ASSESSMENT OF QUALITY OF SOME COMMUNITY'S DRINKING WATER, SANITATION, HYGIENE PRACTICES AND OCCURRENCE OF WATER-BORNE INFECTIONS AMONG RESIDENTS IN IMO STATE

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20174136438

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF PUBLIC HEALTH, SCHOOL OF POSTGRADUATE STUDIES, FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY (PhD.) DEGREE IN PUBLIC HEALTH

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CERTIFICATION

This is to certify that this work "Assessment Of Community Drinking Water, Sanitation, Hygiene Practices And Occurrence Of Water Borne Infections Among Residents In Imo State" was written by NNOLI, MATTHEW CHUKS (20174136438) in partial fulfiiment of the requirements for the award of the Doctor of Philosophy (Ph.D) in Public Health in the Department of Public Health of the Federal University of Technology, Owerri.

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To

GOD ALMIGHTY

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ABSTRACT

A total of 920 residents participated in this study. Largest age grade used was 31-40 years (33.7%), followed by 41-50 which is 214 (23.3%), those less than twenty years were 102 (11.1%). About 600 (65.2%) attained tertiary education, 24% attained secondary education while 6.5% and 4.3% attained primary and non-formal education respectively. 408 (44.3%) were civil servants, 114 (12.4) were artisan, and ½ of the residents earned 21,000 (25.7%). Common sources of drinking water are Spring 38.1%, borehole36.1% and lake/stream 10.4%. 240 (26.1%) of residents had distance to source of water <_ 100 meters and 132 (14.3%) had their distance > 1km. Major water fetchers were children under 15 years; adult female was 202 (22%). 580 (63.1%) do not treat their water, but 326 (35.4%) do treat – 254 (77.9%) use boiling, 30 (9.2%) use alum and clot, 12 (3.7%) do chlorination. 812 (88.3%) store water – 420 (51.7%) stores in plastic bucket/drum, 180 (22.3%) use Geepee and 140 (17.2%) use earth pot. For awareness of WASH protocols, 862 (93.7%) stated Yes, while 32 (3.4%) stated No: 426 (53.4%) knew through schools, 196(24.6%) via radio, 100 (12.5%) via tv and 8 (1.0%) through posters. The aware (83.8%) suffered from WASH-related infections and the unaware (94.5%) suffered too but the difference between these two groups is significant at 5% level ($p<0.001$, $x2 = 13.570$). 492 (53.5%) use water cistern toilet, 216 (23.5%) use latrines while 126 (13.7%) use pour flush latrines. 392 (42.6%) use tissue paper to clean after toilet use, 97% use tissue paper and water, 158 (17.2%) use paper, 94 (10.2%) use tissue paper, water and soap. 874 (95%) wash hand after toilet use while 22 (2.4%) do not. 620 (71.6%) use water and soap to wash hand after toilet use, 246 (28.4%) use water only. 536 (58.3%) have functional toilet: 216 (23.5%) toilet is provided by the age grade, 150 (16/3%) by individuals, and 78 (8.5%) by the government. 812 (88.3%) said proper excreta disposal improves community health, 70 respondents said no. 356 (38.7%) clean toilets weekly, 316 (34.3%) on daily basis and 122 (13.3%) on monthly basis. 882 (95.9%) are aware of hygiene protocols, 38 (4.1%) not aware: 694 (75.4%) use water and soap for hand cleaning, 188 (20.4%) use water only, 16 (1.7%) use detergents while 8 (1%) use water, ash and others. 6 (0.7%) use all methods. 232 (25.2%) wash hands before cooking, 228 (24.8%) wash hands when dirty, 202 (22.0%) wash hands after eating, 8 (0.9%) wash hands after cleaning baby's bottom. 714 (77.6%) bathes twice daily, 190 (20.7%) bathes once daily, 16 (1.7%) bathe twice weekly. Hygiene practice reduce water-borne infections – 876 (95.2%) said Yes while 38 (4.1%) said No, Bacteria found in the study area are Enterococcus faecalis 15%, Klebsiella pneumonia 9%, Staph. Aureus, Bacillus cereus and Pseudomonas aeruginosa 8% each. 80 (8.7%) defecate in stream and trenches, 40 (4.3%) defecate in bushes and polyethene bags. 818 (88.9%) were aware that open defecation leads to disease. Cholera, skin infection, diarrhea, typhoid and malaria were WASH- related infections found.

Keywords: Drinking Water, Sanitation, Hygiene, Water Borne, Infections, Imo State

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Water, Sanitation and Hygiene (WASH) practices in communities is not only to promote hygiene and increase access to quality health but also to support national and local interventions to establish equitable, sustainable access to safe water and basic sanitation services in every community/society (United Nations International Children's' Education Fund, 2010). The provision of water, sanitation, and hygiene has been known to have profound effects on human health (Bartram& Cairncross, 2010). Despite progress made in extending access to safe water and sanitation through the Millennium Development Goals (MDGs), over one third of the global population live in households/communities without safe water, sanitary disposal of human waste, and personal hygiene as basic services to humanity (Cumming, 2014). In recognition of the importance of WASH in this setting, WASH in communities is explicitly captured in the post-2015 Sustainable Development Goals (SDGs) (World Health Organization/UNICEF, 2015).

Lack of access to safe water and basic sanitation, as well as poor hygiene cause nearly 90% of all deaths from enteric diseases like diarrhea and it occurs mainly in children (WHO, 2016). While 87% of the world's population now has access to improved water sources, 39% still lack access to improved sanitation (UNICEF, 2016). Moreover, in developing countries like Nigeria, Bangladesh, Kenya, Gambia, etc., where 1.1 billion people still defecate in the open, and hand

washing with soap practiced were on average only after toilet uses (Curtis, Danquah and Aunger, 2014).

Primary prevention of enteric diseases like (diarrhea, cholera and typhoid fever) through water, sanitation and hygiene interventions is based on reducing the fecal-oral transmission of pathogens, and includes the provision of an improved water supply, water safety planning, household water treatment and safe storage, improved sanitation facilities, and hygiene education (UNICEF, 2018). Piped household water connections, public taps, standpipes, or protected dug wells, springs or rainwater collection, these technologies are referred to as improved water supply. Flush/pour flush toilets to a confined system, improved latrines (e.g. ventilated with slab), or composting toilets is called improved sanitation facilities (UNICEF, 2018). Management of water from the source to tap involves water safety planning (Curtis, Danquah and Aunger, 2014). Water treatment may be carried out at source or in the home, and safe water storage takes place in containers, preventing recontamination of water in the household (Schmidt and Cairncross, 2009). Hand washing after toilet use and before the preparation of food addresses Hygiene education (Cairncross, Hunt, Boisson, Bostoen, Curtis, Fung and Schmidt, 2010).

