STUDIES ON THE QUALITY ASSESSMENT OF PACKAGED (SACHET) WATER PRODUCED IN NIGER - STATE

BY

IHEKORONYE NICHOLAS CHINYEREM

B.TECH (HONS) MICROBIOLOGY (F.U.T. MINNA, 2001)

(M.TECH/SSSE/2003/2004/941)

DEPARTMENT OF MICROBIOLOGY
SCHOOL OF SCEIENCE AND SCIENCE EDUCATION
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

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DEDICATION

This work is dedicated to the blessed Holy Trinity

To my Beloved friend N. Ndukwe

And to Mr. O. Oghonna of NAFDAC Area Laboratory, Kaduna, Nigeria.

ACKNOWLEDGEMET

I give thanks, honour and glory to the Almighty God for His faithfulness towards me in the course of this work. I wish to express my profound gratitude to my knowledgeable supervisor. Professor. S.A. Garba, for his constant availability, guidance and correction of this work.

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DECLARATION

I hereby declare that apart from the references made to other people's work. which have been acknowledged, this is an original record of this work by Ihekoronye Nicholas Chinyerem Ifunanyachukiwu in the Department of Microbiology, Federal University of Technology, Minna, Nigeria.

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IHEKORONYE. C. NICHOLAS
STUDENT

CERTIFICATION

This thesis titled **STUDIES ON THE QUALITY ASSESSMENT OF PACKAGED (SACHET) WATER PRODUCED IN NIGER STATE BY IHEKORONYE NICHOLAS CHINYEREM (M. TECH/SSSE/2003/2004/941)** meets the regulations governing the award of the degree of M. Tech of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

27/7/2006

PROF. S.A. GARBA
Name of Major Supervisor

Signature & Date

13/10/06

PROF. M. GALADIMA
Name of Head of Department

Signature & Date

16/10/06

PROF. G.D. MOMOH
Name of Dean of School

Signature & Date

27/12/07

PROF. J.A. ABALAKA
Name of Dean, Postgraduate School

Signature & Date

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ABSTRACT

Two hundred and fifty (250) packaged (sachet) water samples were collected from five major towns in Niger State and analyzed to ascertain their quality. The samples were adjudged based on microbiological physical, chemical and metallic properties. Using NAFDAC methodology, the results revealed that 2.8% and 2.4% of the water samples were contaminated with coliforms and *Escherichia coli* respectively. Besides *E. coli, Klebsiella aerogenes, Enterobacter aerogenes* and *Pseudomonas aeruginosa* were identified as bacterial contaminants of sachet water samples. It was found that the sachet water produced from Kontangora and Mokwa had more microbial contaminants that those from Minna and Bida. Sixty-Six percent (66%) of the water samples analyzed met the microbiological standard for drinking water set by NAFDAC. The water samples recorded 100%, 78% and 34% acceptability in terms of metallic, physical and chemical properties respectively. The results obtained should help the general public on the right choice of sachet water, and the health implications of drinking contaminated water.

CHAPTER ONE

1.0 INTRODUCTION

Water, one of the most abundant compounds on earth, is special because all life-forms on earth are totally water-dependent, amounting to up to 80% of our bodies and plays diverse chemical roles in humans as well as in flora, soils and air (Leiv, 2005). Water represents one of the basic elements supporting life and the natural environment, a primary component for industry, a consumer item for humans and animals, and a vector for domestic and industrial pollution (Colin and Quevauviller, 1998).

All life are dependent on water. Water exists in nature in many forms- cloud, rain, snow, ice and fog; however, strictly speaking, chemically pure water does not exist for any appreciable length of time in nature. Even when falling as rain, water picks up small amount of gases, ions, dust, and particulate matter from the atmosphere. Then, as it flows over or through the surface layer of the earth, it dissolves and carry with it some of almost everything it touches, including that dumped into it by man. These added substances may be arbitrarily classified as biological, chemical (both organic and inorganic), physical, and radiological impurities. They include industrial, and commercial solvents, metal and acid salts, sediments, pesticides, herbicides, plant nutrients, radioactive materials, decaying animal and vegetable matter, and living microorganisms, such as algae, bacteria,

and viruses. These impurities may give water a bad taste, and colour, odour or cloudy appearance (turbidity), and cause hardness, corrosiveness, staining or frothing. They may damage growing plants and transmit diseases (Theodore, 2003). Water is the life blood of the environment, essential to the survival of all living things- plants, animal and human. On this background therefore, every thing must be done to maintain its quality for today and future. In order to protect water quality standards, governments have fixed standards or concentration limits or guidelines (scientifically determined) that can be tolerated for a particular water use such as drinking, irrigation or recreation like swimming.

The development of water quality standards began in the United States in the early 20^{th} century. Since that time, the total number of regulated contaminants has increased as toxicological knowledge and analytical measurement techniques have improved. Modern testing methods allows the detection of contaminants in extremely low concentrations- as low as one part contaminant per one billion parts water or even, in some cases, per one trillion parts water. Water quality standards are continually evolving, usually becoming more stringent. As a result, the number of regulated contaminants increases over time, and their allowable concentrations in water are lowered (Greenberg et al, 2005).

Drinking water regulations include two types of standards - primary and secondary. Primary standards are designed to protect public health, whereas secondary standards are based on aesthetic factors rather than on health effects. Primary standards specify maximum contaminant levels for many chemicals, microbiological and physical parameters of water quality. They reflect the best available scientific and engineering judgment and take into account exposure from other sources in the environment and from foods. Turbidity is also included in the primary standards because of the tendency to interfere with disinfection.

Secondary standards are guideines or suggested maximum levels of colour, taste, odour, hardness, corrosiveness, and certain other factors (European Community GDWQ, 2005). Water although, one of the most abundant compounds on earth, yet a huge portion of the world's population does not have access to a reliable supply of drinking water. Pollution of water resources is a global problem. According to Leiv (2005) reported that "the total supply of water is astronomical". The investigator also reported that from consumer's point of view, more than 97% of this is found in the ocean and can therefore not be directly used for drinking, of the remaining amount, only approximate one-eight is suitable for drinking". He continued that inspite of efficient natural recycling, we are facing a global water problem, mainly because the world's population has been growing at an

exponential rate for decades. In 1920 there were 1 billion people, 1960, some 3 billion; and today over 6 billion of us. As a result, the average amounts of drinking water available per person has been and as still increasing (Chemical Research Applied to World Needs, CRAWN, 2005).

Similarly, the World Health Organization, WHO (1994) reported that 2.4 billion people do not have access to basic sanitation facilities and more than I billion do not have access to safe drinking water.

WHO (1994) also noted that unclean water causes diarrhoea, which kills about 1.8million people world wide each year, 1million of whom are children under the age of five. Every year, diarrhea strikes about 4 billion people, causing about 4.5% of the global burden of disease. Unclean water also causes cholera, dysentery, guinea worm infection, typhoid, intestinal worm infection, and trachoma (CRAWN , 2005).

WHO statistics relating to water supplies are alarming, "one-sixth of humanity currently lacks access to any form of improved water supply within 1 Km of their homes." An improved drinking water source, is any type of water that is likely to provide sufficient quantities of safe water to a community or individual (CRAWN, 2005).

The situation in Nigeria is worse. Many people in an attempt to grapple with the challenges of the economy, have ventured into small scale business and production, notably "pure" water, with little or no knowledge

of the good manufacturing practices (GMP) and Quality control, thus leaving the unsuspecting consumer at the mercy of these untrained manufacturers.

The Lagos State Ministry of Environment and Physical Planning in its 1995 State of the Environment Report declared that most of the "pure water" packaged and sold indiscriminately to the unsuspecting public for consumption in Lagos are not pure (Dada, 1996). The report further state that most of them are not wholesome, they sustained growth of many micro-organism far above allowable limit of the WHO Standards." This assertion is supported by the report of Osibanjo et al (2000) that 50% of the so called "pure water" products on the streets of Lagos may not be fit for human consumption. In addition, the Federal Ministry of Health gave a statistics in 1994 that only about 30% of Nigerians have access to potable water.

Statistics have shown that in developing nations of the world like Nigeria, 80% of all diseases and over 30% of deaths are water related, (Dada and Ntukekpo, 1996). Because of the magnitude of health hazards associated with water, water sold to the public must be monitored to ensure that the samples do not deviate drastically from the WHO Standards. Although report on chemical and microbiological analyses of "pure water" samples can be found in literatures, there is little or no report on the potability of sachet water produced in Niger State. There is therefore the need for the

present study. The findings will be compared with the standards set by WHO and the National Agency for Food and Drug Administration and Control (NAFDAC).

AIMS AND OBJECTIVES

The main aims and objectives of the study are

1. To carry out sensory analyses of the water samples within Niger state.
2. To determine the microbiological quality of the pure water (sachet water) samples produced in Niger State.
3. To isolate and identify the bacterial contaminants
4. To evaluate the physio-chemical properties and metal content of the water samples.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Nature, Composition and Characteristics of Water

The analysis of water reveals the presence of gases, suspended or dissolved minerals, and organic and inorganic, and microorganisms. Many water components occur naturally, originating from rocks, soils, and air, or from human and animal sources. To these components, anthropogenic substances will be added by human forces, these merely being due to urban, industrial and agricultural activities. Treatment techniques of both urban and industrial waste-water will also lead to the formation and subsequent release of contaminants in processed waters (e.g bromate due to ozonation, various other disinfection by-products) (Rump, 1999). The quality and amounts of various (natural and/or anthropogenic) constituents actually form the basis for the definition of the quality of water, upon which the adequacy for various uses will be decided (e.g. human and domestic animal consumption, domestic or industrial uses, irrigation,etc).

2.2 The Concepts of Pure Water

Water exists in nature in many forms- clouds, rain, snow, ice, and fog; however, strictly speaking, chemically pure water does not exist for any appreciable length of time in nature. According to Theodore (2003), even when falling as rain, water picks up small amount of gasses, ion, dust and

particulate matters from the atmosphere. Then, as it flows over or through the surface layer of the earth, it dissolves and carries along with it some of almost every thing it touches including that which is dumped into it by man. The same view is shared expressed by the Canadian Health Guideline, CHG (2005) for drinking water . The Guidelines state that pure water, often defined as water containing no minerals, or chemicals, does not exist naturally in the environment, and futher indicate that good quality drinking water is free from objectionable colour or odour. However, there is difference between 'pure water' and 'safe drinking water'. Under ideal conditions water may be distilled to produce 'pure water'. Safe drinking water on the other hand, may retain naturally occurring minerals and chemicals, such as calcium, potassium, sodium or fluoride, which are actually beneficial to human health and may also improve the taste of the water (Theodore, 2003). Where the minerals or chemicals occur naturally in concentrations that may be harmful or displeasing, certain water treatment processes are used to reduce or remove the substances. In some cases, some chemicals are actually added to produce good drinking water; the examples of chemicals added are chlorine, used as a disinfectant to destroy microbial contaminants, and fluoride, used to reduce dental cavities (Theodore, 2003).

