EFFECTS OF SMOKE TREATMENT WITH *Xylopia aethiopica* AND *Tetrapleura tetraptera* FRUITS ON THE QUALITY OF DRINKING WATER IN ILLAH COMMUNITY, DELTA STATE, NIGERIA

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CERTIFICATION

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DEDICATION

This work is dedicated to God Almighty for His infinite love, mercy, favour and goodwill despite my short comings.

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ABSTRACT

Water-borne diseases, caused largely by lack of potable water, are among the leading causes of morbidity and mortality. Several indigenous water treatment methods have been developed to enhance the quality of drinking water. In Illah, a combination of dried fruits of *Xylopia aethiopica* and *Tetrapleura tetraptera* are used for household treatment of water without information on its potency in water purification. There is no documented information on the effectiveness of this treatment method in reducing level of water contaminants. This study was therefore designed to determine the effects of treatment with *Xylopia aethiopica* and *Tetrapleura tetraptera* fruits on the quality of drinking water in Illah community, Delta State, Nigeria.

Samples of water from borehole and stream were collected using separate sterile containers in the community. The samples were divided into two parts and baseline analysis was conducted to determine pH, nitrate, iron, lead and Total Coliform Count (TCC) using standard methods. Ten litres of the water sample was left as control while the other 10 litres of water sample was subjected to indigenous water treatment as being practised in the households. In this indigenous water treatment method, 50g dried fruits each of *Xylopia aethiopica* and *Tetrapleura tetraptera* were ground together and burnt with hot charcoal thus, producing smoke. The sterile container was faced upside down directly to the smoke for 10 minutes after which the other ten litres of water sample left for treatment was immediately poured into the container. Samples of the treated water were then collected within 24 hours from the container for analyses. Results obtained for pH, nitrates, iron, zinc, lead and TCC were compared with the WHO guideline limits of 6.5-8.5, 50.0 mg/L, 0.3 mg/L, 3.0 mg/L, 0.01 mg/L and 10.0 cfu/mL respectively. Data were analysed using descriptive statistics and t-test at $p=0.05$.

The pH, nitrates, iron, zinc, lead values for borehole water at baseline and after treatment were: 6.5±0.1 and 6.6±0.1, 20.2±0.2 and 20.3±0.9 mg/L, 0.2±0.01 and 0.1±0.03 mg/L, 0.04±0.01 and 0.01±0.004 mg/L, 0.007±0.0001 and 0.004±0.002 mg/L and for stream water at baseline and after treatment were: 6.2±0.2 and 6.3±0.2, 22.2±1.2 and 21.9±0.8 mg/L, 0.3±0.02 and 0.2±0.05 mg/L, 0.01±0.004 and 0.04±0.003 mg/L, 0.009±0.001 and 0.004±0.003mg/L respectively. These values were within the WHO limits for potable water. However, TCC for borehole (129.0±7.8 cfu/mL) and stream (280.0±95.3 cfu/mL) water exceeded the guideline limits. After treatment, TCC for borehole water was 67.0±11.0 cfu/mL showing a significant difference when compared

with baseline. The treatment reduced TCC in the borehole by 48.0%. The TCC for treated stream water was 203.0±54.9 cfu/mL. The treatment thus, reduced TCC in the stream water by 28.0%.

Treatment of water with *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits reduced the total coliform counts in both borehole and stream water. However, the total coliform counts were higher than the recommended guideline limits for potable water. An alternative water treatment that is more effective should be sought in the community.

Keywords: *Xylopia aethiopica*, *Tetrapleura tetraptera*, Coliform count, Water quality
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ABBREVIATIONS AND ACRONYMS

AOAC - Association of Official Analytical Chemists

APHA - American Public Health Association

ATCC - American Type Culture Collection

CDC - Centers for Disease Control

CREDC - Community Research and Development Centre.

DNA - Deoxyribonucleic Acid

EOKA - ent-15-oxokaur-16-en-19-oic acid

EPA - Environmental Protection Agency

FRN - Federal Republic of Nigeria

HWTG - Household Water Treatment Guide

HWTS - Household Water Treatment and Safe Storage

MDGs - Millennium Development Goals

NASA - National Airspace Agency

NDHS - National Demographic and Health Survey

NDRMP - Niger Delta Regional Development Master Plan

NEEDS - National Economic Empowerment and Development Strategy

NIS - Nigerian Industrial Standard

PAHO - Pan American Health Organization

PORSPI - Policy Research and Strategic Planning Institute

SFH - Society for Family Health

UNDP - United Nations Development Programme

UNICEF - United Nations Children's Fund

USEPA - United States Evironmental Protection Agency

USGS - United States Geological Survey

WHO - World Health Organisation

IJABPT - International Journal of Applied Biology and Pharmaceutical Technology

WRI - World Resources Institute

GLOSSARY OF TECHNICAL TERMS

Dehydration – loss of body fluid as a result of inadequate intake of fluids or excessive loss through sweating, vomiting, or diarrhea

Doubtful Sources – not feeling sure about the source of drinking water for its potability

Essential oils – are odoriferous substances from plants and are extensively used as medicinal products, in the food industry as flavours and in the cosmetic industry as fragrances

Folklore – traditional stories and explanation passed down in a community

Household – a group of people biologically or non-biologically related living in the same apartment and having a number of things in common.

Imiudu – In Illah, imiudu is a common term used by the households when purifying water in a local way.

Molluscicide – a chemical that kills molluscs (snails)

Sanitary survey – an on-the-spot inspection and evaluation by a qualified person of the entire water supply system and household storage containers for possible risks.

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Water covers 71% of the Earth's surface, and is vital for all known forms of life. On Earth, 96.5% of the planet's water is found in oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other water bodies, and 0.001% in the air as vapours, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Only 2.5% of the Earth's water is fresh water, and 98.8% of that water is in ice and ground water. Less than 0.3% of all freshwater is in rivers, lakes, and the atmosphere, and an even smaller amount of the Earth's freshwater (0.003%) is contained within biological bodies and manufactured products (Gleick, 1993). Safe drinking water is essential to humans and other life forms. Access to safe drinking water has improved over the last decades in almost every part of the world. However, it has been estimated that by 2025 more than half of the world population will be facing water-based vulnerability (Kulshreshtha, 1998).

Water plays an important role in the world economy, as it functions as a solvent for a variety of chemical substances and facilitates industrial cooling and transportation (Baroni *et al*., 2007). On average, the body of an adult human being contains 60% water. Most of the water in the human body is contained inside the cells. In fact, billions of cells must have water to live if not dehydration may result (Wang *et al*., 1996). Also the body tends to lose water when engaged in activities like perspiration, bowel movement, and urination. It is then very important to drink enough water a day, and the standard is eight to ten glasses (2 litres) (McDaniels, 2009). This threshold of drinking water balances water loss and keep the body properly hydrated. Water is a major constituent of our bodies and vital organs. Water is involved in many of the body's vital functions viz (Montain, 1999):

- Cell life- Water is a carrier, distributing essential nutrients to cells, such as minerals, vitamins and glucose.
- Chemical and metabolic reactions- Water removes waste products including toxins that the organs' cells reject, and removes them through urine and faeces.

- ❖ Body temperature regulation- Water has a large heat capacity which helps limit changes in body temperature in a warm or a cold environment. Water allows the body to release heat when ambient temperature is higher than body temperature. The body begins to sweat, and the evaporation of water from the skin surface efficiently cools the body.

Water is at the center of life and for this reason nobody can live more than three to five days without drinking water (Montain, 1999).

Lack of access to safe drinking water is a major health problem worldwide, especially in developing countries. This problem is due to the population growth and shifts from rural to urban areas that have placed a lot of stress on the existing water resources and exceeded the capacity of many countries to keep up with demand for services. Also dispersed populations and poor transportation infrastructure in many rural areas could lead to lack of access to safe drinking water (Macy and Quick, 2002). This has led households in the developing world to rely on drinking water from unsafe surface sources and then held in household storage vessels (Mintz *et al*., 1995). Quality of drinking water is of highest importance and this depends on the source and level of contamination or pollution. About 80% of diseases in the tropics for example, cholera, typhoid, diarrhoea, and dysentery are as a result of water source contamination. The level or extent of pollution and contamination is influenced by the human population being covered by the water source (Ojo *et al*., 2011). Discharge of heavy metals into the water-courses is a serious pollution problem which may affect the quality of water supply. Increasing concentrations of these metals in the water constitute a severe health hazard mainly due to their non-degradability and toxicity. Numerous metals such as chromium Cr (III) and Cr (VI), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), cadmium (Cd), etc. are known to be significantly toxic. For instance, drinking water that contains higher than normal levels of copper may cause vomiting, diarrhoea, stomach cramp and nausea. The chronic effects of consumption of high levels of copper are liver and kidney damage (Najua *et al.*, 2008).

Therefore, treatment of water at the minimal level before drinking should be encouraged to curb the spread of these diseases and also to reduce the toxicity of the numerous metals through adsorption techniques.

1.2 Problem Statement

The greatest risk associated with the ingestion of water is the microbial risk due to water contamination by human and/ or animal faeces (WHO, 2004). Lack of access to safe water remained a problem for over a billion people worldwide, while inadequate sanitation services affected at least 2.4 billion people (WHO, UNICEF and Water supply and Sanitation Collaborative Council, 2000; Mintz *et al*., 2001). Poor water quality, sanitation and hygiene account for 1.7 million deaths a year worldwide, mainly through infectious diarrhoea (Ashbolt, 2004). Diarrhoeal disease, which is frequently transmitted by contaminated water, is a leading cause of morbidity and mortality among children under 5years of age in developing countries. Estimates of annual total mortality from diarrhoeal diseases ranges from 2.5 to 3.5 million and more than 80% are among children under 5years of age (Kosek *et al*., 2003). Global morbidity is estimated at 4 billion episodes per year, of which 30% (1.2 billion episodes/ year) are related to contaminated water (Ford, 1999).

A large proportion of the global population now consume untreated, non-piped drinking water, usually consisting of small volumes (<40L/d) collected and stored in the home by users. Typically, people collect water from any available source and store it in a vessel in the home for domestic and potable use, often without treatment and protection from further contamination. In many cases, such collected household water is often heavily contaminated with faecal microbes and poses risks of exposure to water-borne pathogens and thus to infectious diseases (Sobsey *et al*., 2003).

In the Niger Delta area of Nigeria, where the natural water sources have been polluted by oil production activities, only 59 per cent of households have access to improved source of drinking water (NDHS, 2008). Also in Nigeria, only 45 per cent of households in the rural areas have access to improved drinking water sources (NDHS, 2008). The topography of Illah community favours surface runoff and discharge of untreated wastewater into the river. The attendant consequences of surface runoff on water quality have been severally reported by Inanc *et al*. 1988, Martin *et al*. 1998, Bariweni *et al*. 2000 and Izonfuo and Bariweni, 2001.

1.3 Justification of Study

The Niger Delta is one of the world's largest wetlands. The Delta is a vast flood plain built up by the accumulation of sedimentary deposits washed down the Niger and Benue rivers. Heavy metals gain access into the river system from both natural and anthropogenic sources and these get distributed into the water body during the course of their transport. A catchment area containing mineralized rocks (river beds containing solid minerals) will usually have elevated levels of metal as the trace metal content of river water is normally controlled by the abundance of metals in the rocks of the river's catchment area and by their mobility (Olajire and Imeokparia, 2000). Also, different researchers had linked prevalence of different diseases to consumption of unsafe water. Specifically, unsafe water has been associated with Cholera, Diarrhoea, Typhoid and other water-related diseases (Nwidu *et al*., 2008). These diseases occur when people consume water from unsafe sources such as stream, rivers, rainwater and groundwater. Most inhabitants of Delta State, South-South Nigeria where the study was carried out, depend on streams and boreholes that run across the area as the main source of their daily water needs.

Several indigenous water treatment methods have been developed to enhance the quality of drinking water in some Nigerian communities. In Illah community, Delta State, a combination of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits are used for the household treatment of water without information on its potency in water purification. There is no documented information on the effectiveness of this treatment method in reducing level of water contaminants.

The findings from this study may be useful in driving policies and designing intervention that will facilitate access to improved water quality mostly in the rural areas and the realisation of target 10, goal 7 of the Millennium Development Goal (MDG).

1.4 Broad Objective

The broad objective of this study was to assess the effects of smoke treatment with *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits on the quality of drinking water in Illah community, Delta State, Nigeria.

1.5 Specific Objectives

The specific objectives are to:

1. assess the respondents' knowledge of unsafe water supply
2. document the drinking water handling practices and treatment methods
3. assess the sanitary condition of drinking water sources and household storage containers
4. assess the nutrient component and anti-bacterial activity of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits.
5. assess the physico-chemical and bacteriological quality of household drinking water before and after treatment with *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits.

CHAPTER TWO
LITERATURE REVIEW

2.1 Water supply

Water is a fundamental human need for the maintenance of health. Its importance is not only related to the quantity, but also the quality. Access to water in the required quantity is needed to achieve good personal and domestic hygiene practices (Huttly *et al*.,1997); while potable water ensures that ingested water does not constitute a health hazard, even in a life time of consumption (Ezzati *et al*., 2003). It is however estimated that as much as 1.1 billion people do not have access to safe drinking water (WHO, UNICEF and Water supply and Sanitation Collaborative Council, 2000), while the drinking of contaminated water is responsible for 88% of the over four billion cases of diarrhoeal diseases that occur in the world every year, and the 1.8 million deaths that result from them. It is also indirectly responsible for the 50% of childhood malnutrition that is linked to diarrhoeal diseases, and the 860, 000 deaths that result from them each year (Prüss-Üstün *et al*., 2008).

The WHO estimates that 94% of diarrhoeal diseases are preventable through modifications to the environment (Prüss-Üstün *et al*., 2008), with improved access to safe drinking water alone able to reduce diarrhoea episodes by between 20% and 35%, according to two systematic reviews (Fewtrell *et al*., 2005 and Clasen *et al*., 2006). These health benefits, and the fact that a ready access to water saves the time of water drawers for more productive activities explain why access to adequate quantity of safe water was made one of the Millennium Development Goals (United Nations Millennium Development Goals, 2000), and why it was recognized as one of the foundations of Nigeria's developmental efforts documented in the National Economic Empowerment and Development Strategy (NEEDS) (Water Aid Nigeria, 2008).

Target 10, goal 7 of the millennium development goal sets a 2015 target to reduce the proportion of people without access to safe water by half (United Nations Millennium Development Goals, 2000).

This target would however require extra effort to achieve in the rural riverine communities of the Niger delta region, considering the enormous effort required to make the huge water resources in the communities safe for drinking.

According to the 2008 National Demographic and Health Survey, access to safe drinking water is still low in the rural communities of Nigeria, which is likely to be worse in the rural riverine communities of the Niger delta, because of the widespread use of overhung toilets in the communities, and the poor quality of groundwater, linked to saline intrusion and high concentration of iron and manganese, as a result of the geology of the area (Amadi *et al*., 1989).

Communities throughout the Niger Delta region also suffer from a weak infrastructure for the efficient and effective delivery of water supply and access to potable water. The vast majority of the settlement in Niger Delta States depend on streams and wells for their water supply and some rural settlements particularly the larger ones depend on water from boreholes (NDRMP, 2013).

Factors underlying the poor water situation in the region include problems in the operation of the state water system, lack of effective urban planning, inadequate attention from government to the sector and limited involvement of the private sector in water resources management and service provision. Problems relating to state water agencies and their network include, limited coverage; low level of priority attached to the effective management and expansion of the water works; inadequate funding; poor revenue generation such as ineffective mechanisms for the collection of water rates; low political will to effect significant expansion of existing water services and establish appropriate innovative schemes to boost water supply.

The challenges of addressing water supply problems in rural areas are not helped by communities' limited knowledge of the characteristics of safe water as well as the relationship between water and health (NDRMP, 2013).

2.2 Water Pollution

Water pollution is the contamination of water bodies. Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds. Water pollution is a major global problem. The Niger-Delta region located in the coastal part of Nigeria is a waterlogged area as more than eighty percent of the oil producing communities is on water. Before the discovery of oil in the region, it was characterized by natural clean long stretch freshwater and healthy water

lettuce that adds beauty and flavor to the environment. The communities' shorelines have been washed away or eroded due to the high volume of deep-sea exploration and exploitation activities. One of the major oil induced water pollution is oil spillage. With the expansion of oil production, the incidence of oil spills has greatly increased. Available records show that a total of 6,817 oil spills occurred between 1976 and 2001 with loss of approximately three million barrels of oil in the region. Approximately twenty-five percent spilled in swamps and sixty-nine in off-shore (UNDP Report, 2006).

Besides oil spills as source of water pollution, canalization and wastes discharged into freshwater swamps and into the sea are other sources (Akpofure, 2008). In an attempt to shorten travel time and improve access to oil fields and production facilities, oil companies have constructed canals that in some cases have caused salt water to flow into fresh water zones destroying freshwater ecological systems (Uyigue and Agho, 2007).

2.2.1 Types of Water Pollution

There are two types of water pollution, namely:

1. Point Source Water pollution: This type of pollution refers to contaminants that enter a waterway from a single, identifiable source, such as a pipe or ditch. Examples of sources in this category include discharges from a sewage treatment plant, a factory or a city storm drain.
2. Non-point Source Water pollution: This other type of pollution refers to diffuse contamination that does not originate from a single discrete source. It is often the cumulative effect of small amounts of contaminants gathered from a large area. A common example is the leaching out of nitrogen compounds from fertilized agricultural lands (Denver, 1998).

2.2.2 Control of water pollution

Water pollution prevention and control measures are critical to improving water quality and reducing the need for costly wastewater and drinking water treatment. Because water pollution can come from many different sources, a variety of pollution prevention and control measures are needed. Some of the measures that could be used in pollution control include infrastructure and low impact development approaches and techniques that could help manage water and water pollutants at the source, preventing or reducing the impact of

development on water and water quality. The efforts of public water systems, communities, resource managers and the public to protect the lakes, rivers, aquifers, and other water bodies that provide our drinking water should be encouraged to be able to control water pollution (USEPA, 2012).

2.3 Water-related Diseases

Water-related diseases are one of the most critical health problems in the Niger Delta and the health issue most closely linked with environmental degradation. Water-related diseases represent at least 80 percent of all reported illnesses in the region (NDRMP, 2013). Malaria followed by other water-related diarrhoeal diseases such as dysentery, typhoid and cholera are the most common cause of morbidity at the various health establishments in the region (NDRMP, 2013). Water-related health issues are also linked with environmental degradation. Although few water-quality studies exist, the data available on water-related diseases, water supply, and waste management practices illustrate that water contamination and associated diseases are a problem throughout the Niger Delta region (NDRMP, 2013). Poor sanitation and a general low access to potable water are primary reasons why diseases attributable to poor human waste disposal are common in the region. While water is ubiquitous in the region, potable water is difficult to find, especially during the dry season and this leads to disease outbreaks. In addition, 30% of the region is located in brackish or salt water ecosystems. During the wet season, the high water table and flooding degrade water quality by increasing human and other waste contact and creating pools of stagnant water (NDRMP, 2013).

2.4 Water Treatment

Water treatment is described as the process used to make water more acceptable for a desired end-use. The goal of water treatment process is to remove existing contaminants in the water, or reduce the concentration of such contaminants so the water becomes fit for its desired end-use (Household Water Treatment Guide, 2008).

In order to prevent the spread of water-borne infectious diseases, people should take adequate precautions. The city water supply should be properly checked and necessary steps taken to disinfect it. Water pipes should be regularly checked for leaks and cracks. The degree of treatment will depend on the quality of the raw water sourced. The treatment

of water can be on a large and small scale. The treatment of water on a large scale involves the use of water treatment plant outside homes. The treatment processes that take place in this plant are as follows (Charleston water system, 2014):

- **Rapid Mixing**:
  Once water arrives at the plant, the pH is adjusted and water is rapidly mixed with aluminum sulfate (alum), a coagulant that helps the impurities stick together to form bigger particles called floc (Charleston water system, 2014).
- **Flocculation**:
  After rapid mixing, the water flows into flocculation basins, where the flow of water is slowed and the floc has time to grow bigger (Charleston water system, 2014).
- **Sedimentation**:
  Next, the water flows into sedimentation basins, where the heavy floc particles sink to the bottom and are removed (Charleston water system, 2014).
- **Filtration**:
  Now the water travels through large filters made of sand, gravel, and anthracite. Filtration removes any remaining microscopic particles and microorganisms (Charleston water system, 2014).
- **Disinfection**:
  Finally, the water is disinfected to protect it against bacteria. The most common form of disinfection is chlorination. In municipal treatment plants chlorine gas is often used whereas on small scale other forms of chlorine are used, such as granules and tablets. One of the most common forms is the granules of calcium hypochlorite containing a 70% concentration of chlorine. The stages of rapid mixing (coagulation), flocculation, sedimentation and filtration are aimed at removing organic matter thus enabling administered chlorine to act on the pathogens that remain. When water is disinfected one aims to leave a residual of chlorine in the water to deal with additional contamination once the water leaves the point of treatment up to the point of consumption. A normal residual chlorine level is 0.2-0.5mg/litre (Adetokunbo and Herbert, 2003).
- **Distribution**
  The clean water is then pumped into pipes that are delivered to the homes (Charleston water system, 2014).

The treatment of water on a small scale involves the treatment of water for drinking and cooking within the homes which is a widespread practice even when the house may be connected to a source of water supply or a water tap nearby. People are forced to rely on water that is microbiologically unsafe. Evidence has shown that treating water at the household level is effective in improving the microbiological quality of drinking water and in preventing diarrhoea diseases (WHO and UNICEF, 2006; Fewtrell *et al*., 2005; Clasen *et al*., 2006). Boiling or heating of water with fuel is the oldest means of disinfecting water at the household level. It is also the most widely used means of treating water in the homes (Sobsey, 2002; Abadie, 2007).

2.5Water Requirement

The basic physiological requirements for drinking water have been estimated at about 2 litres per person per day (WHO 2006). This is just for survival. But from the standpoint of public health and improvement of the quality of life, water should be provided in adequate volume. It will help to reduce the incidence of many water-related diseases among the people most at risk. The consumption of water however, depends upon climate conditions, standard of living and habits of the people. A daily supply of 150-200 litres per capita is considered an adequate supply to meet the needs for all domestic purposes. It must be available close to the people, else they have to spend hours and a lot of energy, going back and forth to obtain it and the water may be polluted in the process (Park, 2002).

2.6 Safe and Wholesome water

Water intended for human consumption should be both safe and wholesome. This has been defined as water that is:

1. free from pathogenic organisms
2. free from harmful chemical substances
3. pleasant to taste and free from colour and odour
4. usable for domestic purposes

Water is said to be polluted or contaminated when it does not fulfill the above criteria. Water pollution is a growing hazard in many developing countries owing to human activity. Without ample and safe drinking water, health care to the community cannot be provided (Park, 2002).

2.7 Water Quality- Criteria and Standards

The quest for potable water dates back to antiquity. In modern times, it has led to the formulation of specific guidelines and standards to provide a basis for judging the quality of water. These guidelines and standards are exposure limits for bacteriological, viral, chemical and physical agents that have been adopted by governments or appropriate authorities and therefore have legal backing. The purpose of guidelines/standards is to minimize all the known health standards, since it is obviously impossible to prevent all pollution. The United States Environmental Protection Agency sets standards that when combined with protecting ground water and surface water, are critical to ensure safe drinking water (USEPA, 2008). Table 2.1 is showing a comparison of the limits of the World Health Organisation Guidelines and Standard for drinking water quality by Standard Organisation of Nigeria.

2.8 Water Quality

Water quality refers to the physical, chemical and biological characteristics of water. It is most frequently used in reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact and drinking water. Water quality is determined by assessing three classes of attributes: biological, chemical and physical (Diersing, 2009). The national standards for drinking water are developed by the Nigeria standards for drinking water quality. All municipal (public) water supplies must be measured against these standards.

Table 2.1: Drinking water quality guidelines recommended by regulatory agencies

Parameters (Units)	WHO Limits	SON Limits
pH	6.5-8.5	6.5-8.5
Total solids (mg/L)	500-1500	500
Total Dissolved Solids (mg/L)	500	500
Conductivity (µS/cm)	1000	1000
Total Hardness (mg/L)	100-150	150
Alkalinity (mg/L)	200	200
Chloride (mg/L)	250	250
Nitrate-Nitrogen (mg/L)	10	10
Iron (mg/L)	0.3	0.3
Lead (mg/L)	0.01	0.01
Cadmium (mg/L)	0.1	0.1
Manganese (mg/L)	0.05	0.2
Total Coliform (MPN/100ml)	10	10
E.coli (MPN/100ml)	0	0

Source: SON (2007) and WHO (2006)

2.8.1 Biological attributes of water quality

Biological attributes of water are important indicator of water quality. These refer to the number and types of organisms that live in water. The presence of faecal coliforms (over 99 % of which are *Escherichia coli*) in a water body is an indication of possible human/animal waste contamination and the possible presence of pathogenic bacteria. The detection of *Escherichia coli* provides definite evidence of faecal contamination. According to World Health Organisation (WHO, 1997, 2004) standards, faecal coliforms should be absent (0 colony forming units per 100 ml water) in portable water while total coliforms should be less than 10 colony forming units in any 100 ml water sample. The measurement of faecal coliforms can give an indication of the likely chlorine demand and also indicates where more intensive treatment is needed.