Water, sanitation and hygiene interventions also prevent intestinal parasitic infections alongside diarrhea, and these infections also have synergistic effects with malnutrition (Guerrant, Oria, Moore, Oria and Lima. 2016). Studies have

shown how access to safe water, sanitation and adequate hygiene can predict child growth and malnutrition (Bomela, 2017).

Behavioral factors are important in determining the uptake and sustainable adoption of water, sanitation and hygiene technologies and practices. While water, sanitation and hygiene interventions are highly efficient, their effectiveness in part depends on behaviour change and context. The installation and functioning of water and sanitation facilities need to be accompanied by the transfer of knowledge on how to use them, together with sustainable behavior change. Maintenance and periodic replacement of existing services/facilities, and hygiene promotion are also necessary to achieve improvements (Gakidou, Oza, Vidal, Li, Lee and Sousa, 2017).

In Nigeria mostly in Imo State, the prevalence of safe hygiene practices is difficult to estimate but is likely to be even lower than that for water and sanitation (WHO, 2014).

WASH interventions are defined in line with water quantity or supply improvement is any intervention to provide any new or improved water supply or distribution system. This includes the installation of a new hand pump, a household connection to a piped water supply, or a rainwater harvesting technology (Clasen, 2010).

Sanitation is any intervention to provide or promote new or improved sanitation or expand and improve excreta disposal. This includes flush/pour flush toilets, pit

latrines, composting toilets, or connections to onsite (e.g. septic tanks) or off-site systems (e.g. sewerage) (Dangour, 2013).

Hygiene is any kind of intervention to initiate or promote further practice of handwashing with soap or other agents after defecation, after disposal of child faeces, and prior to preparing, eating and handling food. This includes interventions to promote changes in hygiene (group discussions, media campaigns, leaflets, songs, dramas, school initiatives), and interventions providing soap or other agents to improve hygiene and/or equipment to facilitate handwashing (e.g. handwashing stations) (Clasen, 2015).

Poor sanitation, water scarcity, inferior water quality and inappropriate hygiene behaviour are disastrous for children and young adults and are a major cause of mortality for children and young adult (UNICEF, 2015). This condition is also detrimental to the health of people, mostly those who spend long hours in a define institution outside their home.

1.2 Problem Statement

Water quality is a measure of its standards expressed in terms of physical, chemical and microbiological characteristics (Okereke, 2002)The quality of drinking water is a powerful environmental determinant of health (WHO, 2010). It determines its portability. Adequate supply of safe drinking water therefore is universally recognized as a basic human need and one of the most essential factors of civilization (Oyem, Oyem and Ezeweali, 2014).

According to WHO/UNICEF (2019) new joint report, billions of people around the world are continuing to suffer from poor access to water, sanitation and hygiene. Some 2.2 billion people around the world do not have safely managed drinking water services, 4.2 billion people do not have safely managed sanitation services, and 3 billion lack basic handwashing facilities. Lack of access to safe or potable drinking-water and basic sanitation, as well as poor hygiene cause nearly 90% of all deaths from enteric bacterial infections like E. coli, Salmonella, Shigella and Vibrio (WHO, 2009). It occurs most often in children and young adults between 5 and 19 years old (WHO, 2011). In 2013, it resulted in about 161,000 deaths – down from 181,000 in 1990 (Jackson, Iqbal, and Mahon, 2015). Infants, children, and adolescents in South-Central and Southeast Asia experienced the greatest burden of typhoid fever (Crump, Luby and Mintz, 2014). Outbreaks of typhoid fever are also frequently reported from sub-Saharan Africa and countries in Southeast Asia due to unsafe drinking-water and basic sanitation (Muyembe-Tamfum, Veyi, Kaswa, Lunguya, Verhaegen and Boelaert 2009; Baddam, Kumar, Thong, Ngoi, The, Yap, Chai, Avasthi and Ahmed, 2012).

In Nigeria, an estimated 11–20 million people get sick from typhoid and between 128,000 and 161,000 people die from it every year (WHO, 2018). Again, the recent cholera outbreak in Nigeria was recorded in 2018 with the Nigeria Centre for Disease Control (NCDC) reporting 42,466 suspected cases including 830 deaths with a case fatality rate of 1.95% from 20 out of 36 states, January to October 2018 (Nigeria Centre for Disease Control, 2018).

1.3 Objective of the Study

The aim of this study was to assess the quality of community drinking water, sanitation and hygiene practices and the occurrence of water-borne infections in Imo State, Nigeria.

The Specific Objectives of the Study are to:

1. Determine the level of awareness of WASH practices among the subjects in the study area.
2. Assess water supply and its use in the study communities.
3. Determine the level of sanitation practices of the study population.
4. Assess the hygiene practices of the communities.
5. Determine the microbial, on-site physico-chemical qualities of the water consumed, and the practice of open defecation in the community

1.8 Scope of the Study

The study was conducted in Imo State, Nigeria and was delineated to water, sanitation and hygiene and occurrence of water-borne enteric infections within the state. It cuts across the rural and urban areas of the state. It includes children, young and adults that are at risk of water-borne enteric infections due to poor WASH practices. The study further highlighted the availability, accessibility, functional sanitary facilities, quality and quantity of water supply, sanitation practices, and personal hygiene practice as the independent variables while the dependent variable of the study was prevalence ofwater-borne infections in relation to water, sanitation and hygiene.

1.4 Research Questions

i. What is the socio-demographic characteristics of the subjects in the study communities?

ii. What are the levels of awareness of WASH practices among the subjects in the study communities?

iii. What are the sources and nature of water supply and its uses in the study communities

iv. What are the sanitation and hygiene practices of the residents in the study communities of Imo State?

v. What is the on-site physico-chemical qualities and the microbial load of drinking water and the practice of open defecation in the study communities of Imo State?

vi. What is the association between WASH-related infections prevalence and the level of awareness of WASH, water supply and use, sanitation and hygiene practices among people in Imo State?

1.5 Research Hypotheses

$H0_1$: The level of awareness of WASH practices among the subjects in the study area has no relationship with WASH-related infections.

Ha_1: The level of awareness of WASH practices among the subjects in the study area has a relationship with WASH-related infections.

$H0_2$: The level of water supply and its use in the study area has no relationship with WASH-related infections.

Ha_2: The level of water supply and its use in the study area has a relationship with WASH-related infections.

$H0_3$: The level of sanitation and hygiene practices in the study area has no relationship with WASH-related infections.

Ha_3: The level of sanitation and hygiene practices in the study area has a relationship with WASH-related infections.

1.6 Justification of the Study

The provision of safe water, sanitation and hygiene (WASH) has been established to improve health, boost educational achievement, and promote gender equity which has a positive impact on society. However, in previous studies conducted, with public places as the focus group, it was discovered that peoples` knowledge and perceptions about the importance of WASH are very low. Moreover, there is wide disparity between the WASH programs being instituted at public facilities, thus making it difficult to impress the importance of this program among people. In addition, the enlightenment on the need for regular practices concerning WASH is not entrenched in the people. Therefore, the findings in this research work will enable Policy makers, Ministry of budget and Planning, State, Local Government, NGOs and other Stakeholders expend required energy to curb the threat.

