26.1	26.3	26.3	26.4	26.5
7x	26.3	26.5	26.4	26.0	26.2	26.2	26.3
8x	27.2	26.8	26.1	26.3	26.4	26.3	26.5
9x	26.0	26.0	26.1	25.9	26.2	26.0	26.0
10x	26.1	26.0	26.0	26.1	25.9	25.9	26.0
11x	27.5	27.7	27.7	27.6	27.9	27.8	27.7
12x	27.3	27.3	27.0	27.2	27.3	27.3	27.2
13x	27.2	27.3	27.1	26.9	26.8	26.7	27.0
14x	29.2	29.1	29.0	29.2	28.9	29.0	29.1
15x	28.1	28.0	27.2	27.3	27.4	27.4	27.5
16x	27.5	27.4	27.1	27.3	27.3	27.2	27.3
17x	27.1	27.3	27.4	27.5	27.3	27.5	27.3
18x	27.8	27.3	27.0	26.9	26.0	26.9	27.2
19x	27.3	27.2	27.0	26.9	26.8	26.7	27.0
20x	27.2	26.8	26.1	26.3	26.3	26.4	26.5
21x	27.5	27.1	27.0	27.1	26.8	26.7	27.0
22x	27.0	25.9	26.0	26.1	26.2	26.2	26.1
23x	26.1	25.0	25.5	25.8	25.9	25.8	25.9
24x	27.1	27.0	26.8	26.5	26.8	26.9	26.9
25x	27.2	26.8	26.1	26.3	26.3	26.4	26.5
26x	26.3	26.2	26.1	25.9	25.8	25.7	26.0
27x	25.0	26.1	25.5	25.8	25.9	25.8	25.9
28x	26.2	25.4	25.1	25.3	25.3	25.4	25.5
29x	26.0	25.8	25.5	26.3	25.6	25.7	25.8
30x	26.3	25.3	25.1	25.3	25.4	25.3	25.5

Appendix III: Monthly pH of the NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1x	7.3	7.0	6.8	7.0	7.1	7.1	7.1
2x	8.4	8.1	7.9	8.1	8.0	8.1	8.1
3x	7.4	7.3	7.0	7.3	7.1	7.3	7.2
4x	7.5	7.2	6.8	7.2	7.2	7.1	7.2
5x	7.5	7.2	6.8	7.0	7.1	7.0	7.1
6x	7.6	7.4	7.1	7.5	7.3	7.2	7.4
7x	6.5	6.5	6.1	6.5	6.2	6.3	6.4
8x	6.3	6.1	5.8	6.0	6.1	6.2	6.1
9x	6.5	6.5	6.6	6.3	6.4	6.6	6.5
10x	6.6	6.8	6.7	6.6	6.9	6.8	6.7
11x	6.0	6.3	6.4	6.2	6.5	6.3	6.3
12x	6.6	6.4	6.8	6.6	6.5	6.6	6.6
13x	6.4	6.0	6.3	6.3	6.1	6.3	6.2
14x	5.8	6.0	5.9	5.9	6.0	6.0	5.8
15x	6.2	6.1	6.0	5.8	6.3	6.1	6.1
16x	6.5	6.1	6.5	6.3	6.2	6.5	6.4
17x	6.4	6.6	6.5	6.8	6.6	6.6	6.6
18x	6.5	6.5	6.1	6.5	6.2	6.3	6.4
19x	6.3	6.1	6.2	6.5	6.5	6.5	6.4
20x	6.4	6.3	6.0	6.3	6.1	6.3	6.2
21x	7.0	6.9	7.0	7.1	7.0	7.1	7.0
22x	6.1	6.0	6.1	6.0	5.9	6.0	6.0
23x	6.9	6.8	7.0	6.9	6.8	7.0	6.9
24x	6.3	6.5	6.2	6.4	6.3	6.0	6.3
25x	6.2	6.1	5.8	6.0	6.3	6.1	6.1
26x	6.8	6.6	6.9	6.7	6.8	6.6	6.7
27x	5.6	5.8	5.7	5.6	5.9	5.8	5.7
28x	6.5	6.3	6.6	6.4	6.6	6.5	6.5
29x	7.5	7.2	6.8	7.0	7.1	7.0	7.1
30x	6.0	5.8	5.9	6.0	5.8	5.9	5.9

