PHYSIO-CHEMICAL AND MICROBIAL ANALYSIS OF SACHET WATER IN OYE AND IKOLE LOCAL GOVERNMENT AREA OF EKITI STATE.

BY

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A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF WATER RESOURCES MANAGEMENT AND AGROMEEOROLOGY, FACULTY OF AGRICULTURE, FEDERAL UNIVERSITY, OYE EKITI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE (B.SC) DEGREE

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DECLARATION

This is to declare that this project was carried out by ALONGE TITILAYO OMOWUMI with the matriculation number WMA/11/0046, a student of the Department of Water Resources Mana gement and Agro meteorology, Faculty of Agriculture, Federal University, Oye Ekiti, Nigeria.

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CERTIFICATION

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Supervisor's signature Date

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Prof. Agbenin Date

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DEDICATION

This work is dedicated to almighty God, who saw me through "start-to-finish" of a phase of my academic career and my loving parent Mr. and Mrs. Alonge for the love and care they have lavished on me beyond measure.

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ABSTRACT

In the bid to ensure adequate water supply, packaged water has been introduced to provide safe and affordable drinking water. In spite of the varying levels of contamination, sachet water is still well accepted. This study therefore employed both quantitative and qualitative research designs to draw out survey and semi – structured interview responses. The study shows the perception of respondents based on the various sachet water brands, consumption pattern, sachet water safety, price, patronage and, attitudes towards the cross – checking of labeling requirements and respondents' perceived quality of sachet water.

The samples were analyzed physico-chemically and bacteriologically. Eight brands labeled A – H were collected from sachet water vendors (4 samples per area) and were analyzed using standard methods and procedures. Results obtained were compared with WHO standards for drinking water. The Physical examinations of the samples showed they were colourless, tasteless with no offensive odour. The pH values were within the stated WHO standards (6.50 - 8.50). Bacteriological analysis showed that sample D from Ikole (18.00 ± 0.58) MPN/100ml showed positive coliform count and therefore unfit for consumption since they could also contain other microorganisms concerned in gastro-intestinal water borne diseases. The aerobic mesophilic count for sample D from Ikole (2.1×10^2) exceeded the WHO (1.0×10^2) standard. This might be as a result of improper handling, location of water source close to dumping site, purification procedures, and unhygienic handling after production. All other chemical parameters were within the WHO values. This study advocates proper water treatment by water manufacturers and strict monitoring by the regulatory agency.

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1.0 INTRODUCTION

1.1 BACKGROUND

Water is very essential for human well being. It is an essential part of human nutrition and it is also required for maintenance of personal hygiene, food production and prevention of diseases (Adegoke *et al.*, 2012). Water has various uses; it is used for domestic, agricultural and industrial purpose. A reliable supply of clean wholesome water is highly essential for promoting healthy living amongst the inhabitants of any defined geological region (Dada, 2009). It is one of man's priceless resources but generally taken for granted until its use is threatened by reduced availability or quality. Water is not only essential for life, it also remains an important source of disease transmission (Mbah, 2015), and infant mortality in many developing countries. Edema *et al.* (2011) also described it as a key parameter influencing survival and growth of microorganisms in foods and other microbial environments.

Most potable water in Nigeria comes from three sources, which include rain water, surface water and ground water. Similarly, Okeri *et al.* (2009) noted that most of the water consumed in Nigeria is obtained from rain water, lakes, rivers, springs, streams and ground water including boreholes and private wells which do not always produce pure water due to the presence of different contaminants. In nature, all water contain impurities, as water flows in streams, accumulates in lakes and filters through layers of soil and rock in the ground, it dissolves or absorbs substances it comes in contact with, which may be harmful or harmless (Ogambas, 2004).

In many developing countries, availability of water has become a critical and urgent problem and it is a matter of great concern to families and communities who are forced to rely on open streams and lakes, and publicly vended water due to the non-availability of portable public water supply. Increase in human population has also exerted an enormous pressure on the provision of safe drinking water in developing countries (Ibemesim, 2014). Most people living in the major cities of Nigeria do not have access to pipe borne water, probably due to unavailability or inadequacy where obtainable (Omalu *et al.*, 2010). This has led to increased water related diseases which has continued to be one of the major health problems globally, Onifade and Ilori (2008). Onifade and Ilori (2008) equally noted that the high prevalence of diarrhea among children and infants can be traced to the use of unsafe water and unhygienic practices. Anuonye *et al.* in 2012 observed that unsanitary water has particularly developing effects on young children in the developing world. They further reported that each year, greater than 2 million persons, mostly children less than five years of age, die of diarrhea disease. For children in this age group, diarrhea disease accounted for 17% of all death from 2000 to 2003 (WHO, 2005), ranking third among causes of death, after neonatal causes and acute respiration infections (Anuonye *et al*, 2012). To curb this health problem, bottled water was introduced, but only individuals who have a good financial status can afford these products. Low income earners are left with no option but to consume the cheaper sachet packaged water which surfaced in late 1990s.

The production of sachet water in Nigeria started in the late 90s and today the advancement in scientific technology has made sachet water production one of the fastest growing industries in the country. The production of sachet water requires two important raw materials, water source (which is usually borehole or tap water), and the packaging materials (Uduma 2014). However, there have been reported concerns about the quality and safety of sachet water produced not only in Nigeria but also in Ghana.

Sachet water consumers are frequently unaware of the potential health risks associated with exposure to water borne contaminants which have often led to diseases like diarrhea, cholera, dysentery, typhoid fever, legionnaire's disease and parasitic diseases (Omalu *et al.*, 2011). Sachet water like any other food product must be processed and packaged under aseptic condition, free from every possible source of contamination. Although these products are popularly termed "Pure Water", they are usually not free of physical, chemical and microbial contaminants (Oladipo *et al.*, 2009). Occasionally, contamination of sachet water may occur either during the processing, transportation or improper handling by hawkers. Moreover, a greater proportion of the water that is used for the production of sachet water is obtained from boreholes that are exposed to microbial contamination through rainfall runoffs and the fact that they are usually constructed very close to pit toilets.

The problems associated with chemical constituents of drinking water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure, of particular concern are contaminants that have cumulative toxic properties, such as heavy metals and substances that are carcinogenic (Uduma, 2014). The use of chemical disinfectants in water treatment or construction materials used in water supply system usually results in the formation of the chemical by-products, some of which are potentially hazardous (Uduma, 2014). Drinking water is a vehicle for disease transmission. Many drinking water contaminants including various chemicals, physical and microbiological are known to be hazardous to health. (uduma, 2014)

There are several rules and regulations for the production of drinking water in Nigeria such regulations are monitored by the National Agency for Food and Drug Administration and Control (NAFDAC). Surveillance carried out by NAFDAC between 2004 and 2005 revealed that some producers of packaged water indulge in sharp practices such as packaging of untreated water.

production of sachet water under unhygienic conditions, illegal production of unregistered water in unauthorized premises, use of non-food grade sachets and release of packaged water for distribution and sale without date-marking. These malpractices compelled the agency to formulate guidelines for the production of wholesome packaged water (Kalpana *et al.*, 2011). Despite the standards formulated by the NAFDAC to address this problem, the situation has remained bad (Kalpana *et al.*, 2011). Most of the sachet water brands are still below WHO drinking water standards (<2 coliform/100ml) and are therefore of doubtful quality. Efforts need to be intensified in the monitoring activities in this rapidly expanding industry with a view to raising standards (Kalpana *et al.*, 2011). Sachet water (even after treatment) by vendors may contain some contaminants and pathogens (Kwakye-Nuako *et al.*, 2007). There is need to examine this water at the point of distribution to ascertain whether or not they meet NAFDAC/WHO minimum standards for safe drinking water.

This study aimed at determining the prevalence of water-borne pathogens in water samples, producing a baseline data for the assessment of physio chemistry within Oye and Ikole LGA and comparing the bacteriological quality of these water samples to ascertain whether or not they meet local and international standards.

1.2 PROBLEM STATEMENT

Accessibility to water supply is a major problem of human population in Africa especially in rural spaces. Okonko *et al.* (2008) revealed that in many developing countries, availability of water has become a critical and urgent problem and it is a matter of great concern to families and communities that depend on non-public water supply system. This has led to humans in this part of the world getting water from any source without considering the hygienic state. Mberekpe and Ngozi (2014) refer to water quality according as its temperature, the amount and character of its content of mineral particles, solutes and organic matter in relation to its intended use.

All these parameters must be within the minimum permissible limit as recommended by the World Health Organization. World Health Organization (2006) advanced some standards for quality of drinking water and its safety. This standard for potable drinking water borders on such microbial factors as: total coliform of 100ml should be zero; E.coli of CPU/100ml is zero; Streptococcus Faecalis of 50ml is zero; Total plate count of CPU/100ml is zero (WHO, 2006). Standard Organization of Nigeria (2007) has its standard on packaged and unpackaged potable water as: "coliform should be nil; E.coli is also nil; Faecalis Streptococci nil; Spore of sulphide reducing -clostridia nil".

Consumer Affairs Movement of Nigeria in 2007 opined that the National Agency for Food and Drug Administration Control (NAFDAC) is mandated to enforce compliance with internationally defined drinking water guidelines, but regulation of the packaged water industry aimed at good quality assurance has remained a challenge to the agency. Equally, some other agencies of Government such as the Standard organization of Nigeria and the Consumer Protection Agency are empowered to protect consumers from taking unhygienic products. However, there is limited awareness about these agencies and their functions in rural spaces.

Water in sachets is readily available and the price is affordable in rural and urban areas, but there are concerns about its purity. There are many different brands of sachet drinking water that are beautifully packaged, properly labeled and advertised (Ekwunife, et al., 2010). Although these products are popularly termed "Pure Water", they are usually not free of microbial contaminants

(Ezeugwunne *et al*., 2009). Producers of the product subject it to various treatments by different methods before packaging and sale or use in other manufacturing processes. The integrity of the hygienic environment and the conditions where the majority of the water in sachets are produced has also been questioned (CAMON, 2007).

Although nationally documented evidence is rare, there are claims of past outbreaks of water-borne illnesses that resulted from consumption of polluted water in sachets (CAMON, 2007). Therefore maintaining a safe drinking water remains essential to human health as transient bacterial contamination may have implication well beyond a period of acute self related illness (Onifade and Ilori, 2008).

Though, the Federal and State Government supplied water to the populace through dams, Folayan (2007) identified reservoirs designed for water supply in the state. They include Ero with capacity to produce 104,500 metric cubic/day, little Ose (Egbe dam) with capacity to produce 84,999 metric cubic/day, Itapaji (51,750 cubic/day), Ayede (45,600 cunicmetre/day) and Ureje (9,930 cubic meter/ day). However, majority of these inland waters dammed by the Federal and State Governments to provide public water for the people are moribund. It is therefore pertinent that the water meant for human consumption be free of disease-causing germs and toxic chemicals that pose a threat to public health.

1.3 Research Objectives

The general objective of this research is to assess the quality of sachet water in Ikole and Oye local government area of Ekiti State. Toward this goal, the specific objectives are to:

- **a.** determine the physiochemical parameters of sachet water in the study area;
- **b.** determine the microbial indices of sachet water in the study area:

c. assess consumer's perception of sachet water in the study area through the use of questionnaire; and

d. Verify if the sachet water sold in the study area is in conformity or otherwise with the standards set by the regulatory body.