1.7 Significance of the Study

i. This study showed the level of water, sanitation, hygiene (WASH) practices among residents in different communities in Imo State.

ii. The mortality and morbidity data for prevalence of enteric bacterial infections can be used to assess the level of health status of people in the state.

iii. This study also provides a baseline data for governmental and non-governmental agencies to make appropriate budgeting and shape policies that are related to WASH to prevent WASH-related infections among rresidents in Imo State, Nigeria.

iv. The information got from this study can be used to provide the basis for future projections and evaluations of different control strategies.

vi. The study suggested an important role for each intervention in the reduction of enteric (bacterial) infections and notes the health benefits resulting from the reduction of the infections that relate to improvements in water, sanitation and hygiene.

vii. Information from this study helps to establish enteric (bacterial) infections trends for different social, economic and geographical environments within the state.

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CHAPTER TWO

2.0 LITERATURE REVIEW

Concept of Water, Sanitation and Hygiene (WASH)

The concept of WASH as abbreviation of water, sanitation, and hygiene was deemed important because of the impact of deficiencies in each area because they overlap strongly. Addressing these deficiencies together can achieve a strong positive impact on public health. The term "water" in the acronym WASH is generally understood to refer to water supply only, not for example, to integrate water resources management (IWRM) or water resource management in agriculture. WASH continues to be a development priority at the United Nations (UN) and United Nations Children's Fund (UNICEF).

One component of the Sustainable Development Goals is clean water and sanitation (United Nations, 2017). This includes several sub-components, including water quality, sanitation and hygiene, and access to drinking water. UNICEF's declared strategy is "to achieve universal and equitable access to safe and affordable drinking water for all" (UNICEF, 2016).

The UN's Millennium Development Goals included improvement of WASH services in Target 7.C: "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation' (UN, 2015). This has been replaced by the Sustainable Development Goals, where Target 6 aims to "ensure availability and sustainable management of water and sanitation for all"(UNDP, 2015).

Universal, affordable and sustainable access to WASH is a key public health issue within international development and is the focus of Sustainable Development Goal 6 (UNICEF, 2010). Several international development agencies assert that attention to WASH can also improve health, life expectancy, student learning, gender equality, and other important issues of international development (Kooy and Harris, 2012). Access to WASH, in particular safe water, adequate sanitation, and proper hygiene education, can reduce illness and death, and also affect poverty reduction and socio-economic development.

Lack of sanitation contributes to about 700,000 child deaths every year due to diarrhea, mainly in developing countries. Chronic diarrhea has long-term negative effects on children, in terms of both physical and cognitive development (Bill and Melinda Gates Foundation, 2015). In addition, lack of WASH facilities can prevent students from attending school, impose an unusual burden on women and reduce work productivity (UNICEF, 2010).

According to WHO/UNICEF (2019) new joint report, billions of people around the world are continuing to suffer from poor access to water, sanitation and hygiene. Some 2.2 billion people around the world do not have safely managed drinking water services, 4.2 billion people do not have safely managed sanitation services, and 3 billion lack basic handwashing facilities and 673 million people still practice open defecation. Water quality is a measure of its standards expressed in terms of physical, chemical and microbiological characteristics (Okereke, 2002) The quality of drinking water is a powerful environmental

determinant of health (WHO, 2010). It determines its portability. Adequate supply of safe drinking water therefore is universally recognized as a basic human need and one of the most essential factors of civilization (Oyem, Oyem and Ezeweali, 2014).

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2.1.1 Awareness of WASH to People

The provision of safe water, sanitation and hygiene (WASH) has been established to improve health, boost educational achievement, and promote gender equity which has a positive impact on society. However, in previous studies conducted, with public places as the focus group, it was discovered that peoples` knowledge and perceptions about the importance of WASH are very low. Moreover, there is wide disparity between the WASH programs being instituted at public facilities,

thus making it difficult to impress the importance of this program among people (UNDP, 2015).

The majority of the people do not have washing facilities not to talk of soap to clean hands after using the toilets. Many of the public places have overshot their enrollment capacity and this puts much pressure on the limited sanitation facility of which the consequence is having more than 200 people per drop-hole (WHO, 2014). In addition, the enlightenment on the need for regular practices concerning WASH is not entrenched in the people. This can be improved by the availability of information, education and communication (IEC) materials or posters that incorporate WASH knowledge and practices in both the public stays like offices.

2.1.2 Linkages between Water, Sanitation and Hygiene (WASH) and Sustainable Development Goals (SDGs)

The Sustainable Development Agenda is the product of the combination of two international agenda, the momentum initiated by the Millennium Development Goals and various sustainable development processes. The SDGs are thus replacing the Millennium Development Goals (MDGs) and have been developed based on the lessons learned from the MDGs and in line with sustainable development principles, which recognize the inter-dependence of social, environmental and economic factors (WHO, 2014).

According to John et al (2009), diseases related to inadequate water, sanitation and hygiene remains a huge burden in developing countries such as Nigeria. It is

estimated that about 88% of diarrheal diseases are caused by unsafe water supply and inadequate sanitation and hygiene (WHO, 2014). Many communities in Nigeria record high prevalence of diseases related to inadequate water supply, sanitation and hygiene.

At the different community levels, places like schools in rural areas, which often lack drinking water, sanitation and hand washing facilities; alternatively, where such facilities exist, they are often inadequate in both quality and quantity. Schools with poor WASH conditions, and strong levels of person-to-person contact, are high risk environment for both children and adults. This may expose children who are susceptible to environmental hazards. Children's ability to learn may be grossly affected by inadequate water, sanitation and hygiene conditions in several ways. These include but not limited to helminthic infections which affects hundreds of millions of school age children, long term exposure to chemical contaminants in water such as lead, arsenic, mercury etc., also diarrheal diseases and malaria infections.

All these forces many school children to be absent from schools hence giving rise to school absenteeism and which may affect the cognitive ability of the child and hence leading to poor academic performance and outcome. Subsequently in the long run led to poverty, unhealthy lives, poor economic growth, inability to manage and sustain infrastructures and resources, inequality among countries and the opposite of all the goals that the SDG targets to achieve by 2030 (WHO, 2014).

To ensure availability and sustainable management of water and sanitation for all SDG 6 focuses on water-related issues. It consists of eight specific targets: including six on water and sanitation-related outcomes (targets 6.1 to 6.6), and two on implementing the outcome targets (targets 6.a and 6.b), as shown in the table.