Appendix IV: Monthly Turbidity (NTU) of the NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1x	0	0	0.2	0.1	0	0.1	0.1
2x	1.1	1.2	1.4	1.3	1.4	1.5	1.3
3x	1.5	1.3	1.5	1.4	1.4	1.5	1.4
4x	0.9	1.0	1.0	1.1	0.9	1.0	1.0
5x	0.4	0.6	0.6	0.5	0.4	0.4	0.5
6x	0.2	0.3	0.4	0.3	0.4	0.3	0.3
7x	0.8	1.0	0.9	0.8	0.7	0.9	0.8
8x	1.0	0.9	1.0	1.1	1.0	0.9	1.0
9x	1.7	1.4	1.6	1.5	1.6	1.4	1.5
10x	0.7	0.8	0.9	0.8	0.7	0.7	0.7
11x	1.3	1.5	1.4	1.5	1.4	1.5	1.4
12x	2.4	2.7	3.0	2.7	2.6	2.6	2.6
13x	1.6	1.7	1.6	1.4	1.6	1.4	1.5
14x	1.0	0.9	1.0	1.1	0.9	1.0	1.0
15x	0.3	0.4	0.2	0.2	0.3	0.4	0.3
16x	0.8	0.7	1.0	0.7	0.6	0.7	0.7
17x	0.2	0.3	0.4	0.3	0.4	0.3	0.3
18x	0.3	0.5	0.5	0.5	0.4	0.3	0.4
19x	0.7	0.8	0.8	0.7	0.6	0.7	0.7
20x	0.3	0.5	0.6	0.4	0.3	0.4	0.4
21x	0.3	0.2	0.4	0.2	0.3	0.4	0.3
22x	0.4	0.6	0.6	0.5	0.7	0.4	0.5
23x	0.2	0.3	0.4	0.2	0.4	0.3	0.3
24x	0.6	0.6	0.7	0.6	0.6	0.5	0.6
25x	1.1	1.4	1.1	1.3	1.2	1.0	1.2
26x	0.5	0.3	0.6	0.4	0.4	0.3	0.4
27x	1.4	1.6	1.6	1.5	1.7	1.4	1.5
28x	1.0	1.1	1.2	1.2	1.1	1.2	1.1
29x	1.3	1.5	1.4	1.5	1.4	1.5	1.4
30x	1.2	1.0	1.3	1.1	1.4	1.1	1.2

Appendix V: Monthly Conductivity (µs/cm) of the NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1x	12.0	11.5	11.0	10.5	11.0	10.0	11.0
2x	160.0	156.5	157.0	156.0	156.0	154.0	154.6
3x	93.9	94.0	95.1	94.0	94.1	94.1	94.1
4x	11.8	11.9	12.0	11.5	11.4	11.4	11.6
5x	65.9	65.1	66.0	65.0	64.9	65.1	65.1
6x	29.0	29.0	29.5	28.5	29.0	29.0	29.0
7x	49.0	48.0	49.2	47.3	47.0	48.0	48.0
8x	41.9	41.8	42.0	41.8	41.7	41.6	41.8
9x	94.1	93.1	93.0	93.0	92.9	93.0	93.0
10x	72.1	70.4	70.0	70.1	70.0	70.3	71.3
11x	85.6	85.3	85.0	85.1	85.1	85.1	85.1
12x	110.5	105.8	105.7	105.8	105.9	105.8	105.8
13x	117.0	117.0	118.0	115.0	116.0	115.0	116.1
14x	116.0	116.0	116.1	115.2	114.3	113.2	115.1
15x	77.7	77.6	77.2	77.5	77.3	77.6	77.8
16x	79.0	78.0	79.2	77.3	77.0	78.0	78.5
17x	71.0	70.0	72.0	69.6	68.0	70.3	70.0
18x	84.0	84.5	84.5	83.0	84.0	84.0	84.0
19x	77.2	77.8	78.4	75.2	75.7	75.4	76.3
20x	75.6	75.3	75.0	75.1	75.1	75.1	75.1
21x	59.4	59.0	60.0	57.7	57.4	58.8	58.8
22x	92.5	92.3	93.5	92.0	92.3	92.2	92.5
23x	95.3	95.3	96.2	94.5	94.7	95.1	95.1
24x	100.9	100.8	101.1	100.9	100.8	100.8	100.8
25x	151.6	151.2	151.8	150.4	150.2	150.0	150.8
26x	77.2	77.8	78.1	75.7	75.2	75.4	76.0
27x	86.8	87.5	88.0	86.5	87.5	88.5	87.5
28x	87.7	87.6	88.2	87.5	87.3	87.6	87.8
29x	94.9	93.5	93.8	93.5	93.4	93.5	93.8
30x	92.4	92.3	93.0	92.0	92.2	92.2	92.3