1.4 JUSTIFICATION

In many developing countries, availability of water has become a critical and urgent problem and it is a matter of great concern to families and communities at large (Maduka *et al*, 2014). Unsafe water is a global public health threat, placing persons at risk for a host of diarrhea and other diseases as well as chemical intoxication (Maduka *et al*, 2014).Most sachet water manufacturers in Nigeria obtain their raw water mostly from local, municipal piped water or well water, hence adherence to production and analytical standards are doubtful as most of the factories are observed to lack appropriate technology for achieving these (Oyedeji *et al.*, 2010).There is paucity of information on consumers' perception.

The study area (Ikole and Oye) is a semi-urban area which has been under rapid economic development. The presence of the Federal University in both areas has led to this development within the space of four years and is still ongoing. The increase of population in both areas has placed an enormous pressure on the initially available water for the residents. In bid of the sachet water producing factories to meet the increasing demand for sachet water by the increasing population they tend to get more water from unwholesome sources and compromise its quality and thus having effect on the residents.

This study set out to ascertain the physical, chemical and bacteriological quality of the water in selected sachets water brands and to elevate consumers perceptions on sachet water brands in

Ikole and Oye LGA, two rapidly developing and isolated semi-urban areas to identify contributory factors that determine the fate of the packaged water product as it moves from catchment to consumer, and to highlight unharnessed opportunities for policy improvements that would allow for sustained and improved regulation of the sachet water industry

1.5 Research Hypotheses

a. **H_o1:** Physiochemical parameters of sachet water in the study areas are not significantly different from each other:

H_a1: Physiochemical parameters of sachet water in the study areas differ significantly from each other:

b. **H_o2:** Microbial indices of sachet water in the study area are significantly different from each other:

H_a2: Microbial indices of sachet water in the study area do not differ significantly from each other:

c. **H_o3:** consumer's perception of sachet water in the study area are not significantly different from each other

H_a3: consumer's perception of sachet water in the study area differ significantly from each other

e. **H_o4:** sachet water sold in the study area is not in conformity with the standards set by the regulatory bodies.

H_a4: sachet water sold in the study area is in conformity the standards set by the regulatory body.

f. **$H_0$5**: Quantity of sachet water consumed by high income earners in the study areas is lower than the quantity consumed by the low income earners.

H_a5: quantity of sachet water consumed by high income earners in the study areas differs significantly from the low income earners.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 WATER

Water is a vital substance for the survival of all lives. It is abundant in nature and occupies about 70% of the earth's crust. It is a biological medium which exists as solid, liquid and gas. It is the most universally used solvent and common route of transmission of diseases. (Thliza *et al.*, 2015). Water is an essential part of human nutrition and it is also required for maintenance of personal hygiene, food production and prevention of diseases (Adegoke *et al.*, 2012). Unavailability of good quality drinking water is wide spread and this has serious health implications. In developing nations of the world, 80% of all diseases and over 30% of deaths are related to drinking water (Thliza *et al.*, 2015). Only 36% of Nigerians have access to potable water and 6% have access to sound sanitation (WHO, 2014). An estimated 748 million people all over the world lack access to potable water and close to 2.5 billion persons are not provided with adequate sanitation (WHO, 2014).

Anecdotal reports have it that if the right standards and guidelines are strictly adhered to the Millennium Development Goals (MDG) and targets in regard to sanitation safe water could be far reached. The unwholesomeness of water has inherent consequences and several parameters correlate with the unwholesomeness of drinking water. (Cheabu 2014). Some include the presence of feacal coliforms, total coliforms, heavy metals, elevated chemical measures, etc. (Abiola, 2010; Addo et al. 2009; Ifeanyi et al. 2006; Okeri et al. 2009).

2.2 SOURCES OF WATER

Most potable water in Nigeria comes from three sources, which include rain water surface water and ground water (Priscilla *et al.*, 2014). Potable water in Ikole and Oye LGA Ekiti is normally obtained from boreholes, dams and wells. The sachet water sold in various stores and markets is normally obtained from springs or packaged from pipe supplies.

Similarly, Okeri *et al.*, 2009 noted that most of the water consumed in Nigeria is obtained from rain water, lakes, rivers, springs, streams and ground water including boreholes and private wells which do not always produce pure water due to the presence of different contaminants. The authors further stated that the water obtained from these sources is subjected to various treatments by different manufacturing companies before packaging and sale or use in other manufacturing processes. Nwachukwu et al., (2007) also noted that potable water when infected with organisms, loose its qualities and instead becomes harmful to both human and animal population. Potable water is often treated by chlorination. This makes the water free from any coliform organism no matter how polluted the original water may have been (WHO, 2004).

2.3 WATER POLLUTION

Water is considered polluted if some substances or condition is present to such a degree that the water cannot be used for a specific purpose. Owa (2013), defined water pollution to be the presence of excessive amounts of a hazard (pollutants) in water in such a way that it is no longer suitable for drinking, bathing, cooking or other uses. Pollution is the introduction of a contamination into the environment (Webster.com, 2010). It is created by industrial and commercial waster, agricultural practices, everyday human activities and most notably, models of transportation. The three main types of pollution are: Land Pollution. Air Pollution and Water Pollution. Both for the purpose of this research. emphasis are on water pollution and control.

Industrial and agricultural chemicals leached from land enter into water in a great amount and uniform that are resistant to biodegradation. Apart from this rural water usually have excessive amount of nitrite from microbial action on agricultural fertilizer. When ingested nitrite compete for oxygen in the blood (Onifade *et al*., (2008)

2.4 WATER QUALITY

Good quality water is odourless, colourless, tasteless, and free from faecal pollution. Water quality according to Ovie et al., (2005) refers to its temperature and the amount and character of its content of mineral particles, solutes and organic matter in relation to its intended use. World Health Organization (2000) advanced some standards for quality of drinking water and its safety. This standard for potable drinking water borders on such microbial factors as: total coliform of 100ml should be zero: E.coli of CPU/100ml is zero; Streptococcus Faecalis of 50ml is zero: Total plate count of CPU/100ml is zero (WHO, 2006). Standard Organization of Nigeria (2003) has its standard on packaged and unpackaged potable water as: "coliform should be nil: E.coli is also nil; Faecalis Streptococci nil: Spore of sulphide reducing -clostridia nil".

Water quality deals with the physical, chemical and biological characteristics in relation to all other hydrological properties. There are thus several valid reasons to be concerned about drinking water to which people in an area get access to. The need for concern for the safety of drinking water are more in the developing countries where sanitary conditions are low and poverty level is very high. This will also have a significant impact on the transmission of water transmissible diseases.

2.5 SOURCES OF WATER POLLUTION

Pollutants in natural waters could be microbial or chemical in origin (Ndamitso *et al.*, 2013). The chemical pollutants are the organic and inorganic substances whose levels continue to rise due to increased discharge of chemical fertilizers, particles and pesticides from agricultural and industrial activities. The microbial pollutants, on the other hand, include coliform bacteria which are indicator organisms mostly used in bacterial water characterization. They are easily found in animal faeces, soils and raw surface waters (Ezeugwunne et al., 2009).

According to Owa (2013), water pollution arises from various activities, among which are:

1. Sewage leakages
2. High population density
3. oil spillage
4. Industrial waste dumped into our waters
5. Pollution of ground water through drilling activities
6. Flooding during rainy season which carries waste deposits into our waters.
7. Heavy metal
8. Combustion
9. Toxic waste disposal at sea
10. Mineral processing plant (e.g. coal production)
11. Eroded sediments
12. Mining
13. Pesticides
14. Herbicides fertilizers

15. Failing septic system

16. House hold chemicals

17. Animal wastes.

Agricultural, domestic and industrial wastes are the major pollutants of agnatic habitats. The discharge of sewage into water bodies makes them very enormous and unhealthy. Excess fertilizer, herbicides and pesticides when washed by rain into rivers causes serious danger to life. The dyeing industries in Nigeria (tie and dye) produce chemicals such as zinc sulphate and copper salts which are non- biodegradable, when they are discharged into rivers; they produce devastating effects on aquatic environments and human. Pollution poses a serious risk to life especially when the water is a source of drinking and for domestic purposes, for humans polluted waters are potent agents of diseases such as cholera, typhoid and tuberculosis.

When septic tanks are built near the water bodies mixing or seeping of excreta may occur and this may act as a source of waterborne pathogens. Quite a large number of pathogens will be added if the population suffers from an enteric disease. Wastewater from abattoirs and animal processing plants also contribute to the waterborne pathogens. Droppings from nearby birds and faecal materials of domestic and wild animals including those of diseased ones are another potential source (Ibemesim 2014).

2.6 WATER RELATED DESEASES

Onifade 2010 reported that water related disease continue to be one of the major health problems globally. The high prevalence of diarrhea among children and infant can be traced to the use if unsafe water and unhygienic practices. Water related diseases can be grouped into four (Johnson and Paul, 2011; Griffiths, 2007): Water-borne diseases are spread through the ingestion of polluted water; water-based diseases are those diseases that reside in hosts that live in the water body; water-washed (or water scarce) diseases are often communicable diseases which are caused primarily by water scarcity, while water-related vector diseases are those diseases that are spread by insects that depend on water for survival and procreation.

S/N	MAJOR WATERBORNE DISEASES	CAUSE	SYMPTOMS
1.	Cholera	Bacteria	Diarrhea, Vomiting. Dehydration lead to death
2.	Amoebic dysentery	Protozoa	Diarrhea. Dehydration
3.	Diarrhea	Bacteria. Viruses, and Protozoa	Diarrhea. Dehydration
4.	Hepatitis	Viruses HAV, HEV	Body weakness. Loss of appetite. Abdominal discomfort.
5.	Typhoid	Bacteria	Diarrhea. Dehydration
6.	Ascariasis	Parasitic roundworms	Enlargement of liver. Toxicity. Pneumonia Nutritional deficiency.
7.	Dracunculiasis(guinea worm)	Worm	Fever. Burning sensation
8.	Paragoniamiasis	Worm	Cough. Nutritional deficiency

WATERBORNE DISEASES CAUSED BY CHEMICAL SUBSTANCES

S/N	CHEMICAL SUBSTANCE	CAUSE	SYMTOMS
1	Arsenic	High levels of arsenic (GV = 0.01mg/l)	Skin cancer, diabetes, bladder cancer, high blood pressure
2	Fluorosis	High levels of fluorine (GV=1.5 mg\l)	Severe skeletal problems.
3	Methaeglobinemia	High levels of nitrates(GV=50mg/l).	Blueness around the mouth, vomiting, diarrhea.
4	Lead	Petrochemicals	Cancer

2.7 PROBLEMS DUE TO MICROBIOLOGICALLY CONTAMINATED WATER

Definition: Microbiological contamination refers to the non- intended or accidental introduction of infectious material like bacteria, yeast, mould, fungi, virus, protozoa or their toxins and by-products, Gabriel, 2008.Contamination may occur if pathogens are carried unintended from a source to an orifice or an artificial body opening of the host where they then start growing and exerting their harm.