Table 1: Linkages between Water, Sanitation and Hygiene (WASH) and Sustainable Development Goals (SDGs)

Targets	Indicators
Target 6.1 – By 2030, achieve universal and equitable access to safe and affordable drinking water for all	Indicator 6.1.1 – Proportion of population using safely managed drinking water services
Target 6.2 – By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	Indicator 6.2.1 – Proportion of population using safely managed sanitation services, including a handwashing facility with soap and water
Target 6.3 – By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Indicator 6.3.1 – Proportion of wastewater safely treated Indicator 6.3.2 – Proportion of bodies of water with good ambient water quality
Target 6.4 – By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Indicator 6.4.1 – Change in water-use efficiency over time Indicator 6.4.2 – Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
Target 6.5 – By 2030, implement integrated water resources management at all levels, including through trans-boundary cooperation as appropriate	Indicator 6.5.1 – Degree of integrated water resources management implementation Indicator 6.5.2 – Proportion of transboundary area with an operational arrangement for water cooperation
Target 6.6 – By 2030, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Indicator 6.6.1 – Change in the extent of water-related ecosystems over time
Target 6.a – By 2030, expand international cooperation and capacity building support to developing countries in water- and sanitation-related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	Indicator 6.a.1 – Amount of water and sanitation-related official development assistance that is part of a government coordinated spending plan
Target 6.b – Support and strengthen the participation of local communities in improving water and sanitation management	Indicator 6.b.1 – Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management

Source: WHO/UNICEF (2014)

2.2 Water Supply and its Utilization and Sanitation

Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water, there would be no life on earth. It is most important that the water which people drink and use for other purposes is clean water. This means that the water must be potable water (free from disease-causing organisms and chemicals). Disease-causing organisms and chemicals can find their way into water supplies and when this happens the water becomes polluted or contaminated thus leading to various diseases to those that come in contact with it. The benefits of having access to an improved drinking water source can only be fully realized when there is also access to improved sanitation and adherence to good hygiene practices (WHO/UNICEF, 2014).

Water supply means the provision by public utilities, commercial organizations, community endeavors or by individuals of water, usually by a system of pumps and pipes. A recent study by the United Nation Children's Fund (UNICEF) says only two (2) out of every ten (10) schools in Nigeria have basic water supply and functioning sanitary services **(**John, Teague and Graham, 2009**).** Water being a key natural resource as mutually agreed by the humanity, is therefore needed in good quality and quantity. An adequate supply of clean water is a prerequisite for sustaining human life, maintaining ecological systems and for achieving sustainable development (UNICEF, 2011).

For a large percentage of the world's population, drinking water supplies and sanitation services are neither safe nor adequate. Currently, over 1000 million

people do not have access to an adequate supply of safe water for household consumption and nearly 3000 million lack a sanitary means of excreta disposal. The provision of safe water and the management of wastewater have had a central role in reducing the incidence of many waterborne or water-related communicable diseases (UNICEF, 2014).

One of the major achievements of the past 150 years is the extent to which diseases associated with water have become of minor significance in the mortality and morbidity statistics of most developed countries and of some developing countries (especially for richer groups living in major cities). The diseases associated with contaminated water, however, remain serious public health problems for most of the world's population. At the same time, water shortages in many countries are now imposing serious constraints on municipal and community development, as well as on the expansion of food production and the growth of industry. Countries with relatively low per capita levels of available freshwater are finding it difficult to meet the increasing demands for fresh water from expanding populations and the growing demands from agriculture and industry (Esrey, Potash, Roberts, and Shiff, 2011).

2.2.1 Sources of Water Supply

Water supply can be derived from three major sources. The sources are.

Surface Water Supply: Surface water supply is derived from waters that are found on earth’s surface. They include ponds, brooks, streams, rivers, sea and

ocean (Oreyomi, 2005). In Nigeria, most communities depend on surface water as it is their major source of water supply.

Underground Water Supply: Springs Spring is the natural outflow of subsurface or underground water at the earth's surface. It is also called outcropping of the water table. Spring is commonly found on the slopes of hillsides and river valleys as water holes. As a gift of nature, spring can be tapped to complement the water requirements of a household and small community but cannot meet the demand of a big town. This is because some springs are seasonal, and this makes the water yield to be very small and erratic.

The water yield of a spring depends on the position of the water table and can be soft, hard, pure or impure. To drive this point home, spring water derived from shallow spring is open to many abuses and contamination and therefore must be disinfected before consumption. However, water derived from deep seated spring is of good quality and can be consumed with little or no treatment (Oreyomi, 2005).

Wells

(a) Shallow wells: Shallow wells are dug to tap water from the first pervious strata or layers without meeting any impervious strata below water table. The depth of shallow wells are not more than 3m deep and are dug manually. As the name denotes, they are shallow and hence not suitable for adequate water supply because they yield small quantity of water and are seasonal in nature.

They dry up during the dry season. The shallow wells are open to pollution and contamination due to surface wash and other contaminants.

(b) Deep Wells: Deep wells are wells dug to tap water from the water bearing strata that are enclosed between two impervious layers. They are usually more than 30m in depth. The yield of water from this type of well is large and reliable because it is not affected by fluctuation in water level. The water supply from this source is of good quality because much of the pollution is removed due to the time it takes to travel or percolate down to the second aquifers stratum.

(c) Artesian Wells: The digging of hole into the ground to the middle of an aquifer enclosed between two impervious strata making cup shape. The water usually comes out from the well in form of fountain with force (Oreyomi, 2005).

Precipitation: Precipitation (rain, snow, hail, dew, etc.) is the primary source of surface water. Rain is the condensed and vaporized moisture of the atmosphere falling in separate drops. Other forms of rain under this category include hail, ice, snow, dew, mist, etc. Rainwater is soft and remains the purest water that occurs in nature when it is collected or harvested under hygienic conditions. Historically, the use of rainwater as a source of water supply dates back to 4,000 years ago in the Mediterranean region. Equally, ancient Roman villages and cities were

planned to take advantage of rainwater for domestic purposes many centuries ago (Oreyomi, 2005).

2.3 Prevalence of WASH-Related Infections

2.3.1 Water-Borne Infections: Water-borne infections pose very serious threats to society because of their potential to infect large numbers of individuals over a very short time. The common water-borne infections are all incapacitating; many have high rates of death for untreated victims, and are particularly difficult problems for children, the elderly and those with challenged immune system. Water-borne or water related infections encompass illnesses resulting from both direct and indirect exposure to water, whether by consumption or by skin exposure during bathing or recreational water use (Nwabor, Nnamonu, Martins and Ani, 2016). Testing water for each of the possible pathogens, including viruses, protozoans, and worms is impractical. Early in the development of sanitary practice the need for indicators of human contamination was perceived. It includes disease due to water-associated pathogens and toxic substances. A broader definition includes illness related to water shortage or water contamination during adverse climate events, such as floods and droughts, and diseases related to vectors with part of their life cycle in water habitats (Satnwell-Smith, 2010).

Water-related disease is defined as any significant or widespread adverse effects on human health, such as death, disability, illness or disorders, caused directly or

indirectly by the condition, or changes in the quantity or quality of any water. The causes of water related disease include microorganisms, parasites, toxins and chemical contamination of water. Other terms include ‘waterborne disease’, which implies direct spread and is used mainly to refer to disease caused by microbiological pathogens or chemical contaminants in water (Gwatkin and Guillot, 2010).