Appendix: VI: Monthly Chloride (mg/L) of the NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1x	58.9	58.9	59.0	58.8	58.7	58.8	58.8
2x	20.3	22.5	27.0	22.0	21.0	23.6	23.1
3x	41.5	41.6	41.8	41.9	41.6	41.4	41.6
4x	34.2	35.0	34.3	34.1	34.5	34.5	34.3
5x	53.0	52.8	52.8	51.8	52.5	52.8	52.8
6x	33.9	33.6	33.5	34.0	34.0	33.8	33.7
7x	44.2	45.0	44.3	44.1	44.5	44.3	44.2
8x	35.8	35.8	35.8	36.0	35.7	35.7	35.7
9x	40.5	40.2	40.6	40.1	40.3	40.0	40.3
10x	31.1	37.2	37.9	36.8	37.0	37.1	37.1
11x	31.9	31.8	31.5	31.5	31.9	31.4	31.5
12x	26.1	25.4	25.1	25.2	25.2	25.4	25.4
13x	27.8	27.3	27.0	26.9	26.0	26.9	27.2
14x	30.5	31.0	31.5	30.5	29.0	31.0	30.5
15x	29.2	30.0	29.2	29.3	30.0	29.7	29.5
16x	23.9	23.7	23.7	24.0	24.0	23.8	23.8
17x	31.7	31.8	32.5	32.2	32.0	32.0	32.0
18x	30.0	29.3	29.1	29.3	29.2	30.0	29.3
19x	26.4	26.8	26.0	25.9	26.2	25.9	26.2
20x	26.2	26.0	26.1	26.3	27.9	27.8	27.8
21x	46.0	46.1	45.8	46.6	46.7	46.6	46.6
22x	24.2	25.0	24.3	24.1	24.3	24.3	24.3
23x	24.1	24.2	24.9	24.0	23.8	23.3	24.1
24x	31.4	31.5	31.8	31.9	31.5	31.4	31.4
25x	31.4	30.0	32.0	29.0	30.0	30.0	30.0
26x	27.0	25.9	26.0	26.1	26.2	26.2	26.1
27x	26.3	25.3	25.1	25.3	25.5	25.4	25.6
28x	27.5	27.7	27.6	27.5	27.9	27.7	27.6
29x	25.2	26.0	25.3	25.1	25.3	25.3	25.3
30x	28.1	28.2	28.9	28.0	27.8	27.3	28.1