The major risk to human health is faecal contamination of water supplies. Chlorination is one of the most common and effective method of ensuring microbiological safety in water supply. It is a reagent for preventing the reproduction of micro organism in water (Onifade., 2008).Serious ill health can be caused by water contaminated from faeces being passed or washed into river, stream, pool or being allowed to seep into well or borehole (Cheesbrough 2006). There has been a report of borehole water contamination through many domestic waste water and livestock manure especially if there is a puncture in a layer of soil (Obi *et al.*, 2007). These waste and sewage when deposited near the boreholes may travel with percolating rain water directly into the boreholes or may travel along the well-wall or surrounding material of the drill-holes (Obi *et al.*, 2007). There are several variants of the faecal-oral pathway of water borne disease transmission. These include contamination of drinking water catchments (example, human or animal faeces), water within the distribution system (such as leaky pipe or obsolete infrastructure) or of stored household water as a result of unhygienic handling (WHO, 2010). The bacteriological quality of drinking water is of paramount importance and its monitoring must be given the utmost priority. This is so because intake of unwholesome water could have devastating effects on our health, as unsafe drinking water is a key determinant of many microbial diseases with serious complications in immune-competent and immune-compromised individuals (Kwakye-Nuako 2007). Oladipo *et al.*, (2014) worked on the microbial analysis of some vended sachet water in Ogbomoso, Nigeria. The isolates characterized were identified as Bacillus subtilis, bacillus alvei, Pseudomonas putida, Pseudomonas fluorecens, Bacillus cereus, En- terobacter aerogens and Proteus mirabilis. The antibiotic susceptibility profile of the seven isolates was determined and it was discovered that 59.30% was found sensitive to commercial antibiotic disc used while 40.70% were resistant. The bacterial quality of sachet water was investigated at point of sale using standard microbial procedures. The results showed that 87% of the packaged water samples were untreated or produced under unhygienic conditions. The study also showed that about 65% of the polythene sachets used was not food-grade quality. High aerobic colony counts on the order 106 were recorded from 93% of sample examined. The findings revealed that about 90% of packed 'pure water' sold in the country are not fit for human consumption and are hazardous to health. Total viable counts were in the order 105 and 106 colony forming units per ml of samples, while counts of Salmonella species were between 20 and 23 per 100ml of sample. Mean colony counts per ml of sample ranged from 1.51 x 102 to 1.54 x 102 while feacal coliform represented by E. coli were between 98 and 106 cfu/100ml.9

2.8 HEALTH RELATED PROBLEMS DUE TO PHYSICO-CHEMICALLY CONTAMINATED WATER

The chemical and physical quality of drinking water is evaluated on the basis of its chemical and physical components. This is done by assessing the taste, odour, colour, pH, hardness, total alkalinity, dissolved oxygen, carbon dioxide, heavy metals and organic constituents (Denloye 2004).

Previous studies on sachet water phenomenon in Nigeria have shown that factors responsible for its contamination range from sharp practices, poor hygiene of vendors, polluted environment, and non-adherence to WHO/NAFDAC regulations. This examination involves external features such as label which include product information, specific odour, appearance which includes colour, turbidity, and presence of floating particles or extraneous materials. Dada 2009 in his study on sachet water contamination physically examined samples of 'pure water' from the Nigerian market and recorded that none of the identified brands met the compliance levels set by the regulatory authorities in terms of label requirements such as registration number and batch numbers, manufacturing and expiry dates, nutritional information, net volumes and sometimes producers names and contact addresses.

Also, water may contain toxic inorganic chemicals which may cause either acute or chronic health effect. Acute effects include nausea, lung irritation, skin rash, vomiting and dizziness, sometimes death usually occurred. Chronic effect, like cancer, birth defects, organs damage, disorder of the nervous system and damage to the immune system are usually more common (Erah et al., 2002). Inorganic chemicals like lead may produce adverse health effect which include interference with red blood cell chemistry, delay in normal physical and mental development in babies and young children, slit deficit in attention span, hearing and learning abilities of children and slight increase in blood pressure in some adults. Also, presence of chromium in drinking water had been shown to result in chronic toxic effect (including liver and kidney damage, internal hemorrhage and respiratory disorders) in animal and human by ingestion. Although, the sources of metal contaminants of the underground water are uncertain, it may likely be due to natural process and anthropogenic activities (Mustafa 2012)

Chemical contamination of drinking water can result from natural or human-related contamination of surface water or groundwater, or contamination that occurs during the treatment of water (disinfection by-products), or delivery through mains or household water (corrosion). The number of potentially harmful chemical contaminants (if present at sufficient concentrations) identified in drinking water in small amounts has been increasing rapidly over the last twenty years due to the development of analytical methods capable of detecting levels in parts per billion and parts per trillion. These chemicals are usually present at extremely low concentrations when detected. A few of these contaminants have been shown to cause adverse effects in humans when ingested via highly contaminated water. Some of the more common contaminants detected, with their mode of occurrence and health effects under some exposure conditions, are: arsenic (natural; cancer), fluoride (natural; dental and crippling skeletal fluorosis), lead (corrosion of lead pipe;

neurological effects), pesticides (agricultural use and spills; variable effects), nitrate and nitrite (agricultural and sewage; infant deaths), radon (natural geology to indoor air and some groundwater; cancers), sulfates (natural; causing temporary diarrhea to non-residents). In addition, there are an ever-increasing number of synthetic organic compounds released into the environment whose effect on human health is poorly understood, but which it appears may be carcinogenic.

2.9 SACHET WATER

Packaged water also known as sachet water is any water that is in sealed plastic and is distributed or offered for sale which is intended for human consumption (Nwachukwu *et al.*, 2007). Similarly, Israel (2009) defined sachet as a disposable bag often used to contain single use of consumer goods. Yusuf, (2015), also stated that sachet water as any commercially treated water, manufactured, packaged and distributed for sale in sealed food grade containers and is intended for human consumption.

The demand for safe drinking water in Nigeria cannot be overemphasized, considering the inability of the governments to provide adequate pipe-borne water for the rapidly increasing populace. The production of sachet water in Nigeria started in the late 90s and today the advancement in scientific technology has made sachet water production one of the fastest growing industries in the country. According to Ogundipe 2008, the sachet packaged drinking water was introduced into the Nigerian market as a less expensive means of accessing drinking water than bottled water. It also acts as an improvement over the former types of drinking water packaged for sale to consumers in hand filled, hand tied polythene bags. He further reported that the easy accessibility to drinking water in packaged form has resulted in a big and thriving water industry with several hundreds of millions liters' of these water products consumed every year by Nigerians. The introduction of sachet water was aimed at providing safe, hygienic and affordable instant drinking water to the public and to curb the magnitude of water related infections in the country (Ezeugwunne et al., 2009). The production of sachet water starts from boreholes or tap where water is pumped into ground surface reservoir tanks of varying capacities. In the reservoir tanks, the water is left for 24 hours. It is then pumped into coagulation, flocculation and sedimentation tanks, where coagulating chemicals such as alum is added. The sediment water is pumped through series of sand and industrial filters into disinfection tank, where disinfection chemicals are added. The disinfected water is passed through industrial micro-filters, UV-sterilizer and finally into the automated water sealing machine. (Uduma 2014).

Water consumers are frequently unaware of the potential health risks associated with exposure to water borne contaminants which have often led to diseases like diarrhea, cholera, dysentery, typhoid fever, legionnaire's disease and parasitic diseases (Omalu et al., 2011). Earlier investigations conducted in Owerri, Ibadan and Lagos on the safety of drinking water has shown that the quality of some factory-bagged sachet drinking water was noted to be doubtful. This observation was based on studies carried out on water samples to ascertain the presence of heterotrophic bacteria, indicators of faecal contamination (total coliforms, faecal coliforms and enterococci) and for lead, manganese and iron. (Yusuf *et al., 2015*). Lack of information on pathogenic or parasitic organisms associated with drinking water creates some uncertainties in our understanding of the overall quality of drinking water in our markets. Some Sachet waters have been reported to contain bacteria such as Bacillus sp., Pseudomonas sp., Klebsiella sp., Streptococcus sp., and oocysts of Cryptosporidia sp. Apart from environmental contaminants, improper storage and handling by vendors also poses a serious threat to the health of the ignorant consumers (Omalu et al., 2011).

Numerous studies have been carried out on water quality of varying degrees and coverage. Some were carried out on the chemical quality of the water, some the micro- biological quality, some the physical quality and some on the physiochemical quality of the water. For example Alhassan et al., (2008), in their study of sachet water packaged within Kano metropolis, analyzed the physico – chemical characteristics: colour, taste, odour, alkalinity, total hardness, pH, chloride, sodium, potassium, calcium, lead, zinc, chromium, copper, cobalt, nickel and manganese using standard methods. All samples were tasteless, colourless and odourless. The pH, alkalinity and total hardness are within WHO (1983) permissible limit. The concentration of sodium, potassium and calcium was found to be within the acceptable limit and the chloride of most of the samples was above the WHO acceptable limit. Of the heavy metals analyzed lead, chromium, and nickel concentrations were found to be above the WHO permissible limit, while concentrations of copper and zinc were below the WHO (1983), permissible limit. Manganese concentration was found to fall within WHO permissible limit in 70% of the total samples, while 17% of the samples have concentrations above the WHO standard and four of the samples have concentration below the WHO recommendation. Emmanuel *et al.*, (2011) studied the quality of sachet and bottle water in Boltanga municipal of Ghana, Uduma *et al.*, (2014) studied the physiochemical quality of sachet water consumed in Kano metropolis.

A five- year study by Ampofo et al., (2007) saw one hundred and seventy – nine brands of sachet water and seventeen brands of bottled water analyzed for the presence of bacterial pathogens. Seventy – two brands of the sachet water were found to contain total coliform bacteria ranging between 1 and 1800 colony forming units (CFU) per 100 ml. 15 brands had both total and feacal coliform bacteria ranging from 2 to 62 cfu per 100ml. Twenty brands of the sachet water were found consistently contaminated with coliform bacteria were further analyzed for the presence of specific pathogens. Six recorded the presence of Salmonella sp. with values between 1 and 6 cfu, seven recorded the presence of Clostridium sp. with values between 1and 7 cfu per cfu and 15 brands recorded the presence of Bacillus sp. with values between 1 and 72 cfu per ml.

A study carried out in Ado Ekiti by Oluyege et al., (2014) stated that the presence of microorganisms' especially coliform bacteria in packaged water which serve as major sources of water for consumption purposes by the inhabitants of Ado-Ekiti poses great health risk. Since, coliform bacteria have been detected in packaged water especially sachet water, they are therefore not good enough for human consumption according to World Health Organization (WHO) and National Agency for Food and Drug Administration and Control (NAFDAC). In the same vein, a study by Uduma 2014 described that the concentrations of the metals, conductivity, TDS and total hardness were below the threshold limits set by SON/WHO and that the elevated level of pH above WHO/SON permissible limits in some sachet water, pose serious health concern. The pH value below the WHO maximum permissible limits (6.5) affects disinfection efficiency and may have an indirect effect on human health. A study on the storage effects on the quality of sachet water produced within port Harcourt metropolis, Nigeria by Sunday *et al.*, (2011), recommended that expiry date of sachet water produced in Nigeria should not exceed four weeks from the date of production as the storage factor affect the physiochemical qualities of sachet water