Water associated disease covers the wide range of diseases in which water plays apart, such as legionnaires’ disease, as well as diseases related to lack of water for washing and hygiene. The advantage of the term water related disease is that it includes both water-borne and water associated with ill health, although diseases with an indirect association and another major mode of spread are usually excluded from specific surveillance systems. Basically, water-borne diseases can be transmitted through four main routes: Water-borne route, Water-washed route, Water-based route and Insect vector route or water related route.

Water-related disease has also been defined as, “any significant adverse effect on human health, such as death, disability, illness or disorders, caused directly or indirectly by the condition or changes in the quantity or quality of any water” (**Alexandra et al., 2016**). Water-borne diseases are those diseases that are transmitted through the direct drinking of water contaminated with pathogenic microorganisms. This report focuses on the infectious diseases that result from exposure to contaminated water (including drinking-water, wastewater and recreational water) through ingestion, dermal contact or inhalation pathways as

well as vector-borne diseases in which transmission is associated with water and sanitation conditions (e.g. fly- and mosquito-borne diseases, diseases transmitted through flood waters). This report contains information on infections that can be water related. Other exposure pathways may still be possible as transmission routes for outbreaks and sporadic cases are not always identified and/ or reported. Contaminated drinking water when used in the preparation of food can be the source of food-borne infection through consumption of the same microorganisms. Most water-borne infections are characterized by diarrhea, which involves excessive stooling, often resulting to dehydration and possibly death (Nwabor, Nnamonu, Martins and Ani, 2015). According to the World Health Organization, diarrheal disease accounts for an estimated 4.1% of the total daily global burden of disease and is responsible for the deaths of 1.8 million people every year. Further estimates suggest that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene and is mostly concentrated on children in developing countries (WHO/UNICEF, 2010; WHO, 2005; Pruss-Ustun, Bos, Gore and Bartram., 2008). Most water-borne infections are often transmitted via the fecal-oral route and this occurs when human fecal material is ingested through drinking contaminated water or eating contaminated food which mainly arises from poor sewage management and improper sanitation.

Fecal pollution of drinking-water may be sporadic, and the degree of fecal contamination may be low or fluctuate widely. In communities where contamination levels are low, supplies may not carry life-threatening risks and

the population may have used the same source from time immemorial. However, where contamination levels are high, consumers (especially the visitors, the very young, the old and those suffering from immunodeficiency-related diseases) may be at a significant risk of infection.

In rural African regions, fecal contamination of water arises from runoffs from nearby bushes and forest which serve as defecation sites for rural dwellers. Water-borne infections can be caused by protozoa, viruses, bacteria, and intestinal parasites. Some of the organisms remarkable for their role in the outbreak of water-borne disease include Cholera, Amoebic dysentery, Bacillary dysentery (shigellosis), Cryptosporidiosis, Typhoid, Giardiasis, Paratyphoid, Balantidiasis, Salmonellosis, *Campylobacter* enteritis, Rotavirus diarrhea, *E. coli* diarrhea, Hepatitis A, Leptospirosis and Poliomyelitis (Cheesbrough, 2006).

2.3.2 Water-Washed Diseases: Water-washed or water scarce diseases are those diseases which thrive in conditions with freshwater scarcity and poor sanitation. Control of water-washed diseases depends more on the quantity of water than the quality (UNICEF, 2008). Examples of water-washed diseases include Scabies, Typhus, Yaws, Relapsing fever, Impetigo, Trachoma, Conjunctivitis and Skin ulcers. Four types of water-washed diseases are considered here: soil-transmitted helminths, acute respiratory infections (ARI), skin and eye diseases, and diseases caused by fleas, lice, mites or ticks. For all of

these reasons, washing and improved personal hygiene play an important role in preventing disease transmission (UNICEF, 2008; UNICEF, 2015).

2.3.2.1 Soil-Transmitted Helminths (geohelminths): Helminths are intestinal worms (nematodes) that are transmitted primarily through contact with contaminated soil. The most prevalent helminths are ascaris (*Ascaris lumbricoides*), hookworm (*Ancylostoma duodenale* and *Necator americanus*) and whipworm (*Trichuris trichuria*) (Nwabor, Nnamonu, Martins and Ani, 2015). Together, these 'geohelminths' currently infect about one-quarter to one-third of the world's population (UNICEF, 2008; UNICEF, 2015). Over 130 million children suffer from high intensity geohelminth infections; helminths cause about 12,000 deaths each year (WHO, 2002). These diseases can be considered water washed. Improved hygiene and sanitation can reduce their incidence. Mass de-worming of children is also recognized as an effective control measure (UNICEF, 2008; UNICEF, 2015).

2.3.2.2 Acute Respiratory Infections: Acute respiratory infections (ARI) including pneumonia are responsible for approximately19% of total child deaths every year (UNICEF, 2008). Evidence demonstrating that good hygiene practices, especially handwashing with soap, can significantly reduce the transmission of ARIs. In view of the link between ARI and hygiene, it can now be considered a water washed disease (Luby, 2005; Cairncross, 2010; 2003).

2.3.2.3 Skin and Eye Diseases: United Nations Children's Fund 2008 posits that trachoma is the world's leading cause of preventable blindness. About 6 million people are blind due to trachoma and more than 10% of the world's population is at risk. Globally, the disease results in an estimated $2.9 billion in lost productivity each year (UNICEF, 2015). In the US, trachoma is caused by the *Chlamydia trachomatis* bacteria which inflame the eye. After years of repeated infections, the inside of the eyelids may be scarred so severely that the eyelid turns inwards with eyelashes rubbing on the eyeball. Flies are implicated in the transmission of trachoma and are often seen feeding on the discharge from infected eyes. The best control method for trachoma and conjunctivitis is improved access to water for face washing. Ringworm (tinea) is also water washed disease prevalent among children of school age and the aged. This infectious disease affects the skin, scalp and keratinized tissues and is caused by a fungus (United Nations Children's Fund, 2008).

2.3.3 Water-Based Diseases: Water-based diseases are infections caused by parasitic pathogens found in aquatic host organisms. These host organisms include snails, fish, or other aquatic animals. Humans become infected by ingesting the infective forms or through skin penetration. Examples of water-based diseases includes Schistosomiasis (cercariae released from snail, penetrate skin), Dracunculiasis (larvae ingested in crustacean), Paragonimiasis (*metacercaria* ingested in crabor crayfish) and *Clonorchiasis* (*metacercaria*

ingested in fish). These diseases can be prevented through avoiding contact with contaminated water, or use of protective clothing or barrier creams.