Appendix VII: Monthly Total Hardness (mg/L) of the NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1x	1.7	1.6	2.2	2.3	2.0	2.0	2.0
2x	45.4	45.4	46.0	45.1	45.0	45.0	45.3
3x	27.5	27.4	27.0	27.3	27.4	27.5	27.4
4x	16.8	16.9	17.2	16.6	16.6	16.5	16.5
5x	13.9	13.9	14.0	13.5	13.1	13.8	13.6
6x	8.6	8.8	8.7	9.0	8.8	8.9	8.8
7x	12.9	12.7	1.3	13.0	12.8	12.7	13.0
8x	8.2	8.0	7.8	8.0	7.9	7.9	8.0
9x	15.5	14.5	15.0	14.5	14.0	15.0	14.5
10x	14.5	14.6	15.1	14.0	14.0	14.0	14.0
11x	26.2	25.4	25.1	25.3	25.3	25.4	25.5
12x	27.5	27.7	27.2	27.3	27.5	27.5	27.6
13x	41.2	41.1	42.0	41.5	41.0	41.1	41.3
14x	39.9	39.7	40.0	39.6	39.8	39.8	39.8
15x	6.0	6.0	7.1	5.9	5.8	5.8	6.0
16x	6.5	6.3	7.2	5.6	6.7	6.8	6.5
17x	4.0	4.2	4.2	4.0	4.5	3.5	4.0
18x	10.5	10.0	11.0	10.5	10.5	10.0	10.5
19x	6.1	6.1	7.0	5.6	5.7	5.6	6.0
20x	6.5	6.3	7.5	6.7	5.6	6.6	6.5
21x	3.3	3.3	3.5	2.8	2.6	2.8	3.0
22x	12.1	12.1	12.3	12.2	11.9	11.5	12.0
23x	13.4	13.4	13.5	13.3	13.0	13.1	13.3
24x	15.8	15.9	16.2	15.6	15.6	15.5	15.5
25x	20.6	20.2	20.7	20.3	20.4	20.3	20.3
26x	6.2	6.0	7.1	5.6	5.6	5.7	6.0
27x	10.3	10.2	10.5	9.8	10.2	10.0	10.0
28x	10.0	10.5	10.5	11.0	10.5	10.0	10.5
29x	13.2	13.4	13.5	13.0	13.3	13.0	13.2
30x	12.2	12.0	12.5	12.2	11.8	11.6	12.0

Appendix VIII: Monthly Coliform Count of the NAFDAC Registered Sachet Water Samples

Months/Sample Codes	June	July	August	September	October	Nov.
1x	<2	<2	<2	<2	<2	<2
2x	2	2	4	4	2	2
3x	2	4	2	2	2	4
4x	<2	<2	2	4	2	4
5x	7	2	2	2	4	7
6x	4	2	2	4	2	2
7x	4	2	2	2	2	2
8x	2	2	2	4	4	2
9x	4	2	<2	<2	4	2
10x	2	2	2	7	4	2
11x	2	4	4	7	7	2
12x	2	7	7	4	2	2
13x	<2	<2	<2	<2	<2	<2
14x	4	2	<2	4	2	<2
15x	<2	<2	<2	<2	<2	<2
16x	<2	<2	<2	<2	<2	<2
17x	2	2	4	2	2	4
18x	2	4	2	4	2	2
19x	<2	<2	<2	<2	<2	<2
20x	<2	4	2	4	<2	<2
21x	<2	<2	<2	<2	<2	<2
22x	2	7	7	2	2	2
23x	2	4	4	2	2	2
24x	4	2	2	7	2	2
25x	2	2	2	2	7	7
26x	2	4	4	2	2	2
27x	4	4	2	4	2	2
28x	<2	4	2	2	<2	2
29x	2	2	4	4	4	4
30x	<2	<2	2	2	4	4

Appendix IX: Monthly Temperature (^{0}C) of the non-NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1y	27.0	26.6	26.0	27.2	26.9	26.9	26.8
2y	27.4	27.5	27.0	27.2	27.3	27.2	27.3
3y	27.1	27.0	26.5	26.8	26.9	26.8	26.9
4y	26.7	26.6	26.0	26.2	26.6	26.3	26.4
5y	26.2	26.0	25.0	25.3	25.6	25.8	25.7
6y	25.2	24.8	24.1	24.3	24.3	24.4	24.5
7y	26.8	26.7	26.2	26.5	26.6	26.6	26.6
8y	27.2	26.8	26.1	26.3	26.3	26.4	26.5
9y	26.8	26.3	26.0	29.9	26.0	25.9	26.2
10y	27.0	27.0	26.1	26.3	26.4	26.4	26.5
11y	26.7	26.6	26.0	26.3	26.6	26.2	26.4
12y	27.5	27.4	27.1	27.3	27.3	27.2	27.3
13y	27.1	26.9	26.1	26.2	26.4	26.4	26.5
14y	27.0	25.9	26.0	26.1	26.2	26.2	26.1
15y	27.0	26.9	26.2	26.3	26.5	26.3	26.5
16y	31.0	30.9	30.5	30.2	30.3	30.3	30.5
17y	27.0	26.6	26.2	26.7	26.8	26.8	26.7
18y	27.3	27.2	27.0	26.9	26.8	26.7	27.0
19y	27.4	27.1	27.0	26.7	26.9	26.8	27.0
20y	27.2	27.0	26.2	26.7	26.6	26.3	26.7
21y	27.3	27.2	27.1	26.9	26.8	26.7	27.0
22y	27.1	27.0	26.2	26.3	26.4	26.4	26.5
23y	27.3	27.2	27.0	26.9	26.8	26.7	27.0
24y	27.2	27.0	26.2	26.7	26.6	26.3	26.7
25y	26.2	26.0	25.1	25.3	25.7	25.8	25.7
26y	26.8	26.5	26.1	26.4	26.6	26.2	26.4
27y	27.1	26.9	26.1	26.2	26.4	26.4	26.5
28y	25.5	25.4	25.1	25.3	25.3	25.2	25.3
29y	26.2	25.4	25.1	25.3	25.3	25.4	25.5
30y	26.5	26.4	26.1	26.3	26.3	26.2	26.3