Pure water therefore, means different things to different people. Home owners are primarily concerned with domestic water problems related to

color, odor, taste and safety to family health as well as the cost of soaps, detergents, 'softening or other treatments required for improving the water quality (Theodore, 2003). Chemists and Engineers working for the industries are concerned with purity of water as it relates to scale deposition and pipe corrosion (Theodore, 2003). Regulatory agencies are concerned with setting standards to protect public health. Farmers are interested in the effects of irrigation water on the chemical, physical and osmotic properties of soil, particularly as they affect crop production, hence, they are concerned with the water's total mineral contents, proportion of sodium, or content of ions "toxic" to plants (United States Environmental Protection Agency, USEPA, 2005). One means of establishing and assuring the purity and safety of water is to set a standard for various contaminants. A standard is a definite rule, principle or measurements, which are established by governments' authority, professional bodies and international organizations (USEPA, 2005).

The fact that standards are made by this bodies made it rigid, official and legal, but this fact does not necessarily mean that the standards are fair or based on complete sound scientific knowledge. Where human health data or other scientific data are sparse, standards have sometimes been established on interim basis until better information becomes available (Theodore, 2003). From the forgoing, water quality therefore, is best defined in terms of the chemical, physical and biological contents of water.

The water quality of rivers and lake changes with the seasons and geographic areas, even when they are no pollution present (Theodore, 2003). Therefore, no single measure constitutes good water quality. For instance, water suitable for drinking can be used for irrigation, but water used for irrigation may not meet drinking water guidelines (Canadian's Health Guidelines, 2005).

2.3 Key Factors Influencing Water Quality

Many factors affect water quality and its variation through the hydrologic cycle (USEPA, 2005). These are:

- Soil, geologic formations and terrain in the catchments area (river basins)
- Surrounding vegetations and wild life;
- Precipitations and run off from adjacent lands;
- Biological, chemical and physical processes in the water;
- Human activities in the region

Substances present in the air affect rain water quality. Dust, volcanic gases, and natural gasses in the air, such as carbon dioxide and oxygen, and nitrogen are all dissolved or entrapped in rainfall (USEPA, 2005).

Near coastlines precipitation contains high concentration of sodium chloride, while downwind of industrial areas other substances, such as sulphur dioxide, nitrogen compounds, toxic chemical or lead are in the air

and are also collected in the rain as it falls to the ground (Water Quality Management, 2005). Rain reaches the earth surface flowing over (run off) and through (infiltration) the soil and rocks, dissolving and picking up other substances. The run off will increase concentration of soluble substances, whether natural or due to human activities, contained on the surface soils, but it is the seepage that will influence remarkable water chemistry (USEPA, 2005).

Soils contain high concentration of carbon dioxide, which dissolves in the ground water, creating a weak acid capable of dissolving many silicate minerals. In its passage from recharge to discharge area, ground water may dissolve substances it encounters or it may deposit some of its constituents along the way. The final ground water quality will depend on the kind of rock and soil formation through which the ground water flows, and possibly on the residence time (Canadian's Health Guidelines, CHG, 2005). In general, faster flowing water dissolves less material. Ground water, of course, carries with it any soluble contaminants, which it encounters (CHG, 2005). Another factor influencing water quality is the runoff from urban areas. It collects debris littering the streets and take it to the receiving stream or water body.

Moreover, urban run off worsen the water quality in rivers and lakes by increasing the concentrations of substances such as nutrients (phosphorus

and nitrogen), sediments, microbial contaminants (faecal coliforms and pathogens), organic compounds and minerals like salts (chlorides) and petroleum products. Industrial, farming, mining, and forestry activities also significantly affect the quality of rivers, lakes, and ground water (CHG, 2005). For example, farming can increase the concentration of nutrients, pesticides and herbicides and suspended sediments. Industrial activities can increase concentration of metals and toxic chemicals, add suspend sediment, increase temperature, and lower dissolved oxygen in the water. Each of these effects can have a negative impact on the aquatic ecosystem and/or make water unsuitable for established or potential uses (CHG, 2005).

Factors affecting water quality have a different intensity on ground water and surface waters so that the composition of ground water can differ remarkable from surface water (CHG, 2005). Here are some differences:

- For many given sources, quality, temperature and other parameters of ground water are less variable over the course of time;
- In nature, the range of ground water parameter encountered is much larger than for surface water, for example, dissolved solids can range from 25mg/l to 300,000 mg/l in some saline water;
- At any given location, ground water tends to be harder and more saline than surface water, but this is by no means a universal rule. It is

also generally the cause that ground water becomes more saline with increasing depth, but again, there are many exceptions;

- As ground water flows through an aquifer it is naturally filtered. This filtering combined with the long residence time underground, means that groundwater is usually free from disease-causing microorganisms. A source of contamination close to a well, however, can defeat these natural safeguards. Natural filtering also means that ground water usually contains less suspended materials and undissolved solids than surface water (CHG, 2005).

2.4 Safeguarding Water Quality

In order to protect water quality, governments have fixed standards or concentration limits of guidelines (scientifically determined) that can be tolerated for a particular use such as drinking, irrigation or recreation like swimming (CHG, 2005). These standards also affect the selection of raw water sources and the choice of treatment processes. The development of water quality standards began in the United States in the early 20th Century. Since that time, the total number of regulated contaminants has increased as toxicological knowledge and analytical measurement techniques have improved (CHG, 2005). Modern testing methods now allow the detection of contaminants in extremely low concentration as low as one part contaminant per one billion parts water. Or even, in some cases, per one trillion parts

water. Water quality standards are continually evolving, usually becoming more stringent. As a result, the number of regulated contaminants increases over time, and their allowable concentrations in water lowered.

Drinking water regulations include two types of standards: primary and secondary. Primary standards are designed to protects public health, whereas secondary standards are based on aesthetic factors rather than on health effects (CHG, 2005). Primary standards specify maximum contaminant levels for many chemical, microbiological, and physical parameters of water quality. They reflect the best available scientific and engineering judgments and take into account exposure from water sources in the environment and from foods. Turbidity is also included in the primary standards because of its tendency to interfere with disinfection. Secondary standards are guidelines or suggested maximum levels of colour, taste, odour, hardness, corrosiveness, and certain other factors (Guidelines for Drinking-Water Quality, GDWQ 2005).

2.5 Health Effects of Drinking Water Contaminants

Chemicals in drinking water which are toxic may cause either acute or chronic health effects. An acute effect usually follows a large dose of a chemical and occurs almost immediately (GDWQ, 2005). Examples of acute health effects are nausea, lung irritation, skin rash, vomiting, and dizziness, and in the extreme, death. The levels of chemical in drinking water,

however, are seldom high enough to cause acute health problem. They are more likely to cause chronic health effects that occur after exposure to small amount of chemical over a long period of time (GDWQ, 2005). Examples of chronic health effects include cancer, birth defects, organ damage, disorder of the nervous system, and damage to the immune system, although evidence relating chronic human health effects to specific drinking water contaminants is very limited. In the absence of exact scientific information, scientists predict the likely adverse effects of chemicals in drinking water using laboratory animal studies and, when available, human data from clinical reports and epidemiological studies.

The United State Environmental Protection Agency, USEPA (2005) classifies compounds for carcinogenicity potential according to the "weight of evidence" approach as stated in the Agency's Guidelines for carcinogen Risk Assessment. These Guidelines specify five carcinogenicity classifications:

Group A: Human carcinogen (sufficient evidence from epidemiological studies.)

Group B: Probable human carcinogen

Group B1: At least limited evidence of carcinogenicity in humans.

Group B2: Usually a combination of sufficient evidence in animals and in adequate data in humans.

Group C: Possible human carcinogen (limited evidence of carcinogenicity in the absence of human and animal data).

Group D: Not classifiable (inadequate human and animal evidence of carcinogenicity).

Group E: Evidence of non-carcinogenicity for humans (no evidence of carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies).

The possible health effects of a contaminant in drinking water differ widely, depending on whether a person consumes the water over a long period, briefly, or intermittently. Thus, maximum contaminant levels, MCLs and monitoring requirements for systems serving permanent population (public community water systems and non-transient non- community water systems) may be more stringent than those regulations for systems serving transient or intermittent users (public non community water system)(USEPA, 2005). Maximum contamination levels (MCLs) are based, directly or indirectly on an assumed drinking water rate of two liters per person per day. MCLs for organic and inorganic contaminants (except nitrite) are based on the potential health effects of long time exposure, and they provide substantial protection to virtually all consumers. The uncertainty in the process is due in part to the variation in the knowledge of, and the nature of health risks of the various contaminants (USEPA, 1989).

2.6 Description of Causes and Effects of Some Major Water Contaminants

(i). **Cadmium**

Cadmium is found in very low concentration in most rocks, as well as in coal and petroleum and often in combination with zinc. Geologic deposits of cadmium can serve as source to ground water and surface water contamination, especially when in contact with soft, acidic waters. It is introduced into the environment from mining and smelting operations and industrial operations, including electroplating, reprocessing cadmium scrap, and incineration of cadmium containing plastics. The remaining cadmium emissions are from fossils fuel use, fertilizer application, and sewage sludge disposal. Cadmium may enter drinking water as a result of corrosion of galvanized pipe, and also land fill leachates. Acute and chronic exposure to cadmium in animals and humans results in kidney dysfunction, hypertension, anemia, and liver damage. Cadmium has been classified in EPA's Group B1 (probable human carcinogen). Because of cadmium's potential adverse health effects and widespread occurrences in raw waters, it is regulated (USEPA, 1989; Theodore, 2003)

(ii.) Copper

Copper is a reddish-brown metal, often used to plumb residential and commercial structures that are connected to water distribution systems.

Contamination of drinking water by copper occurs as a result of the corrosion of copper pipes that remain in contact with water for a prolonged period of time. Copper is an essential nutrients, but at high doses it has been shown to cause stomach and intestinal distress, liver and kidney damage and anemia. Persons with Wilson's disease may be at higher risk of health effects due to contamination resulting from the corrosion of plumbing materials. Public water systems serving over 50,000 people or fewer that have copper concentrations below 1.3 part per million in more than 90 percent of tap water samples (the USEPA action level) are not required to install or improve their treatment. Any water system that exceeds the action level must also monitor its source of water to determine whether treatment to remove copper in water is needed (USEPA , 1989).