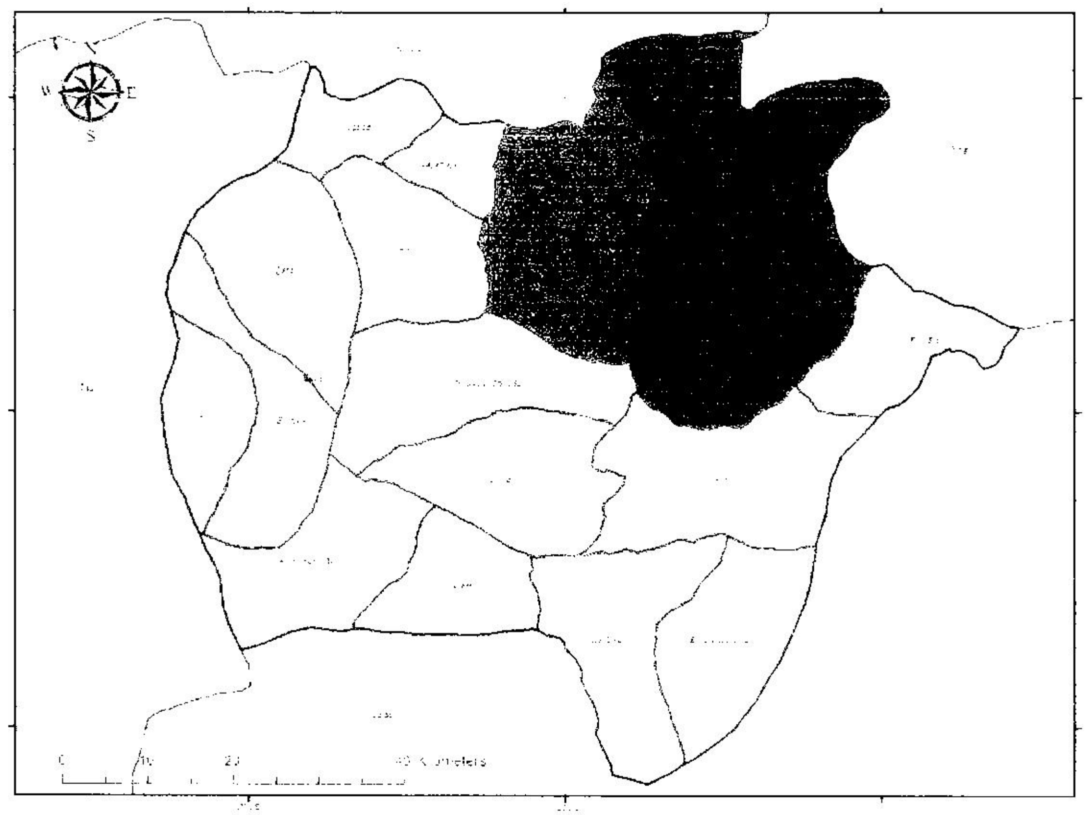
CHAPTER 3

3.0 MATERIAL AND METHODS

3.1 STUDY AREA

Ikole and Oye are Local Government Areas of Ekiti State, Nigeria. It comprises of the following towns and villages: Asin Ekiti, Ootunja Ekiti, Ilotin Ekiti, Usin Ekiti, Ayedun Ekiti and a host of others, while Oye comprises the following towns and villages: Oye Ekiti, Ilupeju Ekiti, Ayegbaju Ekiti, Ire Ekiti, Itapa Ekiti, Osin Ekiti, Ayede Ekiti, Itapaji Ekiti, Imojo Ekiti, Ilafon Ekiti, Isan Ekiti, Ilemeso Ekiti, Omuo Ekiti, Ijelu Ekiti, Oloje Ekiti and a host of others.

There are no distinctive ethnic groups in the Local Government as a greater percentage of the people residents are of the Yoruba Language race. Nearly all the people speak Yoruba Language with negligible dialectical variations.



Map showing the study areas.

3.2 SAMPLE AND DATA COLLECTION

The sachet water samples were collected from (2) different locations: Ikole and Oye local government areas (LGA) of Ekiti state respectively. Four samples of sachet water were purchased from commercial vendors both in Oye and Ikole LGA respectively, making a total of 8 samples from both LGAs. The samples were preserved with ice and transported to the laboratory for the physical, chemical and biological analysis. The pH was determined using a louvibond comparator, electrical conductivity was determined using a conductivity meter. Turbidity was tested using a turbidity meter. Standard methods were used to determine parameters such as total dissolved solid, total hardness, calcium hardness, sulphate, alkalinity and chloride. Atomic absorption spectrophotometer (Phoenx-986 AAS) was used to determine metals. All reagent used for each samples were prepared and the analysis were done repeatedly.

The consumers' perception of sachet water quality was investigated through the use questionnaire. This enabled the researcher to choose the most consumed brands of sachet water in both LGAs for analysis. Factors that contributed to the perception of quality included sachet water companies' adherence to proper labeling requirements and organoleptic properties. All participants in this study were residents of Ikole and Oye LGAs. Some were unreceptive while others gave a proactive consent to take part in the study. The administration of questionnaires and interviews were conducted from Monday to Friday in late April through early March 2016.

After a briefing of participants on the objectives of the study, those who provided passive consent were provided with a validated self-administered questionnaire to answer at their own convenience. Researcher returned a day later to collect the completed questionnaire. Participants who were unable to read or write were assisted by translating the questionnaire into vernacular or Pidgin English in some instances Oye and Ikole dialect with the help of some indigenes who are learned. In all, 101 respondents representing both towns completed and returned their questionnaire.A written set of supple worded topics on worries about sachet water, health beliefs, and perceived quality of sachet water served as the conversation guide whiles allowing respondents to participate in their own style and expression.

3.3 METHODOLOGY

3.3.1 DETERMINATION OF HARDNESS BY TITRATION

Apparatus: Beaker, Conical flask, Retort stand, Burette

Reagents used: 0.01ml EDTA (Ethyl diamine tetra acetic acid)

Procedures for sample analysis

PROCEDURE

- 50ml of water sample was poured in a conical flask and 2ml of buffer solution was added for hardness and was shaken. ½ spatula tip measure of Erichrome black T was also added and then shaken continuously. Titration against 0.01m EDTA solution from burette was done. The colour change from pink to blue to determine the end point.

  Calculation = (ml titrant x 20) mg/L $CaCO_3$

3.3.2 DETERMINATION OF CALCIUM HARDNESS BY TITRATION

Apparatus: conical flask, Beaker, Conical flask, Retort stand, Burette

Reagents: standard EDTA titrant, Murexide Indicator, Sodium hydroxide (NaOH Solution, 1normal)

PROCEDURE

- EDTA was poured in a burette and 50ml of water sample was also measured in a conical flask. 2ml of 1N NaOH solution was added and shaken. Murexide indicator was also added and titration against solution in burette was carried out. The colour changed from pink to purple. The procedure was repeated for other water sample

3.3.3 CALCULATION FOR CALCIUM HARDNESS, CALCIUM ION, MAGNESSIUM HARDNESS AND MAGNESSIUM ION

Calcium hardness = (ml titrant x 20) mg/L $CaCO_3$.

Magnessium ion (mg2+) = MgH x 0.244

Magnessium Hardness (MgH) = TH – CaH

Total Hardness (TH) = MgH + CaH

3.3.4 DETERMINATION OF CHLORIDE IN WATER BY TITRATION

Reagent: potassium chromate (indicator), standard silver nitrate (AgNo3) solution. Standard sodium chloride solution.

PROCEDURE

- 50ml of the water was measured in a conical flask and 3 drops of potassium chromate indicator was added to the sample and was shaken vigorously until colour changed to yellow.

The solution was titrated against AgNo3 until the colour turned from yellow to brick-red colour. The reading along the burette was noted and recorded and the procedure was repeated for other water sample

Calculation = (ml titrant x 10) mg/l. $CaCO_3$.

3.3.5 DETERMINATION OF ALKALINITY BY TITRIMETRIC METHOD

Reagent: 0.2N Hcl

PROCEDURE

- 50ml of water sample was measured into a conical flask and 2-3 drops of mixed indicator was added. the colour turned to green. The initial reading was recorded. Hcl was dropped wisely into the water sample and it changed from green to pink. The final reading was recorded and the procedure was repeated for other water samples.

3.3.6 DETERMINATION OF SULPHATE IN WATER

- Apparatus: Magnetic stirrer. conical flask. Measuring cylinder. pipette. pipette holder. spatula.
- Equipment: U.V Spectrophotometer. Stop watch or electric timer. magnetic stirrer. weighing balance
- Reagents: distilled water. standard sulphate solution. buffer solution A. Barium chloride (Bacl2)

PROCEDURE

- 100ml of the water was measured into a conical flask and 20ml of standard buffer solution A was added to the solution. A magnetic stirrer was added into solution and it was placed on the mixing machine.1g of Barium chloride was added into the solution (Bacl2).The solution was stirred for exactly 1 min at a constant speed. Immediately after stirring, the solution was poured into 10mm cell via tube and read with UV Spectrophotometer at a wavelength of 420 nanometer (nm). This procedure was repeated for other water samples

3.3.7 TEST FOR TURBIDITY

Apparatus: microprocessor turbidity meter

PROCEDURE

- The turbidity meter tube was rinsed well with distill water. The tube was then cleaned thoroughly, ensuring there was no water remaining inside. Distill water was then poured into the tube and inserted into the meter (the essence of this is to calibrate). The water sample was then poured into a tube and inserted in the meter The read button was punched and the reading was taken. This procedure was repeated for other water samples.

3.3.8 TEST FOR COLOUR OF WATER

Equipment:

Lovibond Comparator consist of a housing containing two 150ml glass tubes, 15cm deep and 2.5cm diameter; and a colour disc in which are engraved coloured and permanent glass standards from 0 to 70 units).

PROCEDURE

- Distilled water was poured into one of the 150ml glass tubes and the other tube was filled with the water sample to be analyzed. The colour disc was placed in the analyzer, which should be located where natural light or strong artificial light passes down the tubes to the underlying mirror. The disc was then rotated until a combination is found that appears to have the distilled water colour similar to that of the sample and this was recorded as the colour of the sample.

3.3.9 TASTE AND ODOUR

Equipment: free glass bottle

PROCEDURE

- The free glass bottle was first washed with detergent and rinsed with distilled water to remove odour. The pre-cleaned bottle was filled half way with the water sample, it was then covered and shaken vigorously for about 2-3 sec. The stopper was then removed quickly and odour was observed by placing it near the nostrils. Water sample was also tasted to ascertain its tastes (this is done only when the source of water sample is known).

3.4.0 CONDUCTIVITY

PROCEDURE

- The electrode of the multi-parameter was rinsed with distilled water.

- The water sample was poured into the multi-parameter and the reading was taken on the screen.

3.4.1 pH

Equipment: Lovibond comparator

PROCEDURE

- Distilled water was placed into one of the 150ml glass tubes and the other tube was filled with the water sample to be analyzed and 3 drops of Bromothymol blue was added to give a greenish colour. The pH disc was then placed in the analyzer, which should be located where natural light or strong artificial light passes down the tubes to the underlying mirror. The disc was then rotated until a combination is found that appears to have the distilled water colour similar to that of the sample. This was recorded as the pH of the sample.

3.4.2 ALKALINITY

PROCEDURE

- The burette was filled with 0.02N HCl. 50ml of the sample was measured and 3 drops of mixed indicator was added to give a greenish solution. This solution was then titrated against 0.02N HCl until colour changes to pink.

Calculation – (ml titrant x 20) mg/L $CaCO_3$.

3.4.3 DETERMINATION OF TOTAL DISSOLVED SOLID

Apparatus : Multimeter

PROCEDURE

- Water sample was poured into a beaker and the multimeter probe was inserted into the distill water for calibration (distill water should be zero).The probe was then inserted in the water sample and the reading was recorded

3.4.4 TOTAL IRON TEST

PROCEDURE

- 50ml of sample was measured and 2ml of Conc. HCl was added. 2ml of NH_2OH HCL (Hydroxylamine hydrochloride) solution was also added and the solution was boiled until volume of H_2O is reduced to 15-2oml. It was allowed to cool down and then transferred to a 100ml flask. 10ml of Acetate buffer solution and 1ml of phenanthroline was added. the volume was then added up to 100ml. The result was compared to a set of standard ranging from 0.002 – 2.0.

ITRATE TEST (CADMIUM REDUCTION METHOD)

RE

- 25ml of water sample was poured into a beaker; 75ml of washing solution was then added. The water sample and the washing solution was then poured into the cadmium reduction column. The first 25ml of the sample was discarded and the remaining was collected in a conical flask. 2ml of colour developer was then added to the reduced sample and mixed. Between 10min and 2hrs afterward the absorbance at 543nm was measured against a distilled water reagent blank. The nitrate concentration was then determined by comparing the absorbance with a standard nitrate graph.