2.8.2 Chemical attributes of water quality

Chemical attributes of water affect aesthetic qualities such as appearance, smell and taste. Chemical attributes of water also affect its toxicity and whether or not it is safe to use. Since the chemical quality of water is important to the health of humans as well as the plants and animals that can live in and around streams, it is necessary to assess the chemical attributes of water. Commonly measured chemical parameters include chloride, alkalinity, hardness, nitrates and nitrites, heavy metals like iron, lead and zinc etc.

2.8.2.1 Chloride

Chlorides in groundwater can be naturally occurring in deep aquifers or caused by pollution from sea water, brine, or industrial or domestic wastes. Chloride concentration above 250 mg/l can produce a distinct taste in drinking water. Where chloride content is known to be low, a noticeable increase in chloride concentrations may indicate pollution from sewage sources (Illinois Department of Public Health, 2014). Chloride in water is determined using volumetric method. Water containing chlorides is titrated with silver nitrate solution; chlorides are precipitated as white silver chloride. Potassium chromate is used as indicator, which supplies chromate ions. As the concentration of chloride ions approached extinction, silver ion concentration increased to a level at which reddish brown precipitate of silver chromate is formed which indicates the end point (APHA, 2000).

2.8.2.2 Alkalinity

Alkalinity is a measure of the presence of bicarbonate, carbonate or hydroxide constituents. Alkalinity is not detrimental to humans. Moderately alkaline water (less than 350 mg/l), in combination with hardness, forms a layer of calcium or magnesium carbonate that tends to inhibit corrosion of metal piping. Many public water utilities employ this practice to reduce pipe corrosion and to increase the useful life of the water distribution system. High alkalinity (above 500 mg/l) is usually associated with high pH values, hardness and high dissolved solids and has adverse effects on plumbing systems, especially on hot water systems (water heaters, boilers, heat exchangers, etc.) where excessive scale reduces the transfer of heat to the water, thereby resulting in greater power consumption and increased costs. Water with low alkalinity (less than 75 mg/l), especially some surface waters and rainfall, is subject to changes in pH due to dissolved gases (Illinois Department of Public Health, 2014). Alkalinity is determined by the titration of a measured volume of water with hydrogen chloride (APHA, 2000).

2.8.2.3 Hardness

The hardness of water is a measure of the amount of minerals, primarily calcium and magnesium, it contains. Water softening, which removes these minerals from the water, may be desirable if:

• Large quantities of detergent are needed to produce a lather when doing laundry, or

• Scale is present on the interior of piping or water tanks, laundry sinks or cooking utensils (Illinois Department of Public Health, 2014). Water that contains more than 200 mg/l (milligrams/liter) or 200 ppm (parts per million) as calcium carbonate ($CaCO_3$), or 12 grains per gallon, is considered to be hard and may cause plumbing and laundry staining problems. (Three grains per gallon equals approximately 50 ppm.) Methods used to soften hard water for home use are zeolite softening and reverse osmosis (Illinois Department of Public Health, 2014).

Zeolite softening (ion exchange) depends on the ability of granular materials, called zeolites, to exchange ions present in their structure for ions present in the water. As the hard water percolates through the zeolite bed, the calcium and magnesium ions in the water are exchanged for sodium ions in the bed, making the water soft. The calcium and magnesium

ions are left attached to the zeolite grains. When the exchange capacity of the zeolite is exhausted, it can be regenerated by passing a strong salt (sodium chloride) solution through it. The excess sodium in this solution causes the zeolite to give up the calcium and magnesium ions and take up a new supply of sodium ions. The wash water is then flushed out and the unit is ready to resume the softening process. The softening-regeneration cycle can be repeated almost indefinitely over many years of service. Zeolite softeners usually consist of two tanks: one containing the zeolite and another, called the brine tank, containing a strong salt solution. Most of these tank type softeners use a timer or a sensing device to start the regenerating process automatically. The only maintenance required of the homeowner is to add salt and water to the brine tank (Illinois Department of Public Health, 2014).

Advantages

• Maintenance is low, requiring only the periodic addition of salt water to the brine tank.

• Zeolite softeners produce softened water faster than reverse osmosis units.

• If properly maintained, zeolite softeners can be used almost indefinitely (Illinois Department of Public Health, 2014).

Disadvantages

• Only calcium, magnesium and small amounts of iron will be removed from the water.

• People on salt-restricted diets (for example, persons with high blood pressure) may not be able to drink or cook with this water. Persons on such diets should not use a zeolite softener or should consult their doctor before doing so (Illinois Department of Public Health, 2014).

Reverse osmosis units remove water hardness through a straining action. The hard water enters the unit under normal tap pressure and passes through a special membrane. The membrane allows water molecules and trace levels of contaminants to pass through it. Hardness ions and other contaminants remain on the pressure side of the membrane and are eventually flushed away as waste. Most of these units are equipped with an activated carbon filter that removes chlorine and generally improves the taste of the water. Reverse osmosis units require very little maintenance. The membrane will need to be changed every one to three years and the activated carbon filter will need to be replaced about once a year. Water treated by reverse osmosis is generally supplied only to bathroom and kitchen sinks and to laundry areas (Illinois Department of Public Health, 2014).

Advantages

• The process removes most dissolved minerals from water as well as reduces hardness and certain types of bacteria.

• Water treated by reverse osmosis does not adversely affect people on sodium restricted diets(Illinois Department of Public Health, 2014).

Disadvantages

• Reverse osmosis units are slow and produce more waste water. A little more than one gallon of potable water is produced every six hours. Four to six gallons of waste water are generated in that time.

• High pressure (and the associated electrical energy costs) is required to operate the unit (Illinois Department of Public Health, 2014).

The determination of the total hardness of water is based on a complexometric titration of calcium and magnesium with an aqueous solution of the disodium salt of EDTA at pH value of 10. The determination of calcium in the presence of magnesium is based on the same principle, but at a pH value of 12. In this condition, magnesium ions are precipitated as hydroxide and do not interfere with the determination of calcium. The magnesium present in the sample may be calculated by subtracting the volume of EDTA solution required for the calcium determination from the volume required for the total hardness determination for equal volumes of the sample (APHA, 2000).

2.8.2.4 Nitrate and Nitrite

Nitrate (NO3) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrite (NO2) is not usually present in significant concentrations except in a reducing environment, since nitrate is the most stable oxidation state. It can be formed by the microbial reduction of nitrate. Nitrite can also be formed chemically in distribution pipes by *Nitrosomonas* bacteria during stagnation of nitrate-containing and oxygen-poor drinking-water in galvanized steel pipes or if chloramination is used to provide a residual disinfectant.

Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks (WHO, 2006). Surface water nitrate concentrations

can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes. Some groundwaters may also have nitrate contamination as a consequence of leaching from natural vegetation.

In some circumstances, however, drinking water can make a significant contribution to nitrate and, occasionally, nitrite intake. In the case of bottle-fed infants, drinking water can be the major external source of exposure to nitrate and nitrite. In most countries, nitrate levels in drinking-water derived from surface water do not exceed 10 mg/litre, although nitrate levels in well water often exceed 50 mg/litre; nitrite levels are normally lower, less than a few milligrams per litre (WHO, 2006). In humans, methaemoglobinaemia forms as a consequence of the reaction of nitrite with haemoglobin in the red blood cells to form methaemoglobin, which binds oxygen tightly and does not release it, so blocking oxygen transport. Although most absorbed nitrite is oxidized to nitrate in the blood, residual nitrite can react with haemoglobin. High levels of methaemoglobin (greater than 10%) formation can give rise to cyanosis, referred to as blue-baby syndrome. Although clinically significant methaemoglobinaemia can occur as a result of extremely high nitrate intake in adults and children, the most familiar situation is its occurrence in bottle-fed infants. This was considered to be primarily a consequence of high levels of nitrate in water, although there have been cases of methaemoglobinaemia in weaned infants associated with high nitrate intake from vegetables. Bottle-fed infants are considered to be at greater risk because the intake of water in relation to body weight is high and, in infants, the development of repair enzymes is limited.

In clinical epidemiological studies of methaemoglobinaemia and subclinical increases in methaemoglobin associated with drinking-water nitrate, 97% of cases occurred at concentrations in excess of 44.3 mg/litre, with clinical symptoms associated with the higher concentrations. The affected individuals were almost exclusively under 3 months of age (WHO, 2006). And for these reason the guideline value for nitrate is 50mg/L to protect against methaemoglobinaemia in bottle-fed infants (short-term exposure) and for nitrite is 3 mg/litre for methaemoglobinaemia in infants (short-term exposure) and 0.2 mg/litre (provisional) (long-term exposure). The guideline value for chronic effects of nitrite is

considered provisional owing to uncertainty surrounding the susceptibility of humans compared with animals (WHO, 2006).

2.8.2.5 Heavy metals

Metals in solution may be readily determined by atomic absorption spectroscopy. The method is simple, rapid, and applicable to a large number of metals in drinking, surface, and saline waters, and domestic and industrial wastes. While drinking waters free of particulate matter may be analyzed directly, domestic and industrial wastes require processing to solubilize suspended material. Sludge, sediments and other solid samples may also be analyzed after proper pre-treatment (APHA, 2000).

Lead

Lead is used principally in the production of lead-acid batteries, solder and alloys. The organolead compounds tetraethyl and tetramethyl lead have also been used extensively as antiknock and lubricating agents in petrol, although their use for these purposes in many countries is being phased out (WHO, 2006). Owing to the decreasing use of lead containing additives in petrol and of lead-containing solder in the food processing industry, concentrations in air and food are declining, and intake from drinking-water constitutes a greater proportion of total intake (WHO, 2006). Lead is rarely present in tap water as a result of its dissolution from natural sources; rather, its presence is primarily from household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, water hardness and standing time of the water, with soft, acidic water being the most plumbosolvent. The guideline value of lead is 0.01mg/L (WHO, 2006). Meanwhile, all other practical measures to reduce total exposure to lead, including corrosion control, should be implemented (WHO, 2006). Placental transfer of lead occurs in humans as early as the 12th week of gestation and continues throughout development. Young children absorb 4–5 times as much lead as adults, and the biological half-life may be considerably longer in children than in adults. Lead is a general toxicant that accumulates in the skeleton. Infants, children up to 6 years of age and pregnant women are most susceptible to its adverse health effects. Inhibition of the activity of d-aminolaevulinic dehydratase (porphobilinogen synthase; one of the major enzymes involved in the biosynthesis of haem) in children has been observed at blood lead levels as

low as 5mg/dl, although adverse effects are not associated with its inhibition at this level. Lead also interferes with calcium metabolism, both directly and by interfering with vitamin D metabolism. These effects have been observed in children at blood lead levels ranging from 12 to 120mg/dl, with no evidence of a threshold. Lead is toxic to the central and peripheral nervous systems, inducing sub-encephalopathic neurological and behavioural effects. There is electrophysiological evidence of effects on the nervous system in children with blood lead levels well below 30mg/dl. The balance of evidence from cross-sectional epidemiological studies indicates that there are statistically significant associations between blood lead levels of 30mg/dl and more and intelligence quotient deficits of about four points in children. Results from prospective (longitudinal) epidemiological studies suggest that prenatal exposure to lead may have early effects on mental development that do not persist to the age of 4 years (WHO, 2006). Research on primates has supported the results of the epidemiological studies, in that significant behavioural and cognitive effects have been observed following postnatal exposure resulting in blood lead levels ranging from 11 to 33mg/dl (WHO, 2006).

Iron

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. The corrosion of iron is a complex process that involves the oxidation of the metal, normally by dissolved oxygen, ultimately to form a precipitate of iron(III). This leads to the formation of tubercules on the pipe surface. The major water quality factors that determine whether the precipitate forms a protective scale are pH and alkalinity. The concentrations of calcium, chloride and sulfate also influence iron corrosion. Successful control of iron corrosion has been achieved by adjusting the pH to the range 6.8–7.3, hardness and alkalinity to at least 40 mg/litre (as calcium carbonate), over-saturation with calcium carbonate of 4–10 mg/litre and a ratio of alkalinity to Cl^- + SO_4^{2-} of at least 5 (when both are expressed as calcium carbonate). Silicates and polyphosphates are often described as "corrosion inhibitors," but there is no guarantee that they will inhibit corrosion in water distribution systems. However, they can complex dissolved iron (in the iron(II) state) and prevent its precipitation as visibly obvious red "rust." These compounds may act

by masking the effects of corrosion rather than by preventing it. Orthophosphate is a possible corrosion inhibitor and, like polyphosphates, is used to prevent "red water" (an example of water quality problems arising as a result of excessive corrosion of iron pipes) Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day (WHO, 2006). The guideline value for iron is 0.3mg/L. Iron stains laundry and plumbing fixtures at levels above 0.3 mg/litre; there is usually no noticeable taste at iron concentrations below 0.3 mg/litre (WHO, 2006).

Zinc

Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. The diet is normally the principal source of zinc. Although levels of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05 mg/litre, respectively, concentrations in tap water can be much higher as a result of dissolution of zinc from pipes. For low-alkalinity waters, an increase of pH to 8.5 should be sufficient to control the dissolution of zinc. However, drinking-water containing zinc at levels above 3mg/litre may not be acceptable to consumers (WHO, 2006).

2.8.3 Physical attributes of water quality

Consumers have no means of judging the safety of their drinking-water themselves, but their attitude towards their drinking-water supply and their drinking-water suppliers will be affected to a considerable extent by the aspects of water quality that they are able to perceive with their own senses. It is natural for consumers to regard with suspicion water that appears dirty or discoloured or that has an unpleasant taste or smell, even though these characteristics may not in themselves be of direct consequence to health. The provision of drinking-water that is not only safe but also acceptable in appearance, taste and odour is of high priority. Water that is aesthetically unacceptable will undermine the confidence of consumers, lead to complaints and, more importantly, possibly lead to the use of water from sources that are less safe. Physical attributes also serve as indicators of some forms of pollution. For example, changes in temperature may indicate the presence of certain effluents, while changes in stream width, depth, and velocity, turbidity, and rock size may indicate dredging in the area. Other commonly measured physical characteristics of a

stream include: elevation and catchment area, stream order, forest canopy and total solids (NASA, 2004).

Taste, odour and appearance

Taste and odour can originate from natural inorganic and organic chemical contaminants and biological sources or processes (e.g., aquatic microorganisms), from contamination by synthetic chemicals, from corrosion or as a result of water treatment (e.g., chlorination). Taste and odour may also develop during storage and distribution due to microbial activity. Taste and odour in drinking-water may be indicative of some form of pollution or of a malfunction during water treatment or distribution. It may therefore be an indication of the presence of potentially harmful substances. The cause should be investigated and the appropriate health authorities should be consulted, particularly if there is a sudden or substantial change. The human senses (tongue and nose) can be used to describe the taste and odour respectively in drinking water. Colour, cloudiness, particulate matter and visible organisms may also be noticed by consumers and may create concerns about the quality and acceptability of a drinking-water supply. Drinking-water should ideally have no visible colour. Colour in drinking-water is usually due to the presence of coloured organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. It may also result from the contamination of the water source with industrial effluents and may be the first indication of a hazardous situation. The source of colour in a drinking-water supply should be investigated, particularly if a substantial change has taken place. Most people can detect colours above 15 true colour units (TCU) in a glass of water. Levels of colour below 15 TCU are usually acceptable to consumers, but acceptability may vary. High colour could also indicate a high propensity to produce by-products from disinfection processes. No health-based guideline value is proposed for colour in drinking-water (WHO, 2006). The human eyes can be used to describe the colour of drinking water. To further quantify the level of colour in drinking water, a colourimeter is used.

pH

pH is a measure of how acidic/ basic water is. The range goes from 0 – 14, with 7 being neutral. pH of less than 7 indicates acidic in nature whereas a pH of greater than 7 indicates

a basic nature (alkaline). pH is a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic**,** whereas water that has more free hydroxyl ions is basic (USGS, 2006).

Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. pH is reported in " logarithmic units ". The W.H.O guideline for drinking water quality for pH is between 6.5 and 8.5. Pollution can change water's pH, which in turn can harm plants and animals. The pH of the water sample would be determined using the electronic pH meter which would be standardized at pH 4 and 7 before use.

Temperature

Cool water is generally more palatable than warm water, and temperature will impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems (WHO, 2006).

Turbidity

Turbidity in drinking-water is caused by particulate matter that may be present from source water as a consequence of inadequate filtration or from re-suspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some groundwaters or sloughing of biofilm within the distribution system. The appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances. Particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth. In all cases where water is disinfected, the turbidity must be low so that disinfection can be effective. Turbidity is also an important operational parameter in process control and can indicate problems with treatment processes, particularly coagulation/sedimentation and filtration. Ideally, however, mean turbidity should be below 0.1 NTU for effective disinfection, and changes in turbidity are an important process control parameter (WHO, 2006). A turbidometer can be used to measure the level of turbidity in drinking water.

Total Dissolved Solids (TDS)

The palatability of water with a TDS level of less than 600 mg/litre is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/litre. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances (WHO, 2006). A TDS meter is used to determine the levels of total dissolved solids in drinking water.

2.9 Collection and storage of water in the home

One of the main components necessary for providing safe drinking water is the ability to safely store it in homes of users that do not have a piped water supply at all times. There are many types of vessels used to transport and store water in different parts of the world. These range from traditional pots made from naturally available materials such as gourds or clay, to metal containers made of steel, copper or aluminum, and increasingly plastic. Ideally people should have separate containers for collection and storage of water for drinking and other domestic uses to reduce cross contamination of stored drinking water (Lantagne *et al*., 2007). In Nigeria, increasing access to safe water is a key Millennium Development Goal, as only 56% of households have access to improved sources of water (63 million people- 75% urban, 45% rural; NDHS 2008). Only one in five rural households have clean water at home, and most families collect water from unimproved and unsafe sources, such as rivers or streams. Only 10% of Nigerian households use an appropriate method of water treatment (Society for Family Health, 2012).

Whether the water is obtained from an improved source or disinfected through Solar water Disinfection (SODIS), household chlorination, or some other method, it can become contaminated during or following collection (primarily through contact between water and contaminated hands) or storage (Roberts *et al*., 2001, Jensen *et al*., 2002 and Trevett *et al*., 2004). The storage of water for days (Brick *et al*., 2004) allows the possibility of faecal contamination of otherwise good quality drinking water inside the household. Children may, in particular, cause contamination when they put their faecally contaminated hands or utensils into the household water container (Jensen *et al*., 2002).

Some studies have illustrated this process of (re)contamination during the storage: Roberts *et al*., 2001 performed a randomized intervention trial in a Malawi refugee camp. The study revealed that the water flowing from the source wells had little or no microbial contamination although the water collectors quickly contaminated their water. Analysis of water samples demonstrated that there was a 69% reduction in the geometric means of faecal coliforms levels in household water and 31% less diarrhoea disease in children under 5 years of age among the group using an improved bucket. A field study by Jensen *et al*., 2002 investigating the relative importance of the domestic contamination of drinking water in Pakistan showed that the domestic bacteriological contamination was important only when the water source was relatively clean (<100 *E. coli*/100ml). When the number of *E.coli* in the water source was above this value, intervention to prevent the domestic contamination would have a minor impact on water quality compared to an intervention at the source of water.

Although the bacteriological quality of water at household improved, elimination of direct hand contact with the stored water inside the household could not prevent the occasional occurrence of extreme pollution of drinking water at its source. This showed that extreme contaminations that are often thought to originate within the house had to be attributed to the public domain transmission i.e, filling and washing of the water pitchers. The requirements for provision of safe drinking water in municipal areas, in practice the water supplied in Vellore (South India) was contaminated and current household storage practices increased the level of contamination in at least two-thirds of households (Brick *et al*., 2004). The key factors in the provision of safe household water include the conditions and practices of water collection and storage and the choice of water collection and storage vessels. The bacteriological quality of drinking water from well, spring, borehole, and tap sources and that stored in containers by urban households in Ibadan, Nigeria (West Africa) during wet and dry seasons showed that majority of households relied on wells, which were found to be the most contaminated of all the sources (Oloruntoba and Sridhar, 2007).

At the household level, water quality significantly deteriorated after collection and storage as a result of poor handling. The study therefore, emphasized that there is a need to improve the microbial quality of drinking water not only at source but at the household level through hygiene education, and provision of simple, acceptable, low-cost treatment methods. In

Bahir Dar City, Ethiopia (East- central Africa), the bacteriological and physicochemical quality of drinking water and hygiene-sanitation practices of the consumers showed that the total coliform and thermotolerant coliform counts were higher in household water samples compared to that of tap water (p= 0.0001) (Milkiyas *et al*., 2011).

This is in agreement with an intervention study done in Sri Lanka (South-Central Asia) that showed water stored inside the household had often a worse bacteriological quality than water from the source (Dissanayake *et al*., 2004). Moreover, other studies conducted in Ethiopia indicated that the number of total coliforms in household containers was higher compared to tap water (Mengesha *et al*., 2004 and Dagnew *et al*., 2007). High counts of total coliforms and thermotolerant coliforms at the household drinking water indicated that the water had been faecally contaminated. Poor sanitation and hygiene in households were the main factors for the contamination of water during transportation and after storage at home. This study therefore emphasized the need for strict control and appropriate management of the distribution system for prevention of contamination, water sanitation and hygiene education programs.

According Hassan and Taura, 2013 the dissemination of information on private water testing, personal hygiene and sanitation should be improved when investigating the bacteriological quality of household drinking water in some local government areas of Kano State, Nigeria (West Africa). The study clearly indicated that most (62.3%) of the water sources were highly contaminated. It might be either due to the failure of the disinfections of the raw water at the treatment plant or to the infiltration of contaminated water (sewage) through cross connection and leakage points or poor hygienic conditions. When they compared water from taps and households, the quality of households water was worst, significantly contaminated with coliforms in 94.1% samples of drinking water ($P<0.01$). This could be associated with inadequate hygiene of collection and storage devices.

2.10 Household Water Treatment and Safe Storage (HWTS)

Safe Household Water Storage is a critical component of the Household Water Treatment and Safe Storage (HWTS) system being promoted by the World Health Organisation (WHO) worldwide in areas that do not have piped drinking water. In these areas, it is not uncommon for drinking water to be stored in a pot, jar, crock, or other container in the

home. Even if this drinking water was of acceptable microbiological quality initially, it can become contaminated through hands, unwashed containers and dippers. Drinking water containers with "narrow dispensers" are keys to keeping water from being contaminated while being stored in the home (WHO, 2010). It is being increasingly recognized that drinking water from protected sources is not always free from faecal contamination and that the collection, storage and use of water in the home can frequently lead to contamination. Household Water Treatment and Safe Storage (HWTS) are being promoted to deal with these concerns, as well as to potentially enable water from unprotected sources to be consumed safely. Household water treatment includes filtration, solar disinfection, chlorination, boiling, combined coagulation and disinfection. Recent research suggests that these technologies may be among the most cost-effective ways to provide safe drinking water. However, successful adoption of HWTS which includes considerable behaviour changes requires product availability at a realistic price, combined with suitable promotion strategies (WHO and UNICEF, 2008).

Household Water Treatment and Safe Storage (HWTS) interventions can lead to dramatic improvements in drinking water quality and reductions in diarrhoea disease making an immediate difference to the lives of:

1. those who rely on water from polluted rivers, lakes and, in some cases, unsafe wells or piped water supplies.
2. those who do not have access to safe drinking water in the home
3. many poor people who do not even have an extra bucket in which to separate drinking water from other uses.

Although a range of technologies exist to treat unsafe water, many of which are low cost, but majority of people do not have access to one, let alone a choice of options to treat and store their water safely.

2.11 Use of Medicinal Plants

Medicinal plants are the most important source of life saving drugs for the majority of the world's population (Odesanmi *et al*., 2009). Plants have been an important source of medicine for thousands of years. Even today, the World Health Organization estimates that up to 80% of people still rely on traditional remedies such as herbs for their medicines.

Plants are also, the source of many modern medicines. *Xylopia aethiopica* and *Tetrapleura tetraptera* are medicinal plants of great repute in West Africa (Odesanmi *et al*., 2009)..

Essential oils or their constituents are odoriferous substances from plants and are extensively used as medicinal products, flavours in the food industries and fragrances in the cosmetic industries (Saunders, 2003). Many of these oils have been shown to exert broad spectrum antimicrobial activity (Schelz *et al*., 2006; Hammer *et al*., 1999). Studies have shown that certain essential oils may have the ability to prevent the transmission of some drug-resistant strains of pathogen, specifically *Staphylococcus, Streptococcus and Candida.*

Xylopia aethiopica (Dunal) A. Rich (Annonaceae) is a tall tree of about 20m high and 75cm stem girth. The fruits are rather small and look like twisted bean-pods in clusters of up to 40 green or red monocarps when fresh but turn dark brown when dry (Burkill, 1985). It is variously called African Pepper, Negro pepper (in English), Eeru (Yoruba), Uda (Igbo) and Kimbara (Hausa) languages. It is widely cultivated in West Africa, Central and southern Africa. Almost every morphological part of the plant is used in traditional medicine for managing various ailments including skin infections, candidiasis, dyspepsia, cough and fever. A study investigated the composition of the essential oils from the leaves, stem and root barks, and fresh and dried fruits of the plant and reported their antioxidant properties, and the principal constituents as mono- and sesqui-terpene hydrocarbons (Karioti *et al*., 2004).