(iii) Lead

Materials that contain lead have frequently been used in the construction of water supply distribution systems in private homes and other buildings. The most commonly found materials include service lines, pipes, brass and bronze fixtures, and solders and fluxes. Lead in these materials can contaminate drinking water as a results of the corrosion that takes place when water comes into contact with those materials. At relatively low levels of exposure, these effects may result in red blood cell malfunction, delay in normal mental and physical development in babies and young children,

slight deficit in the attention span, hearing and learning abilities of children, and slight increase in blood pressure of some adults. (USEPA , 1989).

The following steps can be taken to minimize exposure to lead (USEPA, 1989):

- Plumbing should be flushed your plumbing to counteract the effects of "contact time". Flushing involves allowing the cold faucet to run until a change in temperature occurs (minimum of one minute). Water drawn during flushing does not have to be wasted. It can be saved for other uses such as washing dishes or cloths and watering plants.
- Do not consume hot tap water. Hot water tend to aggravate lead leaching when brought in contact with lead plumbing materials.
- For private wells steps can be taken to make water non-corrosive. Water treatment devices for individual households includes filters and other devices to lessen acidity.
- Insist on lead-free material for use in repairs and newly installed plumbing.
- Lead can be removed from tap water by installing point-of-use treatment devices now commercially available, which includes: ion exchange filters, reverse osmosis devices, and distillation units.

Lead has been classified in EPA's group B2 (probable human carcinogens), based upon evidence of kidney tumors in rats by the oral route (USEPA , 1989; Theodore, 2003).

(iv). Aluminium

It is believed that in some waters post precipitation of aluminium may take place after treatment. This could cause increased turbidity and aluminium water quality slugs under certain treatment and distribution changes. The World Health Organization, WHO(1994) stated that "discolouration of drinking water in distribution systems may occur when the aluminium level exceeds 0.1mg/l in the finished water". WHO (1994) further adopted a guidance level of 0.2mg/l in recognition of difficulties in meeting the lower level in some situation. USEPA encourages utilities to meet a level of 0.5mg/l where possible, and upholds that varying water quality and treatment situations necessitate an approach to establish the secondary maximum contaminant level (SMCL).

(v) Iron

At 1.0mg/l a substantial number of people will note the bitter astringent taste of iron in water. Also at this concentration it impacts a brownish colour to laundered clothing and stains plumbing fixtures with a characteristic rust colour. Staining can result at a level of 0.05mg/l, lower than those that are detectable to taste buds (0.1-1.0mg/l). Therefore, the

SMCL of 0.3mg/l represents a reasonable compromise as adverse aesthetic effects are minimized at this level (USEPA, 1989; Theodore, 2003).

(vi) **Manganese**

Concentration of manganese higher than 0.05mg/l may cause a dark-brown or black stain on porcelain plumbing fixtures. As with iron, manganese may form a coating on distribution pipes. These may slough off, causing brown blotches on laundered clothing or black particle in the water (Theodore, 2003).

(vii) **Zinc**

zinc is found in some natural waters, not frequently in the areas where it is mined. It is not considered detrimental to health unless it occurs in very high concentrations. It imparts an undesirable taste to drinking water. For this reason, the SMCL of 5.0mg/l has been set (USEPA, 1989; Theodore, 2003).

(viii). **Sodium**

Sodium is the principal cation in the hydrosphere. It is derived geologically from the leaching of surface and underground deposit of salts (e.g. sodium chloride), and from the decomposition of sodium aluminum silicates and similar minerals. The sodium ion is a major constituent of natural water. Human activities also contribute sodium to water supply, primarily through the use of sodium chloride as a de-icing agent, and as a

washing product. It has been estimated that food accounts for about 90% of the daily intake of sodium, whereas drinking water contribute up to the remaining 10%. In order to afford protection to a segment of the U.S. population on sodium restricted diet, in 1968, the American Heart Association(AHA) recommended a level of 5mg of sodium per 8 ounces of water or 20mg/l while USEPA (1989) suggested a guidance level for sodium of 20mg/l in drinking water for the high risk population. For healthy persons, the sodium content of water is unimportant because the intake from salt is so much greater, but for persons placed on low sodium diet because of heart, kidney, circulatory ailments, or complication in pregnancy, sodium in water must be considered.

(ix) **Sulphate**

High concentration of sulphate in drinking water has three effects:

1. Water containing appreciable amounts of sulphate tends to form hard seals in boilers and heat exchangers

2. Sulphate cause taste effects

3. Sulphate can cause laxative effects with excessive intake.

The laxative effect of sulphate is usually noted in transient users of water supply because people who are accustomed to high sulphate level in drinking water have no adverse response. Diarrhea can be induced at sulphate level greater than 500mg/l but, typically near750mg/l sulphate

cannot easily be removed from water, except by distillation, reverse osmosis or electrolysis, it is recommended that either an alternative source be used or that the high sulphate water be diluted with a lower sulfate containing water (Meyer and Keliher, 1992).

(x) **Chlorides**

The SMCL of 250mg/l for chloride is the level above which the taste of the water may become objectionable to the consumer. In addition to the adverse taste effects, high chloride concentration levels in the water contribute to the deterioration of domestic plumbing, water heater, and municipal water works equipments. High chloride concentration in the water may also be associated with the presence of sodium in water. Elevated concentration of sodium may have adverse health effects on normal, healthy persons. In addition, a small segment of the population may be on a severely restricted diet requiring limitation of their sodium intake. For the preceding reasons, the SMCL for chloride represents a desirable and reasonable level for protection of the public welfare (WHO, 1994; Diamond, 1994).

(xi) **Nitrate**

Most nitrogenous materials in natural water tend to be converted to nitrate, and therefore, all sources of combined nitrogen (particularly organic and ammonia) should be considered as potential nitrate sources. Nitrate occurs naturally in mineral deposits (sodium or potassium nitrates), in soil,

sea water, fresh water, the atmosphere, and in biota. Lakes and other static water bodies usually have less than 1.0mg/l of nitrate/nitrogen. Ground water levels of nitrate/nitrogen may range up to 20ug/l or more, with higher levels characteristically accruing in shallow aquifers beneath areas of extensive developments. A major source of nitrate in drinking water include fertilizer, sewage, and feedlots. The toxicity of nitrate in humans is due to the body's reduction of nitrate to nitrite. These reactions take place in the saliva of humans at all ages and in the gastrointestinal tract of infants during the first three months of life. The toxicity of nitrite is demonstrated by vasodilator/cardiovascular effect at high dose levels and methemoglobinemia at lower dose levels(USEPA,1989).

Methemoglobinemia "blue baby disease" is an effect in which hemoglobin is oxidized to methemoglobin, resulting in asphyxia. Infants up to three months of age are the most susceptible subpopulation with regard to nitrate. This is due to the fact that in the adult and child, about 10% of ingested nitrates is transformed to nitrite, while, 100% of ingested nitrate can be transformed to nitrite in the infants. The effects of methemoglobinemia are rapidly reversible, and there are, therefore no accumulative effects. Nitrate/nitrite has been classified in the EPA's Group D (not classifiable), based upon adequate data in humans and animals. Nitrate compounds have

demonstrated adverse toxic effects in infants. Due to potential toxicity and widespread occurrence in water, it is regulated (Theodore, 2003).

(xii) **Nitrite**

Nitrite is used in fertilizers. It is also found in sewage and may get into drinking water by runoff into surface water or by leaching into ground waters (USEPA, 1989). While excessive amounts of nitrite in drinking water have not been observed, other source of nitrite has caused serious illness and sometimes, death in infants less than six months of age. The serious illness in infants is caused because nitrite interferes with the oxygen-carrying capacity of the child's blood. This is an acute disease in that symptom can develop rapidly (USEPA,1989). However, in most cases, health deteriorates over a period of days. Symptoms include shortness in breath and blueness of the skin. USEPA(1989) has set the drinking water standard at 1mg/l for nitrite to protect against the risk of adverse effects.

(xiii) **Hardness**

Water hardness is caused by the polyvalent metallic ions dissolved in water. Hardness is usually reported as equivalent concentration of calcium carbonate ($CaCO_3$). The concept of water hardness comes from water supply practices. It is measured by soap requirement for adequate leather formation and an indication for the rate of scale formation, and as an indication of the

rate of scale formation in hot waters and low pressure boilers. A commonly used classification of water by hardness contents is given below:

Concentration of hardness description CaCO3 (mg/l)

(0 – 75) (0 – 5) soft

(75 – 150) (5 – 9) moderately high;

(150 – 300) (9 – 18) hard

(300 and up) (18 and up) very hard

Natural sources of hardness principally are limestones, which have been dissolved by percolating rain water. Industrial sources include discharges from operating and abandoned mines. Hardness in fresh water is frequently distinguished as carbonate and non carbonate fractions(USEPA,1989). The carbonate fraction is chemically equivalent to the carbonate present in water. Since carbonates are generally measured as alkalinity, the carbonate hardness is usually considered equal to the alkalinity (USEPA,1989). When water containing carbonate or temporary hardness is heated, carbon dioxide is driven off, converting the bicarbonates to carbonates which precipitate to form the hard scale found in cooking utensils, pipes, hot water tanks, and boilers. The scale reduces the capacity of pipe to carry water and does not transmit heat well. Detergents minimize the adverse effects of hard water in washing and other processes, and proper water softening entirely eliminates the hardness problem. When hardness

exceeds 180mg/l, it generally causes problems and water softner should be considered. Water softened to zero hardness causes corrosion. It is therefore, desirable to blend a proportion of non-softened water with extremely soft water (American Public Health Association, APHA, 1985; USEPA, 1989, Theodore, 2003).

(xiv) **Total dissolved solids(TDS)**

Total dissolved solids (TDS) may have an influence on the acceptability of water in general. In addition, high TDS may be an indication of the presence of excessive concentration of some specific substances not included in the safe drinking water act, which would make the water aesthetically objectionable to the consumer. Greenberg et al (1998) pointed out that the life of home hot water heaters decreases by approximately one year for each additional 200mg/l. The SMCL of 500mg/l for TDS is reasonable because it represents an optimum value commensurate with the aesthetic level to be set as a desired water quality goal (Greenberg et al, 1998).