3.4.6 DETERMINATION OF METALS BY ATOMIC ABSORPTION SPECTRO-PHOTOMETER

Heavy metals in the sachet water samples were determined by Atomic Absorption Spectro-photometer Phoenix-986 (AAS) using the appropriate wavelength for each metal. The AAS was operated at the following wavelength according to the manufacturers instruction (Cd, 228.2nm; Pb, 283nm; Cr, 302.2nm; Mn, 205.1nm)

N.B: The values obtained from these various tests are then compared with the basic standard (NAFDAC, SON and WHO) which tells if the water is potable for consumption

3.4.7 DETERMINATION OF MICROBIAL QUALITY OF WATER SAMPLES

Apparatus and Equipment

MacConkeybroth, conical flask, measuring cylinder, spatula, weighing balancedistilled water, Oven, Autoclave, Incubator, Durham tubes, Pipette, Colony counter, 3 different bottles (universal bottle, mCartney bottle, pijou bottle.)

3.4.8 PRESUMPTIVE TEST

The Most Probable Number (MPN) Technique was used for the water Analysis (APHA, 1998). 10mls of single strength broth was transferred into two test tubes and 10mls of double strength broth was transferred into the remaining column. Durham tubes were put into the tubes and sterilized by autoclaving. 10ml of the sample was inoculated into the tubes with double strength broth, and 0.1ml of the sample into the next column. The test tubes were incubated at 37°C for 24hrs for the estimation of total coliforms and at 44.5°C in a water bath for faecal coliforms for 48hrs. Acid production was determined by colour change of broth from reddish purple to yellow and gas production was checked by gas formation in the Durham tubes. The MPN was then estimated from the MPN table for multiple tube tests.

Data Analysis

Quantitative data collected were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 16.0. Descriptive statistics was used for water quality variables.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents the result of various physical, chemical and biological tests carried out on all the selected sachet water samples and also the questionnaire survey result carried out in Ikole and Oye local government areas (LGAs) of Ekiti State. The questionnaire provided the demographic characteristics of the study area, socio-economics, sensory and quality evaluation in the study areas.

4.1 Demographic characteristics of respondents.

Location	Frequency	Percentage (%)
Ikole	55	54.46
Oye	46	45.54
Total	**101**	**100**

Table 3: Distribution of Respondents by Local Government Area

4.1.1 Distribution of Respondents by Local Government Area

Table 1 provides information on the distribution of respondents by Local Government Area (LGA). 54.46 % of the survey was carried out in Ikole LGA while 45.54 % was interviewed in Oye LGA. This shows that good number of people from both areas responded to filling the questionnaires.

4.1.2 Distribution of Respondents by Age

Figure 1 below presents information on the distribution of respondents by age. Majority (33.39%) of sachet water consumers in the study area are between the ages of 15 and 25 years, 32.67% of the respondents falls between age range of 25 and 35 years, 25.74% of the interviewed population are between the ages of 35 and 45 years while eight respondents representing 7.92% of sachet water consumers are between of the age of 50 years and above. This implies that sachet water is consumed across age strata and the active population consume more of it.

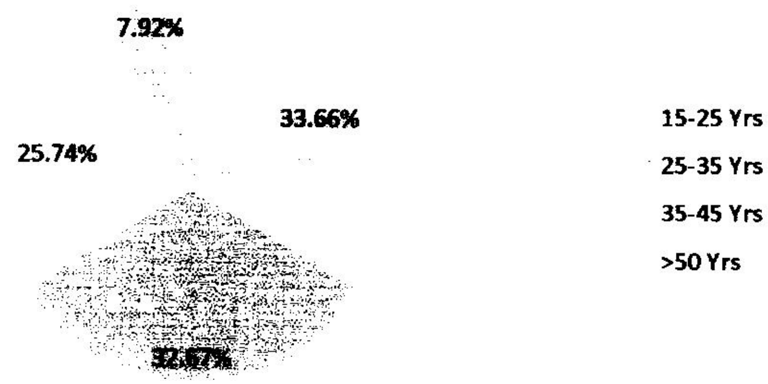


Figure 2: Distribution of Respondents by Age

4.1.3 Monthly Income of Respondents

This shows that 22.77% of the sachet water consumers in the study area earn between ₦10, 000 - ₦20, 000 monthly; 20.97% earns between 30, 000 - 40, 000; 14.85% earns 50,000 - 90,000 and 5000 – 10000 respectively; 16.83% earns above 100, 000 monthly, 9.90% of the respondents gave no response about their monthly income.

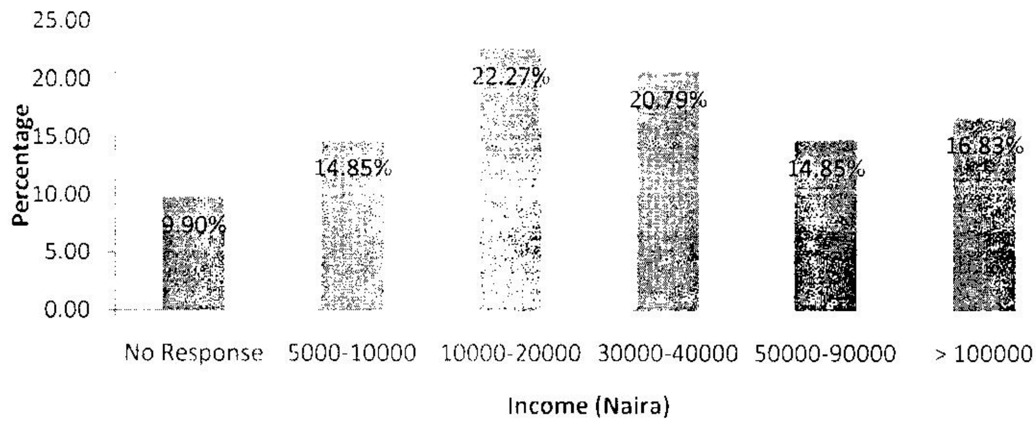


Figure 3: Monthly Income of Respondents

4.1.4: Distribution of Respondents by gender, marital status, occupation and family size

Gender	Frequency	Percentage
Male	53	52.48
Female	48	47.52
Total	**101**	**100**
Marital status		
Single	42	41.58
Married	49	48.51
Separated	3	2.97
Widowed	4	3.96
Divorced	3	2.97
Total	**101**	**100**

were widowed while 2.97% of the interviewed population were divorced. Greater part (24.75%) of the respondents were civil servants, students represent 17.8%, respondents who are traders represent 8.9%, those who are self-employed constitute 5.94%, those in the banking sector were 11.88%, artisans were 17.82%, engineers were 3.96%, farmers were 7.92% while only one respondent (0.99%) was interviewed. The table further shows that 36.63% of the sachet water consumers in the study area had between 2 and 4 household size, those who had between 4 and 6 represent 43.56%, 14.86% of the interviewed population had between 6 to 8 household size, 1.98% were for respondents who had between 8 and 10 household size while 2.97% represent respondent with household size greater than 10.

4.2 Distribution of Respondents by Consumption and Amount Spent Daily

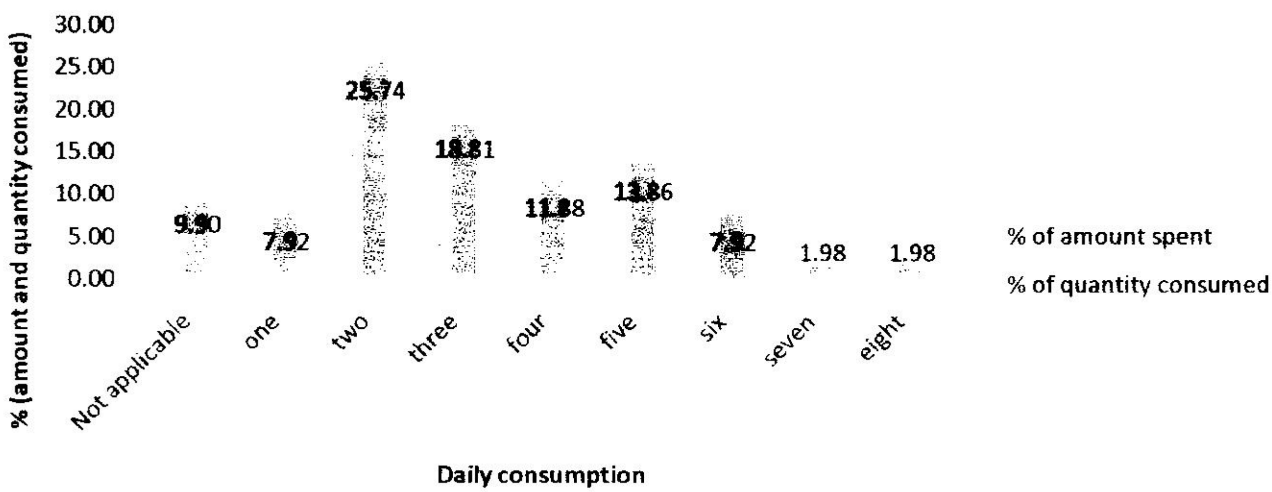


Figure 4: Distribution of Respondents by daily consumption and amount spent

4.2.1 Daily Sachet Water Consumption by Respondents

The daily consumption of sachet water and amount spent by individual is represented in figure 3. This shows that 9.90 % does not consume the products daily, 7.92% consume just one sachet,

Occupation		
Unemployment	1	0.99
Civil servant	25	24.75
Students	18	17.82
Business man/woman	9	8.91
Self employed	6	5.94
Banking	12	11.88
Artisan	18	17.82
Engineer	4	3.96
Farmer	8	7.92
Total	**101**	**100**
Family Size		
2-4	37	36.63
4-6	44	43.56
6-8	15	14.85
8-10	2	1.98
>10	3	2.97
Total	**101**	**100**

Table 4: Distribution of Respondents by gender, marital status, occupation and family size

This table presents the distribution of respondents by gender, marital status, occupation and family size. Majority (52.48%) of the respondents were male while 47.52% were female. Majority (48.51%) were married, 48.51% were single, those who were separated formed 2.97%, 3.96%

25.74% drinks two sachet, 18.81% of the respondents takes 3 sachets, respondents who takes four sachets per day represents 11.88% of the interviewed population. 13.86% consume six sachets, while 7.92%, 1.98% and 1.98% drinks six, seven and eight sachets respectively.

4.2.2: Distribution of respondents on consumption behaviour, how often, reason for taking it and NAFDAC check.

Drink sachet water	Frequency	Percentage
Yes	90	89.11
No	11	10.89
Total	**101**	**100**
How often		
Daily	51	50.50
Weekly	33	32.67
Monthly	6	5.94
No response	11	10.89
Total	**101**	**100**
Reason		
Not applicable	10	9.90
Readily available	55	54.46
Other reasons	18	17.82
No portable water at home	10	9.90
Cheap	8	7.92
Total	**101**	**100**

NAFDAC Check		
Not applicable	12	11.88
Yes	54	53.47
No	35	34.65
Total	**101**	**100**

Table 5: Distribution of respondents by consumption, how often, reason for taking it and NAFDAC check

Result on sachet water consumption by respondents, how often they take it, reasons for taking it and NAFDAC check is presented on Table 3. It reveals that 89.11% said they take water in sachet, 10.89% of the respondents reported that they don't. The result further shows that majority (50.50%) consume sachet water daily, 32.67% take sachet water weekly, 5.94% takes it monthly and 10.98% gave no response on their consumption pattern. The result shows that 9.90% gave no response on why they consume sachet water, majority (54.46%) drink sachet water because it is readily available, 9.90% said they drink sachet water because of lack of potable water at home. 7.92% consume sachet water because it is cheap while 17.82% gave other reasons for not taking water in sachet. With regards to whether the consumers check NAFDAC number before consumption, 54.47% said they do, 34.65% submitted they don't check it while 11.88% gave no response on this. This means that majority of the respondents check the NAFDAC number of sachet water before consumption.