Several reports on the antimicrobial activity of the essential oil as well as crude extracts (both alcoholic and aqueous) of *X. aethiopica* have been made in the literature and it has been shown to have antimicrobial property against a wide range of Gram positive and Gram negative bacteria, and *Candida albicans* (Boakye-Yiadom *et al*., 1977; Thomas, 1989; Tatsadjieu *et al*., 2003; Asekun and Adeniyi, 2004; Okigbo *et al*., 2005). However, all these reports are associated with the dried fruits. Some extracts of this plant have antioxidant properties; others have cytotoxic effects on a wide range of cancer cell lines (Ju *et al*., 2004). A recent study of various Cameroonian spices (Kuete *et al*., 2011) showed that extract of *X. aethiopica* had cytotoxic activity against pancreatic and leukemia cells which made the plant to be considered a potential source of cytotoxic compounds, according to the plant-screening program of the National Cancer Institute. In this report, it was confirmed that the cytotoxic activity of *X. aethiopica* extract against a panel of cancer cell

lines and identify the main compound responsible for this cytotoxic effect: ent-15-oxokaur-16-en-19-oic acid (EOKA). Furthermore, it was shown that EOKA triggers DNA damage and accumulation of the cells in the G1 phase of the cell cycle, followed by apoptosis. The *X. atheiopica* along with *Tetrapleura tetraptera* is used to prepare soup for mothers from the first day of birth to prevent post partum contraction (Odesanmi *et al*., 2009).

Tetrapleura tetraptera is another medicinal plant in Nigeria. *Tetrapleura tetraptera* belongs to the mimosaceae family. It is referred locally to as Aridan-Yoruba and Oshosho in Ibo. It is generally found in the lowland forest of tropical Africa. The fruit consist of a fleshy pulp with small, brownish-black seeds. The dry fruit has a pleasant aroma (Odesanmi *et al*., 2009). It is therefore, used as a popular seasoning spice in Southern and Eastern Nigeria (Odesanmi *et al*., 2009). Its fruits are used for the management of convulsions, leprosy, inflammation, rheumatism, diabetes mellitus, asthma, flatulence, jaundice and fevers (Odesanmi *et al*., 2009). The anti-convulsant activity of the volatile oil from fresh fruits of *T. tetraptera* in mice has been reported (Odesanmi *et al*., 2009). Its leaves are essential for the treatment of epilepsy (Odesanmi *et al*., 2009) and present strong molluscicidal activity (Adewunmi, 1991).

Tetrapleura tetraptera is also reportedly used as a dietary supplement rich in vitamins. Some researchers have revealed the presence of glycosides and tannins in water and ethanolic extracts of *Tetrapleura tetraptera* and observed that such phytochemical metabolites were effective inhibitors of growth of bacterial (Uchechi *et al*., 2010). A study by Uchechi *et al*., 2010 revealed the phytochemical composition and antibacterial activity of ethanolic and water extract of *Tetrapleura tetraptera*. Four known human bacterial pathogens were used. They were *Escherichia coli, Staphylococcus aureus, Salmonella typhi* and *Pseudomonas aeruginosa*. The test plant yielded 2.322% of extract with water and 3.180% of extract with ethanol. Also, phytochemical composition revealed the presence of tannin, saponin, flavonoid, alkaloid, phenol, and hydrocyanic acid (HCN). Both water and ethanol extracts showed strong antibacterial activity. The water and ethanolic extracts gave zones of inhibition against *Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa* and *Salmonella typhi.* They further established that the anti-bacterial activities were attributed to the presence of these phytochemicals.

2.12 Design Criteria for Water Storage Vessels

A variety of different water storage vessel designs may protect water quality. To guide the design and approval of water storage vessels, the Centers for Disease Control and Prevention (CDC) and the Pan American Health Organization (PAHO) proposed the following working design criteria (Witt and Reiff, 1993); A water storage vessel should:

1. be constructed of translucent high-density polyethylene plastic or similar material that is durable, lightweight, non-oxidizing, easy to clean, inexpensive, and is locally produced;
2. hold an appropriate standard volume (e.g, 20L) and have a stable base and a sturdy, comfortable handle for easy carriage;
3. have a single opening of 5 to 8 cm in diameter with a strong, tightly fitting cover that makes it easy to fill th1e container and add disinfectant but difficult to immerse hands or utensils;
4. have a non rusting, durable, cleanable spigot for extracting water;
5. allow air to enter as water is extracted

Water containers that meet the aforementioned criteria have been purchased by the PAHO and the CDC for prices ranging from US $4.60 to $7.25, depending on the place of manufacture and the transportation costs. A container made of high density polyethylene may last an average of 5 to 10 years and as long as 20years, depending on wall thickness. This plastic is used to make milk containers in the United States and is recyclable. Safe containers may also be fabricated from other materials, such as earthenware or tin, but these may offer some disadvantages compared with high-density polyethylene in terms of durability, cost, weight, or other characteristics (Kittayapong and Strickman, 1993).

The design criteria can be met in various ways, and different designs maybe appropriate for different situations. Designs for water storage vessels also can address public health concerns other than enteric illness. For example, the point-of- use disinfection and safe storage strategy may be integrated with filtration of household water that is used for Guinea worm eradication in Africa and Asia (Hopkins and RuizTeben, 1991). In Thailand, plastic screen covers for water storage vessels were designed to prevent the entry and breeding of *Aedes aegypti*, the mosquito vector of dengue fever (Kittayapong and

Strickman, 1993). Figure 2.1 shows different traditional water storage vessels and water storage vessels that have been modified to reduce contamination during storage. Storage vessel A is a traditional Egyptian zir (Hammad and Dirar, 1982);B, plastic container used to sell vegetable oil in Zambia (Tuttle *et al*., 1995); C, traditional cantero from El Salvador; D, sorai used in an intervention trial in India (Deb *et al*., 1986) ;E, tin bucket used in an intervention trial in Malawi (Roberts *et al*., 1994);and F, plastic container meeting the Centers for Disease Control and Prevention/Pan American Health Organization design criteria and used in an intervention trial in Bolivia(Quick *et al*., 1993, Witt and Reiff, 1993). Figure 2.2 also shows different storage containers used mostly in Illah community, Nigeria. Storage vessel A is a bucket; B, clay pot used to store drinking water; C, Jerrycan used for fetching and storing water D, big plastic container used for storing water.

When source water quality is poor, safe water storage vessels alone cannot make water potable, but they can help to preserve water quality after treatment. A preliminary field trial of a new narrow mouthed plastic storage container and point-of- use disinfection was conducted in La Paz, Bolivia, in 1993 (Quick *et al*, 1993). Forty two families that relied on contaminated shallow wells for drinking water were randomly allocated to serve as controls (using traditional water storage containers generally wide- mouthed, uncovered, earthenware jars) or to receive the new water vessel with or without a 5% calcium hypochlorite disinfectant solution. During the study, fecal coliform bacteria and *E. coli* were commonly detected in stored water in control households and in households using the new vessel without disinfectant. However, no faecal coliforms or *E.coli* were detected in stored water samples from households that used both the chlorine solution and the intervention containers. The combined intervention enabled families to produce and store drinking water that met WHO standards for microbiological quality from non-potable water sources.

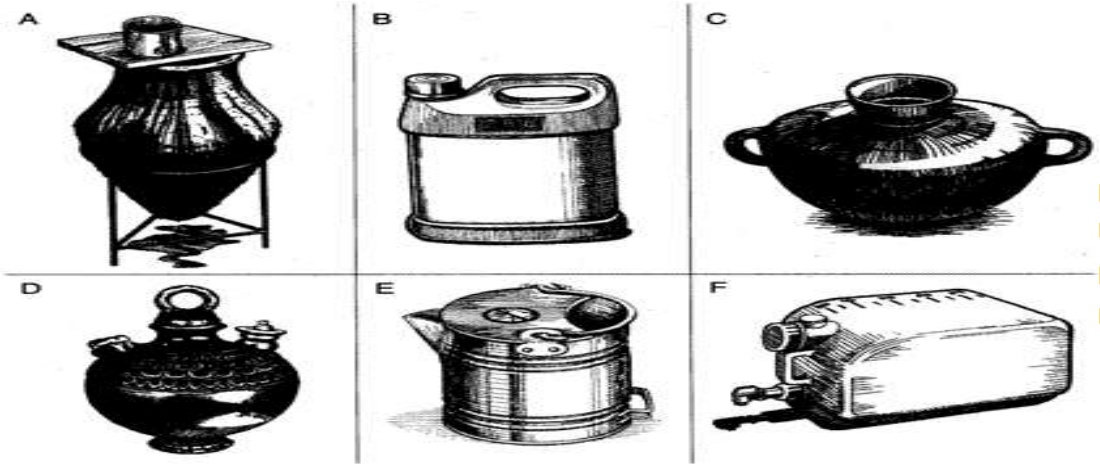


Figure 2.1: Traditional water storage vessels in different countries

Source: (Mintz et al., 1995).

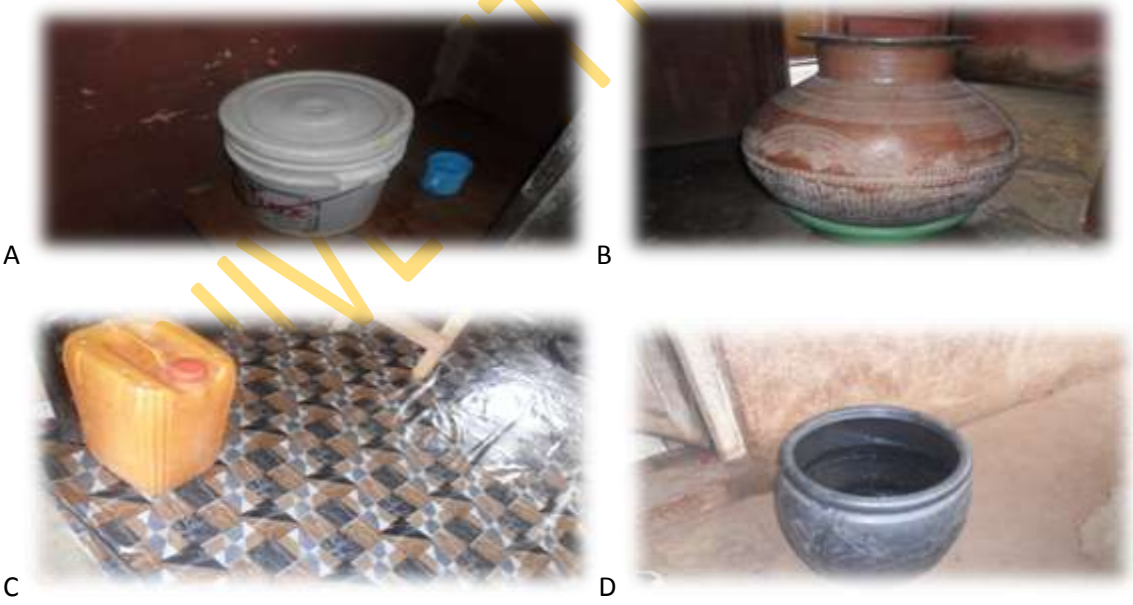


Figure 2.2: Different storage containers used in Illah Community, Delta State, Nigeria

CHAPTER THREE

METHODOLOGY

3.1 Study Area

Delta State is one of the oil producing states in Nigeria located in the Niger Delta region in the south-south geo-political zone. The State covers an area of 17,698 km^2 and coordinates of 5°30' N 6°00' E comprising 25 local government areas. The ethnic groups in the state are Igbo (sub-divided into Aniocha, Ndokwa, Ika and Oshimili collectively referred to as Anioma), Urhobo, Ijaw, Isoko and Itsekiri (Figure 3.1). Delta State is made up of three Senatorial Districts, namely Delta North, Delta South and Delta Central as shown in Table 3.1.The study area is in Oshimili North Local Government Area (LGA) and is one of the 25 local government areas in Delta State, Nigeria (Figure 3.2). It has a population of 4,098,291 consisting of 2,674,306 males and 2,024,085 females (FRN gazette, 2007). The occupations of the people are farming, fishing and trading. Oshimili North Local Government Area is headquartered at Akwukwu-Igbo and comprises prominent towns and communities such as Ibusa, **Illah (the target community)**, and Opkanam as shown in Figure 3.3. Figure 3.4 shows the map of the study area.

3.2 Study Design

This was a community-based descriptive cross-sectional study design which involved field sampling, survey and laboratory analysis.

3.3 Study Population

Women resident in Illah were the study population.

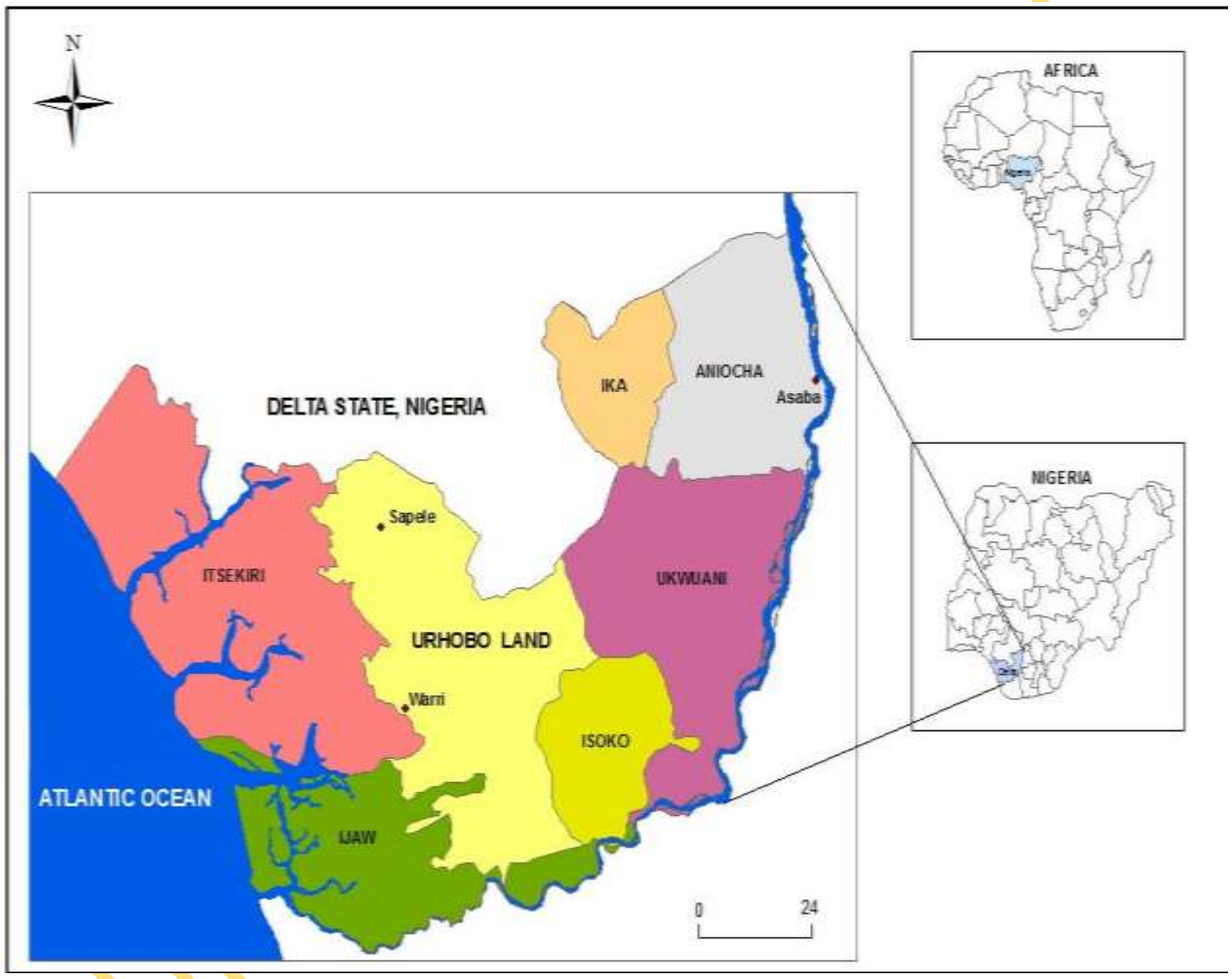


Figure 3.1: Map of Nigeria showing the location of Delta State

Source: Odemerho, 2008.

Table 3.1: Three senatorial districts in Delta State

Delta Central Senatorial District	Delta North Senatorial District	Delta South Senatorial District
Ethiope East	Aniocha North	Bomadi
Ethiope West	Aniocha South	Burutu
Okpe	Ika North East	Isoko North
Sapele	Ika South	Isoko South
Udu	Ndokwa East	Patani
Ughelli North	Ndokwa West	Warri North
Ughelli South	**Oshimili North**	Warri South
Uvwie	Oshimili South	Warri South West
	Ukwuani	

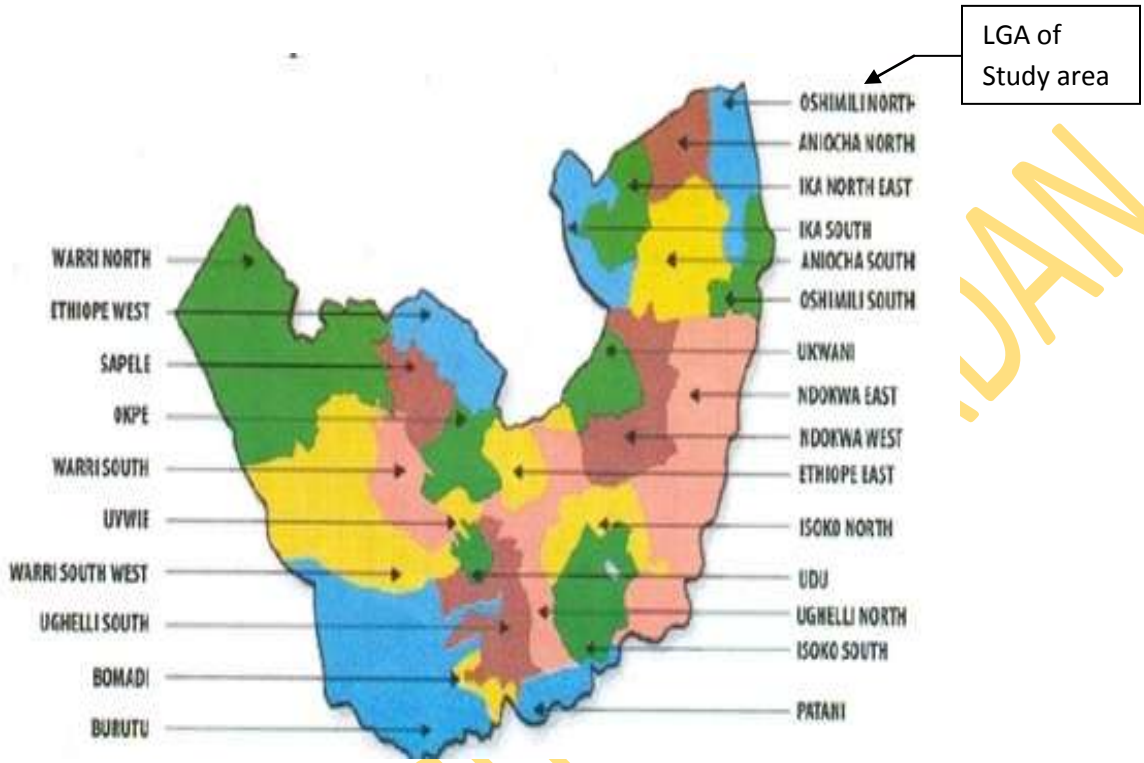


Figure 3.2: Map of Delta State showing the 25 Local Government Areas

Source: Odemerho, 2008.

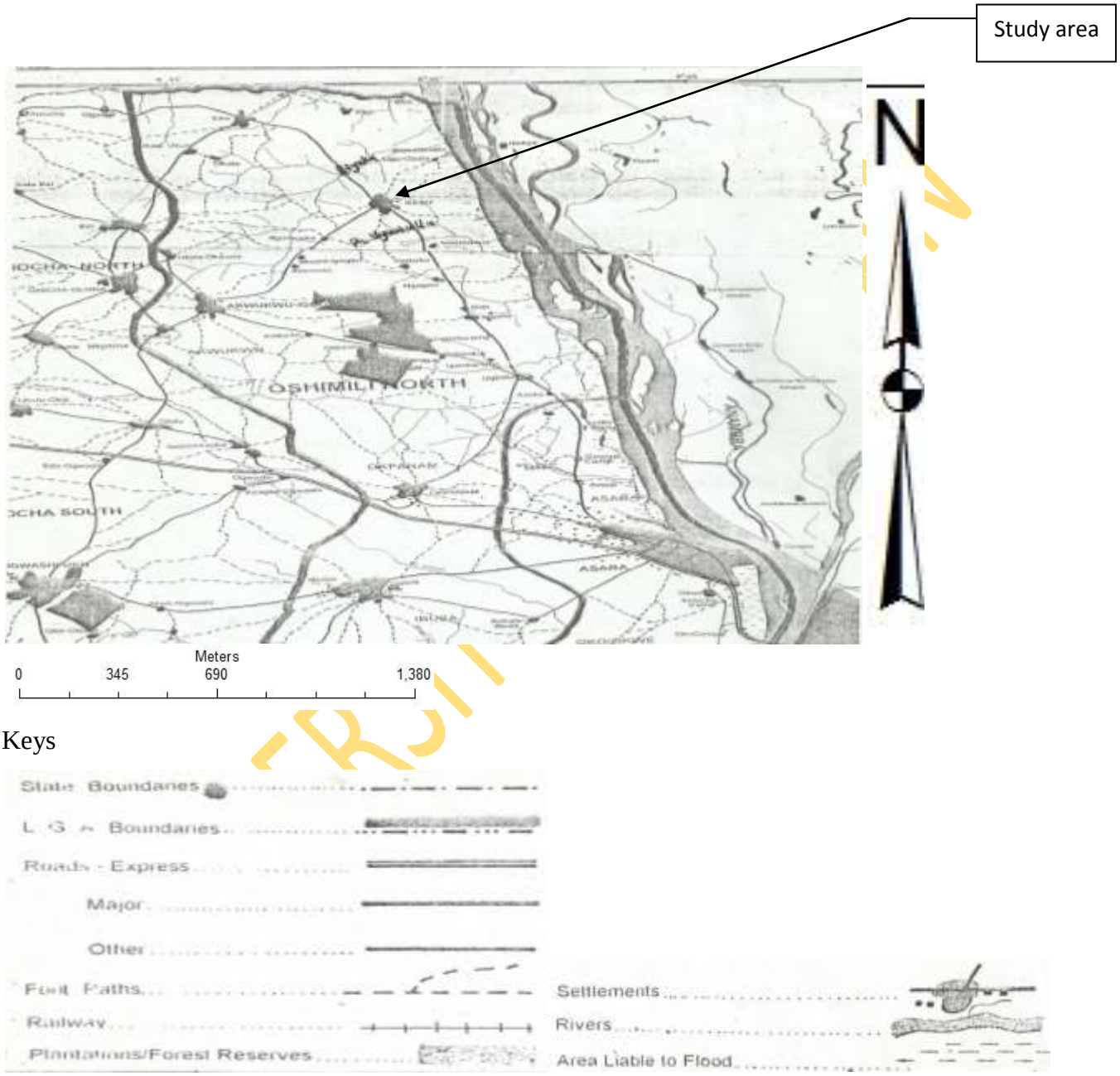


Figure 3.3: Map of Oshimil North LGA of Delta State showing the study area

Source: Town Planning Department, Oshimili North Local Government Authority

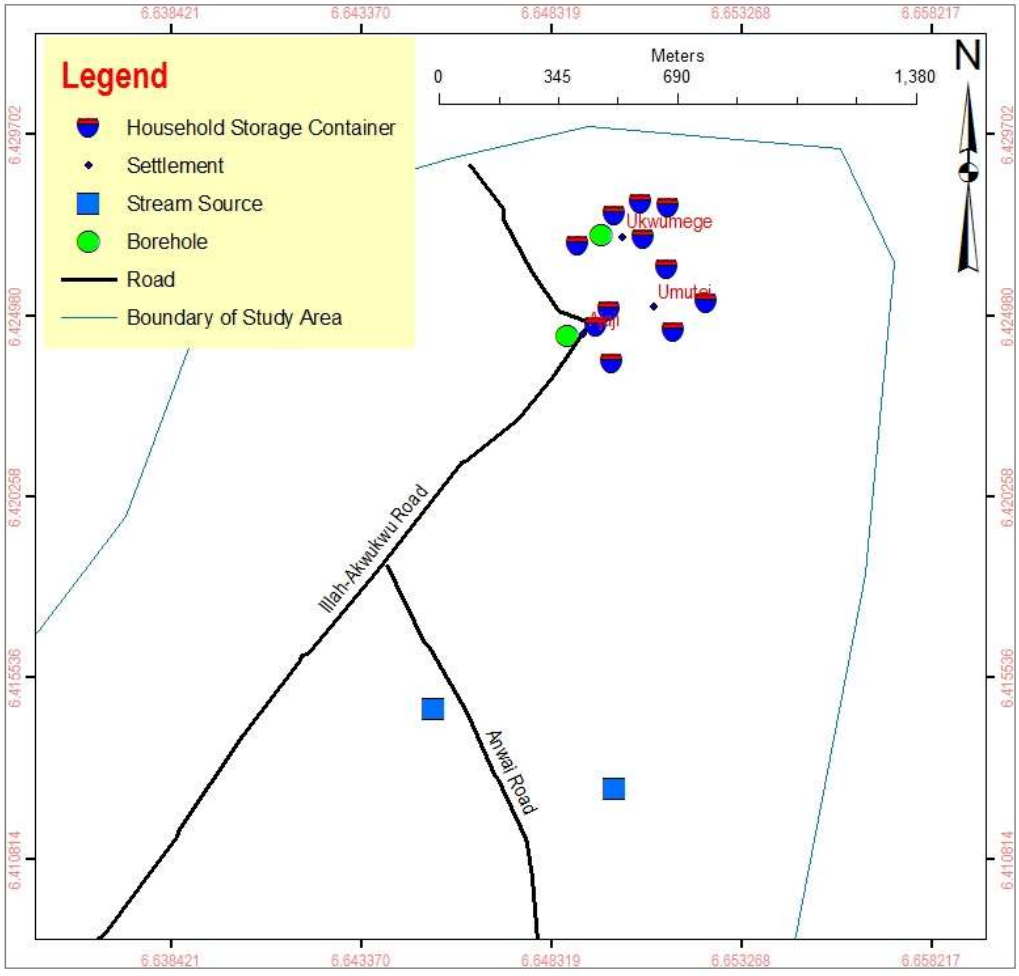


Fig 3.4: Map of the study area showing the sampling sites

3.4 Sample size determination

The determination of the study sample size for this research was calculated based on the sample size formula below by Kish Leslie, 1965:

$$n = \frac{Z_{\alpha}^{2}pq}{d^{2}}$$

Where;

n = sample size

Z_{α} = 95% confidence level (1.96)

p = the proportion of the target population estimated which have a particular characteristic study interest, in this case is the estimated proportion of women in Illah community who use dried fruits of *Xylopia aethiopica* and *Tetrapleura tetraptera* to treat their drinking water which is 20% (pilot study).

p + q = 1 thus q = 1- p

p = 0.2 therefore q = 0.8

d = precision limit (limit of standard error) = 0.04

$$n = \frac{1.96^{2} \times 0.2 \times 0.8}{0.04^{2}}$$

n = 384

In the event of non-response and high reliability associated with a large sample size, the sample size was made up to 400 research participants.