(xv) **Turbidity**

Turbidity in water is caused by the presence of suspended matter, such as clay, silt, fine particles of organic and inorganic matter and plankton and other microscopic organisms. The standard measure of turbidity unit (TU).is an expression of the optical property of a water sample which causes light to

be scattered and absorbed rather than transmitted in straight lines through the sample(Clesceri et al ,1998). As the number of particles increase, more light is scattered and higher turbidity readings are obtained. The measuring instrument is called a nephelometer, and the readings are expressed as nephelometric turbidity units (NTU) or turbidity units. Turbidities in excess of 5TUs are easily detectable in a glass of water and are usually objectionable for aesthetic reasons(Clesceri et al, 1998). Clay or other inert suspended particles in drinking water may not adversely affect health, but water containing such particles may require treatment to make it suitable for its intended use. Following a rainfall, variations in groundwater turbidity may be an indication of surface pollution (Clesceri et al, 1998)

(xvi) PH

High pH level in drinking water is undesirable since it may impart a bitter taste to the water. The high degree of mineralization associated with alkaline water will result in the encrustation of water pipes and appliances water-using. High pH levels also depress the effectiveness of disinfection by chlorination, thereby requiring the use of additional chlorine or longer contact times. A pH range of 6.5-8.5 was determined as that which would achieve the maximum environmental and aesthetic benefits (Greenbarg et al, 1998)

(xvii) **Odour**

Odour for certain substances in water may be detected at extremely low concentrations. This may be indicative of the presence of organic and inorganic pollutants that may originate from industrial and municipal waste discharge or from natural source. The threshold odour number (TON) of water is the dilution factor required before the odour is minimally perceptible (Theodore,2003). A TON of 1 indicates that the water has characteristic odour comparable to odour-free water, while a TON of 4 indicates that a volume of the test water would have be diluted to four times its volume before the odour becomes minimally perceptible. For precise work, a panel of 5 or more testers are required, and the TON is based on the greatest amount of dilution which elicits a positive odour response from one of the testers(Theodore, 2003). The TON of 3 was determined to be appropriate because most of the consumers found the water at this limit acceptable. Determination of odour below this level is difficult because of possible interferences from other sources and availability of the sensing capability of the personnel performing the test. Therefore, the SMCL of 3 TON has been set (Theodore, 2003).

2.7 Prescribed Levels by Regulatory Bodies of Major Drinking Water Constituents

In section 2.6, description of some major constituents of drinking water has been given in this section, the approved standard levels of these constituents are listed in Table 1.

Table 1: Prescribed Levels of major constituents in drinking water

Parameter	NAFDAC Standard	USEPA Standards
pH	6.82 – 8.50	6.5 – 8.5
Dissolved CO_2	Not more than 50	not more than 50
Total alkalinity	" " " 100	" " " 100
Total hardness	" " " 100	" " " 180
Total solids	" " " 500	" " " 500
Suspended solids	" " " 250	" " " 250
Chlorides	" " " 200	" " " 250
Sulphate	" " " 200	" " " 250
Sodium	" " " 150	" " " 50
Potassium	" " " 12	" " " 14
Calcium	" " " 75	" " " 70
Magnesium	" " " 30	" " " 30
All trace metals	Should not be detected	" " " 0.1-0.5
Nitrate	" " "	" " " 01
Nitrite	10^2/ml	" " " 01
Viable Bacterial counts	0 cfu/ml	10^2/ml
Pathogenic organize	0 cfu/ml	0 cfu/ml
Coliform	0 cfu/ml	0 cfu/ml
Escherichia coli		0 cfu/ml

Source- USEPA, (1989): NAFDAC Standard Operating Procedure (2000)

CFU- colony forming units Plate count agar- is used for the viable bacterial counts

Pathogenic organisms are detected using MacConkey agar

(xviii) Microorganisms

Microbiological testing of water is particularly important because it offers the most sensitive method for the detection of faecal, pollution. Any pathogenic microorganism present in water is usually greatly outnumbered by their cells and in general tend to die out more rapidly by chemical treatment (Rump,1999). Although it may be possible to isolate pathogens in contaminated water, especially when it is heavily polluted, large amounts (e.g several litres) of the water need to be examined using conventional techniques. However, accurate evaluation of the organisms involves biochemical, serological and other tests on pure cultures.

Therefore relatively simple and more rapid (indicator) bacteriological tests for the presence of certain intestinal bacteria (in particular, *Escherichia coli* and other coliform organisms) are relied upon. These bacteria are easier to isolate and characterize; and they are always present in the faeces of man and warm blooded animals (and hence in sewage), in large numbers. The presence of faecal indicator organisms in a sample of drinking water, suggests that intestinal pathogene could be present, and that the supply is therefore potentially dangerous to health. However, there is no absolute correlation between the numbers of *E.coli* or other coliform organisms and the actual presence of or numbers of enteric pathogens. There is also no

correlation between the risk of illness occurring and the numbers of *E. coli* (HMSO, 1994)

E. coli in a properly treated water sample indicates the presence of material of faecal origin and thus a potentially dangerous situation. Conversely the absence of faecal organisms is an indication that, probably, intestinal pathogens are also absent in the sample (HMSO, 1994). Of the pathogens, and facultative pathogenic types of bacteria which can occur in contaminated water, the bacteria of the Enterobacteriaceae family are of particular importance. The species of *Shigella*, S*almonella,and Escherichia* ,the so called coliform bacteria, *Proteus, Yersinia and Erwinia* all belong to this family. *Salmonella* and *Shigella* are classed as extremely pathogenic, whereas most of the others are considered as facultatively pathogenic. When testing water for microbiological quality, analyses mainly focus on E. *coli* and coliforms ,with lesser emphasis being placed on *Clostridium perfringens* and Enterococci .In addition , the eggs /cysts/oocysts of various parasites can be present in water (HMSO,1994;Rump,1999)

2.8 Drinking Water Treatment Technologies and Device

(a). **Activated carbon filtrations-** This technology uses any of several carbonaceous materials such as bituminous coal, coconut shells, lignite, peat, or wood (USEPA,1989). It is effective for some organic chemicals, pesticides, taste, odour, trihalomethene. Activation is the process whereby

the carbonaceous materials are fragmented under high heat by stream in the absence of oxygen. Granules and exposed pores are extracted. Certain contaminants in water such as organic chemicals will adhere to the exposed surfaces of many pores, through a variety of sorption processes (USEPA,1989). Studies have shown that this process is most effective in removing large (high molecular weight) impurities and those with relatively low solubility in water.

Activated carbon filter will significantly improves taste and odour of drinking water. Besides, it effectively removes chlorine and specific absorbable organics such as trihalomethane (USEPA,1989) . Activated carbon filter works best when first put in service. With use, the absorption capacity of the carbon becomes used up and the filter no longer removes as much of the contaminants In fact, contaminant can leach off the filter at high concentration than the influent concentration when the filter becomes over loaded (USEPA,1989). The only way to determine if the filter has removed the contaminants to acceptable levels is by repeated testing of the treated water. When using the units to remove health-related contaminants it is preferable to install two units in series with a sample tap in between so that testing can be done to determine when one unit is used up and need to be replaced (USEPA, 1989).

(b) **Chlorination-** Chlorination of individual water system should be considered only as a last resort. Often called well disinfection or shock chlorination, it can be accomplished by mixing a strong chlorine solution with the water in the well and letting it stand for few hours. This will kill the coliforms and most disease-causing microorganisms. As a general practice, a new well should be shock chlorinated before being put to use, and again when ever is open to pull the pump or remove sand and sediments from the bottom of the hole. The amount of chlorine fed can be increased with a simple adjustment of control knob. It is important to inspect the chlorine storage tank and chlorinators frequently to be sure that a supply of chlorine solution is always available and that the equipment are working properly (Theodore, 2003). Calcium hypo chloride, in powder or tablets, can be used as concentrated sources of chlorine to mix a stock of solution. After mixing, only the clear solution should be used while discarding the bottom sediment because it may clog the hypo chlorinator (USEPA, 1989; Theodor, 2003).

(c). **Ultra violet radiation-** This technology uses a special light bulb which produces ultraviolet light. The ultra violet radiation must pass through every particle of water with a minimum dose to be effective in water purification. In clear water this is not difficult to achieve. However, turbid water may allow disease-causing microorganisms to "hide behind" particles, shielding them from coming in contact with the killing radiation. When operating

properly, ultraviolet radiation can produce water free from bacteria and virus (up to 99.9% killing rates). The process leaves no residue, taste or odour. Some UV systems have a meter that measures the UV light transmitted through the water (Theodore, 2003). A quartz window at the side of the irradiating chamber allows the UV rays to activate a photo electric cell which measures the intensity of the UV. The major problem with most UV system is the collection of sediments and growth of algae inside the irradiation chamber. New designs are available which may help to eliminate this problem. In one new UV system, water flow through Teflon tubes surrounded by irradiating UV lights. This eliminates the fouling on the quartz tubes and appears to be an effective and relatively maintenance-free method (USEPA, 1989; Theodore, 2003).

(d) **Ion exchange**

In exchange is effective for hard water (water-containing) calcium, manganese, irons and some metals. Ion exchange is a combined physical and chemical process in which ions that are dissolved in water are transferred to and held by a solid material or exchange resin. The systems used for water softening contain a cation exchange resin. Positively charged sodium ions are used to coat most common cation exchange resin. When water containing dissolved cation contacts the resin, the cations are exchanged for or trade places with the loosely held sodium ion on the resin. In this way the

calcium and magnesium ions responsible for hardness are removed from the water and placed on the exchange resin, a process that makes the water "soft". In this process however, sodium ions are added to the water(Theodore, 2003). Eventually a point is reached where very few sodium ion remains on the resin, thus no more calcium or magnesium ion can be removed from the incoming water. The resin at this point is said to be "exhausted" or "spent" and cannot accomplish further water treatment until it is recharged or regenerated (Theodore, 2003)

(e) **Reverse Osmosis**

Reverse osmosis is effective for certain inorganic chemicals, dissolved solid and nitrites. Reversed Osmosis (RO) treatment decreases the dissolved impurities in water. It successfully treats water with high salt content, cloudiness, and dissolved minerals such as sulphates, calcium, nitrate, sodium, potassium, manganese, chloride, nitrite, fluoride boron and orthophosphate (USEPA, 1989). RO is also effective with some detergents, some taste, colour and odour-producing chemicals, certain organic contaminants, and specific pesticides. RO unit operates by passing water under pressure at the tap through celluloid or non celluloid membranes. A cellulose acetate membrane will not be degraded by chlorine present in municipal water system (Theodore, 2003).

A polyamide membrane will be degraded and therefore, must be preceded by an activated carbon filter for chlorine removal when chlorinated water is to be treated. RO removes 90-95% of most dissolved contaminants. (USEPA, 1989;Theodore, 2003).

(f) **Air Stripping**

Air stripping is effective for some volatile organic chemicals, hydrogen sulphide, iron. In air stripping column water flows downward by gravity while air is pumped upwards from the bottom of the column by a mechanical blower (USEPA, 1989). As the water flows down the column it passes over a packing material which increases the area of the air-liquid inter-phase. Volatile organic compounds are transferred from the water to the air which is vented outside. The volatile organic chemical (VOCs) which is most commonly detected in ground water can be removed by air stripping. In point of application, up to 90% removal of VOCs can be expected (USEPA, 1989).