4.2.3: Daily Consumption, Amount Spent and Adequacy

Quantity consumed	Frequency	Percentage
Not applicable	10	9.90
One	8	7.92
Two	26	25.74
Three	19	18.81
Four	12	11.88
Five	14	13.86
Six	8	7.92
Seven	2	1.98
Eight	2	1.98
Total	**101**	**100.00**
Amount spent		
Not applicable	10	9.90
10	8	7.92
20	26	25.74
30	19	18.81
40	11	10.89
50	15	14.85
60	8	7.92
70	2	1.98
80	2	1.98
Total	**101**	**100.00**

Adequacy		
Not applicable	10	9.90
Yes	65	64.36
No	26	25.74
Total	**101**	**100.00**

Table 6: Daily Consumption. Amount Spent and Adequacy

Table 4 provides information on the daily consumption, amount spent and adequacy of sachet water to the respondents. It illustrate that 7.92% of the respondents consume just one sachet of water daily, majority (25.74%) drink two sachets daily, 18.81% of the interviewed takes 3 sachets daily, 11.88% make use of 4 sachets daily, 13.86% drink 5 sachets daily, 7.92% drink 6 sachets daily, 1.98% of the respondents take 7 to 8 sachets respectively while 9.90% of the respondents gave no information. Moreover 7.92% of the respondents spend #10 on sachet water daily, 25.74% spend #20 daily, 18.81% spend #30 each day, 11.88% spend #40 per day, 13.86% spend #50 everyday, 7.92% spend #60 daily and 1.98% spend #70 to #80 on a daily basis. This illustrates that the quantity of sachet water consumed daily by each respondent is equivalent to the amount spent. 64.36% of the respondents reported that the quantity they buy is adequate for them, however 25.74% of the respondents counteracted that the quantity bought is not sufficient while 9.90% supplied no information on the adequacy.

4.2.4: Quality Check, Reason and Consumption Safety

Believe in sachet water quality	Frequency	Percentage
Not applicable	10	9.90
Yes	77	76.24
No	14	13.86
Total	**101**	**100.00**
Reason		
Not applicable	87	86.14
Taste and odour	1	0.99
Taste only	6	5.94
Particles	4	3.96
Source	2	1.98
Colour	1	0.99
Total	**101**	**100**
Consumption safety		
Not applicable	11	10.89
Yes	77	76.24
No	13	12.87
Total	**101**	**100**

Table 7: Quality Check, Reason and Consumption Safety

Respondents information on their believe on sachet water quality, reasons for checking and consumption safety is presented on Table 5. The result showed that 77 respondents representing 76.24 % reported that they believe sachet water is of good quality, 13.86% reported that they don't believe sachet water is of good quality while 9.90% gave no response. Majority (76.24%) of the respondents believes that sachet water available in the study area are safe for consumption. 12.87% believes the product is not safe for consumption while 11 respondents representing 10.89% of respondent provided no information on the consumption safety of sachet water in the study areas.

4.2.5: Distribution of Respondents by Sensory Evaluation of Sachet Water

Do sachet water have odour	Frequency	Percentage
Not applicable	12	11.88
Yes	35	34.65
No	54	53.47
Total	**101**	**100.00**
If yes, name brand		
Not applicable	75	74.3
A	2	2.0
B	3	3.0
C	15	14.9
D	2	2.0
E	1	1.0
F	1	1.0

H	2	2.0
Total	**101**	**100**

Table 8a: Distribution of Respondents by Odour Check and Perception on Brands

Majority (52.48%) of the respondents gave no information on the perception of odour in sachet water in the study areas. 34.65% submitted that they perceived odour in some brands while majority said they have not perceived odour in any of the brands. On brands identified to have odour, 14.85% perceived odour in sample C. 1.98% (each) in sample A, D and H respectively. 3 respondents representing 2.97% perceived odour in sample B. one respondent (each) perceived odour in samples E and F while majority (74.26%) gave no information of the brand in which they have perceived odour. This implies majority of the sachet water in the study areas do not have offensive odour. A result on the perception of water colour by respondents is presented on Table 6b. 93.07% of the respondents provided no information on the sachet water brand with respect to colour. 2.97% (each) of the respondents said they noticed colour in samples C and D while one respondent (0.99%) observed colour in sample E. On the strength of colour observed. 10.89% gave no information. 11.88% believes the sachet water in the study area is slightly coloured whereas 77.23 believes there is no colour in products available in the study area. Distribution of respondents by their perception on the taste of sachet water in the study areas shows that 27.72% of the respondents gave no response on sachet water taste. 66.34% said that sachet water is tasteless while 5.94% respondents that some sachet water in the study areas has taste. 84.16% did not identify any brand with taste, one respondent each perceived taste in samples B and E respectively. Seven respondents (6.93%) observed taste in sample C, 1.98 % did notice taste in samples D and H while 2.97% observed taste in sample G.

Name brands with colour	Frequency	Percentage
Not applicable	94	93.07
C	3	2.97
D	3	2.97
E	1	0.99
Total	**101**	**100**
Colour Rate		
No Response	11	10.89
Slightly coloured	12	11.88
Not coloured	78	77.23
Total	**101**	**100**
Taste		
No Response	28	27.72
Tasteless	67	66.34
has taste	6	5.94
Total	**101**	**100.00**
If yes, brand		
Not applicable	85	84.16
B	1	0.99
C	7	6.93
D	2	1.98
E	1	0.99
G	3	2.97

H	2	1.98
Total	**101**	**100**

Table 8b: Distribution of Respondents by Sensory Evaluation of Sachet Water

4.2.7: Distribution of respondent by particle check

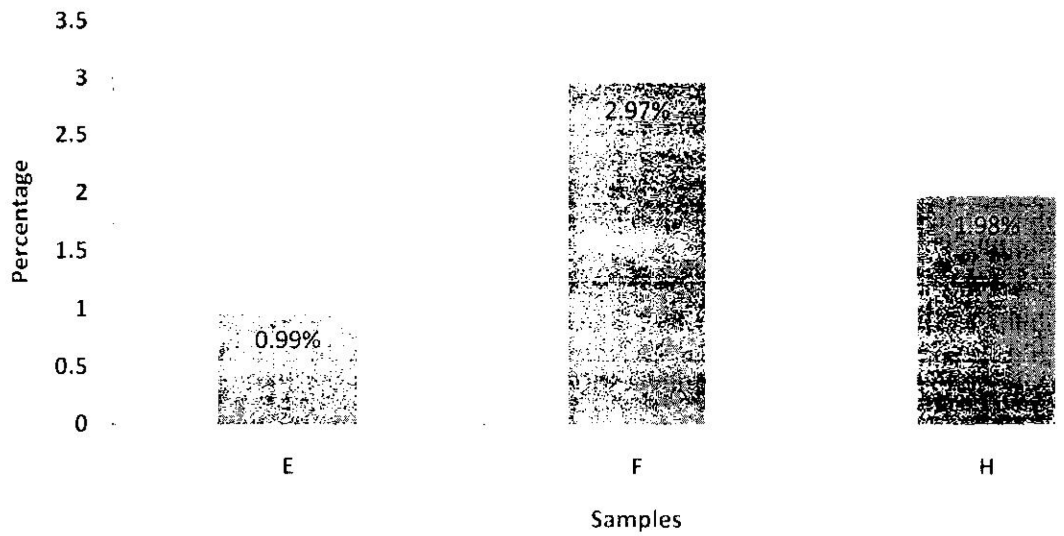


Figure 5: Distribution of Respondents by Particle Check

Figure 4 presents information of the brand that respondents sighted particles. 2.97% observed particles in sample F. 1.98% sighted particles in sample H whereas 0.99% of the respondents said that sample E has particles. The percentage of respondents who sighted particles in the sachet water pointed out is low. This is further corroborated by the result of the physico-chemical analysis as turbidity was not detected.

4.2.7: Distribution of respondents by quality check and health implication

Table 7 below provides information on the perception of respondents on the quality and health implications of sachet water consumption in the study area. 70.30% believes it is important to check the quality of products. 13.86% don't believe in this assertion while 15.84% gave no response on the importance of quality check. 21.78% of the respondents said they don't have clue on if sachet water consumption has health implications, 8.91% believes it has health implications though 69.31% submitted it has no health implications. 1.98% of the respondent mentioned stomach ache as a health problem associated with sachet water consumption, dysentery account for 2.97% while 97.05% had no information on the nature of health problem associated water sachet water consumption. 95.05% of the interviewee gave no response on the number of persons affected by the intake of unsafe sachet water, 2.99% of the respondents said only one person was affected, 0.99% said about two to three members of the household was affected respectively.

This table also gave the information that 3.96% of the respondents ascertained that sachet water was the cause of the health problem. 0.99% said it was not the cause of their health problem while 95.05% didn't give any response. 57.43% of the respondents confirmed that the sachet water they consume is produced under hygienic condition, 20.79% negated it while 20.79% had no hint of the state of the conditions in which they were produced. 8.91% of the respondents reported that they have drank expired sachet water before, majority (76.24%) haven't taken an expired sachet water before while 14.85% gave no information and some of them weren't sure. Greater part (93.07%) of the respondents gave no information on the effect which the intake of expired sachet water had on them. 0.99% said it had no effect, 0.98% pointed out typhoid as the effect, though 4.95% mentioned dysentery as the effect.

Quality importance	Frequency	Percentage
Not applicable	16	15.84
Yes	71	70.30
No	14	13.86
Total	**101**	**100.00**
Health implication		
Not applicable	22	21.78
Yes	9	8.91
No	70	69.31
Total	**101**	**100.00**
Nature of health problem		
Not applicable	96	95.05
Stomach ache	2	1.98
Dysentry	3	2.97
Total	**101**	**100.00**
Number of those affected		
not applicable	96	95.05
One	3	2.97
Two	1	0.99
Three	1	0.99
Total	**101**	**100.00**
Cause of problem		
Not applicable	96	95.05

Yes	4	3.96
No	1	0.99
Total	**101**	**100.00**
Hygienic condition		
Not applicable	21	20.79
Yes	58	57.43
No	22	21.78
Total	**101**	**100.00**
Have you drank expired sachet water before		
Not applicable	15	14.85
Yes	9	8.91
No	77	76.24
Total	**101**	**100.00**
Effect		
Not applicable	94	93.07
No effect	1	0.99
Typhoid	1	0.99
Dysentry	5	4.95
Total	**101**	**100**

Table 9: Distribution of respondents by quality check and health implication

4.2.8: Distribution of respondent by consumer's demand and marketing channel

Price satisfaction	Frequency	Percentage
Not applicable	11	10.89
Yes	27	26.73
No	63	62.38
Total	**101**	**100.00**
Most purchased		
Not applicable	11	10.89
SW	79	78.22
BW	6	5.94
WW	5	4.95
Total	**101**	**100.00**
Marketing channel		
Not applicable	12	11.88
Producer	45	44.55

Retailer	44	43.56
Total	**101**	**100.00**
Quantity purchased		
Not applicable	12	11.88
Bulk	46	45.54
Unit	43	42.57
Total	**101**	**100.00**
Reason for quantity purchased		
Not applicable	39	38.61
Daily consumption	5	4.95
Leakage	2	1.98
Good hygiene	4	3.96
Cheap	26	25.74
Costly	1	0.99
Out of home	3	2.97

Family	10	9.90
Storage	6	5.94
To make it available	1	0.99
To get chilled one	2	1.98
Just to satisfy thirst	2	1.98
Total	**101**	**100.00**

*** SW =sachet water; BW = bottled water; WW = well water

Table 10: Respondents on Consumers' Demand and Marketing Channel

Table 8 gives information on consumers' demand and marketing channel. Majority (62.38%) of persons interviewed said they aren't satisfied with the price charged for sachet water, 26.3% were satisfied while 10.89% of the respondents did not give response. Greater part (78.22%) of them purchases sachet water, 4.95% go for well water, and 5.94% buy bottled water while 10.89% gave no information. Most (44.55%) of the respondents procure sachet water from the producers, 43.56% buy form the retailer while 11.88 gave no information.