3.5 Sampling Procedure

Study area was chosen purposively since it is a major area where some households use the combination of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits to treat their drinking water. A five-stage random sampling technique was employed in this study.

- Illah community made up nine neighbourhoods was divided into three major strata using the distinctive feature on the map (major roads to separate them). In each stratum, only 1 of 3 neighbourhoods was picked by balloting.
- The households in each stratum were then numbered to obtain the total number of households in the community. Proportional allocation of sample size was done by dividing

the number of households in each stratum by the total number of households in the strata then multiplying by the calculated sample size (400) to determine the proportion of households taken from the number of households in each stratum for the study (Table 3.1).

- Simple balloting was used to pick the proportion of households from the number of households in each stratum. From each selected household, a respondent was selected for the study.
- From the 400 households, 56 households indicated they used the combination of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits to treat their drinking water.
- Only 11 of 56 households consented for their household water to be subjected to laboratory analysis.

Proportional sample size of data

$$= \frac{\text{number of households in each stratum}}{\text{total number of households in the strata}} \times \text{calculated sample size}$$

Table 3.2: Proportion of sample taken from the number of households in each stratum

Strata	Number of households	Proportional sample taken
A	240	158
B	168	111
C	198	131
Total	606	400

3.6 Data Collection

Data collection was done using the following tools.

3.6.1 Questionnaire

A semi-structured questionnaire was used to elicit information on the current household water sources, knowledge of unsafe water sources, handling practices and treatment method from each woman in selected household. The design of the questionnaire was done through a review of literature. This instrument has four major sections: Section A: Socio-demographic characteristics, Section B: Knowledge of unsafe water and its implication, Section C: Drinking water sources and water handling practices and Section D: Health related and Environmental factors (Appendix I). After development of questionnaire, it was pre-tested in-house among women in Umuagwu quarters of Asaba, Oshimili South LGA of Delta State. In the pre-test, the questionnaire was administered to 10% of the sample size of the study population (i.e. 40 respondents). The Cronbach's Alpha method was used to determine the reliability of the questionnaire. An alpha coefficient above 0.5 was obtained; indicative of the reliability of the questionnaire. The Alpha coefficient obtained from the analysis of the pre-test was 0.65, an indication that the questionnaire was valid and reliable to elicit vital information from the respondents. Nine research assistants and three residents with minimum educational level of secondary school leaving certificate and having excellent ability to speak, read, and write the local language were recruited and trained on administration of questionnaires to the respondent. A total number of 400 questionnaires were administered to women in the selected households.

3.6.2 Sanitary Inspection Forms

These forms were designed to capture the sanitary conditions of commonly used sources (borehole and stream) and household storage containers where drinking water samples were collected in the community (Appendix II – IV).

3.7 Sample collection and preservation

3.7.1 Samples of Dried fruits used for indigenous water treatment

Samples of *Xylopia aethiopica* (Dunal) A. Rich and *Tetrapleura tetraptera* (Schum. α Thonn.) Tant dried fruits (Plates 3.1 and 3.2) were collected from the central market in Illah community purposively. All the samples collected from the field were then identified in the herbarium at University of Ibadan by a Botanist and were taken to the laboratory for analyses.

3.7.2 Water samples

Water samples from borehole and stream were purposively collected for the determination of physico-chemical and microbiological quality. Prior to the collection of water samples from consented households, an indigenous water treatment was carried out. In this indigenous water treatment method, a hot charcoal was kept on a flat surface (flat tray). Quantities of oil palm mesocarp fibre (Plate 3.3) was added on top of the hot charcoal, after which 50g dried fruits each of *Xylopia aethiopica* and *Tetrapleura tetraptera* were ground together using clean mortar and pestle and added on top of the hot charcoal with oil palm mesocarp fibre, thus, producing a smoke. The washed and dried storage container (clay pot) was faced upside down directly to the smoke for 10 minutes after which 10 litres of water from the selected source was immediately poured into the container. Samples of the treated water were then collected day 1, 2 and 3 after treatment from the clay pot for the determination of physico-chemical and microbiological quality.

Sample Collection for Physico-chemical analysis

Plastic kegs of 2 litres capacity and plastic bottles of 60mls capacity were used to collect water samples for physico-chemical and heavy metal analyses respectively from the boreholes, streams and household storage containers. The sample collection containers were previously washed with detergents and rinsed with distilled water.

Sample Collection for microbial analysis

The containers that were used for sample collection were properly washed, rinsed with distilled water, dried and sterilized in an oven at temperature of 170^0C for 1 hour. All the containers were closed until the point of sample collection. Samples were collected from borehole, stream and storage containers under aseptic condition.

Borehole water: The faucet was cleaned by swabbing with cotton wool soaked with 70% alcohol after which the tap was turned on to allow water run for five minutes to clear the water lines. The faucet was then sterilized for a minute with the flame from a spirit lamp. The water was allowed to run for five minutes to clear the water lines and bring in fresh water. Sample bottles were carefully opened and the outside of the cap was held in order not to contaminate the container or cap. The container was filled and the top replaced. Immediate transportation of samples to the laboratory for storage in refrigerator was made and analyses were done within 24 hours.

Stream water: The cover of the sterile sample bottle was aseptically removed, and the mouth of the bottle was faced upwards. The neck was plunged downwards about 30 cm below the water surface, and then the neck was tilted slightly upwards to let it fill completely before carefully replacing the cap and cover. The sample bottle was covered, labeled, dated, and taken to the laboratory immediately for storage in the refrigerator. Analyses were done within 24 hours

Treated borehole and stream water samples: The cover of the sterile sample bottle for microbial analysis and clean sample bottle for physico-chemical analyses was aseptically removed, and the mouth of the bottle was faced upwards. The treated water samples were collected aseptically from the storage container into sterile sample bottles and clean container for microbial and physico-chemical analyses using sterile cup. The cups were washed effectively with detergent, rinsed with distilled water and further sterilized in an oven at temperature of 170^0C for 1 hour. The cups were closed until the point of sample collection. As soon as the sample bottles were filled up with treated water, they were covered up by replacing the cap and cover. The samples were immediately stored in ice packs and transported to the laboratory for analyses within 24 hours.

3.7.3 Sample Identification and Handling

All samples were given serial numbers. Location of sample, date, time and type of sample collected were coded and recorded. The samples for bacteriological analysis were placed in the cooler with ice packs to prevent bacterial growth.

Plate 3.1: Dried fruit of *Xylopia aethiopica* (Dunal) A. Rich

Plate 3.2: Dried fruit of *Tetrapleura tetraptera* (Schum. α Thonn.) Tant

Plate 3.3: Oil palm mesocarp fibre

3.8 Laboratory analysis

3.8.1 Water samples

3.8.1.1 Physico-chemical analysis

pH

The pH of the water samples was determined by the use of calibrated electronic pH meter (Denver instruments, model 215). The pH meter was calibrated using buffer solutions of pH 4.0 and 7.0 at a temperature of 25^0C. 100mls of each of the samples was measured in a beaker and the pH and temperature probe were inserted into the water samples. The pH reading was taken. In between readings, the probe of the pH meter was rinsed with distilled water to avoid contamination.

Heavy metals

The heavy metal content was determined using an Atomic Absorption Spectophotometer (Buck Scientific Model 210 VGP). This was done after Nitric acid digestion procedure for water samples (USEPA, 1996).

Nitric acid digestion

Nitric acid digestion was performed using the procedure recommended by the USEPA (1996). A 100mL of water sample was measured into 125mL erlenmeyer flask and 2mL of concentrated HNO3 was added. The mixture was boiled gently for 30 – 45 minutes until it remained 10mL to oxidise all easily oxidisable matter. After cooling, the remaining 10mL mixture was transferred to 100mL volumetric flask and diluted to 100mL with deionised water.

Heavy metal analysis

The concentrations of lead (Pb), iron (Fe) and zinc (Zn) in the final solutions were determined by an atomic absorption spectrophotometer (AAS).

Nitrate

Stock nitrate solution was prepared by dissolving 721.8 mg anhydrous potassium nitrate and diluting to I Litre with distilled water. Then 10mL stock nitrate solution was diluted to 1 Litre with distilled water to get the standard nitrate solution. Nitrate standards were prepared in the range 0.1–1.0 mg/L N diluting 1.00, 2.00, 4.00, 7.00 and 10.0 mL standard nitrate solution to 10 mL with distilled water. 1 drop of sodium arsenite solution was added and mixed.

A series of reaction tubes in test tube stand was then set up. 10 mL sample was then added to the reaction tubes. The stand with those tubes was then placed in a cool water bath and 2 mL NaCl solution was then added and mixed well.

A 10 mL sulphuric acid solution was added and again mixed well and allowed to cool. 0.5 ml brucine-sulphanilic acid solution was then added. The tubes were then swirled and mixed well and placed in boiling water bath at temperature 95°C.

After 20 minutes, the samples were then removed and immersed in cool water bath. The samples were then poured each on the cuvette of the spectrophotometer and read along with the standards against the reagent blank at 410 nm. A standard curve for absorbance value of standards against the concentration of NO_3^- N was then prepared. The concentration of NO_3^- N in the sample from the known value of absorbance was then read. The sample nitrate was computed using the equation below as outlined in APHA, 2000.

$$NO_3 \text{ in } mg/L = mg/L \text{ nitrate} - \text{Nitrogen} \times 4.43$$

Where,

$$\text{Nitrate} - \text{N in } mg/L = \frac{\mu g NO_3^- - N}{mL \text{ sample}}$$

3.8.1.2 Bacteriological analysis

Analysis of water for the presence of total and faecal coliforms was carried out using the multiple tube fermentation technique (APHA, 2000).

Media preparation and sterilization: Oxoid MacConkey broth was used. Thirty-five grams of MacConkey broth was carefully weighed and dissolved in 1000mL of sterile distilled water to give single strength MacConkey broth. Seventy grams of MacConkey broth was also carefully weighed and dissolved in 1000mL of sterile distilled water to give double strength MacConkey broth. Prior to the media preparation, fifteen fermentation tubes with inverted Durham tubes were properly washed, rinsed with distilled water and sterilized in the oven at 170^0C for 1 hour. After dissolution of the media, the double strength medium was dispensed into five sterile fermentation tubes with inverted durham tubes (for indication of gas formation) in 10mL volumes and single strength MacConkey broth was dispensed into two sets of 5 sterile fermentation tubes with inverted durham tubes (for indication of gas formation) in 5mL volumes and then sterilised at 121 °C for 15 minutes using an autoclave.

Serial dilution of water samples: Two serial dilution of the sample water was prepared: 1:10 sample and 1: 100 samples. The 1:10 dilution series was prepared by pipetting 1 mL from original sample and diluted to 10mL with 9mL distilled water while 1:100 dilution series was prepared by diluting 1mL of sample from 1:10 serial dilution and diluted to 10 mL with 9mL distilled water.

Estimation of Total Coliform and *E.coli* Counts: After sterilization and dilution, 10mL of the original sample was measured using sterile pipette into each of the five tubes containing 10mL of the double strength media already prepared. One (1mL) of the 1:10 sample already prepared was measured using sterile pipette into each of the five tubes containing 5mLs of the prepared single strength medium while 1mL of 1:100 sample prepared was measured using sterile pipette into each of the five tubes containing 5mLs of the single strength media already prepared. Different sterile pipette was used for each measurement during inoculation. The tubes were then incubated at 37 °C for 24 + 2 hours after which each bottle was swirled gently. Presence of gas in the Durham's tubes as well as growth and acid production evidenced by colour change were the presumptive evidence for the presence of coliform bacteria in the sample. The negative tubes (no gas, no colour change and turbidity) were re-incubated for a further 24 hours and then re-examined for gas production.

With reference to tables of most probable number (MPN) as outlined in APHA 2000, the MPN of presumptive coliform present in 100mL of the water sample was estimated. All presumptive bottles which showed growth, gas production or acidic reaction within 24 + 2 hours and 48 + 3 hours of incubation were submitted for confirmatory test to confirm the presence of *E.coli*. Using a sterile loop (3 mm in diameter), loopfuls of culture were aseptically transferred from positive presumptive bottles to fermentation bottles containing sterile brilliant green lactose bile broth with inverted durham's tubes and then incubated at 37 °C for 48 + 3 hours. The MPN value was then calculated from the number of positive brilliant green lactose bile broth tubes which showed gas formation in the inverted durham tube.

3.8.2 Samples of *Xylopia aethiopica* (Dunal) A. Rich and *Tetrapleura tetraptera* (Schum. α Thonn.) Tant dried fruits

3.8.2.1 Physico-chemical analysis

Moisture content, ash, crude fibre, crude fat, and crude protein were determined using standard methods (AOAC, 1990).

Moisture Content

Moisture content was determined by oven drying at 105°C. Two clean flat crucibles were dried in an oven and cooled in a desiccator. The weights of two cooled crucibles were taken. This whole process was repeated until a constant weight (W_1) was maintained for each crucible. Two grams of ground *Xylopia aethiopica* (Dunal) A. Rich dried fruit was introduced and spread in one crucible while 2g of ground *Tetrapleura tetraptera* (Schum. α Thonn.) Tant dried fruit was introduced in the same manner into the other crucible and weighed accurately (W_2). The two crucibles with its content were transferred into the oven at 105°C and dried for 24 hours. The hot crucibles were transferred into a desiccator, allowed to cool and weighed. The crucibles were returned to the oven for 24 hours and again cooled in a desiccator and weighed. This process was repeated until a constant weight (W_3) was reached. The sample percentage moisture content was computed in the equation below as outlined in AOAC, 1990.

$$\% \text{ Moisture content} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

Where,

W_1= Final constant weight of crucible

W_2= Weight of crucible + moist sample

W_3= Weight of crucible + dried sample

Ash content

Two crucibles were cleaned, dried in the oven, cooled in a desiccator and weighed. This process was repeated until a constant weight (W_1) was maintained for each crucible. Two grams of ground *Xylopia aethiopica* (Dunal) A. Rich dried fruit was introduced and spread in one crucible while 2g of ground *Tetrapleura tetraptera* (Schum. α Thonn.) Tant dried fruit was introduced in the same manner into the other crucible and weighed accurately (W_2). The two crucibles with its content were then transferred into a muffle furnace at 600°C for 30 minutes until fully ashed. After complete ashing, the two crucibles with the ash were cooled in a desiccator and weighed (W3). The sample percentage ash content was computed in the equation below as outlined in AOAC, 1990.

$$\% \text{ Ash content} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

Where,

W_1= Final constant weight of crucible

W_2= Weight of crucible + moist sample

W_3= Weight of crucible + ash

Crude Fibre content

Crude fibre was determined using the trichloroacetic acid TCA method of (AOAC, 1990). About 2g of each sample was weighed into two 500ml Erlenmeyer flasks separately and 100 ml of TCA digestion reagent was added. They were then brought to boiling and refluxed for exactly 40 minutes counting from the start of boiling. The flasks were removed from the heater, cooled a little then filtered through a whatman No. 4 filter paper (15cm). Each of the residues was washed with hot water stirred once with a spatula and transferred to two porcelain dish seperately. Each sample was dried overnight at 105°C. After drying, it was transferred to two desiccators separately and weighed as W1. They were then burnt in a muffle furnace at 500°C for 6 hours, allowed to cool, and reweighed as W2. The percentage crude fibre was calculated as follows

$$\% \text{ Crude fibre} = \frac{W_1 - W_2}{W_0} \times 100$$

Where,

W_1= Weight of crucible + fibre + ash

W_2= Weight of crucible + ash

W_0= Weight of sample

Fat content

Fat content was determined using the soxhlet extraction method as outlined in AOAC, 1990. Two grams of each ground sample (*Xylopia aethiopica*, and *Tetrapleura tetraptera* dried fruit) was weighed accurately (W). Two flat bottom flasks were weighed (W_1) and two extractors were mounted on each of them. After which two thimbles were held half way separately into the extractors and each weighed ground sample was carefully transferred into each of the thimble. Each thimble was then plugged with cotton wool each, and dropped carefully into each of the extractor. Then, 25mL of petroleum ether solvent was measured into the flask and the fat content was extracted for 5 hours. After extraction, the solvent was evaporated by drying in the oven 105^0C for 12 hours. Each flask and its contents were cooled in a desiccator and weighed (W_2). The percentage fat content was calculated as follows:

$$\% \text{ Total Fat content} = \frac{W_2 - W_1}{W} \times 100$$

Where,

W = Weight of sample used

W_1 = Weight of flasks alone

W_2 = Weight of flasks + Fats (Ether Extract)

Protein Content

The protein content was determined using a micro-Kjedhal method (AOAC, 1990) which involves wet digestion, distillation, and titration. The protein content was determined by weighing 2g of sample into a boiling tube that contained 25mL concentrated sulfuric acid, 5g anhydrous sodium sulphate, 1g copper sulphate and two tablets of selenium (catalyst) alongside anti-bumping granules (glass beads). Tubes were heated at low temperature for digestion to occur. The digest was left to cool and diluted with 100mL distilled water, 10mL of 40% NaOH, and 5mL sodium thiosulphate, anti-bumping agent was added, and then the sample was diluted with 10 ml of boric acid. The NH_4 content in the distillate was determined by titrating with 0.1 N standard HCl using a 25mL burette. The protein value obtained was multiplied by a conversion factor, and the result was expressed as the amount of crude protein.

$$\% \text{ crude protein} = \frac{V \times 0.1N\ HCL \times 0.014 \times F}{\text{Weight of sample}} \times 100$$

Where,

V= titre value

F= conversion factor

Total Carbohydrate Content

Carbohydrate content was determined by difference using the method of Egounlety and Awoh (1990), by subtracting the total sum of the percentage of moisture, ash, crude fibre, fat and protein content from hundred (100).

Heavy metal determination

The concentration of heavy metals was determined using an Atomic Absorption Spectophotometer (Buck Scientific Model 210 VGP). This was done after the Nitric-Perchloric acid digestion procedure (AOAC, 1990).

Nitric–perchloric acid digestion

Nitric-perchloric acid digestion was performed using the procedure recommended by the AOAC (1990). Ground sample (2g) was digested by the wet digestion method. It was first digested with 10mL HNO_3 at gentle temperature (60-70°C) for 20 minutes. Then the sample was digested with $HClO_4$, at high temperature (190°C) till the solution became clear. The digested sample was transferred to 250mL volumetric flask and volume was made with distilled water and then filtered through a Whatman No. 1 filter paper (11cm).

Estimation of mineral and heavy metal contents

The filtered sample solution was aspirated to the atomic absorption spectrophotometer to estimate concentrations of iron (Fe), Zinc (Zn) and Lead (Pb). The concentration of metal in the dry solid sample was calculated as follows:

$$\text{mg metal/kg sample} = \frac{A \times V}{D}$$

Where,

A= mg/L of metal in processed sample from calibration curve

V= final volume of the processed sample in mL

D= Weight of dry sample in gram

3.8.2.2 Antibacterial activity

Preparation of extracts

Dried and milled fruit materials were extracted with ethanol using the soxhlet extraction method as outlined in AOAC, 1990. A 150g of each ground sample (*Xylopia aethiopica*, and *Tetrapleura tetraptera* dried fruit) was placed into two different extractors. Then 300ml of ethanol was poured into each of the two flat bottom flasks. The two extractors with the weighed samples were then mounted on each of the flat bottom flasks with solvent after which extraction for 10 hours continued on the boiling water bath. After extraction, the extracts were evaporated to dryness by transferring the extracts from each flat bottom flask into a conical flask and placing in boiling water bath for 12hours. After evaporation to dryness, the concentrate gotten was siphoned into a container of known weight (W_1) after which the weight of the container with the concentrated extract was taken (W_2) to give the percentage yield. The percentage yield of the samples was calculated as follows as outlined in AOAC, 1990:

$$\% \text{ yield} = \frac{W_2 - W_1}{W} \times 10$$

Where,

W= Weight of dried sample in grams

W_1= known weight of container without concentrated extract in grams

W_2= Known weight of container with concentrated extract in grams

For *Xylopia aethiopica*

Where,

W = 150g

W_1= 63.178g

W_2= 93.416g

$\therefore$ % yield = 20.2%

For *Tetrapleura tetraptera*

W = 150g

W_1= 65.906g

W_2= 92.903g

$\therefore$ % yield = 18.0%

After estimating the percentage yield of each concentrate, 1g of concentrate was weighed and dissolved in 2mL ethanol to give 100% concentrated extract.

Assay for Antimicrobial Activity of the Extracts

This was carried out to determine if the extracts had antimicrobial activity and was done using a modification of the method of Tagg and Mc-Given (1971). Two different strains of *Escherichia coli* and *Pseudomonas aeruginosa* from Department of Microbiology Laboratory, University of Ibadan were used to assess the inhibitory response of the extracts at different concentrations on the sterile petri dishes. The reference strains used for the screening were *Escherichia coli* (ATCC 25922) and *Pseudomonas aeruginosa* (ATCC 27853).

1. Preparation of overnight culture: 13g of Nutrient broth was carefully weighed and dissolved in 1000ml of sterile distilled water. 5ml of the broth was dispensed into four McCarteny bottles and sterilized at 121°C for 15minutes. A loop full of each of the test organism (*E.coli* E1, *E.coli* E2, *Pseudomonas aeruginosa* P1 and *Pseudomonas aeruginosa* P2) was inoculated into each bottle with sterile nutrient broth and incubated at 37°C for 24 hours.
2. Dilution of Organism: 1ml of the overnight culture was serially diluted into 9ml of sterile distilled water to give 10^6cfu/ml of test pathogen.
3. Preparation of the seeded Agar plates: 28g of Mueller-Hinton agar was dissolved in 1000 ml of distilled water and sterilized at 121°C for 15minutes. 1ml of the diluted organism (10^6cfu/ml of the test pathogen) was inoculated into the Petri dishes, the sterilized Mueller-Hinton agar was allowed to cool a little and then aseptically poured into Petri dishes containing 10^6cfu/ml of the test pathogen, it was carefully swirled to ensure uniform growth throughout the Mueller-Hinton agar during incubation and allowed to set at room temperature for about 45 minutes.
4. Extract Preparation: Serial dilutions of the extract samples were prepared from the 100% concentrated extracts. 1ml of the 100% concentrated extract was diluted in 9ml sterile distilled water to give a 10^{-1} dilution. 1ml of the 10^{-1} dilution was then added to another 9ml sterile distilled water to give dilution of 10^{-2}. Then 1ml of the 10^{-2} dilution was added to another 9ml sterile distilled water to give dilution of 10^{-3}. Into 2ml sterile vials, 0.5ml of each of the dilutions was added to get the combinations and was mixed thoroughly.
5. Agar diffusion method: Wells of 10mm in diameter were bored into the already set seeded Mueller-Hinton agar plates with the aid of a sterile cork borer. 60µl of extracts combinations in

the vials were introduced into the well in the seeded Mueller-Hinton agar plates along side with 60µl of sterile distilled water (which serve as negative control) introduced also into the well in the seeded Mueller-Hinton agar plate and kept at room temperature for about one hour to allow diffusion into the agar medium. The plates were then incubated at 37°C overnight for 18 hours after which antimicrobial activity was determined. The antimicrobial activity was determined by measuring the diameter of the inhibition zone (in mm) around the wells using a transparent ruler. Clear zones surrounding each well indicate positive results, while a negative result does not show any clearance around the wells.