Aeration is also effective in removing certain inorganic contaminants including hydrogen sulphide and iron. The removal efficiency of air stripping columns is largely dependent on the type of VOCs present in the water and the ease with which they are stripped from the water.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Collection of Samples

A total of two hundred and fifty (250) packaged water samples were collected from fifty different individual producers in five major towns in Niger State in this order: Minna (70 samples); Kontagora (75 samples); Suleja (50 samples); Bida (30 samples); and Mokwa (25 samples). Majority of the samples were obtained from designated sales points while others were bought directly from the manufacturers, and stored in the refrigerator, but not allowed to freeze. The samples were analyzed to ascertain their level of compliance with NAFDAC and WHO prescribed standards, based on these parameters: Sensory (appearance, odour, taste); physical (net volume, colour, pH, total solids, suspended solids, total dissolved solids); chemical (free dissolved CO_2, phenolphthalein alkalinity, methyl orange alkalinity, chloride content, total hardness, sulphate content, Nitrate, Nitrite); Metals (potassium, sodium, calcium, magnesium, iron, copper, zinc, manganese, lead, cadmium); and microbiological quality (Total plate counts, coliforms, *Escherichia coli* and other pathogenic bacteria).

3.2 Determination of Sensory Parameters

(i) Appearance

The water sample was poured into a clean beaker and viewed directly with the naked eye. The result was recorded as, clear-colour liquid, colourless liquid with particles or coloured liquid with particles.

(ii) Odour

A clean and dry conical flask was filled with the water sample to approximately two third full and examined for odour, by smelling using a panel of five members. The result was read as unobjectionable if the sample had no odour, objectionable if the sample had odour, repulsive, if the sample had strong odour.

(iii) Taste

The water sample was poured into a clean dry conical flask. A sip of the water sample was taken to ascertain the taste. The result was recorded as, unobjectionable if the water had no taste, objectionable if the water had taste. This aspect was certified by panel of five members.

3.3 Determination of Physical Parameters

(i) Net Volume.

The water sample was poured into the graduated cylinder to the 50 ml mark and the net volume was determined.

(ii) **Colour**

Nessleriser Cylinder was slot into its compartment in the Lovibond Comparator and a clean and dry Nessleriser cylinder was filled with the sample and made up to the 50ml mark. This was slotted into the sample compartment in the comparator. Another clean and dry Nessleriser cylinder was filled with distilled water and made up to the 50ml mark. This was placed in a blank compartment. Both samples were viewed in the comparator simultaneously. The Nessleriser Disc NSA was scrolled such that the colour of the blank matched that of the sample. The reading on the Nessleriser Disc NSA was recorded.

(iii) **pH**

A pH meter was switched on and allowed to stand for 15 minutes, it was then calibrated with buffer solution of standard pH. The electrode was rinsed with distilled water and then dipped into the water sample. The pH of the water was indicated in the meter.

(iv) **Total solids**

Fifty millilitres 50ml of the sample was pippetted into a weighed flat silica dish (W1), the water was dried off on a water bath. The dish was transferred into a hot air oven previously set at 105^0C and allowed for 3hours. The dish was then cooled in a desiccator and reweighed. The dish was returned into

the hot air oven for 30 minutes. This process was repeated until a constant weight (W2) was achieved. The total solid was calculated as:

Total solids (mg/l) = (W1 – W2) 20000 (mg/l)

(v) **Total dissolved solids**

The electrode of the Hanner's instrument was rinsed with distilled water and the knob was adjusted to zero while dipping in distilled water. The electrode was removed and dipped into water sample and the values that appeared on the screen was recorded as the total solids.

(vi) **Suspended solids**

The suspended solids were obtained by subtracting the values of the total dissolved solid from the values of the total solids.

3.4 Determination of Chemical Parameters

(i). Free dissolved carbon dioxide

A burette was filled with the 0.02N sodium hydroxide solution to 25ml mark. 50ml of the water sample was pippetted into conical flask and 2 to 3 drops of phenolphthalein indicator was added. The content of the burette was titrated against that of the conical flask. The volume of 0.02N sodium hydroxide solution used in course of the titration was recorded and titration was repeated.

Calculation: 1ml of 0.02N sodium hydroxide = 10 ppm of CO2 in a 100ml sample expressed as $CaCO_3$ (mg/l).

(ii) **Phenolphthalein alkalinity**

Fifty millilitres (50ml) of the water sample was pippetted into a clean dry conical flask and 2 drops of phenolphthalein indicator was added. A burette was filled with 0.02N sulphuric acid to the zero mark and titrated against the content of the conical flask. The phenolphthalein alkalinity was calculated as:

1ml 0.02N sulphuric acid = 10ppm of phenolphthalein alkalinity in a 100ml sample as Ymg/l CaCO3.

(iii). **Chloride contents**

A test tube was filled with 10ml of water sample and the pH was adjusted to 7. 3 drops of chloride reagent A was added. A yellow colour developed and a direct reading titrator was filled with chloride reagent B. The titrator was inserted into the centre hole of test tube cap. The titrator was refilled and titration continued. The results was recorded. Parts per million chloride test result may be converted to grammes per gallon (gpg) chloride: gpg chloride = ppm chloride x 0.058

(iv) **Total hardness**

A burette was filled with the EDTA solution to its zero mark and 1ml of ammonium chloride/hydroxide buffer solution was added to 50ml of the sample. 3 drops of solochrome black T indicator was added and mixed. The wine red solution in the conical flask was then titrated with the EDTA

solution. The volume of EDTA solution used was recorded and the titration was repeated. Total hardness of the sample was calculated as:

1ml 0.02N EDTA sodium salt = 10ppm total hardness expressed as $CaCO_3$.

(v) **Sulphate**

A test tube was filled to the 10ml mark with the water sample and one sulfate turb was added. The sample was matched with standards by comparing the degree to which the black lines were obscured by the turbidity (cloudiness) of the sample. Sulphate content was calculated based on the degree of turbidity.

(vii) **Nitrate-Nitrite Test**

(a). **Nitrate**

A sample bottle was filled with the water sample and test tube to bottle line (2.5ml) with water from the sample bottle and diluted with mixed acid Reagent. The content was mixed and left for two minutes.

One level measure (avoid any excess of Nitrate)-reducing reagent was added, shaken and left to stand for 10 minutes. The content was mixed and the colour matched with standard. To convert to ppm Nitrate (NO_3) the test was multiplied by 4.4

(b) **Nitrite test**

A sample bottle was filled with the water sample from where a test tube was filled to 2.5ml mark . The content was diluted to top 5.0ml mark

with mixed acid reagent and a colour developing reagent was added. The content was left to stand for 10 minutes. The content was mixed before inserting the tube into the Nitrate – N comparator and the sample colour was matched to a colour standard. The result was recorded as ppm Nitrite – Nitrogen.

3.5 Determination of metals

(i) **Sodium**

Three separate titrations were carried out to determine the anions and cations in aqueous solutions.

There were:

A: HCO_3 determined by pH titration

B: SO_4 and Cl- determined by pH titration after ion exchange

C: Ca++ and Mg++ determined by total hardness titration.

A: Bicarbonate and carbonate anions

A test tube was filled to the 10ml mark with the water sample and 3 drops of acidity indicator was added, The plunger was pressed until red orange colour was formed. The result was read directly from the titrator in ppm $CaCO_3$ (HCO_3^- and CO_3).

B: Sulphate and chloride anions

The water sample was passed through an ion exchanger column to exchange the associated cations (Na, Ca, Mg, etc.) for hydrogen ions which

were then titrated with sodium hydroxide solution. Two identical resin column were furnished. Each column could be used to exchange 20 water samples, after which it was discarded. A resin column was attached to a test tube. Another test tube was filled half full with deionized water and 4ml of deionized water was added until clear discharge was formed. 5ml of sample water was added to the resin column and all the water sample was discarded, sample water was added to the column until the discharge reaches the 15ml line on the test and the third test tube was filled to the 10ml line with this treated sample. 3 drops of total alkalinity indicator was added. The second direct reading titrator was filled with the NaOH. The test result was read and recorded from the titrator as B.

C: Calcium and magnesium cations

A test tube was filled to the 12.9ml mark with the water sample and 5drops of hardness reagent was added. The direct reading titrator was filled with hardness reagent and titrated until the colour changed from red to clear blue. The result was recorded as C

The sodium content of the water sample was calculated from the formula.

Result A + Result B – Result C x 0.46=ppm sodium.

(ii) **Iron**

A test tube was filled to its 5ml line with the water sample and

5drops of iron conditioning reagent was added. 0.05g of iron reagent powder was added and the content was left for 10 minutes, it was then inserted into the octa – slide viewer. The sample colour was matched to a colour standard and the result was recorded as ppm iron.

(iii) **Zinc**

Two millilitres of the water sample was added to 5ml of demineralized water in a test tube and 5drops of zinc conditioning Reagent was added, mixed and left for 1 minute to eliminate copper interference. One level of scoop of zinc reagent powder was added and shaken for 15 seconds. This was inserted into zinc comparator and sample colour was matched with a colour standard. The result was recorded as ppm zinc. If the reading was higher than 10ppm, higher standard procedure was taken.

3.6 Microbial Counts and Isolation

Microbial counts and isolation were carried out according to the standard methods for the analysis of water as outlined by the 'American Public Health Association, APHA, (1985). These are discussed under each sub-section below:

(i). **Total plate counts**

1.0ml of the sample were poured into petri dishes and 15.0ml of lauryl sulphate broth was added to the different dishes, mixed thoroughly and left to solidify. Incubated at 37^0C for 48hours. Plate that showed discrete

colonies were counted by means of colony counter as colony farming unit per ml (cfu/ml)

(ii). **Enumeration of Coliforms**

The most probable Number (MPN) method of American Public Health Association, APHA (1985) was used for the enumeration of coliforms. This involves the:

(a) **Presumptive test**

Five (5) tubes of the presumptive medium (Lauryl sulphate broth) of the 10ml quantities of water, five tubes of the medium (single strength) of 5ml quantities each with 1ml water and another set of 5 tubes of 5ml quantities each with 0.1ml of the water were prepared.

The inoculated tubes and bottles were incubated at 37^0C for 48 hours and the presence or absence of gas formation was recorded.

(b) Confirmed test

Tubes that showed gas formation were gently shaken and rotated and one to three loopfuls of the medium was transferred to a fermentation tube containing Brilliant Green Lactose Broth. (BGLB) broth. The medium was incubated at 37^0C for 24 hours.