Figure 6: Distribution of Respondents by Marketing Channel

4.2.9: Distribution of Respondents by Perception of Sachet Water Packaging and Storage

Packaging Quality	Frequency	Percentage
Not applicable	12	11.88
Yes	81	80.20
No	8	7.92
Total	**101**	**100.00**
Storage check		
Not applicable	13	12.87
Yes	43	42.57
No	45	44.55
Total	**101**	**100.00**
Mode of storage		
Not applicable	62	61.39
Refrigeration	22	21.78
At room temperature	7	6.93
On a plank	1	0.99

In a bucket	4	3.96
In the pack	3	2.97
In a pot	2	1.98
Total	**101**	**100.00**

Table 11: Distribution of Respondents by Perception of Sachet Water Packaging and Storage

Table 10 gives information on the storage check, packaging quality and mode of storage of sachet water consumers. 80.20% of the respondents made certain that sachet water are well packaged, 7.92% counteracted that they are not well packaged while 11.88% gave no information. 44.57% of the respondents do not store sachet water, 42.57% of the respondents store it though 12.87% gave no information. 2.28% of the respondents store their sachet water in the refrigerator, 6.93% keep at room temperature, 0.99% lay up on a plank, 3.96% hoard it in a bucket, 2.97% leave it in the nylon used to package it form the factory, 1.98% store it in a pot while majority (61.39%) of the respondents gave no information on their mode of storage.

4.3.0 Average daily consumption by respondent with respect to their monthly income.

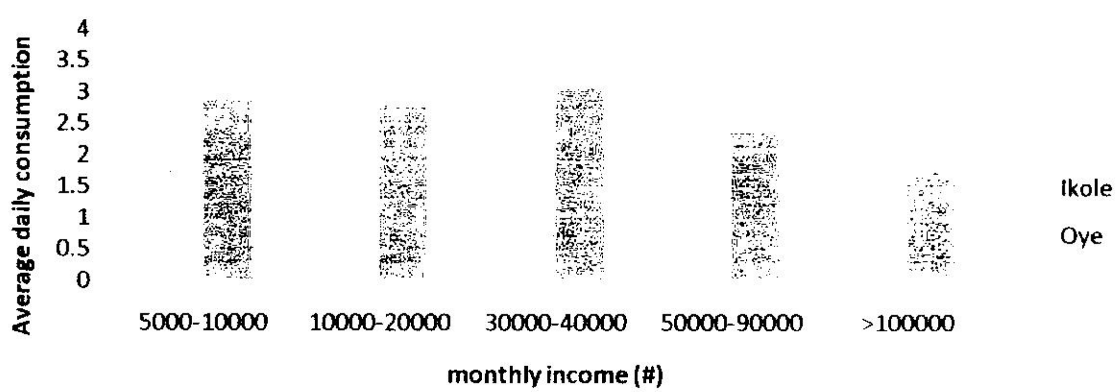


Figure 7: Average daily consumption by respondents

This figure shows the consumption pattern of sachet water by respondents with respect to their monthly income. It reveals that low income earners consume sachet water than the high income earners. This may be due to the fact that the high income earners have alternative drinking water such as bottle water or probably they have a borehole sunk in their resident.

4.3.1 Perception of consumers on sachet water quality

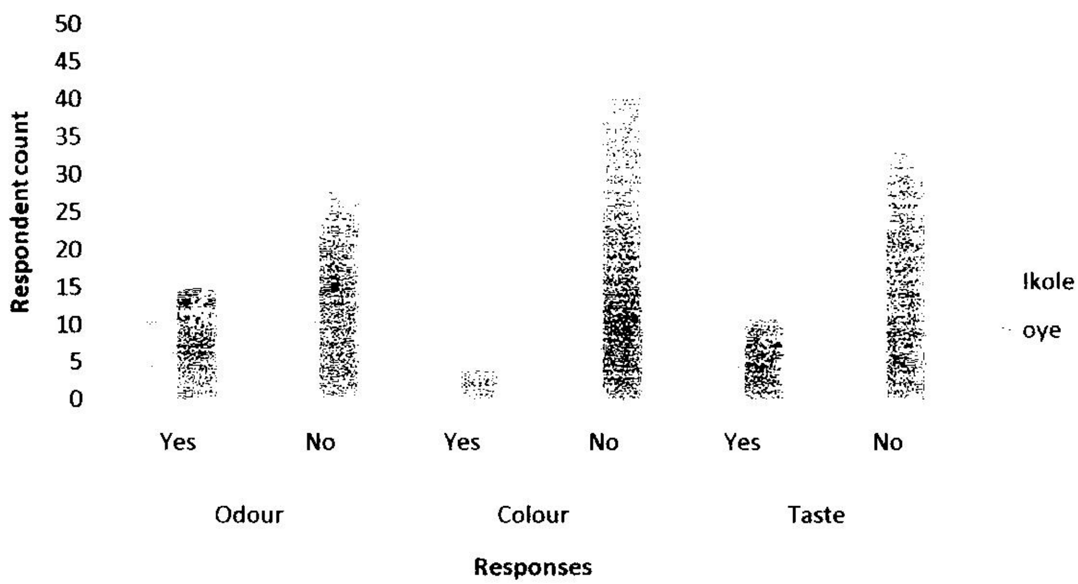


Figure 8: Perception of respondent on the aesthetic quality of sachet water

Figure 7 shows the perception of the respondents on the quality of sachet water consumed in the study areas. Majority of the responses shows that the sachet water consumed in both areas are of good quality. The result illustrate that there are little responses as to whether the sachet water consumed has an undesirable odour, taste and colour. This implies that the sachet water sold has good aesthetic value

	IKOLE				Average	OYE				Average
Parameters	Sample A	Sample B	Sample C	Sample D		Sample E	Sample F	Sample G	Sample H	
pH	7.20 ± 0.06^{b}	7.40 ± 0.06^{b}	7.40 ± 0.06^{a}	7.20 ± 0.06^{b}	7.30	7.2 ± 0.06^{b}	7.2 ± 0.06^{b}	6.7 ± 0.35^{b}	7.4 ± 0.06^{b}	7.13
Conductivity (mg/L)	0.04 ± 0.01^{a}	0.10 ± 0.01^{a}	0.07 ± 0.01^{b}	0.04 ± 0.01^{a}	0.06	0.07 ± 0.01^{b}	0.04 ± 0.01^{c}	0.07 ± 0.01^{b}	0.04 ± 0.01^{a}	0.06
Chloride (mg/L)	22 ± 0.58^{c}	31 ± 0.58^{f}	20 ± 0.58^{b}	18 ± 0.58^{a}	22.75	25 ± 0.58^{d}	21 ± 0.58b^{c}	33 ± 0.58^{g}	29 ± 0.58^{e}	27
Calcium(mg/L)	6 ± 0.58^{a}	15.2 ± 0.06^{c}	12.8 ± 0.58^{d}	12.4 ± 0.58^{d}	11.60	8.8 ± 0.58^{bc}	9.6 ± 0.58^{c}	7.2 ± 0.58^{ab}	9.6 ± 0.58^{c}	8.80
Nitrate(mg/L)	0.22 ± 0.06^{d}	0.00^{a}	0.00^{a}	0.32 ± 0.01^{c}	0.30	0.00^{a}	0.12 ± 0.01^{c}	0.23 ± 0.01^{d}	0.08 ± 0.01^{b}	0.14
Mg(mg/L)	4.4 ± 0.56^{a}	5.6 ± 0.56^{a}	4 ± 0.56^{a}	16 ± 0.56^{d}	7.50	16 ± 0.56^{d}	11.2 ± 0.56^{c}	8 ± 0.56^{b}	12.8 ± 0.56^{c}	12.00
Total Alkalinity(mg/L)	52 ± 0.58^{f}	72 ± 0.58^{g}	94 ± 0.58^{h}	40 ± 0.58^{d}	64.50	30 ± 0.58^{b}	34 ± 0.58^{c}	24 ± 0.58^{a}	44 ± 0.58^{e}	33
Total Dissolved Solid (mg/L)	30 ± 0.58^{a}	70 ± 0.58^{d}	50 ± 0.58^{c}	40 ± 0.58^{b}	47.5	30 ± 0.58^{a}	70 ± 0.58^{d}	50 ± 0.58^{c}	40 ± 0.58^{b}	47.50
Sulphate (mg/L)	0.00^{a}	0.00^{a}	22.5 ± 0.58^{c}	34 ± 0.58^{d}	28.25	0.00^{a}	18 ± 0.58^{b}	0.00^{a}	0.00^{a}	18
Manganese (mg/L)	30 ± 0.58^{a}	70 ± 0.58^{d}	50 ± 0.58^{c}	40 ± 0.58^{b}	47.5	30 ± 0.58^{a}	70 ± 0.58^{d}	50 ± 0.58^{c}	40 ± 0.58^{b}	47.50

Iron(mg/L)	11 ± 0.58^{b}	14 ± 0.58^{c}	$10 \pm 0.58a^{b}$	9 ± 0.58^{a}	11.00	40 ± 0.58^{g}	28 ± 0.58^{e}	20 ± 0.58^{d}	32 ± 0.58^{f}	30
Zn(mg/L)	27 ± 0.58^{a}	52 ± 0.58^{d}	52 ± 0.58^{d}	40 ± 0.58^{c}	42.75	62 ± 0.58^{f}	52 ± 0.58^{d}	38 ± 0.58^{b}	56 ± 0.58^{e}	52
Coliforms, MPN/100ml	0.00^{a}	0.00^{a}	0.00^{a}	18 ± 0.58^{b}	18	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00

Table 12: Biochemical Properties of Sachet Water Brands from the Study Areas

± S.E with different superscripts differs at significantly at $P < 0.05$

4.3.2 Aerobic mesophilic count of sachet water in the study areas

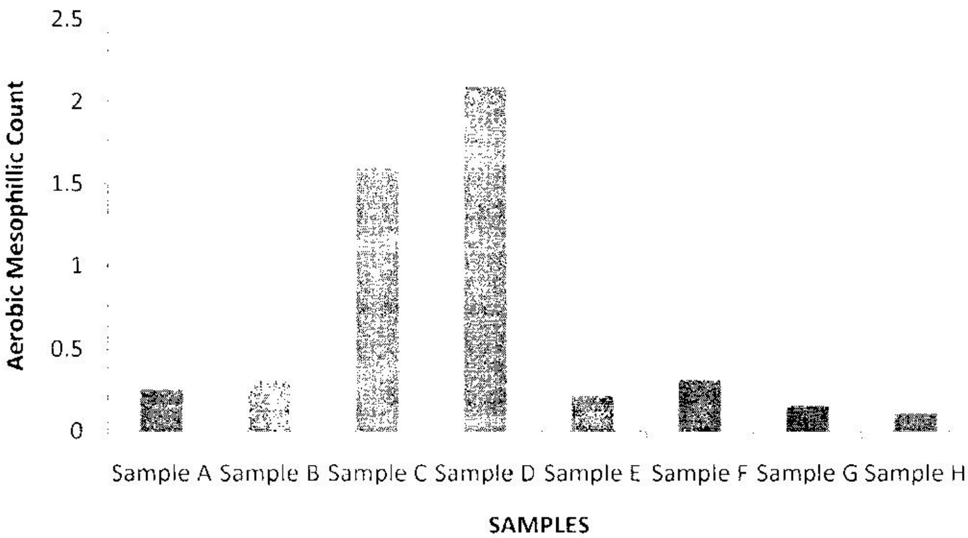


Figure 7: Aerobic Mesophilic Count of Sachet Water

Figure 9 shows that the aerobic mesophilic count of most water samples were within the set standard ($1.0x10^2$) except samples 3 and 4 from Ikole. This indicate the presence of bacteria population in the water samples which may be due to poor sanitary practice and non- adherence to good manufacturing process.