6. Antibiotic Susceptibility Test: Antibiotics (Ceftazidime (30µg), Cefuroxime (30µg), Gentamicin (10µg), Ciprofloxacin (5µg), Ofloxacin (5µg), Augmentin (30µg), Nitrofurantoin (300µg) and Ampicillin (10µg)) were used as postitve control. 1ml of the overnight culture was serially diluted into 9ml of sterile distilled water to give 10^{-2}dilution of test pathogen. A 10^{-2}dilution of test pathogen was inoculated into sterile Mueller-Hinton agar plates by spread plate method using sterile swab sticks. Using a pair sterile forcep, strips of antibiotic test discs which were loaded with those antiobiotics mentioned above were applied to the center of the seeded Mueller-Hinton agar plates and gently pressed to the surface after which the antibiotic sensitivity plates were allowed to stand for 15 minutes and were then incubated overnight at 37°C for 18 hours. Subsequently, the plates were examined for bacterial growth inhibition and the inhibition zone diameter (IZD) measured to the nearest millimetre using a transparent ruler. A standard table of antibiotic susceptibilities (Table 3.3) as outlined in the Performance Standards for Antimicrobial Susceptibility Testing, 2012 was used to determine whether the strain was resistant (R), intermediate (I) or susceptible (S) to the specific treatment tested.

Table 3.3: Inhibition zone diameter interpretive standards

			Zone diameter (mm)		
Reference bacteria	Antimicrobial agent	Disk content	Sensitive (S)	Intermediate (I)	Resistant (R)
E.coli ATCC 25922	Ceftazidime	30µg	≥ 21	18 - 20	≤ 17
	Cefuroxime	30µg	≥ 18	15 -17	≤ 14
	Gentamicin	10µg	≥ 15	13 - 14	≤ 12
	Ciprofloxacin	5µg	≥ 21	16 - 20	≤ 15
	Ofloxacin	5µg	≥ 16	13 - 15	≤ 12
	Augmentin	30µg	-	-	-
	Nitrofurantoin	300µg	≥ 17	15 - 16	≤ 14
	Ampicillin	10µg	≥ 17	14 - 16	≤ 13
Pseudomonas aeruginosa ATCC 27853	Ceftazidime	30µg	≥ 18	15 - 17	≤ 14
	Cefuroxime	30µg	-	-	-
	Gentamycin	10µg	≥ 15	13 - 14	≤ 12
	Ciprofloxacin	5µg	≥ 21	16 - 20	≤ 15
	Ofloxacin	5µg	≥ 16	13 - 15	≤ 12
	Augmentin	30µg	-	-	-
	Nitrofurantoin	300µg	-	-	-
	Ampicillin	10µg	-	-	-

3.9 Informed consent and Ethical consideration

The ethical principles guiding the use of human participants in research were taken into consideration in the design and conduct of study. Ethical approval was provided by Ministry of Health (MOH), Delta State Ethics Review Committee (see a copy of ethical approval in appendix VI). Permission was obtained from the head of the community and the elders in council in charge of each neighbourhood that make up Illah community. Participation in the study was made voluntary and informed consent was obtained from each participant involved in the study (See appendix I). Each participant was provided with information about what the study was all about. No identifier such as name of participants was required and all information provided was kept confidential.

3.10 Data management and analysis

The questionnaires were serially numbered for control and recall purposes and data collected were checked for completeness and accuracy before it was then edited and coded manually. A term plate (file structure) was designed using SPSS (version 16.0) for entering of the coded data. Each questionnaire was then entered into the file structure. The socio-demographic data were analysed using descriptive statistics. The knowledge of unsafe water was on a scale of 31points comprising 7 knowledge questions whose scoring was based on positive option for correct response, and zero for incorrect response. All correct responses in each questionnaire were summed up to a total score. Then the scores were pooled together into SPSS for analysis using descriptive statistics (mean, standard deviation, maximum and minimum) to get the mean knowledge score. Knowledge score $\geq$ mean score was grouped into good knowledge and knowledge score $<$ mean score was grouped into bad knowledge. The water handling practices was on a scale of 16 points comprising of 4 water handling practice questions whose scoring was based on positive option for correct response, and zero for incorrect response. All correct responses in each questionnaire were summed up to a total score. Then the scores were pooled together into SPSS for analysis using descriptive statistics (mean, standard deviation, maximum and minimum) to get the mean handling practice score. Handling practice score $\geq$ mean score was grouped into good handling practice and Handling practice score $<$ mean score was grouped into bad handling practice. Descriptive statistics was employed to determine the proportion of respondents with good knowledge and practice and also

bad knowledge and practice respectively. Chi-square was used to test the association between qualitative variables from the questionnaire.

The sanitary inspection form was on a scale of ten points comprising 10 questions designed for a yes or no answer with scores ranging from 0 – 2 (low risk), 3 – 5 (medium risk), 6 – 8 (high risk) and 9 – 10 (very high risk). The results from sanitary inspection were analysed using descriptive statistics to get the mean, standard deviation, maximum value, minimum value and percentages.

The water quality parameter measurements at four collection points (before treatment, days 1, 2 and 3 after treatment) were recorded on spread sheets. A coding guide was then developed and all variables were entered into SPSS version 16.0 software. Descriptive statistics (mean, standard deviation, maximum and minimum values) was used to summarise levels of water quality parameters at collection points. ANOVA was used to determine the statistical difference in the mean levels of water quality parameters at different sample collection points (before treatment, days 1, 2 and 3 after treatment). A multiple comparison test (Ducan's new multiple range test) was used to determine whether the mean levels of water quality parameters at different sample collection points differ significantly in an analysis of variance (ANOVA). All analysis was carried out at 5% level of significance.

CHAPTER FOUR

RESULTS

4.1 Socio-demographic characteristics

All respondents in the study were females. The results of the survey showed that the overall mean age was 38.9±12.8 years of which 94 (23.5%) were below 30years, 252 (63.0%) were within 30 – 50 years and 54 (13.5%) were above 50years of age. Majority 317 (79.2%) of the respondents were married, 51 (12.8%) were single and 32 (8.0%) were widowed and divorced (Table 4.1).

Majority of the respondents were Christians (Figure 4.1) and Igbo (Table 4.1). The highest level of education attained by all respondents in the study revealed that majority 194 (48.5%) of the respondents had up to secondary school education; 90 (22.8%) had up to primary school education; 73 (18.2%) had up to tertiary education and 42 (10.5%) had no formal education (Figure 4.2). From the socio-economic status of respondents, majority 150 (37.5%) engaged in trading while 10 (2.5%) females engaged in nothing other than being full time housewives (Figure 4.3).

On income of respondents, 89.1% of respondents had an income of < N50,000 per month and 6.7% earned between N50,000 – N100,000 per month; 3% earned between N100,000 – N150000 per month; while only 1.2% of the respondents earned ≥N150,000 per month (Figure 4.4).

4.2 Water Supply

The sources of drinking water for the respondents in Illah were borehole, well, stream, and packaged water. Majority 250 (62.5%) of the respondents in Illah community depend on borehole as their source of drinking water, 98 (24.5%) depend on stream, 31 (7.8%) depend on well, and 21 (5.2%) depend on packaged water as their sources of drinking water (Figure 4.5). Table 4.2 shows the responses of the respondents about the distance of these water sources to their respective households and the time of the day they fetch their drinking water. In Illah community, 153 (38.2%) respondents indicated that the source of drinking water was less than 1km from their households, 140(35.0%) said it was about 1-3km, 64 (16.0%) said it was within the household while 43 (10.8%) said it was above 3km from their residence. Considering the time of the day they fetch their drinking water from the sources, 197 (49.2%) respondents indicated that they fetch anytime of the day, 153 (38.3%) said that they fetch in the morning, 38 (9.5%) said that they fetch towards evening, 7 (1.8%) said they fetch in the afternoon while 5(1.2%) said they fetch at night.

Table 4.1: Socio-demographic Characteristics of respondents in Illah community

N=400

Socio-demographic factors	Number	%
Sex		
All females	400	100
Age		
< 30	94	23.5
30 – 50	252	63.0
> 50	54	13.5
Marital status		
Single	51	12.8
Married	317	79.2
Widowed	21	5.2
Divorced	11	2.8
Ethnicity		
Ibo	378	94.5
Non – Ibo (*)	22	5.5

*This includes Yoruba, Hausa, Urhobo, Ebira.

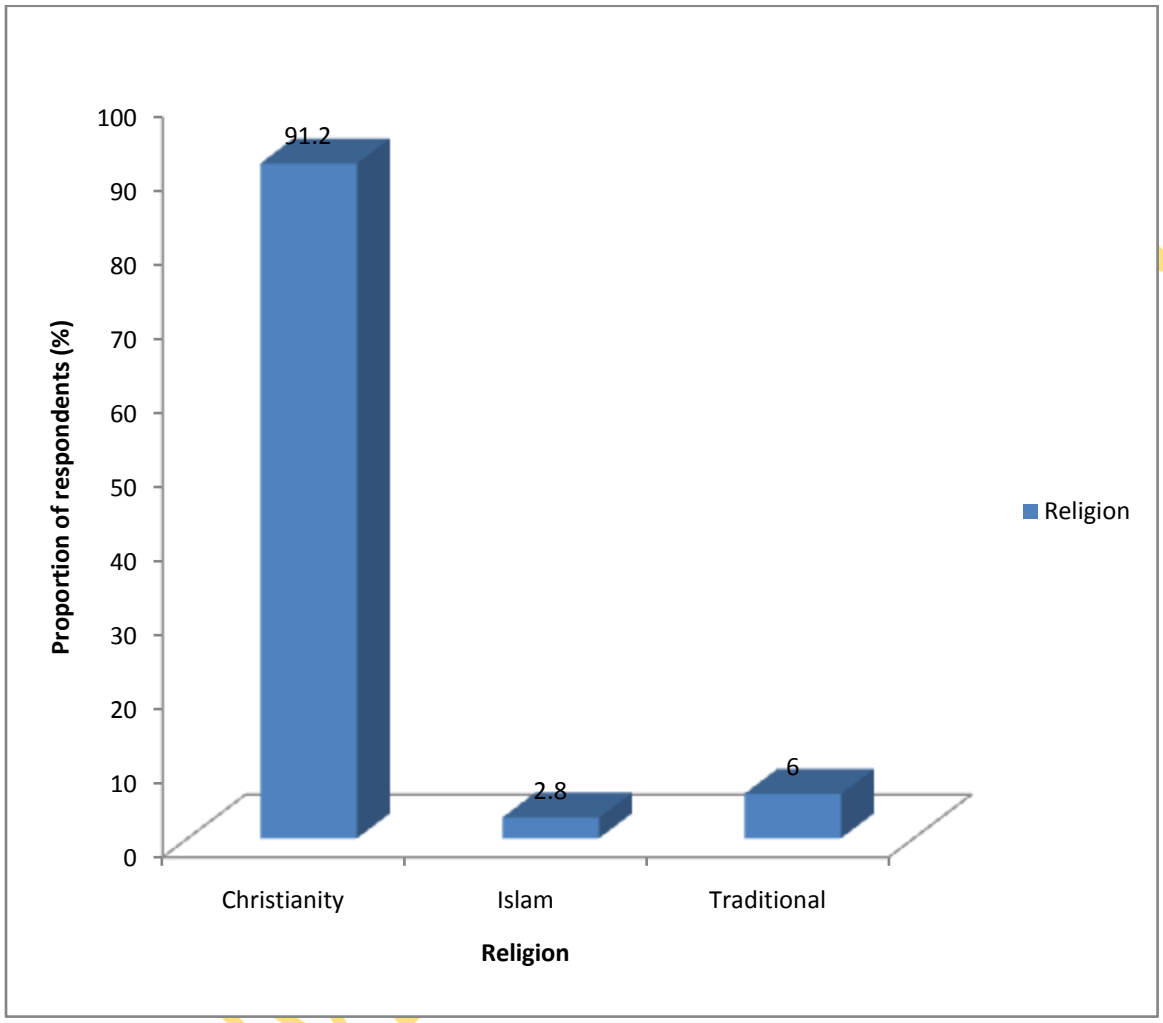


Figure 4.1: Distribution of respondents' religion in Illah community

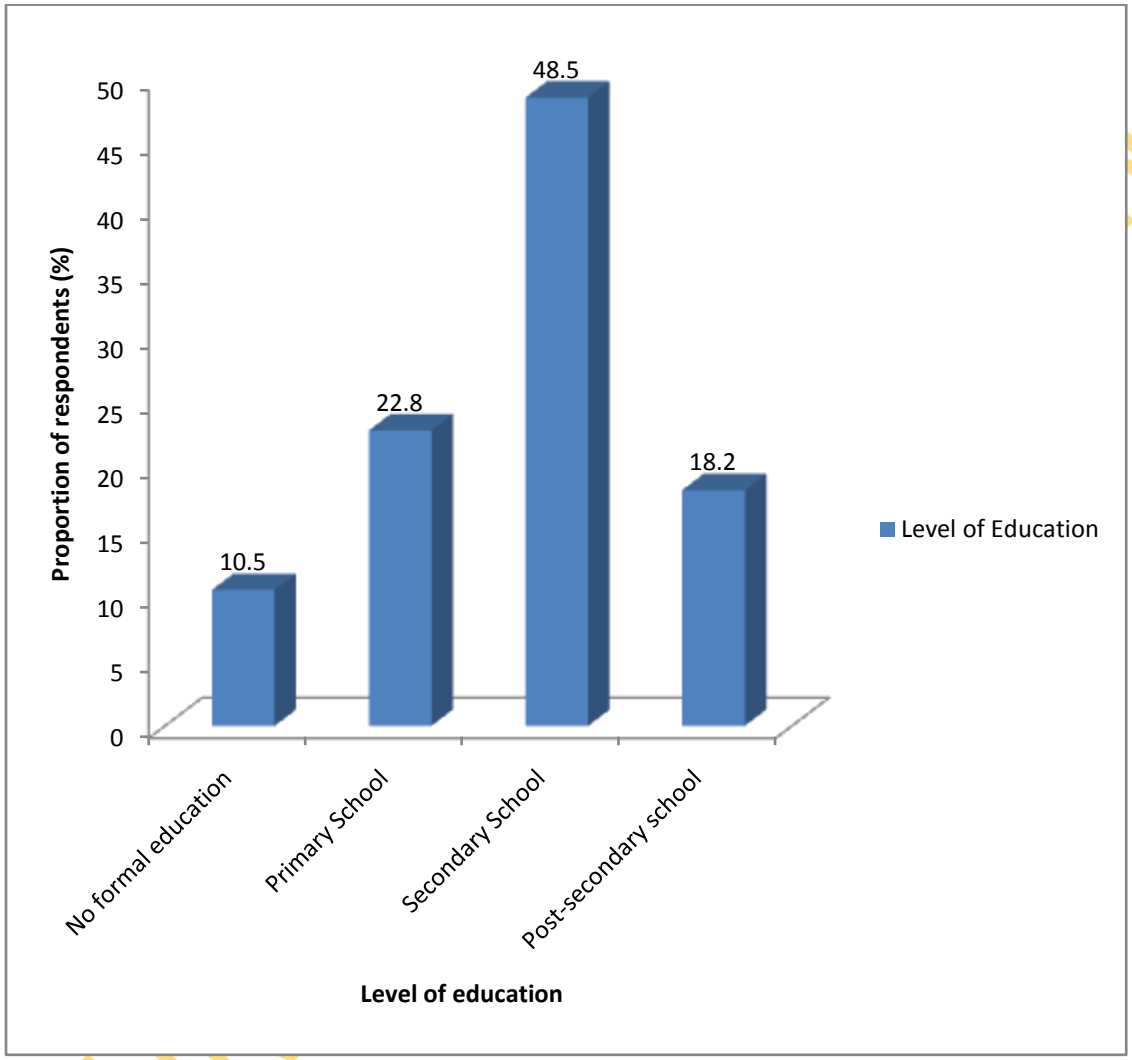


Figure 4.2: Respondents' level of education in Illah community

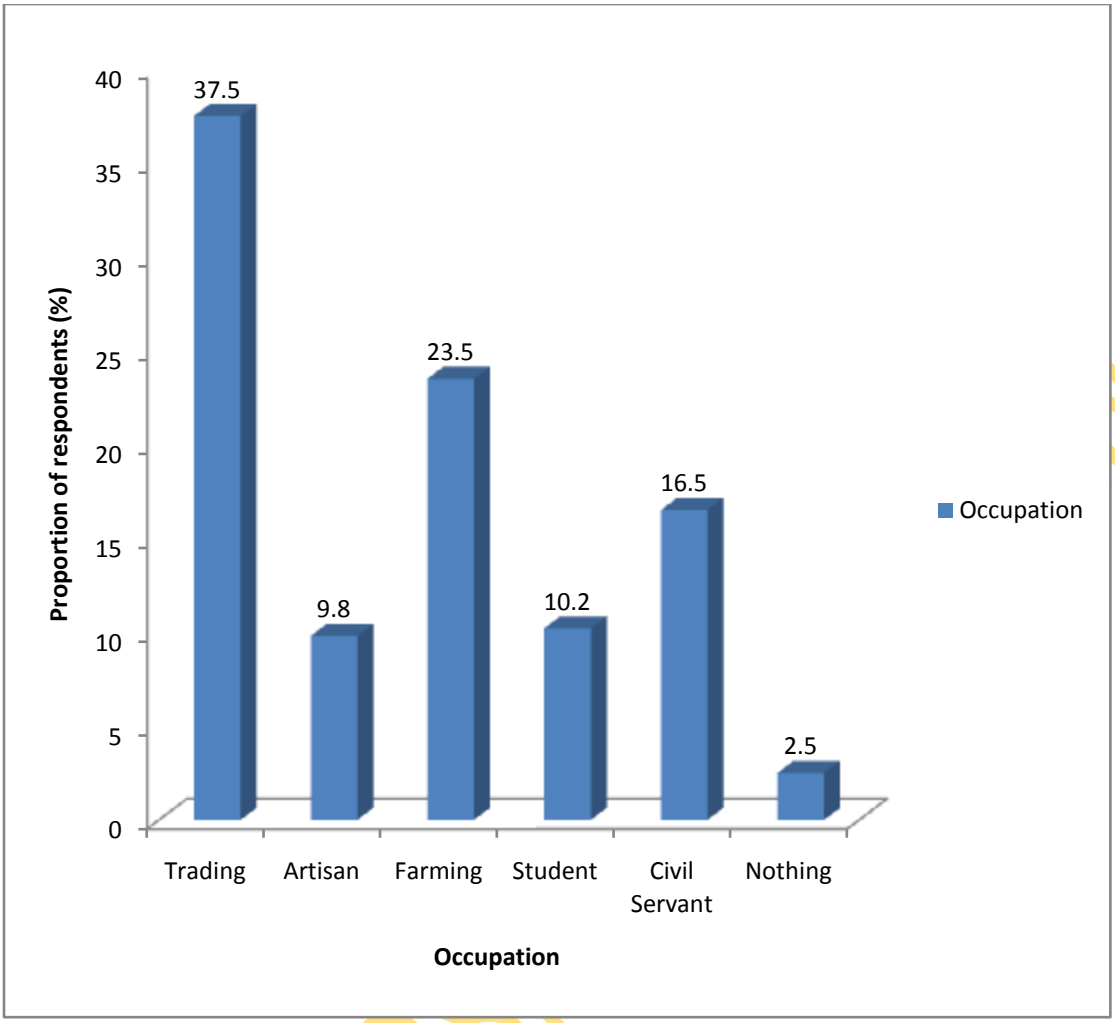
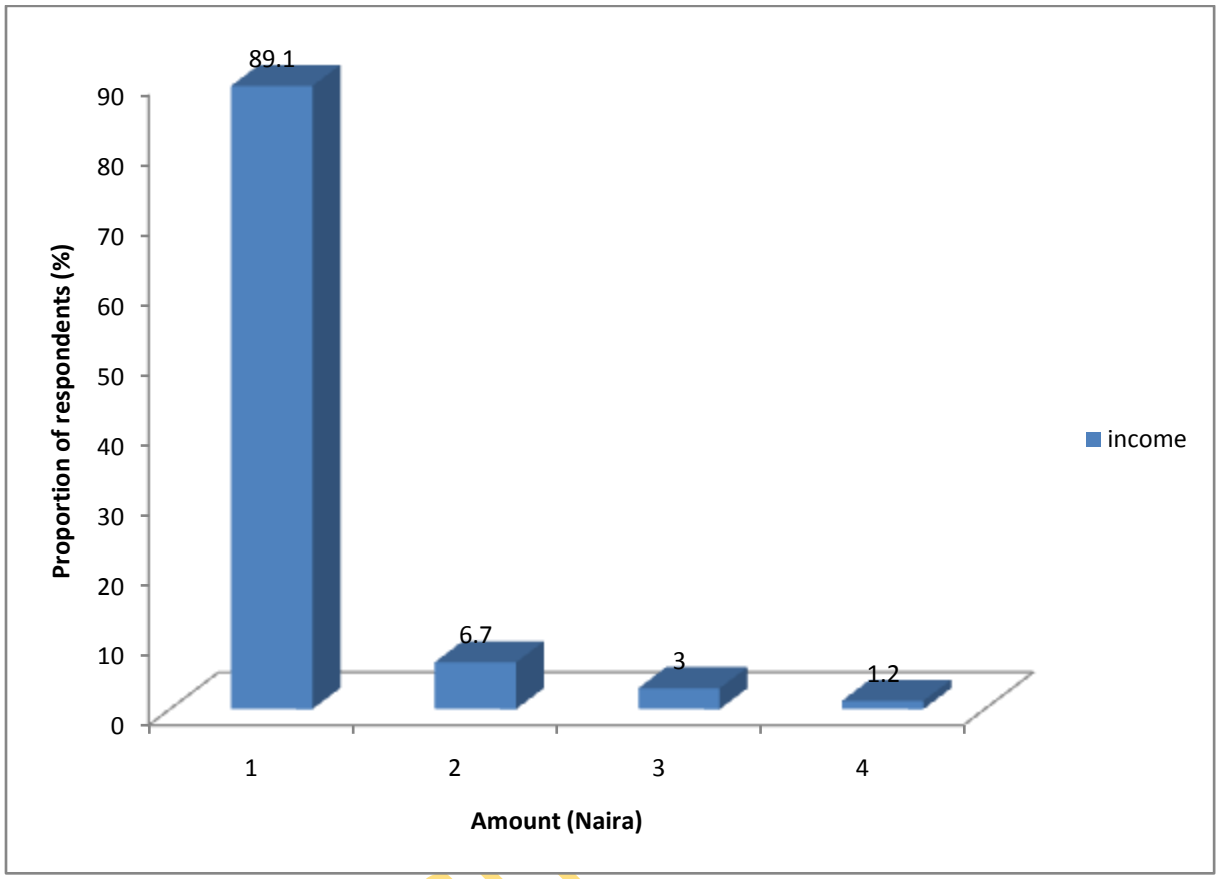


Figure 4.3: Respondents' occupation in Illah community



1 = < N50, 000

2 = N50, 000 – N100, 000

3 = N100, 000 – N150, 000

4 = >N150, 000

Figure 4.4: Income level of respondents per month

4.3 Water handling Practices

Results of the survey showed that during transportation, majority of the respondents 368 (92%) covered their drinking water container (Table 4.3). Also majority of the respondents 360 (90%) claimed not to use the bucket for fetching drinking water for other domestic purposes (Table 4.3).

The results of the survey also showed that majority of respondents in the households 73.9% stored their drinking water in wide-mouthed containers (plastic drum, clay pots and other containers) while 26.1% stored drinking water in narrow-mouthed containers (plastic kegs and bottles) (Table 4.4). From observation, some of these wide mouthed containers with covers were dirty.

Before the storing of the drinking water in the storage containers, majority 216 (65.2%) of the respondents in the households indicated that they do something to their drinking water to make it safe to drink. Majority 93 (35.6%) of the respondents in the households said they let the water stand and settle, 85 (32.6%) said they boil, 56 (21.5%) indicated that they use dried fruits of *Xylopia aethiopica* and *Tetrapleura tetraptera* for water (borehole and stream water) purification (This is an indigenous treatment method in the community)∗, 16 (6.1%) said they treat with chemicals like alum and chlorine to their water before storing and drinking, 10 (3.8%) claimed to use filter, and 1 (0.4%) of the respondents claimed she performed solar disinfection of water before storing and drinking (Table 4.3).

To draw drinking water from the storage containers, a large proportion drew water by dipping 284 (71.0%), while 100 (25.0%) drew theirs by pouring and 16(4.0%) made use of taps to draw their water from the storage containers (Table 4.4).