(c) **Completed test**

EMB plates from each tubes of BGLB that showed gas were streaked and incubated at 37^0C for 24 hours. Typical well-isolated coliform colonies

were transferred to lactose broth and to nutrient agar slant. Formation of gas in the fermentation tube was recorded and a gram-stained preparation was made from the agar slant cultures. The formation of gas in the secondary lactose broth tube and the demonstration of Gram-negative non-spore forming, rod-shaped bacteria was considered a satisfactory completed test, demonstrating the presence of a member of the coliform group in the samples examined.

The number of coliforms in any sample that showed positive results were calculated according to the Tables of most probable number (MPN) index of APHA (Appendix 4).

3.6 Confirmation test for *E. coli*

The completed test for the coliform family does not lead to a conclusion of the particular organism within the family isolated. To confirm that the indicator organism for drinking water contamination, *E. coli* was present, EC broth was used to culture the isolate from the completed test. After gently, but thoroughly shaking the culture, 1.0ml was transferred to the EC broth in a tube and mixed together. Incubation was carried out at 37^0C for 24 hours. Growth after 24 hours confirmed the presence of the indicator organism.

3.7 Characterization and Identification of Isolates

The bacterial isolates were characterized using the following biochemical tests:

(i) Gram staining

A small portion of each of the isolates was picked with a sterile wire loop and emulsified in a drop of distilled water placed on a clean slide and spread uniformly over the surface of the slide to form a dried smear. 0.5% crystal violet was added to the smear and allowed to act for 1 minute, and lugol's iodine was applied to act as a mordant for 1 minute. The smear was washed with acid alcohol until the original visible colour of the initial dyes had disappeared and the smear was rinsed with water. The smear was then counter stained with safranin for 30 seconds, after which it was rinsed with water and blot dried with filter paper. It was examined under the microscope using the oil immersion objective.

(ii). Methyl red-Voges Proskauer (MR-VP) test

This test is used to distinguish *E. coli* and *Enterobacter aerogenes*, both of which are coliform bacteria with many characteristics in common.

Tubes of MR-VP broth were inoculated with the test organisms and incubated at 37^0C for 2 – 3 days. After incubation, the methyl red test was performed on the tubes thus: 5 drops of methyl red indicator was added to each tube. A red colour gave a positive (acid) test for *E. coli*, while a yellow

colour indicated the presence of *E. aerogenes*. The absence of neither red nor yellow colour indicated the absence of both bacteria, but other coliforms may be present. The VP test was performed thus: 1ml of ∞-naphthol plus 1ml of 40% KOH solution were added to the tubes containing the organisms from coliform test (Completed). Solutions were agitated and allowed to stand for about 1 hour, after which observation was made. A pink to red colour indicated the presence of *E. aerogenes.* with acetyl methyl carbinol (i.e VP- positive for *E. aerogenes),* while a reddish – brown colour indicated a negative (i.e VP – negative for *E. coli*). If none of these two colours emerged, then any other coliform should be suspected.

(ii) **Urease production**

The slants from completed test media were inoculated with the test organisms leaving one slant uninoculated to serve as a control. Two urea-free slants were inoculated with the same cultures to act as another control. All slants were incubated at 37^0C for 5 – 6 days with daily observation for colour change. A change in colour from yellow to pink indicated a positive result while no colour change indicated a negative result.

(iv) **Indole production**

Two tubes of tryptone broth were inoculated with the test organisms while the third tube was uninoculated to serve as control. The tubes were incubated at 37^0C for 48hours. Change in colour of the broth from blue to

green indicated positive result while no colour change indicated negative result.

(v) **Coagulase test**

A loopful of normal saline was placed on a clean slide and emulsified with a small amount of the isolate until a homogenous suspension was obtained. A control was set up without isolate. A drop of human plasma was added to each of the suspensions and stirred for 5-10 seconds. Agglutination of the content of the slide indicated positive result while no agglutination indicated a negative result.

(vi) **Citrate utilization**

Using sterile inoculating needle, portions of the isolate were picked and stabbed into Simon's citrate agar slants, while one slant was left unstabbled to serve as a control. The slants were incubated at 37°C for 4– 5 days. Change in colour of the medium indicated a positive result, while no change in colour indicated the negative result.

(vii) **Sugar fermentation**

Different portion of the cultures were inoculated into lactose, sucrose and dextrose broth containing Durham tubes and incubated at 37°C for 48hours . Production of acid and gas in the tubes indicated positive result, while no acid and gas production indicated negative result.

(viii) **Growth pattern on nutrient agar**

Growth pattern of the isolates on nutrient Agar was determined by streaking the isolates on nutrient agar and incubating them at 37^0C for 24 hours. After the incubation period the growth patterns were observed.

CHAPTER FOUR

4.0 RESULTS

4.1 Physical Qualities of Water

The results showed that the declared net volume ranged between 470ml and 670 ml (Table 2). All the samples were colourless, and had pH ranging from 6.7 – 8.0 (Table 2). The results showed that the total solids content of the samples were satisfactory. However, eleven, out of the fifty samples contained unsatisfactory level of suspended solids. This number included five samples collected from Mokwa, four samples from Kontagora and one each from Minna and Suleja (Table 2).

The results also showed that only one sample contained unsatisfactory level of total dissolved solids of all the fifty samples analyzed (Appendix 6). Overall results of the physical parameters showed that thirty-nine of the samples were satisfactory while the unsatisfactory samples were eleven (Appendix 6)

Table 2: Physical properties of water samples analyzed

Parameters	Range of values					
	Bida	Minna	Suleja	Kontagora	Mokwa	NAFDAC Standard
Net volume (ml)	530 – 620	480 – 630	510 – 600	470 – 670	515 - 640	None
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
PH	6.7 – 7.8	7.2 – 7.8	7.7 – 7.8	7.2 – 8.0	7.3 – 7.5	6.8 – 8.5
Total solids (mg/l)	90 – 130	75 – 286	90 – 261	90 – 138	95 – 135	500
Suspended solids (mg/l)	07 – 20	05 – 66	10 – 106	08 – 30	30 - 56	25
Total dissolved solids (mg/l)	60 – 120	60 – 220	80 – 155	60 – 125	45 - 80	200

4.2 Chemical Qualities of Water Samples

The results of the chemical qualities of the water samples are shown in Table 3. The level of nitrate in water samples collected from Kontagora and Mokwa exceeded the recommended level and ranged from 1.1 to 39.6 mg/l and 1.1- 30.8mg/l respectively, while eight samples from Bida, two from Minna, and two from Suleja equally exceeded the recommended level. Eleven out of the fifty had nitrate content higher than the recommended level. Out of this number, three samples were from Bida, three from Mokwa, two from Suleja, and one sample each from Minna and Kontagora (Appendix 7). The results showed that the sulphate and chloride contents of all the samples were satisfactory (Table3). The results of the Total hardness of the samples revealed that two of the samples, 5 and 7, levels of hardness were unsatisfactory in comparison to the recommended level (Table 3). Phenolphthalein alkalinity was not detected in any of the samples, but the levels of methyl orange alkalinity were-satisfactory in 48 out of the fifty samples (Table 3). The content of free dissolved carbon dioxide (CO_2) in all the samples were satisfactory (Table3)

Table 3: Chemical properties of water samples analyzed.

	Range of values					
Parameters	Bida	Minna	Suleja	Kontagora	Mokwa	NAFDAC Standard
$FDC0_2$ (mg/l)	03 – 05	2.5 – 6.0	2.5 – 6.5	2.5 – 12	2.5 – 6.0	50
PA (mg/l)	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	50
MOA (mg/l)	06 – 150	15 – 150	01 – 05	03 – 40	11 – 20	50
Chloride content(mg/l)	10 – 25	06 – 8.5	4.5 – 6.0	05 – 17	11 – 15	200
Total hardness(mg/l)	07 – 103	43 – 150	02 – 7.5	03 – 6.2	02 – 03	100
Sulphate (mg/l)	10 – 18	18 – 50	16 – 20	05 – 40	20 – 50	200
Nitrate (mg/l)	01 – 44	0.01 – 8.8	0.0 – 10	1.1 – 39.6	1.1 – 30.8	0.0
Nitrite (mg/l)	0.0 – 0.5	0.0 – 0.7	0.0 – 05	0.0 – 20	0.0 – 20	0.0

$FDCO_2$ - Free dissolved carbon-dioxide; PA – Phenolphthalein alkalinity; MOA – Methyl Orange Alkalinity

4.3 **Metallic Content of the Water Samples**

The results showed that the levels of the metals in all the fifty water samples were satisfactory (Table 4), meaning that none exceeded the acceptable limit set by NAFDAC. Zinc, copper, manganese, lead, and cadmium were not detected in any of the water samples analyzed (Appendix 9).

Table 4:Metal contents of water samples analyzed

	Range of values					
Parameter	Bida	Minna	Suleja	Kontagora	Mokwa	NAFDAC Standard
Potassium	04 – 10	03 – 08	02 – 08	0.5 – 01	02 – 02	12
Sodium	9.2 – 51	07 – 25	11 – 20	0.5 – 02	03 – 04	150
Calcium	01 – 40	10 – 30	02 – 18	01 – 02	0.5 – 0.5	75
Magnesium	0.5 – 16	06 – 18	01 – 02	0.5 – 01	0.0 – 0.0	30
Iron	0.3 – 0.3	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.3
Copper	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0. – 0.0	0.0 – 0.0	0.05
Zinc	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	05
Manganese	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.05
Lead	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.05
Cadmium	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0.0 – 0.0	0

All the units are in mg/l

4.4 Microbial Counts

Table 5 shows the presence of coliforms *E. coli* for the two hundred and fifty samples of water, representative of the fifty different sources from the five different towns in Niger State of Nigeria. Seven (14%) out of the fifty samples showed presence of colforms,.while six (12%) out of the samples were contaminated with *E. coli* .

4.4.1 Coliforms and *E. coli*

Table 6 shows the number of water samples from each source that contained coliforms and *E.coli.* Seven samples (2.8%) out of the 250 water samples analyzed had coliforms while only six water samples (2.4%) had *E.coli* (Table 5). None of the water samples collected in Bida had coliforms and *E.coli.* The results (Table 6) revealed that the coliform load ranged from 1 to 14 MPN/(cfu/ml), while the counts of *E. coli* in the water samples ranged from 1 to 1 MPN/(cfu/ml). It was observed that water samples collected from Mokwa had high load of the organisms (Table 6). According to the MPN index of American Public Health Association (1975), the total number of coliforms recorded in this analysis were thirty-seven, (37) cfu/ml.(Table 5)

Table 5: Presence of coliforms and *E. coli* in water samples analysed

Source	**No of samples**	**No with coliforms**	**No with *E. coli***
Bida	30	0 (0.0)	0 (0.0)
Minna	70	1 (1.4)	1 (1.4)
Suleja	50	2 (4.0)	1 (1.4)
Kontagora	75	3 (4.0)	3 (4.0)
Mokwa	25	1 (4.0)	1 (4.0)
Total	250	7 (2.8)	6 (2.4)

Numbers in parenthesis are percentage occurrence of organisms in water samples analysed.