Appendix X: Monthly pH of the non-NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1y	8.3	8.0	7.8	8.0	8.1	8.1	8.1
2y	8.4	8.6	8.5	8.8	8.6	8.6	8.6
3y	8.5	8.6	8.5	8.4	8.6	8.3	8.5
4y	8.4	8.3	8.0	8.3	8.1	8.3	8.2
5y	6.6	6.4	6.8	6.6	6.5	6.6	6.6
6y	5.9	6.2	6.5	6.1	6.5	6.5	6.4
7y	6.8	8.1	7.9	8.1	8.0	8.1	8.1
8y	6.6	6.4	6.8	6.6	6.5	6.6	6.6
9y	5.3	6.0	5.8	5.9	5.8	6.0	5.9
10y	5.5	6.7	6.9	6.9	6.8	6.8	6.8
11y	6.6	6.3	6.5	6.4	6.5	6.6	6.5
12y	5.3	5.1	5.8	5.0	5.1	5.2	5.3
13y	5.5	5.3	5.2	5.4	5.3	5.0	5.3
14y	5.2	5.5	5.5	5.3	5.1	5.5	5.4
15y	6.2	6.1	6.0	5.8	6.3	6.1	6.1
16y	5.0	5.3	5.4	5.2	5.5	5.3	5.2
17y	5.1	5.0	5.1	5.0	4.9	5.0	5.0
18y	6.5	6.5	6.1	6.5	6.2	6.3	6.4
19y	6.0	6.1	6.0	6.0	5.9	6.1	6.0
20y	7.1	7.0	6.9	7.0	7.1	7.0	7.0
21y	7.4	7.6	7.1	7.5	7.3	7.2	7.4
22y	8.5	8.5	8.6	8.3	8.4	8.6	8.5
23y	6.6	6.5	6.3	6.5	6.4	6.6	6.5
24y	6.4	6.6	6.8	6.6	6.5	6.6	6.6
25y	7.5	7.3	7.2	7.4	7.3	7.0	7.3
26y	7.4	7.6	7.5	7.8	7.6	7.6	7.6
27y	7.3	7.0	6.8	7.0	7.1	7.1	7.1
28y	6.0	6.3	6.4	6.5	6.2	6.3	6.3
29y	6.8	7.0	6.9	6.8	7.0	6.9	6.9
30y	6.3	6.1	6.0	5.8	6.1	6.2	6.1