In pooling and scoring their water handling practices, majority (53.2%) of the respondents had good practice (Table 4.5)

Association between the respondent's level of education and their water handling practices was not statistically significant ($p>0.05$) (Table 4.6)

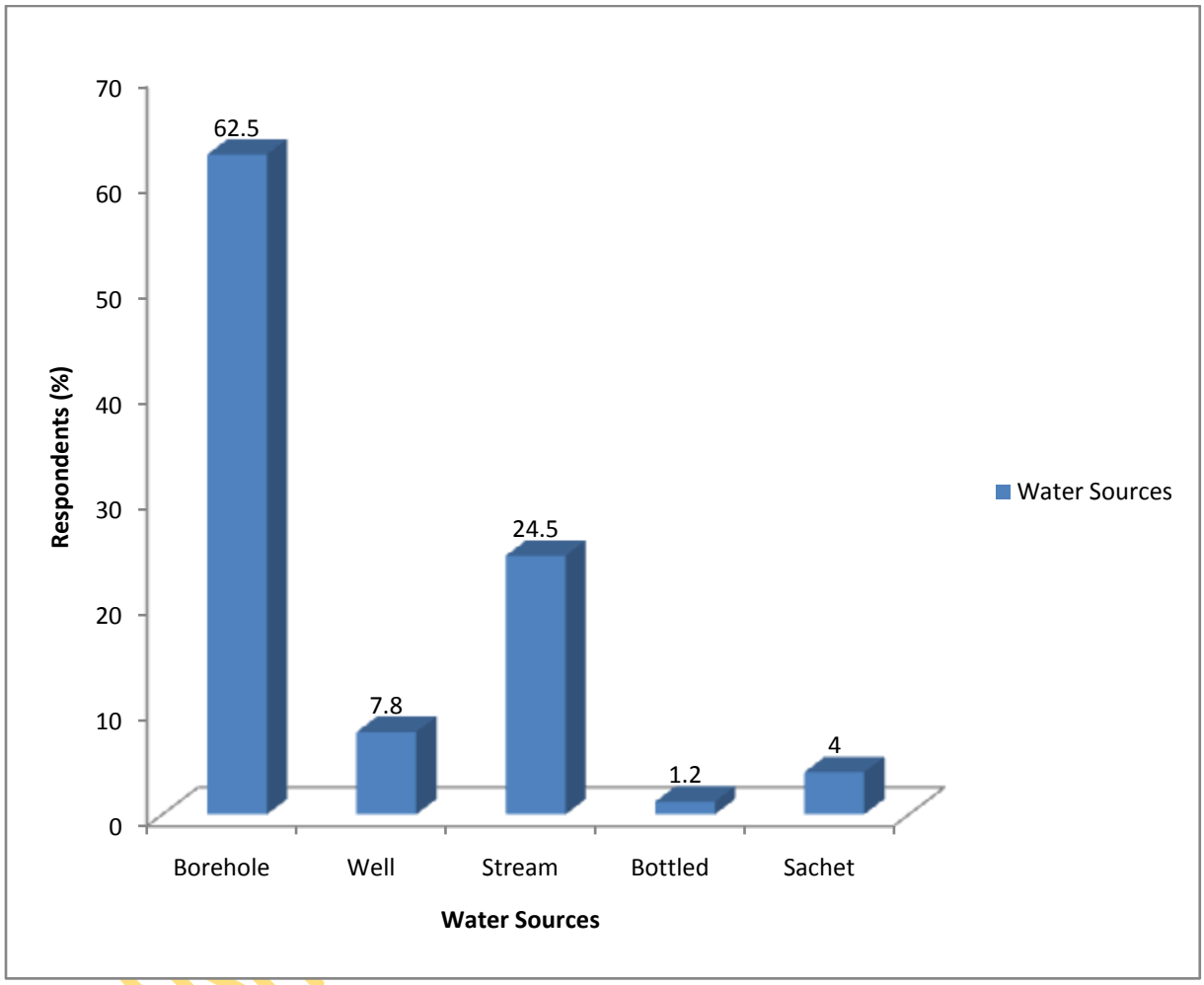


Figure 4.5: Respondents' drinking water sources in Illah community

Table 4.2: Water Supply

N= 400

Questions	Number	%
What is the distance of the water source from the household?		
Within the household	64	16.0
Less than 1km	153	38.2
1-3km	140	35.0
Above 3km	43	10.8
What time of the day do you fetch drinking water?		
Morning	153	38.3
Afternoon	7	1.8
Evening	38	9.5
Night	5	1.2
Anytime	197	49.2

Table 4.3: Water Handling Practices

N= 400

Questions	Number	%
Do you use the bucket for fetching drinking water for other domestic purpose		
Yes	40	10.0
No	360	90.0
Cover drinking water during transportation		
Yes	368	92.0
No	32	8.0
Do you do anything to water to make it safe to drink?		
Yes	261	65.2
No	139	34.8
What do you usually do to make the water safe to drink?(n= 261)		
Boil	85	32.6
Add bleach/chlorine/Alum	16	6.1
Use water filter	10	3.8
Stand& Settle	93	35.6
Use of *Xylopia aethiopica* and *Tetrapleura tetraptera*	56	21.5
Solar disinfection	1	0.4
How often do you perform any of the techniques chosen above?(n=261)		
Daily	64	24.5
Weekly	63	24.1
Seldom	82	31.4
When dirty	52	20.0
Where do you keep your drinking water?		
In the room	254	63.5
Outside room	12	3.0
In the Kitchen	126	31.5
Outside Kitchen	8	2.0

Table 4.4: Water Storage

N= 400

Questions	Frequency	%
What do you use as storage container for drinking water?		
Jerican	101	25.3
Big Plastic containers	205	51.2
Clay Pots	89	22.2
Bottles	3	0.8
Cooler	2	0.5
How often do you clean this storage container?		
Daily	125	31.2
Weekly	108	27.0
Seldomly	29	7.3
When dirty	138	34.5
Do you have special container for collecting water from the storage container?		
Yes	376	94.0
No	24	6.0
How many container(s) do you have for collecting water from the storage container?		
One	172	43.0
Two	151	37.8
Three	23	5.7
More than three	54	13.5
How do you collect drinking water from the storage container?		
By dipping	284	71.0
By pouring	100	25.0
Use of tap	16	4.0

Table 4.5: Water handling practice score

Water handling practice of respondents (16 point scale)	Number	%	Mean	Min	Max
Good handling practice (≥13)	213	53.2	13.6±2.9	0	16
Bad handling practice (< 13)	187	46.8			

Table 4.6: Association between the respondents' level of education and water handling practices

Level of Education attained	Water handling practices					
	Good practice		**Bad practice**		**Total**	
	Number	**%**	**Number**	**%**	**Number**	**%**
No formal Education	27	64.3	15	35.7	42	100
Primary Education	43	47.8	47	52.2	90	100
Secondary Education	105	54.1	89	45.9	194	100
Post-secondary Education	37	50.7	36	49.3	73	100

$x^2 = 3.387$ p = 0.336

4.4 Knowledge of Unsafe water

Majority 66.2% of respondents had good knowledge of unsafe water while 33.8% of respondents had poor knowledge on unsafe water (Table 4.7). Association between the respondents' knowledge of unsafe water and their water handling practices was not statistically significant ($p>0.05$) (Table 4.8). Association between the respondents' level of education and their knowledge of unsafe water was statistically significant ($p<0.05$) (Table 4.9)

4.5 Waste disposal and sanitary practices

The disposal of human excreta, refuse, wastewater and sanitary practices of respondents were assessed. All the respondents indicated the type of toilet facility in their household. Majority 223 (55.8%) of the respondents claimed they use flush/pour flush toilet, few (2.7% and 4.2 %) indicated the use of bucket toilet and no facility/bush/field respectively. (28.0% and 9.3%) used pit latrine with slab and pit latrine without slab respectively. For anal cleaning, majority (45.0%) of the respondents claimed to use tissue, (39.0%) said they use water and (16.0%) said they use paper. Majority (87.2%) of the respondents claimed to wash their hands after toilet visits (Table 4.10).

Majority (56.3%) of the respondents claimed to dispose their solid wastes via refuse dumping, (36.7%) claimed to dispose their solid wastes via burning in pit and (7.0%) indicated the use of sanitary landfill to dispose of their solid wastes (Table 4.10). Majority (66.2%) of the respondents claimed to pour away their waste water, (14.3%) said they reuse their waste water and (19.5%) claimed to dispose of their waste water via soak away pit (Table 4.10).

4.6 Sanitary condition of drinking water sources and their household storage containers of the respondents that perform the indigenous household treatment method in Illah Community

Observation using the sanitary inspection showed that the mean risk score for the water sources (4.25 ± 1.3) was higher than that of the household storage containers (0.60 ± 0.7) (Table 4.11). Majority (75%) of the water sources had medium sanitary risk and (25%) had high sanitary risk where as in the households, all household storage containers had low sanitary risk (Figure 4.6).

Table 4.7: Knowledge score

Knowledge level of respondents (16 point scale)	Number	%	Mean	Min	Max
Good knowledge (≥24)	265	66.2	24.7±4.5	0	31
Bad knowledge(< 24)	135	33.8			

Table 4.8: Association between the respondents' knowledge of unsafe water and water handling practices

Knowledge assessment	Water handling practices					
	Good practice		**Bad practice**		**Total**	
	Number	**%**	**Number**	**%**	**Number**	**%**
Good knowledge	135	50.9	130	49.1	265	100
Bad knowledge	78	57.8	57	42.2	135	100

$X^2 = 1.678$ p = 0.195

Table 4.9: Association between the respondents' level of education and knowledge of unsafe water

Level of Education attained	Knowledge of unsafe water					
	Good knowledge		**Bad knowledge**		**Total**	
	Number	**%**	**Number**	**%**	**Number**	**%**
No formal Education	19	45.2	23	54.8	42	100
Primary Education	44	48.9	46	51.1	90	100
Secondary Education	140	72.2	54	27.8	194	100
Post-secondary Education	62	84.9	11	15.1	73	100

$X^2 = 34.935$ p = 0.000

Table 4.10: Waste disposal and Sanitary Practices

N=400

Questions	Number	(%)
Is there a toilet in your household?		
Yes	372	93.0
No	28	7.0
Type of toilet facility in the household		
Flush/Pour flush	223	55.8
Pit latrine with slab	112	28.0
Pit latrine without slab	37	9.3
Bucket toilet	11	2.7
No facility/Bush/Field	17	4.2
Sharing of toilet with other household?		
Yes	182	45.5
No	218	54.5
Hand-washing materials in the household		
Yes	359	89.8
No	41	10.2
Washing of hands after toilet visit		
Yes	349	87.2
No	51	12.8
What do you normally use for anal cleaning?		
Water	156	39.0
Paper	64	16.0
Tissue	180	45.0
How does your family manage solid waste?		
Refuse dumping	225	56.3
Burning in pit	147	36.7
Sanitary landfill	28	7.0
How often is your waste disposed?		
Rarely	9	2.2
Occasionally	89	22.3
Often	133	33.2
Very often	169	42.3
How does your family manage waste water?		
Soak-away pit	78	19.5
Pouring away	265	66.2
Reuse	57	14.3
Where do you normally put your waste?		
In the Kitchen	21	5.3
Outside the Kitchen	154	38.5
On the corridor	31	7.7
Outside the house	194	48.5
Is there animal raising in or around the house?		
Yes	199	49.75
No	201	50.25

Table 4.11: Mean risk score of drinking water sources and household drinking storage containers of the respondents that perform the indigenous water treatment method in Illah

	N	Mean	Standard deviation	Minimum	Maximum	Range
Water Sources	4	4.25	1.3	3	6	3
Storage containers	11	0.55	0.7	0	2	2

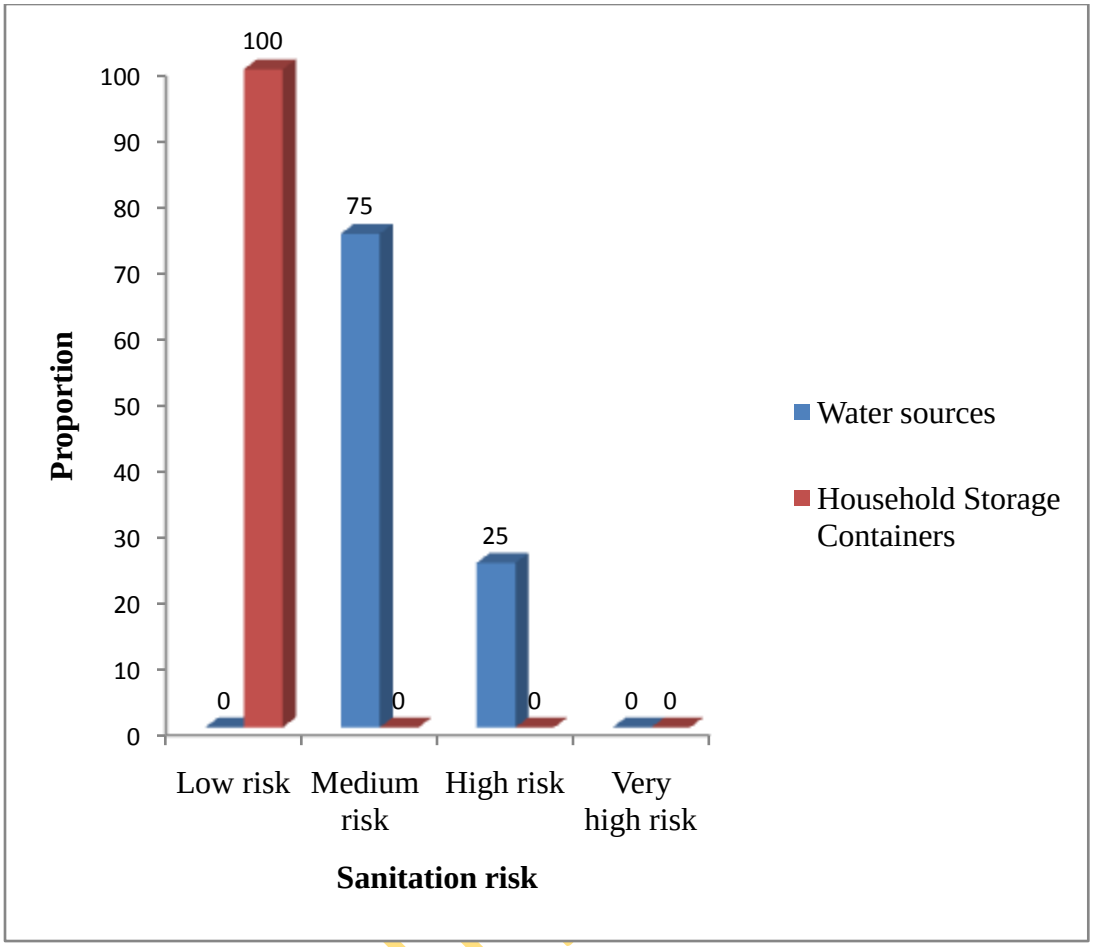


Figure 4.6: The sanitary condition of water sources and household storage containers of the respondents who perform the indigenous water treatment method in Illah.

4.7 Physico-chemical parameters of drinking water from borehole and stream source before and after treatment

The pH values of the raw water samples from the water sources (borehole and stream) were 6.5±0.1 and 6.2±0.2 respectively. These values obtained were within the WHO guideline limits. After treatment, the pH values for borehole water on days 1, 2 and 3 were: 6.6±0.1, 6.6±0.1 and 6.9±0.1 respectively showing a significant difference ($p<0.05$). pH values for treated stream water on days 1, 2 and 3 were: 6.3±0.2, 6.7±0.2 and 6.7±0.1 respectively with significant difference($p<0.05$) (Tables 4.12 and 4.14). The pH values of treated borehole and stream water samples on days 1, 2 and 3 were within the WHO limits. The treated borehole and stream water showed no reduction but increase in the levels of pH within three days after treatment.

The nitrate values of the raw water samples from the borehole and stream were 20.2±0.2 and 22.2±1.2 mg/L respectively and these values were within the guideline limits of potable water. The nitrate values of the borehole water on days 1, 2 and 3 after treatment were: 20.3±0.9, 20.5±0.9 and 19.7±0.6mg/L respectively with no significant differences ($p>0.05$). The nitrate values of the treated stream water on days 1(21.9±0.8mg/L), 2 (21.9±0.2mg/L) and 3(20.8±0.3mg/L) showed no significant difference ($p>0.05$). Nitrate values obtained for the treated borehole and stream water on days 1, 2 and 3 were within the guideline limits (Tables 4.12 and 4.14). The treated borehole water showed increase in the levels of nitrates on days 1 and 2 by 0.5% and 1% respectively with reduction in nitrate levels on day 3 after treatment by 4%. The treated stream water showed reduction in the levels of nitrates on days 1 and 3 by 1% and 5% respectively with no reduction or increase in nitrate levels on day 2 after treatment.

Zinc values for the raw water samples from the borehole (0.04±0.01mg/L) and stream (0.01±0.004 mg/L) sources were within the WHO guideline limits. The zinc values of the treated borehole water on days 1 (0.06±0.01mg/L), 2 (0.06±0.02mg/L) and 3 (0.06±0.01mg/L) were within the limits with no significant difference ($p>0.05$). Zinc values of treated stream water on days 1, 2 and 3 were: 0.04±0.003, 0.05±0.02 and 0.04±0.04mg/L respectively with no significant difference ($p>0.05$) (Tables 4.12 and 4.14). The values obtained for treated stream water on days 1, 2 and 3 were within the WHO guideline limits. The treated borehole water showed increase in zinc levels on day 1 by 50% but no reduction or increase in zinc levels on days 2 and 3 after treatment. The treated

stream water showed increase in zinc levels on days 1 and 2 by 300% and 25% respectively with a reduction in zinc levels on day 3 after treatment by 20%.

The iron values in the raw water samples from the borehole (0.2±0.01mg/L) and stream (0.3±0.02 mg/L) sources were within the guideline limits. The iron values of treated borehole and stream water on days 1, 2, 3 were: 0.1±0.03mg/L, 0.1±0.02mg/L, 0.2±0.05mg/L; and 0.2±0.05mg/L, 0.3±0.03mg/L, 0.3±0.03mg/L respectively with significant differences in the treated borehole water ($p<0.05$) and no significant difference in the treated stream water ($p>0.05$) across the 3days after treatment (Tables 4.12 and 4.14). The iron values of the treated borehole and stream on days 1, 2 and 3 were all within the limits. The treated borehole water showed significant reduction ($p<0.05$) in iron levels on day 1 by 50% with no reduction or increase in iron levels on day 2 but showed increase in iron levels significantly ($p<0.05$) on day 3 after treatment by 100%. The treated stream water showed significantly reduction in zinc levels on day 1 by 33% with no reduction or increase in iron levels on days 2 and 3 after treatment.

The lead values of the raw water samples from the borehole and stream sources were 0.007±0.0001 and 0.009±0.001mg/l respectively and these values were within the guideline limits. After treatment, the lead values of the treated borehole and stream water on days 1, 2 and 3 were: 0.004±0.002, 0.005±0.004, 0.005±0.003mg/L; and 0.004±0.003, 0.006±0.004, 0.008±0.006 mg/L respectively with no significant difference ($p>0.05$) (Tables 4.12 and 4.14). The lead values obtained for both treated borehole and stream water on days 1, 2 and 3 were all within the limits. The treated borehole water showed reduction in lead levels by 43% with increase in lead levels by 25% on day 2 and no reduction or increase in lead levels on day 3 after treatment. The treated stream water showed reduction in lead levels by 56% on day 1 with increase in lead levels on days 2 and 3 after treatment by 50% and 33% respectively.

4.7.1 Bacteriological parameters of drinking water from borehole and stream source before and after treatment

Total Coliform Counts for borehole (129.0±7.8cfu/100mL) and stream (280.0±95.3cfu/100mL) however exceeded the guideline limits of potable water (Tables 4.13 and 4.15). After treatment, total coliform counts for borehole water on days 1, 2 and 3 were: 67.0±11.0, 121.0±18.2 and 126.0±18.2cfu/100mL respectively showing significant differences ($p<0.05$). The treated borehole

water showed significant reduction ($p<0.05$) in levels of total coliforms by 48% on day 1 with increase in total coliform counts on days 2 significantly ($p<0.05$) and 3 by 81% and 4% respectively after treatment. Total Coliform Counts for treated stream water on days 1, 2 and 3 were: 203.0±54.9, 76.0±2.9 and 173.0±28.9cfu/100mL respectively with significant differences ($p<0.05$). The treated stream water showed reduction in levels of total coliforms on days 1 and significantly ($p<0.05$) 3 by 28% and 63% respectively with an increase in the total coliform counts by 128% on day 3 after treatment. The total coliform counts in the treated water on days 1, 2 and 3 were still higher than the guideline limit.

Esherichia coli Counts for borehole (24.0±5.2cfu/100mL) and stream (133.0±37.5 cfu/100ml) exceeded the guideline limits. After treatment, *Esherichia coli* Counts of treated borehole and stream water on days 1, 2 and 3 were: 11.0±9.9cfu/100ml, 18.0±4.6cfu/100ml, 23.0±4.6cfu/100ml; and 83.0±24.7cfu/100ml, 16.0±15.3cfu/100ml, 30.0±17.3cfu/100ml respectively with significant differences ($p<0.05$) (Tables 4.13 and 4.15). The treated borehole water showed significant reduction ($p<0.05$) in *E.coli* counts by 52% on day1 with increase in *E.coli* counts on days 2 and 3 after treatment by 64% and 28% respectively. The treated stream water showed significant reduction ($p<0.05$) in *E.coli* counts on days 1 and 2 by 38% and 81% with increase in *E.coli* counts by 88% on day 3 after treatment. The *E.coli* counts in the treated borehole and stream water on days 1, 2 and 3 still exceeded the guideline limits.

Parameter	Borehole water (n=2)					WHO STD
	Before treatment	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment	p-value	
pH	6.5±0.1[a]	6.6±0.1[a]	6.6±0.1[a]	6.9±0.1[a]	0.000[*]	6.5-8.5
Lead (mg/L)	0.007±0.0001[a]	0.004±0.002[a]	0.005±0.004[a]	0.005±0.003[a]	0.174	0.01
Iron (mg/L)	0.2±0.01[b]	0.1±0.03[a]	0.1±0.02[a]	0.2±0.05[b]	0.000*	0.3
Zinc ((mg/L)	0.04±0.01[a]	0.06±0.01[a]	0.06±0.02[a]	0.06±0.01[a]	0.127	3

Table 4.12: Physico-chemical characteristics of borehole water

Nitrate (mg/L)	20.2±0.2[a]	20.3±0.9[a]	20.5±0.9[a]	19.7±0.6[a]	0.207	50

Parameter	**Borehole water (n=2)**	**WHO STD**

[a, b] are means from least to the highest. Means within the same superscript are not significantly different.
Means within the same row with different superscript are significantly different $p<0.05$
*$p<0.05$

Table 4.13: Bacteriological characteristics of borehole water

	Before treatment	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment	p-value	
Total coliform counts(cfu/100mL)	129.4±7.8[b]	66.9±11.0[a]	120.6±18.2[b]	125.6±18.2[b]	0.000*	10
E.coli counts(cfu/100mL)	23.8±5.2[b]	11.3±9.9[a]	17.5±4.6[ab]	22.5±4.6[b]	0.002*	0

[a, b] are means from least to the highest. Means within the same superscript are not significantly different.
Means within the same row with different superscript are significantly different $p<0.05$
*$p<0.05$

Table 4.14: Physico-chemical characteristics of stream water

Parameter	Stream water (n=2)					WHO STD
	Before treatment	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment	p-value	
pH	6.2±0.2[a]	6.3±0.2[a]	6.7±0.2[b]	6.7±0.1[b]	0.006[*]	6.5-8.5
Lead (mg/L)	0.009±0.001[a]	0.004±0.003[a]	0.006±0.004[a]	0.008±0.006[a]	0.501	0.01
Iron (mg/L)	0.3±0.02[b]	0.2±0.05[a]	0.3±0.03[ab]	0.3±0.03[ab]	0.056	0.3
Zinc ((mg/L)	0.01±0.004[a]	0.04±0.003[a]	0.05±0.02[a]	0.04±0.03[a]	0.151	3
Nitrate (mg/L)	22.2±1.2[a]	21.9±0.8[a]	21.9±0.2[a]	20.8±0.3[a]	0.159	50

[a, b] are means from least to the highest. Means within the same superscript are not significantly different.
Means within the same row with different superscript are significantly different $p<0.05$
*$p<0.05$

Table 4.15: Bacteriological characteristics of stream water

Parameter	Stream water (n=2)					WHO STD
	Before treatment	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment	p-value	
Total coliform counts(cfu/100mL)	280.0±95.3^{b}	203.0±54.9^{b}	76.0±2.9^{a}	173.0±28.9^{ab}	0.015*	10
E.coli counts(cfu/100mL)	133.0±37.5^{c}	83.0±24.7^{b}	16.0±15.3^{a}	30.0±17.3^{a}	0.002*	0

$^{a, b}$ are means from least to the highest. Means within the same superscript are not significantly different.
Means within the same row with different superscript are significantly different $p<0.05$
*$p<0.05$

4.8 Physico-chemical properties of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits

The physico-chemical properties of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits are reported in Table 4.16. The moisture content of the *Xylopia aethiopica* was 19.6%, crude fibre was 28.7% and the iron content was 9.9mg/kg.

4.8.1 Antimicrobial Activity of the Extracts of *Xylopia aethiopica* and *Tetrapleura tetraptera* against *E. coli* and *Pseudomonas aeruginosa*

The two strains of *E.coli and Pseudomonas aeruginosa* showed no inhibition of growth in their reaction against distilled water (negative control) and also the study extracts at various concentrations (Tables 4.17 – 4.20) but in the positive control, some antibiotics like gentamicin, ciprofloxacin, ofloxacin and nitrofurantoin produced an effect against the test organisms as shown in Table 4.34. The two strains of *E.coli and Pseudomonas aeruginosa* were nonsusceptible in their reaction against ceftazidime, cefuroxime, augmentin and ampicillin (Table 4.21).