NAFDAC Standards: No coliform, nor *E coli* should be present per (ml) of sachet (drinking) water.

Table 6: *E. coli* and other coliforms (cfu/ml) count

Source	Sample No.	Coliforms	E.coli	NAFDAC Standard
Bida	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	0	0	0
	5	0	0	0
	6	0	0	0
Minna	7	0	0	0
	8	0	0	0
	9	0	0	0
	10	0	0	0
	11	0	0	0
	12	0	0	0
	13	1	1	0
	14	0	0	0
	15	0	0	0
	16	0	0	0
	17	0	0	0
	18	0	0	0
	19	0	0	0
	20	0	0	0
Suleja	21	0	0	0
	22	0	0	0
	23	0	0	0
	24	5	1	0
	25	0	0	0
	26	0	0	0
	27	0	0	0
	28	0	0	0
	29	0	0	0
	30	3	0	0
Kotangora	31	0	0	0
	32	0	0	0
	33	0	0	0
	34	0	0	0
	35	0	0	0
	36	0	0	0
	37	0	0	0
	38	0	0	0
	39	0	0	0
	40	0	0	0
	41	0	0	0
	42	4	1	0
	43	0	0	0
	44	5	1	0
	45	5	1	0
Mokwa	46	0	0	0
	47	0	0	0
	48	14	1	0
	49	0	0	0
	50	0	0	0
	Total	**37**	**6**	**0**

4.4.2 **Total viable counts**

Table 7 shows the total viable counts in the water samples analyzed. The results revealed that water samples collected from Bida, Minna and Mokwa had higher bacterial load than those collected from Suleja and Kontagora. Specifically, samples from Bida had the highest counts ($3.4x10^1$ –$8.6x10^2$ cfu/ml), while samples from Suleja had the lowest counts ($1.0x10^0$ –$3.4x10^2$).

Table 7: Counts of Total viable bacteria in sachet water samples analyzed

Source	Total viable counts (cfu/ml)
Bida	$3.4 \times 10^1 - 8.6 \times 10^2$
Minna	$3.5 \times 10^1 - 7.1 \times 10^2$
Suleja	$1.0 \times 10^0 - 3.40 \times 10^2$
Kontangora	$1.0 \times 10^1 - 3.9 \times 10^2$
Mokwa	$2.2 \times 10^2 - 4.28 \times 10^2$

NAFDAC standard : Number of viable bacteria in (ml) of sachet water should not exceed 10.0×10^1

4.5 Identification of Microorganisms in the Water Samples

Microorganisms identified in the water samples were bacterial species belonging to the genera, *Escherichia, Enterobacter, Klebsiella* and *Pseudomonas* (Appendix 5). *E. coli* accounted for 8.8% ,*Klebsiella.aerogenes* 25.0%, *Pseudomonas.aeruginosa* 36.8%, and *Enterobacter aerogenes* 29.4% (Table 8). Generally, *pseudomonas aeruginosa* was more consistently isolated.

Table 8: Frequency of occurrence of microbial isolates obtained from water samples analyzed.

Bacteria	**Occurrence of isolates**	**% Occurrence**
Escherichia coli	6	8.8
Klebsiella aerogenes	17	25.0
Pseudomonas aeruginosa	25	36.8
Enterobacter aerogenes	20	29.4
Total	**68**	**100.00**

$$\% \text{ Occurrence} = \frac{\text{Occurrence of individual organism}}{\text{Total sum of occurrence}} \times 100$$

4.6 **Acceptability and Rejectability of the water samples analyzed.**

All samples from the five towns studied had acceptability value of 100% in terms of metal contents while the acceptability value was 34% with regards to the chemical parameters (Table 9).The acceptability value for the samples was 22% in terms of the physical parameters. It was observed that water samples from Kontagora were not too favoured in considering the chemical and physical parameters studied.

Table 9: Acceptability and reject ability of the water samples with respect to chemical, physical and metallic contents.

Location	Metals Content		Chemicals Parameters		Physical Parameters	
	S	UNS	S	UNS	S	UNS
Minna	14	0	8	6	13	1
Suleja	10	0	8	6	9	1
Kontagora	15	0	1	14	11	4
Bida	6	0	0	6	6	0
Mokwa	5	0	0	5	0	5
Total	50	0	17	33	39	11

Key: S – Satisfactory (acceptability); UNS – Unsatisfactory (rejectability)

CHAPTER FIVE

5.0 DISCUSSION

The results of this study showed that only 15 water samples contained counts of microorganisms (in cfu/ml) below allowable limit set by NAFDAC and WHO. Others exceeded the limit set by these agencies. *Escherichia coli* have occurred above safe limits prescribed by NAFDAC and this is an indication that these samples are microbiologically unsafe for human consumption.

Chemical analyses showed that seventeen (34%) out of the fifty samples were chemically acceptable for human consumption, while thirty-three (66%) were unsatisfactory. Of the ten chemical parameters tested, nitrate constituted the major contaminant, followed by nitrite. This condition was prevalent among water samples from Bida, Kontagora and Mokwa. Virtually all the samples from Mokwa contained nitrate and nitrite, as well as those from Bida. Since, almost, every manufacturer claim having registration with NAFDAC, it can be inferred that there is a trend of deviation from the Agency's standard after registration is secured, or there is a slow or complete break down of surveillance exercises by NAFDAC inspectoral team in Niger State. Nitrate and Nitrite has been reported to be a major cause methemoglobinemia known as blue baby disease in infants at

lower dose and also causes vasodilator / cardiovascular effect at high dose levels (USEPA, 1989).

While the metal content was satisfactory, the physical characteristics of the samples deviated from the prescribed standard. Eleven out of the fifty samples were unsatisfactory. The major contaminants were suspended and dissolved solids. This proves beyond doubt that the result shown for the preponderance of nitrate and nitrite in the samples was not a fallacy. The results obtained in this study are in agreement with those of other workers. Oyeku et al (2001) had reported the contamination of sachet water by microorganisms and chemical substances. According to HMSO, (1994), the presence of faecal indicator organisms in a sample of drinking water denotes that intestinal pathogens could be present and that the supply is therefore potentially dangerous to health. Dike, (1997) had detected the presence of mixed population of microorganisms in drinking water serving a public population. The presence of these contaminants call for public concern, because of the health hazards associated with them, and debilitating consequences in the individuals affected by them.

To combat the effect of pathogenic organisms, many producers may have resorted to chlorination. Chlorine-injured enteropathogenic *Escherichia coli* has been shown to exhibit reduced ability to colonize the small intestine

and initiate diseases, Desmonds et al (1990) also reported that the virulence of *Salmonella spp. Yersinia* and more markedly *E. coli* is reduced after exposure to chlorine. This is in support of the view that an all round water treatment procedures should be adopted and maintained on a regular basis.

On the contrary, there is an observed disparity, some "pure" water producers only observe microbiological standard, neglecting the chemical quality and vice versa. Report on investigations of well water in Katsina by Adesiyun et al (1983), pipe borne and private well waters in Samaru village, by Alabi and Adesiyun (1986) showed poor microbiological quality. Agbu et al (1988) carried out bacteriological and chemical analyses of public well water in Zaria City. They found that all the twenty water samples were negative for Salmonella. Shigella, and Yersinia species; but four chemical parameters (lead,copper,fluoride,iron) exceeded the World Health Organization standard.

It is no doubt that if the producers had relied on municipal water supply, and consequently carried out additional treatments on their own, they should be able to produce acceptable water. But it is a common knowledge that greater percentage of the producers, if not all, do not obtain water from the municipal supply, but make use of bore-hole water. Since they cannot afford the cost of modern technological equipment for the

treatment of bore-hole water, they produce sub-standard water for the uninformed consumers. It is possible that the problem is due to the fact that unqualified production staff are employed.

5.1 CONCLUSION AND RECOMMENDATION

The chemical, physical and microbiological analyses of "packaged water" showed that greater number of waters that are being hawked in the streets, towns and villages of Niger State do not meet the WHO and NAFDAC standards for potable water. It is therefore envisaged that this situation can improve if NAFDAC intensifies effort to ensure that every registered producer of sachet water are made to comply with the standards. This means that from time to time the inspectoral team should monitor the activities of the manufacturers. Attention should be paid to areas where water samples contained contaminants far above the safe limits set by the regulatory agencies. The public should be enlightened on the danger of drinking contaminated sachet water.

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APPENDIX I

CULTURE MEDIA COMPOSITION AND PREPARATION

LAURYL SULFATE BROTH for the selective enrichment of Coliforms

Tryptose	20.Og
Lactose	5.0g
Sodium chloride	5.0g
Lauryl sulfate sodium salt	0. lg
di-potassium hydrogen phosphate	2.25g
Potassium dihydrogen phosphate	2.75g

Suspend 35.6g in 1 litre of dematerialized water; dispense into test tubes fitted with fermentation tubes. Autoclave at 121°C for 15minutes. Store at PI I 6.8± 0.2 at 25°C (Hopkin & Williams Ltd, Chadwelf, England.)

McConkey Broth- for the selective enrichment of pathogenic organisms.

Peptone from casein	20.Og
Lactose	lO.Cg
Ox bile, dried	5.0g
Bromocresol purple	0.01 g

Suspend 35g in 1 litre *or* more of demineralized water; dispense into reaction tubes fitted with fermentation tubes. Autoclave at I21°C for 15 minutes. Store at PH 7.1 ± 0,2 at 25°C.(Antec Diagnostic Products. U.K.)

APPENDIX 2

McCONKEY AGAR - for the isolation of Salmonella, Shigella and Coliform bacteria.

Peptone from casein	17.0g
Peptone from meat	3.0g
Sodium Chloride	5.0g
Lactose	10.Og
Bile Salt mixture	1.5g
Neutral red	0.03g
Crystal violet	0.00 lg
Agar-agar	13.5g

Suspend 50g in 1 litre of demineralized water by heating in a boiling water bath or in a current of steam. Autoclave at 121°C for 15 minutes. Store at PI I 7.1± 0.2 at 25°C. .(Antec Diagnostic Products. U.K.)

Ecoli.Broth- for the selective enrichment of *E. Coli*.

Peptone from casein	20.Og
Lactose	5.0g
Bile Salt mixture	1.5g
Sodium Chloride	5.0g
di-potassium hydrogen phosphate	4,0g
Potassium dihydrogen phosphate	1.5g

APPENDIX 3

Suspend 37g or 74g in 1 litre of demineralized water; dispersible into tubes fitted with fermentation tubes. Autoclave at 121°C for 15 minutes store of PH 6.9± 0.2 at 25°C. (Oxoid chemicals Ltd, Hampshire, England).