2.3.4 Insect Vector-Based Diseases or Water Related Diseases

These diseases are not directly related to drinking water quality. They are those diseases that are caused by insect vectors which breed in or around water bodies. Humans become infected by being bitten by these insect vectors (UNICEF, 2008). However, consideration of vector control during the design, construction and operation of surface water reservoirs and canals (for drinking water or irrigation purposes) can reduce the potential for water related disease transmission. Prevalence of water related diseases are high in tropical Africa as a result of poor environmental management and sanitation.

Drainages are often waterlogged, hence constituting breeding sites for these insect vectors. Malaria is one of the water-related diseases endemic in 117 countries with about 3.2 billion people living in risk areas all over the world (UNICEF, 2015). The report further stated that there are about 350 to 500 million clinical cases of malaria worldwide each year with over 1million deaths. About 59% of all clinical cases occur in Africa, 38% in Asia, and 3% in the Americas. The most common vector insects are mosquitoes and flies. Mosquito-borne diseases are malaria, yellow fever, dengue fever, filariasis and fly-borne diseases are Onchocerciasis (River-blindness) and Loasis. According to Guillot and Loret

(2010), they classified water related diseases into different sub-categories including fresh water and marine waters.

Table 2: Sub-categories of water-related diseases

Category	Description of category	Type of Water exposure	Subcategories	Examples
Waterborne microbiological disease	Diseases related to consumption of pathogens consumed in water; most due to human or animal fecal contamination of water	Drinking Water	(i) Treated or untreated (raw) water (ii) Public (municipal) supplies or private supplies	Cholera, Typhoid fever, viral gastroenteritis e.g. due to Norovirus
Waterborne chemical disease	Diseases related to consumption of chemicals consumed in water; most due to industrial and agricultural contamination of water	Any water used for washing/ personal hygiene	(i) Treated or untreated (raw) water (ii) Public (municipal) supplies or private supplies	Arsenicosis
Water hygiene Diseases	Diseases whose incidence, prevalence or severity can be reduced by using safe (clean) water to improve personal and domestic hygiene	Recreational Water	i) Disease related to variations in water quality (ii) Disease related to water shortage	Scabies, shigellosis; trachoma
Water contact Diseases	Caused by skin contact with pathogen infested water or with chemical contaminated water	Untreated freshwater sources	fresh water sources (ii) marine waters	Schistosomiasis (bilharzia); cyanobacteria
Water vector habitat diseases	Diseases where vector lives all or part of its life in or adjacent to a water habit	Drinking water and untreated water sources	(i) rivers, streams (ii) small collections of stagnant water e.g. water butt	Malaria (mosquitoes); filiariasis (mosquitoes); onchocerciasis (aquatic flies); schistosomiasis (snails); trypanosomiasis (tsetse flies)

Excreta disposal Diseases	Diseases related to unsanitary disposal of human waste (feces and urine)	Drinking or raw water sources	(i) diseases related to human/animal waste in drinking water (ii) diseases related to direct/ indirect contact with feces/ urine	Ascariasis; fecal-oral infections e.g. shigellosis; schistosomiasis; trachoma
Water aerosol Diseases	Diseases related to respiratory transmission, where a water aerosol containing suspended pathogens enters airway	Drinking or raw water sources	(i) water used in industrial/ residential buildings (ii) raw water sources	Legionellosis (legionnaires' disease; humidifier fever); Norwalk-like viral gastroenteritis

Source: Guillot and Loret (2010)

Most fecal–oral infections are transmitted on hands and during food preparation, rather than through drinking contaminated water directly. There are major routes of diseases transmission, which can include the following:

(i) Transmission via fingers and hands, contaminated by feces through unwashed hands.

(ii) Fecal contaminated food, which has been prepared by unwashed hands or grown in contaminated soil (Moe & Rheingans, 2006).

(iii) Through flies,

(iv) Through fluids. This is mainly water pathogenically contaminated at source or during collection, transportation or storage.

(v) Through fields, people working in fields, or children playing where pathogens are present

2.4 Diseases Associated with Poor Water Sanitation

Eade and Williams (2005) emphasized that sanitation is vital in primary health care. They went further to state that over 25 million people die every year from diseases related to inadequate and poor sanitation. The most common diseases associated with poor sanitation are diarrhea and dysentery, typhoid, bilharzia, malaria, cholera, worms, eye infection and skin diseases. Contaminated water and poor hygiene are the major causes of diarrheal diseases, the most common group of communicable diseases, highly prevalent among poor people living in crowded conditions with inadequate facilities (Blackett, 2011). According to UNICEF (2005) the following diseases are caused by inadequate water supply. They include:

2.4.1 Arsenicosis: Long-term exposure to concentrations of arsenic even in small doses in drinking-water cause painful skin keratosis (hardened lesions) and can result in cancers of the skin, lungs, bladder and kidney. Millions of people are potentially in danger from arsenic poisoning since they rely on water supplies that are contaminated with arsenic (mainly from natural sources) and do not have a safe water alternative or are unaware of the risks.

2.4.2 Cholera: Cholera is an acute bacterial infection of the intestinal tract. It causes severe attacks of diarrhea that, without treatment, can quickly lead to acute dehydration and death. Cholera is a world-wide problem, especially in emergency situations. It can be prevented by access to safe drinking water, sanitation and

good hygiene behavior (including food hygiene). In 2002, over 120,000 cholera cases were reported worldwide.

2.4.3 Fluorosis: Fluorosis is a serious water bone disease caused by high concentrations of fluoride occurring naturally in groundwater. Fluorosis is endemic in at least 25 countries across the globe. The total number of people affected is not known, but a conservative estimate would number in the tens of millions (WHO, 2013).

2.4.4 Intestinal Worms: People become infected with intestinal parasitic worms (also known as Helminthes) through contact with soil that has been contaminated with human feces from an infected person, or by eating contaminated food. Intestinal worms infect about 10 per cent of the population in the developing world and, depending upon the severity of the infection, lead to malnutrition, anemia or retarded growth. In fact, roundworm and whipworm alone are estimated to affect one-quarter of the world's population.

2.4.5 Malaria: Malaria is a serious disease caused by a parasite carried by certain types of mosquitoes. Humans are infected when bitten by the mosquitoes. Each year, there are 300 million to 500 million cases of malaria throughout the world. Reducing the mosquito population in households and communities by eliminating standing water (caused by poor drainage and uncovered water tanks) can be an important factor in reducing malaria cases.

2.4.6 Trachoma: Trachoma is an eye infection spread mainly through poor hygiene caused by lack of adequate water supplies and unsafe environmental

sanitation conditions. About 6 million people are blind today because of trachoma. It affects women two to three times more than men. Children are also especially susceptible. Studies have found that providing adequate water supplies could reduce infection rates by 25 per cent.

2.4.7 Typhoid: Typhoid fever is a bacterial infection caused by ingesting contaminated food or water. Symptoms are characterized by headaches, nausea and loss of appetite. About 12 million people are affected by typhoid every year.

2.5 Control of Vector-Borne Diseases

The density of vectors in a community should be minimized by clearing the surrounding bushes and drainages.