Table 4.16: Physico-chemical properties of dried *Xylopia aethiopica* and *Tetrapleura tetraptera* fruits

Properties	*Xylopia aethiopica*	*Tetrapleura tetraptera*
Moisture Content (%)	19.6	13.5
Total Ash (%)	8.5	4.6
Crude Fibre (%)	28.7	37.5
Total Fat (%)	14.8	14.6
Crude Protein (%)	2.7	1.1
Total Carbohydrate (%)	25.7	28.7
Iron (mg/kg)	9.9	0.2
Zinc mg/kg)	12.0	10.7
Lead (mg/kg)	ND	ND

ND- Not detected

Table 4.17: Antimicrobial activity (mm) of the study extracts against *E.coli* strain E1

Xy\Te	0	100%	10^{-1}	10^{-2}	10^{-3}
0	–	–	–	–	–
100%	–	–	–	–	–
10^{-1}	–	–	–	–	–
10^{-2}	–	–	–	–	–
10^{-3}	–	–	–	–	–

Clear zones surrounding each well indicates positive results, while negative results does not show any clearance around the wells

Xy- ***Xylopia aethiopica***

Te-***Tetrapleura tetraptera***

Table 4.18: Antimicrobial activity (mm) of the study extracts against *E.coli* strain E2

Xy\Te	0	100%	10^{-1}	10^{-2}	10^{-3}
0	–	–	–	–	–
100%	–	–	–	–	–
10^{-1}	–	–	–	–	–
10^{-2}	–	–	–	–	–
10^{-3}	–	–	–	–	–

Clear zones surrounding each well indicates positive results, while negative results does not show any clearance around the wells

Xy- ***Xylopia aethiopica***
Te-***Tetrapleura tetraptera***

Table 4.19: Antimicrobial activity (mm) of the study extracts against *P. Aeruginosa* strain P1

Xy\Te	0	100%	10^{-1}	10^{-2}	10^{-3}
0	–	–	–	–	–
100%	–	–	–	–	–
10^{-1}	–	–	–	–	–
10^{-2}	–	–	–	–	–
10^{-3}	–	–	–	–	–

Clear zones surrounding each well indicates positive results, while negative results does not show any clearance around the wells

Xy- ***Xylopia aethiopica***

Te-***Tetrapleura tetraptera***

Table 4.20: Antimicrobial activity (mm) of the study extracts against *P. aeruginosa* strain P2

Xy\Te	0	100%	10^{-1}	10^{-2}	10^{-3}
0	–	–	–	–	–
100%	–	–	–	–	–
10^{-1}	–	–	–	–	–
10^{-2}	–	–	–	–	–
10^{-3}	–	–	–	–	–

Clear zones surrounding each well indicates positive results, while negative results does not show any clearance around the wells

Xy- ***Xylopia aethiopica***

Te-***Tetrapleura tetraptera***

Table 4.21: Zones of Inhibition (mm) of antibiotic susceptibility testing of strains of *E.coli* and *P. aeruginosa*

Antibiotics	*E.coli* strain E1	*E.coli* strain E2	*P. aeruginosa* strain P1	*P. aeruginosa* strain P2
Ceftazidime	- (NS)	- (NS)	- (NS)	- (NS)
Cefuroxime	- (NS)	- (NS)	- (NS)	- (NS)
Gentamicin	15 (S)	- (NS)	14 (I)	14 (I)
Ciprofloxacin	20 (I)	12 (NS)	18 (I)	7 (NS)
Ofloxacin	17 (S)	10 (NS)	9 (NS)	- (NS)
Augmentin	- (NS)	- (NS)	- (NS)	- (NS)
Nitrofurantoin	26 (S)	- (NS)	- (NS)	- (NS)
Ampicillin	- (NS)	- (NS)	- (NS)	- (NS)

S- Susceptible I-Intermediate NS- Nonsusceptible

CHAPTER FIVE

DISSCUSSION

5.1 Demographic characteristics

The age of the respondents as shown in the results obtained revealed that majority of them were in their reproductive age. All respondents in the study were females. This agrees with the study on a simple method to improve water quality conducted in a Bolivian community (Quick *et al*., 1996) which concluded that the mean age of respondents was within the reproductive age group with majority being females. Illah is an Ibo speaking community and Ibos are mainly Christians even though people from other ethnic groups were found to be living among the respondents.

The level of education could enhance the quality of household drinking water and sanitation practices. Educated households with formal education up to primary school are more likely to have a better awareness and understanding of water quality issues than the uneducated ones (Tambekar *et al*., 2008). The results of this study revealed that majority of the respondents with at least secondary school education had better knowledge and understanding of unsafe water issues than the uneducated ones.

5.2 Water supply and Use

The study revealed that majority of the respondents depended on the boreholes as the source of drinking water which was not treated to the level that could prevent the transmission of disease causing organisms. This is in agreement with the National Bureau of statistics that water in the majority of the Niger Delta States originates from unsafe supply facilities, including streams, rivers, ponds, unprotected wells, boreholes and vendor trucks (Faith *et al*., 2012**)**. This high dependence of respondents on borehole water was found to be due to the closeness of the sources to the households. Another study indicated that unfavourable condition of water supplies might have been due to a variety of reasons, such as disagreements on the payment of operational costs after construction, poorly engineered boreholes, pressure loss, and damaged taps and pipes (Hunter *et al*., 2009). Ideally people should have separate containers for collection and storage of water for drinking and other domestic uses to reduce cross contamination of stored drinking water (Lantagne *et al*., 2007), in line with this, majority of the respondents do not use the same containers for fetching drinking water for other domestic purposes. The type of containers for storing drinking water varied from one household to the other of which majority of respondents in the study made

use of open mouthed containers (plastic containers and coolers) with lids, some of which from observation were unhygienic, and may lead to proliferation of micro-organisms. The use of open mouthed containers also may lead to the majority of respondents dipping bowls, cups and hands thereby leaving room for contamination. This was in agreement with the finding that unhygienic handling of storage facilities led to water contamination in a study which assessed households' drinking water quality in Ibadan (Oloruntoba, 2005).

5.3 Waste disposal and sanitary practices

The result of this study revealed that more than half of the respondents indicated the use of flush/pour toilets while 28% said they use pit latrine with slabs. World Resource Institute (1996) noted that the hygienic disposal of human excreta is a corner stone of all public health services and that the prevention of faecal-borne diseases that are transmitted through contaminated water, fingers, flies, and foods are best done by the provision of well constructed sanitary latrines. Lack of access to improved water and sanitation, along with hygiene has led to epidemics of water borne disease like diarrhoea, especially in tropical developing countries (Brick *et al*., 2004). Majority (45.0%) of the respondents claimed to use tissue and 39.0% of respondents indicated the use of water for anal cleansing material after defecation. The respondents claimed to have hand washing materials and use these materials to wash their hands after toilet visits in their home and this is in agreement with the finding that regular hand-washing after defecation and before handling water minimizes the risk that water used and stored in the home is contaminated with dirty hands (UNICEF, 2013). Hand-washing after defecation and before handling water can have an impact on drinking water quality particularly in areas where drinking water is not often poured out of the storage container but rather dipped out by some means.

The proper disposal of domestic waste which often contains leaves, papers and kitchen garbage among others is also important in the control of infections. The presence of one or more of these materials was observed around the houses and water sources. The presence of refuse around may not only serve to contaminate the sources, but may also breed flies that transmit communicable diseases or serve to contaminate hands and toys of children who do a lot of mouthing activities when playing. The waste materials can also block the drainages causing overflow of waste water to houses and water sources like rivers and wells thereby causing pollution. Improper management of

waste water was also reported. The waste water flows long distances and may serve as means of contaminating water sources.

5.4 Water Treatment Options

The study revealed that majority of the respondents treated their drinking water. The most common method for treatment used by majority of these respondents was leaving the water to stand and settle which could be as a result of their belief that when the water is left to stand and settle, the particles will settle down thereby believing the germs would settle down with the particles. This is was at variance with Brick *et al*; (2004) and Sobsey (2008) that chlorination and boiling were widely used methods for treating drinking water in the households that can reduce the level of total coliforms and *E.coli*. Also from the majority of the respondents that treated their drinking water, some used specific combination of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits. This may be due to its low cost, availability in the market and also the belief that these dried fruits have medicinal properties that can protect them from sickness and death when used.

5.5 Physico-chemical Characteristics of Raw and Treated Water

The pH is an important parameter which determines the suitability of water for various purposes (Chandaluri *et al*., 2010). The pH of water could make the water corrosive (at low pH) or result in taste complaints (at high pH).The fluctuations in optimum pH ranges may lead to an increase or decrease in the toxicity of poisons in water bodies (Ali, 1991). The mean pH levels in the borehole water before and after treatment were within the WHO permissible limit. The mean pH levels in the stream water was lower than the 6.5 recommended by the WHO before and day 1 after treatment only but increased within the WHO permissible limit at days 2 and 4 after treatment. The acidic nature of the samples agrees with the assertion that the pH changes in water quality may be as a result of introduction of contaminants (Oloruntoba *et al*., 2006). The generally low pH values obtained in the water samples might also be due to the high levels of free CO_2 in the water samples (Edema *et al*., 2001). The level of nitrate in the water samples is low generally. The WHO standard for nitrate is 50mg/L and above this limit may cause cyanosis disease or blue baby syndrome in infants less than 3months (WHO, 2006).

The concentration of trace metals in borehole and stream water before and after treatment with *Xylopia aethiopica* and *Tetrapleura tetraptera* was low for all the metal ions (Zinc, Iron and Lead). All the sources were safe from excessive concentration of all the trace metals since they were all

below the WHO limit. This is in conformity with other studies conducted in Niger Delta region (Bariweni *et al*., 2000; Izonfuo and Bariweni, 2001 and Asonye *et al*., 2007).

5.5.1 Bacteriological Quality of Raw and Treated Water

The household water supplies were of poor bacteriological quality. The poorer the quality of water, the more the number and types of organisms that can live in it (NASA, 2004). The average total coliform and *E.coli* counts/100ml in the stream was 280/100mL and 133/100mL respectively while that of the borehole water was 129/100mL and 24/100mL respectively None of the water samples from the water supplies satisfied WHO guidelines for drinking water. This is in line with the National Bureau of statistics that water in the majority of the Niger Delta States comes from unsafe sources, including streams, rivers, ponds, unprotected wells, boreholes and vendor trucks (Faith *et al*., 2012**)**. The coliform and *E.coli* counts in the stream water was far higher than that of the samples from the borehole source. This may be due to the topography of the study area which favours surface runoff and discharge of untreated wastewater into the stream. The unprotected nature of the stream may also live room for animals to come around to drink water and defecate thereby contaminating the stream. Contamination from the borehole source may be as a result of leakages in distribution lines (due to old age) and construction works which could result in infiltration of soil- borne pathogens. The presence of coliform group and *E.coli* is due to faecal or environmental contamination and it is an indication of the likely presence of other pathogenic bacteria like *Salmonella* spp., *Shigella* spp. and *Streptococcus* spp which are capable of causing very serious diseases.

Treatment with the dried fruits of *Xylopia aethiopica* and *Tetrapleura tetraptera* in selected households reduced total coliforms and *E.coli* count in the borehole water from day 1 after treatment only while for those who made use of stream water, the treatment reduced the bacterial contaminants from day 1 to day 2 after treatment. This reduction in bacterial counts may be as a result of the antimicrobial activity reported by some researchers in the volatile oils and phytochemical compounds released from the dried fruits during heating into the storage container (clay pot) (Boakye-Yiadom *et al*., 1977; Thomas, 1989; Tatsadjieu *et al*., 2003; Asekun and Adeniyi, 2004; Okigbo *et al*., 2005). As the days after treatment increases, the potency of the volatile compounds in the drinking water reduced which may be as a result of continuous opening and closing of the storage container leading to a gradual escape of these compounds and re-

introduction of microbial contaminants at the same time. The re-introduction of these microbes could be as a result of method of collection. The type of container used in collecting water from the drinking storage container might have been contaminated. Also, hands could be dipped into the containers during the process of collection. This finding confirms that of Tambekar *et al*., 2005 that dipping hand into water led to contamination.

5.6 Nutrient Composition and Antibacterial activity of the dried fruits of *Xylopia aethiopica* and *Tetrapleura tetraptera*

These fruits have nutritional qualities which when used in the right proportions could be of tremendous benefit to the body. Lead was not detected; this indicated that lead is not present in detectable amount in the fruits. This is beneficial to consumers, since it has been reported that some of these minerals like lead, cobalt and cadmium are highly toxic even at low concentrations (Asaolu *et al*., 1997). Ideally the distilled water which served as negative control is not expected to have an effect on the growth of bacteria, in line with this, the two strains of *E.coli and Pseudomonas aeruginosa* showed no inhibition of growth in their reaction against distilled water. Antibiotics which served as the positive control ideally produce an expected effect on the growth of micro-organisms, in line with this, some antibiotics like gentamicin, ciprofloxacin, ofloxacin and nitrofurantoin produced an effect against the test organisms as shown in Table 4.21. The study also revealed that crude extracts (alcoholic) of *Xylopia aethiopica* and *tetrapleura tetraptera* could not prevent the growth of test organisms in the media. This was not in agreement with several reports on the antimicrobial activity of the essential oil as well as crude extracts (both alcoholic and aqueous) of *Xylopia aethiopica* and *Tetrapleura tetraptera* been made in the literature which have been shown to have antimicrobial property against a wide range of Gram positive and Gram negative bacteria (Boakye-Yiadom *et al*., 1977; Thomas, 1989; Tatsadjieu *et al*., 2003; Asekun and Adeniyi, 2004; Okigbo *et al*., 2005).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Addressing issues relating to water quality can lead to a drastic reduction in health problems associated with the consumption of water from unwholesome sources. This is also a major step towards the achievement of target 10, goal 7 of the millennium development goal. But this requires a more integrated approach – linking action at local, national and global levels. The study sought to assess the effect of treatment with *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruit on drinking water quality in Illah community, Delta State. In doing so, information on demographic characteristics, sources of water, knowledge of unsafe water, water handling practices, water treatment options, waste disposal, and sanitation conditions of sources and storage containers were assessed using interviewer administered questionnaire and sanitation inspection form. Water samples from borehole and stream were purposively collected for the determination of physico-chemical and microbiological quality. Prior to the collection of water samples from consented households, an indigenous water treatment was carried out. In this indigenous water treatment method, a hot charcoal was kept on a flat surface (flat tray). Quantities of oil palm mesocarp fibre (Plate 3.3) was added on top of the hot charcoal, after which 50g dried fruits each of *Xylopia aethiopica* and *Tetrapleura tetraptera* were ground together using clean mortar and pestle and added on top of the hot charcoal with oil palm mesocarp fibre, thus, producing a smoke. The washed and dried storage container (clay pot) was faced upside down directly to the smoke for 10 minutes after which 10 litres of water from the source was immediately poured into the container. Samples of the treated water were then collected day 1, 2 and 3 after treatment from the clay pot for the determination of physico-chemical and microbiological quality. Samples for microbial analysis were collected in sterile labeled bottles and those for physico-chemical analyses were collected in clean containers

During the course of the study It was also observed that in Illah, a combination of dried fruits of *Xylopia aethiopica* and *Tetrapleura tetraptera* are used for household treatment of water without information on its potency in water purification. There is no documented information on the effectiveness of this treatment method in reducing level of water contaminants.

At the end of the study, the following conclusions were drawn:

The higher the level of education (tertiary) can be a major factor in achieving appropriate knowledge of unsafe water. Borehole water supplies were mostly used and were not treated to the level that could prevent the transmission of disease causing organisms.

The water samples collected from the water supplies in the community were all contaminated with stream water having more coliform counts than the WHO guideline limits. The household water supplies therefore had poor water quality.

Treatment with the combination of *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits reduced the levels of coliform counts in borehole and stream water on day 1 after treatment as a result of the anti-microbial activity reported in the volatile oil as well as the phytochemical compounds extracted from the dried fruits. As the days after treatment progressed, the levels of coliform counts increased gradually as a result of continuous opening and closing of the storage container when collecting water to drink which is critical to the gradual escape of volatile compounds and re-introduction of microbial contaminants at the same time.

The media introduced into the drinking water containers was a factor that contributed to the re-introduction of contaminants into the drinking water. Areas where drinking water was not poured out of the storage container, dipping out by some means becomes inevitable and for this reason soiled hands may come in contact with potable water.

Finally, treatment using a combination of *Xylopia aethiopica* and *Tetrapleura tetraptera* reduced the levels of bacteriological contaminants especially on the first day after treatment but it did not improve the quality of drinking water because it indicated higher coliform count compared to the WHO guideline limit for potable water.

This study therefore emphasizes the need for an alternative water treatment that is more effective.

6.2 Recommendations

1. There should be proper water quality monitoring and adequate water supply by the government to supplement inadequate supply from other sources.
2. Water should be adequately treated at source before use.
3. Use of drinking water storage containers with “narrow dispensers” that will minimize contact with hands during collection should be encouraged.

4. There should be proper training of respondents on wastewater management to reduce the risk of contaminating water sources
5. There should be regular training of respondents on more effective alternative water treatment methods, water storage and handling to ensure improvement in water quality at the household level.

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APPENDIX I

QUESTIONNAIRE (ENGLISH)

QUESTIONNAIRE ON THE EFFECTS OF SMOKE FROM TREATMENT WITH *Xylopia aethiopica* AND *Tetrapleura tetraptera* FRUITS ON DRINKING WATER QUALITY IN ILLAH COMMUNITY, DELTA STATE.

Dear respondent,

I am a student of the Department of Environmental Health Sciences, Faculty of Public Health, University of Ibadan. I am presently carrying out a research on the effects of smoke from treatment with *Xylopia aethiopica* and *Tetrapleura tetraptera* dried fruits on drinking water quality in Illah community, Delta state. I wish to kindly request your voluntary participation by providing honest answers to the following questions, as this would increase the quality of the findings. I assure you that the information provided in this questionnaire will be kept strictly confidential and used solely for the purpose of research. Please note that you do not need to write your name on this questionnaire. Thank you for your cooperation.

I agree to participate in this study, tick ☐

Questionnaire Serial number …….

SECTION A SOCIO- DEMOGRAPHIC CHARACTERISTICS

1. Sex (1) Male [ ] (2) Female [ ]
2. Marital Status 1.) Single [ ] 2.) Married [ ] 3.) Divorced [ ] 4.) Widowed [ ] 5) others, please specify ……..
3. Ethnicity 1. Yoruba [ ] 2. Hausa [ ] 3. Igbo [ ] 4. Others, please specify ……
4. Religion; (1) Christian [ ] (2) Islam [ ]
   (3) Traditional [ ] (4) Other (Specify) ------
5. Age in years (at last birthday) ……
6. Educational Status 1. No formal Education [ ] 2. pry school [ ] 3.secondary school [ ] 4.post secondary [ ]

7. Occupation 1. Trading [ ] 2. Artisan [ ] 3. Farming [ ] 4. Student [ ] 6. Civil servant [ ] 7.Others please specify ……..

8. Income ……

9. Number of children ever born . [ ]

10. Number of children alive. [ ]

11. Did you give birth in the last 12 months ? 1.Yes [ ] 2. No [ ]

12. Is the child alive now? 1.Yes[ ] 2. No [ ]

13. If dead, how many months old was the baby at the time of death. [ ]

SECTIONB KNOWLEDGE OF UNSAFE WATER AND ITS IMPLICATION FOR HEALTH

14. Which of the following sources of water is the best for drinking? 1) Tap [ ] 2) Well [ ] 3) Borehole [ ] 4) Spring [ ] 5) Rain water [ ] 6) bottled water [ ] 7) sachet water [ ] 8)others……..

15. Why do you think it's the best?
.....

16. Do you think any of these can contaminate water?

1. Faeces	Yes	No	Don't Know
2. Urine	Yes	No	Don't Know
3. Chemicals	Yes	No	Don't Know
4. Soap	Yes	No	Don't Know

17. What do you know about the qualities of good drinking water?

1. A good quality drinking water should be clean and clear	Yes	No	Don't know
2. A good quality drinking water should have sweet taste	Yes	No	Don't know
3. A good quality drinking water should have odour	Yes	No	Don't know
4. A good quality drinking water should have a good smell	Yes	No	Don't know

18. Do you think any of the following are water-related diseases?

1. Diarrhea	Yes	No	Don't know
2. Guinea worm	Yes	No	Don't know
3. Dysentery	Yes	No	Don't know
4. Typhoid	Yes	No	Don't know
5. Cholera	Yes	No	Don't know

19. Through which other means apart from only drinking unsafe water can water-related diseases be contacted?

1. Using it to bath	Yes	No	Don't know
2. Using it to wash	Yes	No	Don't know
3. Using it to wash fruits	Yes	No	Don't know
4. Using it to cook	Yes	No	Don't know

20. Do you think water related diseases can kill? 1. Yes [ ] 2. No [ ]

21. Do you know that micro-organisms live inside water? 1. Yes [ ] 2. No [ ]

22. What do you know about these organisms called microbes?

1. They are not visible to the eyes	Yes	No	Don't know
2. They can cause diseases to human body.	Yes	No	Don't know
3. They die after some days.	Yes	No	Don't know
4. They can make the water become coloured.	Yes	No	Don't know
5. They make us fat	Yes	No	Don't know
6. They can be removed by treating the water	Yes	No	Don't know

23. The following are methods that can be used to treat unsafe water.

1. Boiling	Yes	No	Don't know
2. Alum	Yes	No	Don't know
3. Filtration	Yes	No	Don't know
4. Solar disinfection	Yes	No	Don't know
5. Chlorination	Yes	No	Don't know
6. Water guard	Yes	No	Don't know
7. Salt	Yes	No	Don't know

SECTION C DRINKING WATER SOURCES AND WATER HANDLING PRACTICES

24. What is the main source of drinking water for members of your household? 1) Tap [ ] 2) Well [ ] 3) Borehole [ ] 4) Spring [ ] 5) Rain water [ ] 6) bottled water [ ] 7) sachet water [ ] 8)others……
25. How far is that main source of drinking water for members of your household from your house ? 1) In the house [ ] 2) Less than 1km [ ] 3) Between 1-3km [ ] 4) Farther than 3km [ ].
26. What is the main source of water used by your household for other purposes such as cooking and hand washing? 1) Tap [ ] 2) Well [ ] 3) Borehole [ ] 4) Spring [ ] 5) Rain water [ ] 6) bottled water [ ] 7) sachet water 8)others……..
27. How far is that main source of water used by your household for other domestic purposes from your house ? 1) In the house [ ] 2) Less than 1km [ ] 3) Between 1-3km [ ] 4) Farther than 3km [ ].
28. What time of the day do you fetch drinking water?
    1) Morning [ ] 2) afternoon [ ] 3) evening [ ] 4) night [ ] 5) anytime [ ]
29. Do you use the bucket you use in fetching drinking water for other domestic use?
    1) Yes [ ] 2) No [ ]
30. Do you cover your drinking water during transportation?
    1) Yes [ ] 2) No [ ].
31. Do you do anything to the water to make it safe to drink? 1. Yes [ ] 2. No [ ]
32. What do you usually do to make the water safe to drink? 1. Boil [ ] 2. Add bleach/ chlorine/Alum [ ] 3. Use water filter [ ] 4. Solar disinfection [ ] 5. Let it stand and settle [ ] 6. Performing the indigenous household treatment [ ] 7. Others …….....
33. How often do you perform any of the techniques chosen by you in question 31? 1) daily [ ] 2) weekly [ ] 3) seldomly [ ] 4)when dirty [ ] 5) Others……
34. Where do you keep your drinking water? 1) in the room [ ] 2) outside the room [ ] 3) in the kitchen [ ] 4) outside the kitchen [ ] 5) others (*please specify*)……
35. What do you use as storage container for drinking water? 1) Jerican [ ] 2)big plastic container [ ] 3)clay pot [ ] 4)metal tank [ ] 5)others (*please specify*)……..

36. How often do you clean this storage container? 1) daily [ ] 2) weekly [ ] 3) seldomly [ ] 4)when dirty [ ]

37. Do you have special container for collecting water from the storage container?
1) Yes [ ] 2) No [ ].

38. How many container(s) do you have for collecting water from the storage container.
a) 1 [ ] b) 2 [ ] c) 3 [ ] d) more [ ]

39. Who fetches water for the household?

1.Children under 10	Yes	No
662. Children above 10	Yes	No
3. Adult male	Yes	No
4 Adult female	Yes	No
5. Adult male and adult female	Yes	No

40. How do you collect drinking water from the storage container?
1) by dipping [ ] 2) by pouring [ ] 3) use of tap [ ].

SECTION D HEALTH RELATED AND ENVIRONMENTAL FACTORS

50. Is there a toilet in your household?
1) Yes [ ] 2) No [ ].

51. What type of toilet facility do you use in your household? 1. Flush or pour flush toilet [ ] 2. Pit latrine with slab [ ] 3. Pit Latrine without slab [ ] 4. Bucket Toilet [ ] 5. No facility/ bush / field [ ] 6. Others ……..

52. Do you share this toilet facility with other households? 1. Yes [ ] 2. No [ ]

53. What does your household mainly use for cooking? 1. Electricity [ ] 2. Gas cooker [ ]3. Kerosene stove [ ] 4. Charcoal[ ] 5. Firewood [ ]6. Others
……

54. Do you have hand-washing materials in the household? 1. Yes [ ] 2. No [ ]

55. Do you wash your hand with any of the hand-washing materials after toilet visit?
1. Yes [ ] 2. No [ ]

56. What do you normally use after defecation? 1) Water [ ] 2) Paper [ ] 3) Tissue [ ] 4) others(*please specify*)……

57. How do the small children in the house access the toilet?

1. They use paper or nylon	Yes	No

2.They use potty	Yes	No
3. They use the bush	Yes	No

58. How does your family manage solid waste? 1) Refuse dumping [ ] 2) Burning in pit [ ] 3)sanitary landfill [ ] 4)others [ ] (*please specify*)……

59. How often is your waste disposed?
1) rarely [ ] 2) occasionally [ ] 3) often [ ] 4) very often [ ].

60. How does your family manage waste water? 1) Through drainage sewer [ ] 2) soak away pit [ ] 3) pouring away [ ] 4) re-use [ ] 5)others [ ] (*please specify*)……

61. Where do you normally put your waste?
1) in the kitchen [ ] 2)outside the kitchen [ ]3) on the corridor [ ]d) outside the house[ ] e) others[ ](*please specify*)……..