Appendix XI: Monthly Turbidity (NTU) of the non-NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1y	1.1	1.4	1.1	1.3	1.2	1.0	1.2
2y	1.5	1.6	2.0	1.9	1.9	1.8	1.8
3y	2.1	2.2	2.4	2.3	2.4	2.5	2.3
4y	3.6	3.8	4.0	3.6	3.0	3.7	3.8
5y	0.3	0.6	0.5	0.7	0.5	0.5	0.5
6y	2.4	2.6	2.5	2.6	2.4	2.7	2.5
7y	2.2	2.2	2.4	2.3	2.5	2.4	2.3
8y	1.4	1.7	1.7	1.6	1.7	1.6	1.6
9y	1.0	0.9	1.0	1.1	0.9	1.0	1.0
10y	1.6	1.4	1.5	1.6	1.4	1.7	1.5
11y	1.7	1.7	1.4	1.6	1.6	1.7	1.6
12y	1.5	1.9	1.7	1.5	1.9	1.7	1.7
13y	1.7	1.9	1.7	1.8	1.9	2.0	1.9
14y	1.0	1.1	1.0	1.2	1.1	1.2	1.1
15y	2.0	2.3	2.0	2.4	2.2	2.1	2.2
16y	2.3	2.5	2.3	2.5	2.4	2.5	2.4
17y	1.7	1.7	1.7	1.6	1.6	1.7	1.6
18y	1.5	2.0	1.5	1.9	1.8	1.9	1.8
19y	1.3	1.5	1.3	1.5	1.4	1.5	1.4
20y	0	0.1	0	0.2	0	0.1	0.1
21y	1.1	1.4	1.1	1.3	1.2	1.0	1.2
22y	1.1	1.2	1.1	1.3	1.4	1.5	1.3
23y	1.0	1.2	1.0	1.3	1.4	1.1	1.2
24y	1.8	1.5	1.8	2.0	1.9	1.9	1.8
25y	1.3	1.1	1.3	1.1	1.0	1.2	1.2
26y	1.4	1.6	1.4	1.6	1.4	1.7	1.5
27y	1.6	1.8	1.6	1.6	2.0	1.7	1.8
28y	1.1	1.2	1.1	1.0	1.2	1.1	1.1
29y	1.3	1.5	1.3	1.5	1.4	1.5	1.4
30y	1.2	1.1	1.2	1.3	1.4	1.5	1.3

Appendix XII: Monthly conductivity (µs/cm) of the non-NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1y	100.8	100.5	100.3	100.5	100.6	100.5	100.5
2y	161.3	161.1	161.0	161.3	161.0	161.0	161.1
3y	104.8	104.2	104.0	104.3	104.3	104.4	104.1
4y	187.2	186.1	185.0	186.0	186.1	186.0	186.0
5y	77.5	77.3	77.0	77.5	77.2	77.4	77.3
6y	198.0	197.3	197.0	197.2	197.3	197.1	197.3
7y	125.1	124.5	124.0	124.3	124.8	124.5	124.5
8y	114.2	114.0	113.2	114.1	114.0	114.0	114.0
9y	94.3	93.1	93.0	93.0	92.9	93.1	93.1
10y	155.0	153.3	153.0	153.0	153.5	153.5	153.5
11y	154.3	154.0	153.9	154.0	154.0	154.1	154.0
12y	140.5	139.4	138.5	139.4	140.0	139.5	139.5
13y	197.0	196.7	196.5	196.8	196.8	196.8	196.8
14y	94.2	93.3	93.0	93.1	93.3	93.1	93.3
15y	100.2	99.8	99.2	99.7	99.8	99.7	99.8
16y	174.7	174.2	174.0	174.1	174.1	174.3	174.1
17y	97.0	96.5	96.1	96.6	96.5	96.5	96.5
18y	103.0	103.0	102.2	102.0	102.0	102.1	102.0
19y	98.2	97.5	97.2	97.0	97.8	97.6	97.8
20y	71.2	70.5	70.0	70.1	70.0	70.3	70.3
21y	113.7	113.5	113.0	113.0	112.8	112.6	113.0
22y	207.5	207.4	207.1	207.3	207.4	207.3	207.3
23y	90.0	88.5	88.1	88.6	88.9	88.7	88.8
24y	105.0	104.6	104.2	104.4	104.6	104.7	104.6
25y	110.2	109.7	109.5	109.3	109.2	109.5	109.6
26y	103.0	102.9	102.0	102.1	102.2	102.1	102.1
27y	103.0	113.3	110.0	111.0	113.3	112.0	112.0
28y	160.0	159.1	159.0	159.1	159.0	159.2	159.1
29y	108.6	108.4	108.1	108.3	108.3	108.4	108.3
30y	85.6	85.3	85.1	85.5	85.4	85.3	85.3