Doors and windows should be screened at homes and other institutions like schools, hospitals, hotels etc.

School children and staff should be protected from potentially disease-transmitting vectors.

2.5.1 Cleaning and Waste Disposal: Classrooms and other teaching areas are regularly cleaned, to minimize dust and molds.

i. Outside and inside areas are maintained free of sharp objects and other physical hazards.
ii. Solid waste is collected from classrooms, kitchens and offices daily and is disposed of safely.
iii. Wastewater is disposed of quickly and safely.

Table 3: Diseases related to water and sanitation endemic in Sub-Saharan Africa

Group	Disease	Route leaving host	Route of infection
Disease which are often water-borne	Cholera,	Faeces	Oral
	Typhoid,	Faeces/urine	Oral
	Infectious hepatitis,	Faeces	Oral
	Giardiasis, Amoebiasis	Faeces	Oral
	Dracunculiasis	Cutaneous	Oral
Diseases which are often associated with poor hygiene	Bacillary dysentery	Faeces	Oral
	Enteroviral diarrhea	Faeces	Oral
	Malaria, Paratyphoid fever	Anal Faeces	Oral/bite
	Pinworm (Enterobius)	Cutaneou	Oral
	Amoebiasis	Bite	Oral
	Scabies Skin,	Cutaneous	Cutaneous
	Sepsis,		
	Lice and typhus, Trachoma,	Cutaneous	Cutaneous/bite
	Conjunctivitis	Faecal	Cutaneous Oral
Diseases which are often related to inadequate sanitation	Ascariasis	Faecal	Oral
	Trichuriasis		
	Hookworm (*Ancylostoma/Necator*)		
Diseases with part of life cycle of parasite in water	Schistosomiasis	Urine/faeces	Percutaneous
Diseases with vectors passing part of their life cycle in water	Dracunculiasis	Cutaneous	Oral

Source: ***Nwabor, Nnamonu, Martins and Ani, (2016)***

2.5.2 Water Quality and Diarrhea

The prevalence of contamination from man-made pollution and waste to naturally occurring toxins and the wide range of ways contaminated water can enter the human body are staggering. Everyday people are put at risk through drinking contaminated water, eating food prepared in bowls or with utensils washed with contaminated water, through poor personal hygiene, bathing and washing in unhygienic water (Clasen, Schmidt, Rabie, Roberts and Cairncross, 2007). Over

3 million people die each year nearly all from developing countries with 80% of the total disease burden coming from the poor countries (WHO, 2007). It is estimated that up to half of all hospital beds in the world are occupied by victims of water contamination.

The biggest killer is diarrhea contracted from micro-organisms in water contamination by sewage resulting in 1.8million child deaths per year. In places like Sub-Saharan Africa and South Asia, up to half of all cases of malnutrition are caused by diarrhea. Various studies and outbreak incidences have found an association between poor water quality and diarrhea (WHO/UNICEF, 2010).

2.5.3 Sanitation Practices in Community levels

Sanitation is one of the greatest problems facing developing countries due to inadequate facilities, poor funding, and poor implementation of policies as well as wrong lifestyle (Cairncross *et al*., 2010). Sanitation is vital to health, and it generates economic benefits and contributes to the dignity and social development of any nation. Sanitation is the promotion of hygiene and prevention of disease through the provision and access to safe water and adequate sanitation facilities, and good individual hygiene practices.

Traditionally, sanitation is the provision of facilities and services for the safe disposal of human urine and feces (UNICEF/WHO, 2012). It is also referred to as the maintenance of hygienic condition through services such as garbage collection and wastewater disposal (WHO, 2015). The key to man's health lies

largely in his environment as in its modern concept; environment includes not only water, air and soil but also the social and economic condition under which people live (Park, 2011). Sanitation also refers to a set of necessary measures taken to improve and protect the health and well-being of the people.

The word 'sanitation' can be applied to the immediate living place and to an entire environment. When applied to an environment it is termed environmental sanitation, which is defined by the Federal Ministry of Environment (2005) as "The principles and practice of effecting healthful and hygienic conditions in the environment to promote public health and welfare, improve quality of life, reduce poverty and ensure a sustainable environment". This definition indeed is quite appropriate within the parlance of this discuss, as it sees environmental sanitation as improvement in hygienic conditions directed not only to the improvement of health and welfare but also productivity i.e., reduction in poverty and ensuring sustainable development (Alabi, 2010)

Environmental Sanitation is the control of all factors in man's physical environment that exercise or may exercise a deleterious effect on his physical development, health and survival (WHO, 2010). According to the National Sanitation Foundation of USA, the word sanitation is defined as "a way of life, a quality of living that is expressed in the clean home, farm, business, neighborhoods and community (Park, 2011).

Sanitation is an important aspect of public health that is poorly addressed in developing nations. The number of people without improved sanitation facilities

globally stands at 2.6 billion, and of these 533million is in sub-Sahara Africa (WHO/UNICEF, 2010). Sanitation related diseases debilitate and kill one million Africans every year (Alabi, 2010) and more than 2.4 billion people in the world currently lack access to adequate sanitation and are forced to dispose-off their excreta in unimproved and unsanitary conditions. Those who suffer from this, lack most basic human needs and also tend to be victims of poverty, ill health and an overall poor quality of life (WHO, 2013).

In several parts of the developing world sanitation lags in all infrastructure development. In Sub-Saharan Africa 66% of the population had no access to basic sanitation services in 2008 (WHO/UNICEF, 2010). In developing country like Nigeria, the main diseases of the environment are diarrheal disease, lower respiratory infections, unintentional injuries and malaria. In children under the age of five, one third of all disease is caused by the environmental factors such as water and air pollution (WHO, 2010). One of the most significant diseases that arise from poor sanitation is diarrhea. Deaths resulting from diarrhea are estimated to be between 1.6 and 2.5 million every year (WHO, 2012) and National records show that every year, about six hundred thousand (600,000) episodes of diarrhea occur in children under the age of five (Alabi,2010).

Similarly, there have been increasing number of cases of cholera over the years from January to December 2010; Nigeria reported 41,787 cases including 1,716 deaths from 222 Local Government Areas (LGAs) in 18 states of the country. In addition to the disease burden, Nigeria loses about N455 billion annually which

is equivalent to1.3% of gross domestic product (GDP), due to poor sanitation as reported by water and sanitation program of the World Bank. Most of the affected are young children below the ages of five. Other diseases that are caused by poor sanitation include schistosomiasis, trachoma, soil transmitted helminthiasis, and malaria (WHO, 2013).

2.5.4 Sanitation and Diarrhea Diseases

The health consequences of inadequate water and sanitation services include an estimated 4 billion cases of diarrhea and 1.9 million deaths each year, mostly among young children in developing countries (Waterwiki, 2010). Diarrhea diseases lead to decreased food intake and nutrient absorption, malnutrition, reduced resistance to infection and impaired physical growth and cognitive development. Water and sanitation interventions to reduce diarrhea disease incidence in developing countries fall into four general categories: Water provision, household water treatment, hand washing promotion and sanitation. Each of these interventions is proven to reduce diarrheal disease incidence.