62. Is there an open gutter within your compound? 1)Yes [ ] 2) No [ ].

63. Is there an open gutter around or near your house? 1)Yes [ ] 2) No [ ]

64. Is there animal raising in or around the house? 1) Yes [ ] 2) No [ ]

65. Do you have a separate room which is used as a kitchen? 1) Yes [ ] 2) No [ ]

66. Do you have any under-five child/children in the household? 1) Yes [ ] 2) No [ ]

67. If yes, how many are they in the household? …….

68. If yes have any of the under-five children in the household being ill with any of the following diseases at any time in the last 2weeks?

DISEASE	YES	NO	DON'T KNOW
1.Diarrohoea			
2.Cholera			
3.River blindness			
4.Typhoid			
5.Infectious hepatitis			

6. Giardiasis			
7. Amoebiasis			
8. Dracunculiasis (guinea worm)			

69.If yes do any of the under-five children in the household have any of the following diseases now?

DISEASE	YES	NO	DON'T KNOW
1.Diarrohoea			
2.Cholera			
3.River blindness			
4.Typhoid			
5.Infectious hepatitis			
6. Giardiasis			
7. Amoebiasis			
8. Dracunculiasis (guinea worm)			

70. What other illness dothe under-five child or children in your household have at any time in the last 2weeks?

.....

71. What other illness do the under-five child or children in your household have now?

.....

..

Thanks for your cooperation.

APPENDIX II

SANITARY INSPECTION FORM FOR STORAGE CONTAINERS

A) General information:

a) Village/Community Name –
b) Household no-
c) Date and Time of visit-

B) Specific Diagnostic Information for Inspection

		Yes	No
1	Are containers used for collecting water clean (not rusted)?		
2	Is the container used to store any other liquid?		
3	Does the container have a cover?		
4	Is that same container used for washing and or bathing plus other activities?		
5	Is the storage container kept at ground level?		
6	Is the container liable to rust, cracked, leaking or un-sanitary?		
7	Is the utensil used to draw water from the drinking container also used for drinking?		
8	Is the area around the storage container un-sanitary?		
9	Do animals have access to the drinking water container?		
10	Do small children have access to take water from it themselves?		

C)Results and Comments

1)Risk Score (Tick as appropriate).

a) 9-10= very high
b) 6-8= high
c) 3-5= medium
d) 0-2= low

2) The following important points of risk were noted ……
……..……..……
……(listnos 1-10).

3) Additional Comment ……..
.....

APPENDIX III

SANITARY INSPECTION FORM FOR STREAM

A) General information:

a) Village/Community Name -
b) Well no/water source code-
c) Date and Time of visit-

B) Specific Diagnostic Information for Inspection

		Yes	No
1	Is the stream protected?		
2	Does spilt water flood the collection area?		
3	Is there a dump site within 100m of the stream?		
4	Can animals have access within 10m of the stream?		
5	Is there a latrine uphill and/or within 30m of the stream?		
6	Does surface water collect uphill of the stream?		
7	Do people wash or bath around or even inside the stream?		
8	Do people enter the stream with their legs inside when fetching water?		
9	Do people urinate or defeacate inside the water?		
10	Are there farming activities around the stream?		

C) Results and Comments

1)Risk Score (Tick as appropriate).

a) 9-10= very high
b) 6-8= high
c) 3-5= medium
d) 0-2= low

2) The following important points of risk were noted ……
……..……..……
……(list nos 1-10).

3) Additional Comment ……..
.....

APPENDIX IV
SANITARY INSPECTION FORM FOR BOREHOLE

A) General information:
a) Village/Community Name -
b) Well no/water source code-
c) Date and Time of visit-

B) Specific Diagnostic Information for Inspection

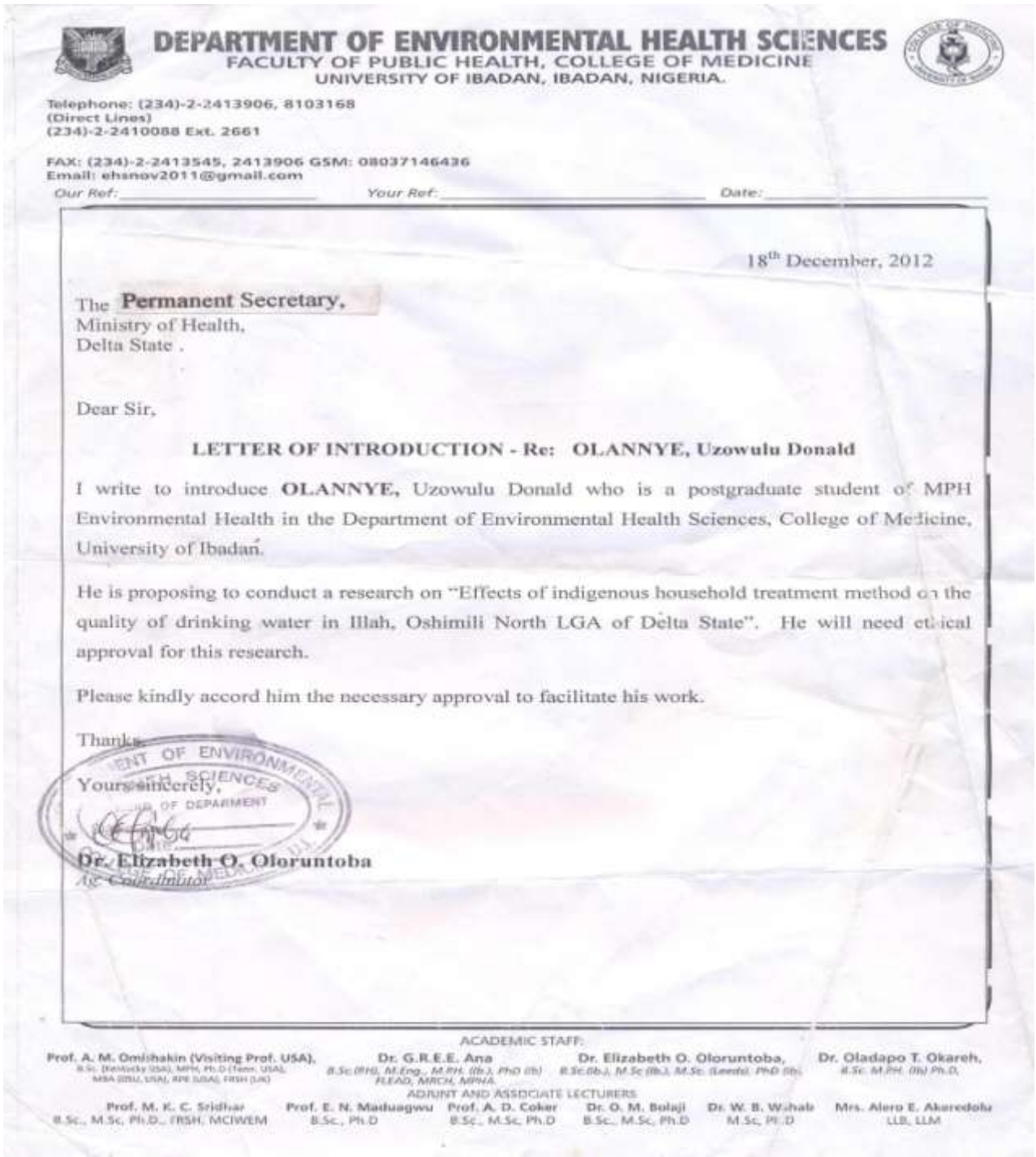
Risk
1. Is there a latrine within 10 m of the borehole? Y/N
2. Is there a latrine uphill of the borehole? Y/N
3. Are there any other sources of pollution within 10 m of borehole (e.g. animal breeding, cultivation, roads, industry etc)? Y/N
4. Is the drainage faulty allowing ponding within 2 m of the borehole? Y/N
5. Is the drainage channel cracked, broken or need cleaning? Y/N
6. Can animals come within 10 m of the borehole? Y/N
7. Is the apron less than 2 m in diameter? Y/N
8. Does spilt water collect in the apron area? Y/N
9. Is the apron or pump cover cracked or damaged? Y/N
10. Is the handpump loose at the point of attachment (or for rope-washer pump is the pump cover missing)? Y/N
Total Score of risks ……../10

C)Results and Comments
1)Risk Score (Tick as appropriate).
a) 9-10= very high
b) 6-8= high
c) 3-5= medium
d) 0-2= low
2) The following important points of risk were noted ……
……..…….……(list nos 1-10).

3) Additional Comment ……..
.....

APPENDIX V

INTRODUCTORY LETTER ISSUED BY DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES



DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES
FACULTY OF PUBLIC HEALTH, COLLEGE OF MEDICINE
UNIVERSITY OF IBADAN, IBADAN, NIGERIA.

Telephone: (234)-2-2413906, 8103168
(Direct Lines)
(234)-2-2410088 Ext. 2661

FAX: (234)-2-2413545, 2413906 GSM: 08037146436
Email: ehsnov2011@gmail.com

Our Ref: _____ Your Ref: _____ Date: _____

18th December, 2012

The **Permanent Secretary,**
Ministry of Health,
Delta State .

Dear Sir,

LETTER OF INTRODUCTION - Re: OLANNYE, Uzowulu Donald

I write to introduce **OLANNYE,** Uzowulu Donald who is a postgraduate student of MPH Environmental Health in the Department of Environmental Health Sciences, College of Medicine, University of Ibadan.

He is proposing to conduct a research on "Effects of indigenous household treatment method on the quality of drinking water in Illah, Oshimili North LGA of Delta State". He will need ethical approval for this research.

Please kindly accord him the necessary approval to facilitate his work.

Thanks.

Yours sincerely,

Dr. Elizabeth O. Oloruntoba
Ag. Coordinator

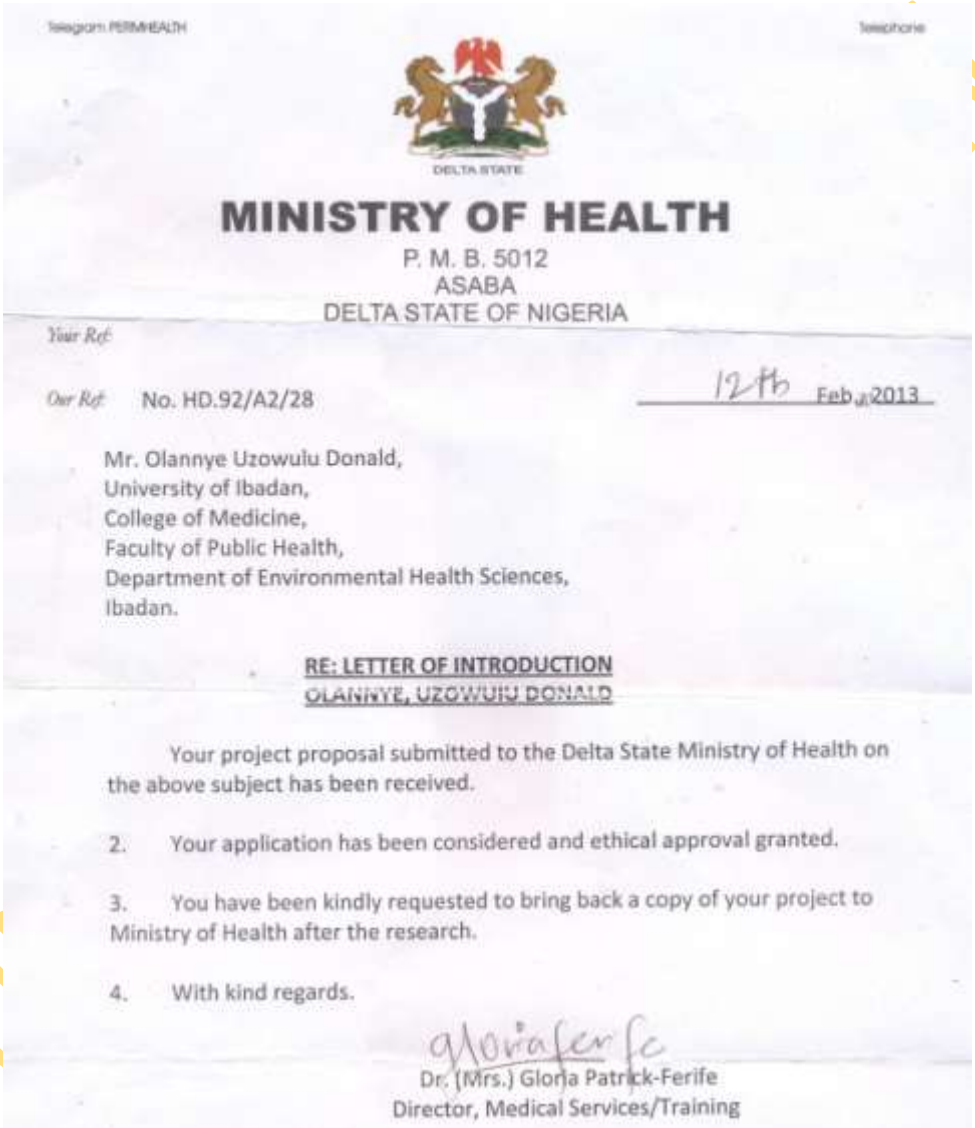
ACADEMIC STAFF:

Prof. A. M. Omishakin (Visiting Prof. USA), Dr. G.R.E.E. Ana, Dr. Elizabeth O. Oloruntoba, Dr. Oladapo T. Okareh,

ADJUNT AND ASSOCIATE LECTURERS

Prof. M. K. C. Sridhar, Prof. E. N. Maduagwu, Prof. A. D. Coker, Dr. O. M. Bolaji, Dr. W. B. Wahab, Mrs. Alero E. Akeredolu

APPENDIX VI
ETHICAL APPROVAL FOR THIS RESEARCH ISSUED BY MINISTRY OF HEALTH DELTA STATE



Telegram: PERMHEALTH Telephone

DELTA STATE

MINISTRY OF HEALTH

P. M. B. 5012
ASABA
DELTA STATE OF NIGERIA

Your Ref:

Our Ref: No. HD.92/A2/28 12th Feb, 2013

Mr. Olannye Uzowulu Donald,
University of Ibadan,
College of Medicine,
Faculty of Public Health,
Department of Environmental Health Sciences,
Ibadan.

RE: LETTER OF INTRODUCTION
OLANNYE, UZOWULU DONALD

Your project proposal submitted to the Delta State Ministry of Health on the above subject has been received.

2. Your application has been considered and ethical approval granted.

3. You have been kindly requested to bring back a copy of your project to Ministry of Health after the research.

4. With kind regards.

Dr. (Mrs.) Gloria Patrick-Ferife
Director, Medical Services/Training

APPENDIX VII

CORDINATES OF WATER SOURCES AND STORAGE CONTAINERS FROM ELEVEN HOUSEHOLDS WHO CONSENTED FOR THEIR TREATED WATER TO BE SUBJECTED FOR ANALYSIS

	WATER SOURCES		STORAGE CONTAINERS	
1	N6◦ 24. 6231'	E6◦ 38. 2581'	N6◦ 24. 9784'	E6◦ 38. 5335'
2	N6◦ 24. 7521'	E6◦ 38. 9948'	N6◦ 24. 8873'	E6◦ 38. 7148'
3	N6◦ 24. 7521'	E6◦ 38. 9948'	N6◦ 24. 2313'	E6◦ 38. 9106'
4	N6◦ 25. 4671'	E6◦ 38. 9221'	N6◦ 25. 4823'	E6◦ 38. 9669'
5	N6◦ 25. 4671'	E6◦ 38. 9221'	N6◦ 25. 5113'	E6◦ 39. 0283'
6	N6◦ 25. 4671'	E6◦ 38. 9221'	N6◦ 25. 506'	E6◦ 38. 9882'
7	N6◦ 25. 6016'	E6◦ 39. 077'	N6◦ 25. 5709'	E6◦ 39. 0776'
8	N6◦ 25. 6016'	E6◦ 39. 077'	N6◦ 25. 5366'	E6◦ 39. 0545'
9	N6◦ 25. 6016'	E6◦ 39. 077'	N6◦ 25. 4168'	E6◦ 39. 0745'
10	N6◦ 25. 6016'	E6◦ 39. 077'	N6◦ 25. 4125'	E6◦ 39. 1011'
11	N6◦ 25. 6016'	E6◦ 39. 077'	N6◦ 25. 3894'	E6◦ 39. 1635'

APPENDIX VIII
PREPARATION OF MEDIA AND REAGENTS

1. Stock nitrate solution:

   A 721.8 mg anhydrous potassium nitrate was dissolved and diluted to 1 litre with distilled water. 1mL = 0.1 mg N.

2. Standard nitrate solution:

   A 10mL stock nitrate solution was diluted to 1 litre with distilled water. 1mL = 1g N

3. Sodium arsenite solution: 5.0 g $NaAsO_2$ was dissolved and diluted to 1 litre with distilled water.

4. Brucine-sulphanilic acid solution:

   A 1g brucine sulphate and 0.1 g sulphanilic acid was dissolved together in 70 mL of hot distilled water. 3 mL conc. HCl was then added to the mixture and left to cool and made up to 100mL.

5. Sulphuric acid solution:

   A 500mL conc. H_2SO_4 was carefully added to 125mL distilled water and left to cool to room temperature.

6. Sodium chloride solution:

   A 300g NaCl was dissolved and diluted to 1litre with distilled water.

7. Single Strength:

   Thirty-five grams of MacConkey broth powder was measured into a conical flask. Two hundred mls of distilled water was added to dissolve the powder and was made up to 1 litre.

8. Double Strength:

   Seventy grams of MacConkey was weighed and put in a sterile conical flask. Two hundred mls of distilled water was added to dissolve the powder and was made up to 1 litre.

APPENDIX IX
RAW DATA

Water sources each household used

Household Number	Source
1	Stream 1
2	Stream 2
3	Stream 2
4	Borehole 1
5	Borehole 1
6	Borehole 1
7	Borehole 2
8	Borehole 2
9	Borehole 2
10	Borehole 2
11	Borehole 2

Physico-chemical properties of the water sources (First week)

	Stream 1	Stream 2	Borehole 1	Borehole 2
pH	5.99	6.37	6.47	6.63
Zinc (mg/L)	0.014	0.006	0.025	0.060
Iron (mg/L)	0.270	0.294	0.200	0.188
Lead (mg/L)	0.0096	0.0089	0.0072	0.0067
Nitrate (mg/L)	21.707	23.036	20.378	19.492

Bacteriological properties of the water sources (First week)

	Stream 1	Stream 2	Borehole 1	Borehole 2
Total coliform (cfu/100mL)	170	340	120	140
E.coli (cfu/100mL)	90	170	40	20

Physico-chemical properties of the treated water at households (First week)

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
pH	1	6.01	6.48	6.78
	2	6.36	6.89	6.60
	3	6.35	6.77	6.78
	4	6.64	6.17	6.79
	5	6.58	6.61	6.75
	6	6.72	6.74	6.81
	7	6.65	6.69	6.88
	8	6.66	6.71	6.80
	9	6.64	6.69	6.88
	10	6.50	6.60	6.79
	11	6.64	6.68	6.91

Physico-chemical properties of the treated water at households (First week) continued

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
Zinc (mg/L)	1	0.039	0.020	0.001
	2	0.045	0.067	0.080
	3	0.036	0.049	0.048
	4	0.035	0.024	0.035
	5	0.035	0.047	0.047
	6	0.047	0.034	0.047
	7	0.064	0.068	0.066
	8	0.070	0.068	0.068
	9	0.072	0.074	0.068
	10	0.070	0.071	0.070
	11	0.071	0.079	0.076
Iron (mg/L)	1	0.245	0.266	0.280
	2	0.147	0.280	0.220
	3	0.200	0.229	0.285
	4	0.145	0.144	0.260
	5	0.181	0.161	0.172
	6	0.154	0.162	0.192
	7	0.100	0.145	0.258
	8	0.121	0.130	0.149
	9	0.100	0.150	0.184
	10	0.126	0.136	0.154
	11	0.100	0.118	0.120

Physico-chemical properties of the treated water at households (First week) continued

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
Lead (mg/L)	1	0.0017	0.0016	0.0018
	2	0.0050	0.0086	0.0098
	3	0.0060	0.0069	0.0073
	4	0.0083	0.0014	0.0049
	5	0.0020	0.0028	0.0030
	6	0.0028	0.0035	0.0038
	7	0.0027	0.0095	0.0099
	8	0.0020	0.0021	0.0029
	9	0.0021	0.0030	0.0032
	10	0.0031	0.0037	0.0039
	11	0.0038	0.0045	0.0057
Nitrate (mg/L)	1	21.264	22.150	21.264
	2	23.036	22.372	20.821
	3	21.707	21.929	21.707
	4	21.264	22.106	19.492
	5	19.492	18.606	18.163
	6	20.821	20.821	20.378
	7	21.707	19.935	19.492
	8	19.935	21.264	19.492
	9	18.163	19.049	19.935
	10	20.378	19.935	19.492
	11	21.264	19.935	19.492

Bacteriological properties of the treated water at households (First week)

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
Total Coliform (cfu/100mL)	1	140	90	170
	2	260	60	210
	3	260	90	170
	4	70	110	110
	5	90	120	140
	6	60	70	120
	7	40	130	120
	8	60	110	110
	9	70	170	120
	10	90	130	90
	11	70	140	140
E.coli (cfu/100mL)	1	70	0	20
	2	110	20	20
	3	110	40	40
	4	20	20	20
	5	20	20	20
	6	20	20	20
	7	0	20	20
	8	0	20	40
	9	20	20	20
	10	0	20	20
	11	20	0	40

Physico-chemical properties of the water sources (Second week)

	Stream 1	Stream 2	Borehole 1	Borehole 2
pH	6.05	6.25	6.29	6.65
Zinc (mg/L)	0.006	0.002	0.035	0.040
Iron (mg/L)	0.284	0.318	0.216	0.180
Lead (mg/L)	0.0050	0.0099	0.0060	0.0071
Nitrate (mg/L)	19.935	22.593	19.492	21.264

Bacteriological properties of the water sources (Second week)

	Stream 1	Stream 2	Borehole 1	Borehole 2
Total coliform (cfu/100mL)	170	330	120	130
E.coli (cfu/100mL)	90	140	20	20

Physico-chemical properties of the treated water at households (Second week)

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
pH	1	6.07	6.52	6.84
	2	6.32	6.91	6.74
	3	6.37	6.83	6.80
	4	6.56	6.57	6.81
	5	6.50	6.57	6.77
	6	6.52	6.60	6.83
	7	6.55	6.71	6.92
	8	6.74	6.73	6.88
	9	6.68	6.71	6.96
	10	6.66	6.66	6.83
	11	6.68	6.56	6.93

Physico-chemical properties of the treated water at households (Second week) continued

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
Zinc (mg/L)	1	0.041	0.030	0.003
	2	0.047	0.055	0.076
	3	0.046	0.051	0.054
	4	0.037	0.006	0.041
	5	0.045	0.045	0.043
	6	0.049	0.040	0.045
	7	0.054	0.054	0.060
	8	0.054	0.070	0.054
	9	0.062	0.088	0.050
	10	0.058	0.073	0.050
	11	0.051	0.059	0.060
Iron (mg/L)	1	0.243	0.272	0.282
	2	0.145	0.292	0.238
	3	0.236	0.231	0.295
	4	0.143	0.140	0.272
	5	0.179	0.173	0.176
	6	0.158	0.176	0.210
	7	0.108	0.155	0.240
	8	0.119	0.140	0.151
	9	0.114	0.146	0.176
	10	0.128	0.144	0.158
	11	0.084	0.122	0.138

Physico-chemical properties of the treated water at households (Second week) continued

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
Lead (mg/L)	1	0.0007	0.0012	0.0022
	2	0.0052	0.0094	0.0162
	3	0.0068	0.0071	0.0085
	4	0.0103	0.0016	0.0057
	5	0.0028	0.0030	0.0042
	6	0.0036	0.0047	0.0048
	7	0.0031	0.0165	0.0161
	8	0.0032	0.0033	0.0035
	9	0.0035	0.0044	0.0042
	10	0.0039	0.0041	0.0043
	11	0.0046	0.0057	0.0061
Nitrate (mg/L)	1	20.821	21.707	19.492
	2	22.150	21.929	21.264
	3	21.150	21.486	19.935
	4	21.707	22.637	19.935
	5	20.378	22.150	20.821
	6	21.264	21.707	21.264
	7	18.163	20.378	17.720
	8	19.492	18.606	19.935
	9	19.049	19.935	19.492
	10	20.821	20.378	19.049
	11	20.821	20.821	19.935

Bacteriological properties of the treated water at households (Second week)

	Household Number	Day 1 after treatment	Day 2 after treatment	Day 3 after treatment
Total Coliform (cfu/100mL)	1	140	70	110
	2	210	90	170
	3	220	70	170
	4	80	190	110
	5	70	90	120
	6	90	120	110
	7	60	140	140
	8	60	140	130
	9	40	110	170
	10	60	120	110
	11	60	140	170
E.coli (cfu/100mL)	1	40	0	20
	2	80	20	20
	3	90	20	60
	4	20	20	20
	5	20	20	20
	6	20	20	20
	7	0	20	20
	8	0	20	20
	9	0	0	40
	10	0	20	20
	11	20	20	20