Appendix XIII Monthly Chloride (mg/L) of the non-NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1y	20.3	22.1	29.0	22.0	21.0	23.5	23.0
2y	21.2	21.7	21.4	21.0	21.1	20.5	21.1
3y	18.0	18.0	18.1	18.2	18.0	18.1	18.0
4y	14.8	14.8	14.8	15.5	15.2	15.3	15.0
5y	30.4	32.2	30.0	32.0	35.0	33.5	33.4
6y	21.5	20.5	20.3	20.7	20.8	20.3	20.5
7y	19.0	19.0	19.0	19.2	19.0	19.1	19.0
8y	18.0	18.0	18.2	18.0	18.1	18.2	18.0
9y	22.9	23.5	22.8	22.3	22.5	22.8	22.8
10y	17.5	17.4	17.0	17.3	17.1	17.0	17.3
11y	16.5	16.5	17.2	17.5	17.0	17.3	17.0
12y	25.0	25.0	25.1	25.0	25.1	25.8	25.1
13y	15.1	15.0	15.1	15.0	15.1	14.8	15.0
14y	25.2	24.8	24.2	24.3	24.4	24.5	24.6
15y	25.0	24.8	25.0	25.0	25.1	25.6	25.0
16y	15.8	15.4	15.9	16.6	16.4	16.1	16.0
17y	26.8	27.2	26.1	26.3	26.3	26.4	26.5
18y	18.8	18.7	18.7	18.6	18.2	18.2	18.5
19y	21.3	22.1	28.0	23.0	21.5	23.5	23.3
20y	48.9	48.0	49.2	47.2	47.0	48.0	47.9
21y	18.7	18.7	18.8	18.2	18.2	18.6	18.5
22y	14.8	14.8	14.8	15.5	15.2	15.3	15.0
23y	26.2	25.4	25.3	25.1	25.3	25.4	25.5
24y	18.0	18.0	18.0	18.2	18.2	18.1	18.0
25y	16.2	16.5	16.8	16.5	16.4	16.4	16.5
26y	17.2	17.8	17.5	17.4	17.5	17.4	17.5
27y	18.0	18.0	18.0	18.2	18.2	18.3	18.0
28y	14.8	14.8	15.2	15.2	15.5	15.3	15.0
29y	16.8	16.8	16.2	17.5	17.2	17.3	17.0
30y	25.1	25.0	25.1	25.0	25.1	25.8	25.0

Appendix XIV: Monthly Total Hardness (mg/L) of the non-NAFDAC Registered Sachet Water Samples Collected in Kano Metropolis, 2012

Months/Sample Codes	June	July	August	September	October	Nov.	Mean
1y	23.2	23.5	22.3	27.2	21.0	23.0	23.3
2y	17.6	17.8	17.6	17.5	17.6	17.7	17.6
3y	37.2	36.9	36.8	36.5	36.9	36.9	36.8
4y	34.0	34.7	34.9	34.0	33.3	33.5	34.0
5y	23.3	23.5	23.2	23.1	23.0	23.0	23.1
6y	36.5	37.0	36.0	35.5	35.5	36.0	36.0
7y	34.8	34.8	35.0	35.8	35.0	35.2	35.1
8y	31.1	31.5	32.0	31.0	31.0	30.0	31.1
9y	17.0	16.8	17.0	16.8	16.5	16.4	16.8
10y	30.1	29.8	29.1	28.8	28.5	28.5	29.1
11y	43.5	40.4	40.0	42.0	40.0	40.6	40.6
12y	43.5	44.3	43.7	42.5	43.5	43.4	43.5
13y	36.0	36.0	36.2	36.0	36.2	36.2	36.0
14y	34.7	34.0	34.9	34.0	33.8	33.7	34.1
15y	35.5	36.0	35.0	35.5	35.7	35.3	35.5
16y	43.1	42.1	42.4	42.5	41.8	42.0	42.3
17y	25.1	25.5	25.3	25.2	25.3	25.4	25.3
18y	26.8	26.7	26.2	26.6	26.5	26.6	26.6
19y	30.5	30.3	29.5	28.5	28.5	29.5	29.5
20y	5.1	4.7	4.8	4.2	4.2	3.8	4.5
21y	28.3	28.0	29.3	2.8	28.3	28.0	28.3
22y	46.1	46.0	47.0	46.0	45.8	46.2	46.1
23y	17.8	17.6	17.5	17.6	17.7	17.6	17.6
24y	34.5	32.5	33.5	34.0	33.5	33.5	33.5
25y	39.5	37.7	38.5	39.8	37.7	37.5	38.5
26y	30.0	30.7	30.1	30.0	29.5	30.2	30.0
27y	41.0	40.7	39.8	40.5	40.6	40.3	40.5
28y	43.7	44.2	44.3	44.0	44.1	43.8	44.0
29y	38.5	38.7	38.2	37.0	37.5	38.0	38.0
30y	20.3	20.3	20.0	20.4	20.2	20.4	20.2