Plate -- Count Agar - for the determination of Aerobic mesophiles (total microbial content)

Peptone from casein	5.0g
Yeast extract	2.5g
D(+)-glucose	l.Og
Agar-agar	14.0g

Suspend 22.5g in 1 litre of demineralized water by heating in a boiling water bath or in a current of steam. Autoclave at 121 C for 15 minutes. Store at PH 7.0± 0.2 at 25°C. (Oxoid chemicals Ltd, Hampshire, England).

APPENDIX 4

MPN index for various combination of positive and negative results when one 50ml portion, five 10ml portions and five1ml portion (1 table) or one used.

Number of Positive Tubes			MPN Per ml
50ml	10ml	1ml	
0	0	0	1
0	0	1	1
0	0	2	2
0	1	0	1
0	1	1	2
0	1	2	3
0	2	0	2
0	2	1	3
0	2	2	4
0	3	0	3
0	3	1	5
0	4	0	5
1	0	0	1
1	0	1	3
1	0	2	4
1	0	3	6
1	1	0	3
1	1	1	5
1	1	2	7
1	1	3	9
1	2	0	5
1	2	1	7
1	2	2	10
1	2	3	12
1	3	0	8

APPENDIX 4. CONTINUED

Number of Positive Tubes			MPN Per ml
50ml	10ml	1ml	
1	3	2	14
1	3	3	18
1	3	4	21
1	4	0	13
1	4	1	17
1	4	2	22
1	4	3	28
1	4	4	35
1	4	5	43
1	4	0	24
1	5	1	35
1	5	2	54
1	5	3	58
1	5	4	160
1	5	5	240

SOURCE: APHA,(1985)

APPENDIX 5

Cultural and Bio-Chemical Characteristics of Isolates from the water samples analyzed

Growth on Nutrient Agar	Gram Reaction	MR – VP	Coagulase	Urease	Citrate	Indole	Sucrose	Lactose	Dextrose	Growth at 5^0c	Pigmentation	Growth at 42^0c	Organism
White, moist glistening growth	NEG SHORT RODS	(+) (-)	-	-	-	+	A	+	AG	-	-	-	*Escherichia coli*
Slimy, white somewhat translurent raised growth	NEG RODS	(-) (+)	-	+	+	-	AG	AG	AG	-	-	-	*Klebsiella aerogenes*
grWhite, moist glistening growth	NEG SHORT RODS	(-) (+)	-	-	+	-	A	+	AG	-	-	-	*Enterobacter aerogenes*
Confluent growth green pigmentation produced	RODS NEG	(-) (+)	-	-	+	-	-	-	-	-	+	+	*Pseudomonas aeruginosa*

KEY

A = Acid production
G = Gas production
AG = Acid and Gas production
(+) = Positive result; (-) = Negative result; NEG = Negative

APPENDIX 6

Physical properties of water samples analysed.

Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	STD
Net vol(ml)	620	560	590	530	600	590	580	520	530	540	480	590	630	580	580	560	580	600	580	560	-
Colour	Colorless	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PH	7.8	6.9	7.4	6.7	7.3	7.5	7.8	7.8	7.5	7.6	7.8	7.5	7.4	7.6	7.2	7.5	7.4	7.6	7.5	7.3	6.8-8.5
TS(mg/1)	130	90	115	80	127	90	286	95	80	81	80	80	100	75	79	80	100	80	85	80	500
SS(mg/1)	10	10	15	20	7	10	66	15	20	21	20	20	10	5	9	40	20	20	15	20	25
TDS	120	80	100	60	120	80	220	80	60	60	60	60	90	70	70	70	80	60	70	60	200
Comments	S	S	S	S	S	S	US	S	S	S	S	S	S	S	S	S	S	S	S	S	S

APPENDIX 6. CONTINUED

21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	STD
515	590	510	550	555	530	510	535	600	535	550	670	540	545	540	555	630	470	560	560	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.7	7.7	7.8	7.8	7.8	7.7	7.8	7.7	7.9	7.8	7.8	7.2	7.6	7.8	7.4	7.5	7.9	7.8	8.0	7.3	6.8-8.5
90	96	95	95	90	90	90	90	261	95	135	120	138	130	128	90	130	110	110	103	500
10	11	10	15	15	10	10	15	106	10	15	20	18	20	28	30	30	20	20	20	25
80	85	85	80	85	80	80	80	155	85	120	100	120	90	100	60	90	90	90	85	200
S	S	S	S	S	S	US	S	US	S	S	S	S	S	US	US	S	S	S	S	

APPENDIX 6. CONCLUDED

41	42	43	44	45	46	47	48	49	50	STD
560	520	530	515	490	640	515	590	525	525	-
-	-	-	-	-	-	-	-	-	-	-
7.9	7.8	8.0	7.9	7.9	7.3	7.5	7.4	7.4	7.5	6.8-8.5
100	110	133	100	108	101	100	135	100	95	500
20	28	8	10	20	56	30	55	40	35	25
80	83	125	90	88	45	70	80	60	60	200
S	S	S	S	S	S	US	S	US	S	

S = Satisfactory: US = Unsatisfactory: STD = Standard: Samples 1-6 from Bida: 7-20 = Minna

21-30 = Suleja: 31-45 = Kontagora: 46-50 = Mokwa: TS = Total Solids: SS = Suspended solids

TDS = Total dissolved solids

APPENDIX 8

Chemical analysis of water samples analyzed

Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	STD
FDCO2	4.5	4	5	3	5	5	5	j	3	2.5	2.5	5	2.5	3	3	6	2.5	2.5	2.5	2.5	50
PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
MOA	22	10	10	6	150	10	150	23	26	26	30	30	15	27	25	23	20	27	23	16	50
Cc	25	10	17	18	10	20	30	6	8.5	7	7	13	6	13	8	7	8	8	7.5	7.5	200
TH	60	7	96	20	103	52	150	43	70	45	70	65	90	60	50 1	70	60	47	53	45	100
SP	15	18 1	18	10	18	18	18	25	25	30	35	35	40	40	42	42	50	50	50	50	200
AM																					0.05
NT	44	40	20	2.2	1	1	8.8	1			1	1		1	1				0.01		0
NTr	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0
PVC																					-
Comment	us	Us	us	us	us	us	us	us	s	s	us	us	s	us	us	s	s	s	s	s	

APPENDIX 8. CONTINUED

21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	STD
6	6.5	4	3.5	2.5	5	3	3	4	3	5	12	2.5	3	2.5	5	3	2.5	2.5	2.5	50
0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	50
1	5	4	4	4	3	3	3	3	3	40	32	36	35	20	30	38	35	40	20	50
4.5	4.5	5	4.5	5	5	5	5	23	6	7	7	6	5	17	7	8	8	8	10	200
2	2	2	2.5	2	2	2.2	2	7.5	2	4	3	3	4	5	3.2	6.2	5	6	3.5	100
18	16	18	16	20	20	18	20	20	20	20	5	8	10	15	20	20	12	5	50	200
															-	-	-	-	-	0.05
-	-	-	-	-	-	-	-	10	10	1.1	1.1	1.1	1.1	39.6	1.1	1.1	1.1	1.1	1.1	0
0	0	0	0	0	0	0	0	5	5	0	0	0	0	20	0	0	0	0	0	0
															-	-	-	-	-	-
s	s	s	S	s	s	s	S	us	us	us	us	us	us	us	us	us	us	us	us	

APPEDIX 8. CONCLUDED

41	42	43	44	45	46	47	48	49	50	std
2.5	3	2.5	2.5	2.5	4	6	5	3	2.5	50
0	0	0	0	0	0	0	0	0	0	50
40	40	40	25	30	20	20	17	11	20	50
10	10	10	5	6	15	15	13	14	11	200
5	5	5.5	6	5	2	2	2	3	3	100
40	15	20	20	20	20	30	50	30	50	200
-	-	-	-	-	-	-	-	-	-	0.05
11	1.1	1.1	1.1	0	30.8	2	1.1	2	1.1	0
	0	0	0	0	20	1	0	1.1	0	0
-	-	-	-	-	-	-	-	-	-	
us	us	us	us	s	us	us	us	us	us	

S = satisfactory, US= unsatisfactory, STD = standard, FD CO2 = Free dissolved CO2 (ppm),

PA = phenolphthalein alkalinity (mg CaCO3/l), MO = methyl orange alkalinity (mg

SP = Sulphate, NT = Nitrate; NTr = Nitrite

APPENDIX 9

Metal Content Analyses of Water Samples analysed

Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	55	16	17	18	19	20	STD
Potassium	4	6.9	4	4	5	10	3	7	8	8	8	4	6	7	6	5	5	5	7	5	12
Sodium	9.2	15.6	10	9.2	12.4	51	7	15.6	20	20	25	10	14	16.5	14	12	9	14	19	12	150
Calcium	20	1	30	6	35	40	10	15	11	11	22	21	30	20	18	23	20	18	19	15	75
Magnesium	12	0.5	14	4	16	15	5	00	6	6	16	14	18	14	12	15	14	10	11	8	30
Iron	0.3	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
copper	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Zinc	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5
Manganese	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
comment	S	S	S	S	S	S	S	S	S	S	S		S	S	S	S	S	S		S	

Metal Content Analyses of Water Samples analysed

Parameter	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	STD
Potassium	4	2	3	2	3	2	2	2	8	4	1	1	0.5	1	1	1	1	1	1	J	12
Sodium	11	14	14	14	15	15	14	15	20	16	I	1	0.5	1	2	2	2	2	2	1	150
Calcium	18	-	-	-	-	-	-	-	2	2	S	1	1	1	1	-	1	1	1		75
Magnesium	2	-	-	-	-	-	-	-	1	1	0.5	0.5	1	0.5	0.5	-	0.5	0.5	0.5	0.5	30
Iron	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
copper	ND	ND	ND	ND	ND	ND	ND	ND	ND	D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Zinc	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5
Manganese	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
comment	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	

APPENDIX 9 CONCLUDED

Parameter	41	42	43	44	45	46	47	48	49	50	STD
Potassium	1	1	1	1	1	2	2	2	2	2	12
Sodium		2	2	1	2	4	4	4	4 .	3	150
Calcium	1	1	1	1	1	-	-	-	0.5	0.5	75
Magnesium	0.5	0.5	0.5	0.5	0.5	-	-		-	-	30
Iron	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
copper	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Zinc	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5
Manganese	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
comment	S	S	S	S	S	S	S	S	S	S	

S= satisfactory, ND= not detected, STD = Standard, all the parameters in mg/l