From the result, none of the samples had any objectionable appearance, odour, colour or taste. This showed that all the sachet water samples had good aesthetic value. This is similar to the works of Uduma, (2014) who reported that sachet water samples had good aesthetic value. In the study area the pH values ranged from 7.20-7.4 (Ikole), and 6.7-7.4 (Oye), which implied that all the samples are within the acceptable level of WHO. The conductivity was found to be between 10-70 µs/cm (Ikole & Oye) and was significantly different at ($P > 0.05$). Also, it was noticed that all the sachet water both in Ikole and Oye LGAs were within the WHO prescribed level of 1000 µs/cm. There is no health standard guideline for conductivity (WHO, 2011). Hence, EC has no direct adverse effects to human health, as the values in the sachet water are within the permissible limit set by the WHO. Turbidity which measures cloudiness of water was within the acceptable limit of WHO and NIS of less than 5NTU as turbidity was not detected in any of the samples. This implies that the water samples were relatively clear and contain little or disease causing microorganism. This is supported by the works of Shittu 2008 who reported high turbidity is often associated with higher level of disease causing microorganism, such as bacteria and other parasites.

The presence of total dissolved solids (TDS) in water may affect its taste (WHO, 1996). It has been reported that drinking water with extremely high concentration of TDS may be unacceptable because of its flat insipid taste (Mustapha *et al.* 2013). The total alkalinity of all water samples are within WHO (80 to 120 mg/l) and NAFDAC (100 mg/l) standard. It ranges from 40-94 (Ikole) and 24-44 (Oye), with the mean value of ± 0.58, and was significantly different at ($P > 0.05$).

Moreover, the copper content of all the water samples used in this study were in conformity with WHO standard of 1 mg/l as the presence of copper was not detected. Although, presence of copper above the standard set by WHO may cause gastrointestinal distress with a shorter term exposure, while a long term exposure may experience liver or kidney damage as reported by EPA, 2012.

In study areas the chloride value ranges from 18-31±0.58mg/L (Ikole) and 21-33±0.58mg mg/L (Oye). The ion showed significant difference ($P > 0.05$) in sample 2 from Ikole. According to WHO standards, concentration of chloride should not exceed 250 mg/l. Thus, all the chloride concentration of all the water samples was in conformity with World Health Organization standard. Chlorides is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl) and NaCO2 and are added through industrial waste, sewage, sea water etc. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damage metallic pipes and structure as well as harm growing plants as reported by Mohammed *et al.*, 2013.

Sulfate is mainly derived from the dissolution of salts of sulfuric acid and abundantly found in almost all water bodies. High concentration of sulfate may be due to oxidation of pyrite and mine drainage etc. Sulfate concentration in natural water ranges from a few to a several hundred mg per liter but no major negative impact of sulfate on human health has been reported (Mohammed *et al.*, 2013). The WHO has established 250 mg/l as the highest desirable limit of sulfate in drinking water. In these study areas concentration of sulfate was not detected in some samples and the samples which had sulphate content were within the acceptable limit with a mean value of ± 0.58 and were significantly different at ($P < 0.05$). High level of sulphate is harmful to human health as

Nitrate values obtained for the sachet water ranged from 0.22-0.32 mg/l (Ikole) and 0.08-0.32mg/l (Oye). The WHO allows maximum permissible limit of nitrate in drinking water is 10 mg/l. Thus, results indicate that the concentration of nitrate in study sites is within the acceptable limit. Nitrate was not detected in samples 2, 3 from Ikole and sample 1 from Oye. This could be attributed to their utilization by microorganisms for growth and reproduction (Sunday *et al.*, 2011). Nitrate is one of the most important diseases causing parameters of water quality particularly blue baby syndrome in infants. They get into water through chemical fertilizers, soil, foods, glass and explosives (ANL, 2005; WHO, 2007).These compounds are very soluble in water and can enter surface water when it rains or groundwater through leaching. Nitrate is a normal component of the human diet it is converted to nitrite when ingested and it reacts with haemoglobin in the blood causing methemoglobin that could result in coma and death especially in infants.

The iron contents of the water samples used in this study were in agreement with the WHO standard of 0.3 mg/l. with the exception of sample 3(Oye) which had a iron content of 0.35mg/L. Though this metal is not regarded as being hazardous to health but in fact considered essential for good health because of its role in the transportation of oxygen in the blood. Thus the recommended limit of 0.3 mg/l for iron in water is based on taste and appearance rather than on any detrimental health effect. When its level in water exceeds the 0.3 mg/l limit, the water may have a metallic taste and an offensive odour. Also, water system piping and fixtures can be clogged (Ndamitso *et al.*, 2013).

Copper is a transition metal that is stable in its metallic state and forms monovalent (Cu^{+}) and divalent (Cu^{2+}) ions. It is an essential nutrient required by the body in minute quantities. Dissolved copper sometimes imparts a light blue or blue-green colour and an unpleasant metallic, bitter taste to drinking water (ATSDR, 2002). It is a potential health hazard that causes various health problems when people are exposed to it at levels above the permissible value. Short periods of exposure can cause gastrointestinal disturbance, including nausea and vomiting while use of water whose copper level exceeds the maximum value over many years causes liver or kidney damage (EPA, 2011b). Copper Accumulates in liver and brain. The fate of elemental copper in water is complex and influenced by ph, dissolved oxygen and the presence of oxidizing agents and chelating compounds or ions (Ruqia Nazi *et al.*, 2015).. Concentration of copper in all the water samples were not detected and thus, are within the maximum permissible limit set by WHO. The maximum permissible limit set for copper by WHO is 1.0mg/l. None of the water samples in these study areas had copper content and are therefore within the acceptable range. High level of copper in water may be due to the corrosive nature of their treatment systems which when kept under control. could minimize the level of this metal (EPA, 2011b).

Water hardness is expressed in terms of the total concentration of calcium and magnesium ions when presented as the calcium carbonate content of the sample (AMC, 2006). According to World Health Organization (WHO) total hardness of water should be 100 mg/l. In study areas, hardness ranges from 37-52± 0.58 mg/l Oye and 38-62±0.58 mg/l in Ikole town. This result shows that the total hardness of water is according to the WHO standards and it is not harmful for local inhabitants. The calcium contents of the samples ranged from 15-38 ± 0.58 mg/l (Oye) to 7.20-9.6 ± 0.58 mg/l (Ikole) and all these were below the WHO permissible value for this metal. If the hardness is assumed to be mainly due to the concentrations of calcium and magnesium salts, all the samples analyzed were "soft" according to AMC's classification (2006). These samples could, therefore, be good for domestic purposes although they can easily dissolve such dangerous metals as lead, cadmium and chromium (Kendall, 2010). Magnesium content of water samples ranges from 9-14±0.58 (Ikole) and 20-40±0.58 (Oye).

The maximum permissible limit for chromium (Cr), cadmium (Cd) and lead (Pd) in water is 0.05mg/l, 0.003mg/l and 0.01mg/l respectively. In all the samples, chromium, cadmium and lead were not detected and therefore within the permissible limit set by WHO. Contamination of drinking water with high level of copper may lead to chronic anemia (AsmaIqbal *et al.*, 2011). Lead accumulates with age in bones aorta, and kidney, liver and spleen. It can also enter the human body through uptake of food (65%), water (20%) and air (15%). EPA has found cadmium to potentially cause the following health effects when people are exposed to it at levels above the maximum contaminant level MCL for relatively short periods of time nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure. At the long term it causes kidney, liver, bone and blood damage

It was observed that the mean most probable number of faecal Coliforms (MPN)/100ml of the eight sachet water samples analyzed were found to fall within the excellent category. Sachet water samples A, B, C, E, F, G, H had no coliform count per 100ml while sample D had coliform count of 18MPN/100ml of water sample. This also suggest that A, B, C, E, F, G, H are not contaminated, the presence of E.coli which was discovered in sachet water sample D signified that sample D was contaminated and therefore not safe for human consumption. This is in line with the works reported by Oladipo *et al.*.(2009) who reported that that water with bacteria are not safe for human consumption hence, the water source should be re- examine.

Similar to Oyedeji *et al.*, (2009), the absence of coliform bacteria in most brands of bottled drinking water was attributed to better hygienic practices observed in the industry compared to the sachet water producing industry. Ajayi *et al.*, (2008) had reported an earlier study of packaged drinking waters in Ibadan, Nigeria in which larger proportions of sachet water were found to show positive coliform counts compared to bottled water.

The results of the questionnaire survey support the physico-chemical analysis result. Consumers perception of sachet water sold in the study areas are not significantly different from each other. A greater part of the respondents believes that the sachet water sold in both study areas are of good quality and according to the analysis result, all the physic-chemical and microbial parameters are in conformity with WHO standard. This implies that the sachet water sold in the study areas is relatively safe for human health.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The study was carried out to assess the physical, chemical and biological properties of sachet water in Ikole and Oye Local Government Areas of Ekiti State. results from the laboratory analysis show that all the physical and chemical parameters conform with WHO standards. However, coliform count did not conform to the WHO permissible limit. The overall results showed that the sachet water produced in the study area were relatively safe for drinking according to the World Health Organization standards for potable water. The biological analysis of coliform count shows that sample D (Oye) is biologically unfit based on WHO standard. The presence of bacteria in this study might be as a result of improper handling, location of water source close to dumping site, purification procedures, and unhygienic handling after production. Water with such bacteria are not safe for human consumption, hence the water source should be re-examined. It is therefore vital that the sachet water produced in the study area be monitored regularly by NAFDAC to ensure conformity to standards. The degree of mesophilic count calls for close monitoring of these products in the area because of the public health implications. The minimum physico-chemical pollution recorded from the water samples might be as a result of adherence to production process hygiene principles of these sachet water factories and this was corroborated by questionnaire responses.

5.2 RECOMMENDATIONS

It is generally evident that water borne diseases are due to improper disposal of refuse, contamination by sewage, surface runoff and other human activities. Therefore public water supplies used in the production of sachet water must be made to satisfy all the conditions required for portability. To achieve this goal the producers, the consumers and government should work hand in hand to attain this aim for the betterment of all.

On the part of the producers, publicly sold sachet water should be adequately treated before they are packaged and sold.

Also packaged water consumers should be aware of the possible dangers of consumption of poorly packaged water especially the sachet water and the potential health risk associated with such.

Lastly, the national regulatory bodies and Ministries of Health should exercise more stringent surveillance programmes and educate the producers and the consumers alike on the need to ensure portable water quality, proper labeling (this include batch number, manufacture date and expiry date) and certification. Regulatory activities that promote core hygiene values (e.g., hand washing, general cleanliness of storage environment and vendor containers) and a proper handling culture could produce the desired improvements rather than a persistent focus on end-product monitoring, which does not always give a complete picture in terms of microbiological risk assessment.

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