Appendix XV: Monthly Coliform Count of the non-NAFDAC Registered Sachet Water Samples

Months/Sample Codes	June	July	August	September	October	Nov.
1y	4	2	4	2	2	2
2y	4	7	4	4	4	7
3y	2	4	2	7	7	9
4y	2	2	2	4	7	4
5y	2	7	4	2	7	9
6y	2	2	4	7	7	7
7y	2	7	4	7	4	7
8y	2	2	4	4	7	4
9y	<2	<2	2	2	4	4
10y	2	2	4	4	4	4
11y	2	4	2	7	4	4
12y	2	2	4	4	7	4
13y	2	2	4	4	4	4
14y	4	2	2	2	4	4
15	7	2	4	4	4	7
16y	2	4	4	2	2	2
17y	2	7	4	4	4	4
18y	2	7	4	4	2	7
19y	2	2	4	4	2	2
20y	<2	<2	<2	<2	<2	<2
21y	2	2	7	7	4	4
22y	2	2	4	4	2	2
23y	2	2	7	7	7	4
24y	2	2	2	4	4	4
25y	2	2	4	4	4	7
26y	2	2	4	4	4	7
27y	<2	<2	2	4	4	4
28y	2	7	4	7	4	7
29y	2	2	4	4	4	4
30y	<2	4	4	<2	<2	4

Appendix XVI: NAFDAC Registered Sachet Water with their NAFDACT Registration number Collected in Kano Metropolis, 2012.

Sample Code	**Brand Name**	**NAFDAC Reg. No.**
1 x	SANIZ	A_1 – 5525 L
2 x	HAUSU	B_1 – 3408
3 x	AL-MARA'I	01 – 0096 L
4 x	MUMINA	A_1 – 5303 L
5 x	SAFA	B_1 – 5251 L
6 x	SPRING	A_1 – 0639 L
7 x	AFUWA	A_1 – 9840 L
8 x	ANNUSHUWA	01 – 1236 L
9 x	CHRANN	01 – 3145
10 x	MY-FAVOURITE	01 – 0181 L
11 x	SVS	B_1 – 2847 L
12 x	FASCO	01 – 3214 L
13 x	MAI-SHANU	A_L – 7481 L
14 x	K-WALIMA	A_1 – 7517 L
15 x	AL-MAFKIR	A_1 – 7701 L
16 x	ROLINKSS	01 – 8665 L
17 x	HILAL	01 – 4481 L
18 x	LYMANS	A_1 – 6263 L
19 x	A. S MAI BARGO	A_1 – 3194 L
20 x	HUSSAB	A_1 – 2930 L
21 x	MOST STANDARD	01 – 4249 L
22 x	MAI-BARGO	01 – 4508 L
23 x	ADALCI	A_1 – 3130 L
24 x	AKARAM	B_1 – 4602 L
25 x	ZUBAIRAWA	01 – 9409 L
26 x	MASO KANO	B_1 – 4302 L
27 x	GABALE	B_1 – 1219 L
28 x	AL-FARAJI	A_1 – 0914 L
29 x	KEND	B_1 – 1757 L
30 x	UMMINA	01 – 4478 L

Appendix XVII: Sachet Water factory in Gwale Local Government Area, Kano 2012