Survey by the Department of Physical and Health Knowledge and Practice among secondary school children in Zaria, Nigeria; observed that poor knowledge and practice of personal health and environmental health increased prevalence of diarrhea among children of school age (Ingrid, 2008). Organizations are often faced with the difficult decision of where to focus limited resources to improve water and sanitation conditions. Selecting the most appropriate interventions for

a specific location depends on existing water and sanitation conditions, cultural acceptability, hydrology and water quality, implementation, feasibility and local conditions (Waterwiki, 2010). According to WHO Health related MDG's 4 and 7, countries were to reduce child mortality rate and also ensure environmental sustainability by the year 2015.

Currently, 1.1 billion people worldwide lack access to safe water supplies which include household connections, public standpipes, bore-holes and protected dug wells, protected springs and rainwater collection (UNICEF, 2006). According to a report by WHO/UNICEF, (2008) on global statistics on children, water and hygiene, water supply, sanitation and diarrhea are closely related. Poor hygiene, inadequate quantities and quality of drinking water and lack of sanitation facilities cause millions of the world's poorest people to die from preventable diseases each year. Women and children are the main victims. The link between water, sanitation and diarrhea includes: - Contaminated water that is consumed and may result in waterborne diseases including viral hepatitis, typhoid, cholera, dysentery and other diseases that cause diarrhea. Without adequate quantities of water for proper hygiene, skin and eye infections, for example trachoma spread easily (UNICEF, 2006). In some areas like Turkana, the prevalence rate is 42% (AMREF, 2011).

Inadequate water, sanitation and hygiene account for a large part of the burden of illness and health in developing countries. Approximately 4 billion cases of diarrhea per year cause 2.2 million deaths, most of them children under the age

of five with about 15% of deaths in developing countries. Diarrheal diseases account for 4.3% of the total global burden (62.5 million DALYS). An estimated 88% of this burden is attributable to unsafe drinking water supply, inadequate sanitation and poor hygiene. These risk factors are second after malnutrition, in contributing to the burden of the disease. Improving global access to clean water and sanitation is one of the least expensive and most effective means to improve public health and save lives. The concept of clean water and sanitation as essential to health is not a novel idea. Hippocrates in 350 B.C is quoted to have recommended boiling of water to inactivate impurities.

A proceeding from the royal society of London on appropriate technologies for environmental health on water, sanitation and diarrhea observes that in the developed countries where water and sanitation services are nearly universal, hygiene-related diseases have been significantly reduced. This has been through the protection of water sources and installing sewerage systems. This, however, is not the case in developing countries and as a result, millions suffer and die from preventable illnesses including diarrhea every year. The solution lies on integrating public health into engineering problem solving. The paper recommends partnerships with local communities to implement water and sanitation solutions that consider environmental, cultural and economic conditions (UNICEF, 2006).

2**.6.3 Areas of Focus in Community Sanitation** The areas of focus include:

2.6.3.1 Sanitation Science and Technology: Sanitation Science and Technology are designed process to help develop and bring to scale innovative approaches to dealing with human waste that are affordable, safe, sustainable and centered on the needs of the user. The re-invent the toilet challenge (RTTC) is a key part of this effort because it encourages the development of waterless, hygienic toilets that do not require piped water or a sewer connection. The goal is to develop clean, safe, durable, and affordable toilets for the poor that cost less than five cents per user, per day and do not need to be connected to a sewer. Also, to create a latrine that would decompose once the pits are filled, allowing for the eventual conversion of the land into farming and other uses (UNICEF, 2010).

2.6.3.2 Delivery Models at Scale: This initiative supports the wide-scale implementation of an effective approach to rural sanitation that can end open defecation and upgrade unsafe latrines. The core of this approach involves stimulating both demand for, and supply of, improved sanitation in rural communities. Achieving a high rate of adoption, and sustaining it over time, will require a deeper understanding of what people want, what they will keep using, and the policies and practices needed to support those changes at scale (UNICEF, 2014). The emerging consensus in the sanitation field suggests that community-led sanitation approaches are effective at reducing unsanitary practices and achieving open defecation-free (ODF) status. By supporting a range of approaches to demand-driven rural sanitation through a number of partners,

WASH will help to improve the models for triggering and sustaining demand for safe sanitation. In addition to triggering demand, these programs encourage local entrepreneurs to offer a range of affordable, desirable sanitation products and build the capacity of local government to support improved sanitation (UNICEF, 2014).

2.6.3.3 Policy and Advocacy: Policy and advocacy work is designed to encourage and support sanitation policies that work for the poor. This part of the strategy involves working to improve the policy and regulatory environment. It focused in building the capacity of local governments to support improved sanitation by informing governments about successful sanitation approaches and encourages a policy environment that will accelerate access to sustainable sanitation. The goal of policy and advocacy is to encourage other donors and the private sector to invest in scaling up successful approaches to educate target populations, mostly the rural and urban poor in Africa and Asia, about safe sanitation and hygiene (UNICEF, 2010; 2014).

2.6.3.4 International Guidelines on Sanitation Facilities: Guidelines for international standards of sanitation facilities in community settings require the provision of basic sanitation facilities, (separate for boys and girls); provision of water and soap (or ash) for hand washing after using the latrines and before meals, and the provision of safe drinking water. According to Adams *et al* (2009), the number of toilets should be:

One toilet per 25 pupils for girls and one for female staff in school premises.

One toilet and one urinal (or 50cm of urinal wall) per fifty (50) boys and one for male staff in school premises. They further stated that they should be hygienic use in the provided sanitary facilities and easy to clean as well as having convenient hand washing facilities close by for the users.

Statistics from the Global Annual Assessment on Sanitation and Drinking Water (GLAAS, 2010), indicate that over 2.6 billion people do not use improved sanitation facilities while nearly 900 million people do not use drinking water from an improved source (WHO/UNICEF, 2010). The same document indicates that less than half of the rural population is using improved sanitation facilities as compared with 76% of their urban counterparts.

The lack of sanitation facilities contributes directly to soil transmitted helminth (STH) infections. Due to open defecation, helminth cysts are very easily transmitted to their human hosts leading to chronic infestation in given areas. Children are especially vulnerable as they walk and play bare foot in their surroundings, and their health and cognitive functions are adversely affected by a high helminth load. Children are estimated to represent about one third (400 million) of the global soil transmitted helminth burden (The Task Force on Global Health, 2010).

2.6.3.5 Community-Led Total Sanitation (CLTS)

Community-Led Total Sanitation (CLTS) is an approach which helps rural communities to understand and realize the negative effects of poor sanitation and empowers them to collectively join hands and find solutions to their

inadequate sanitation situation (WaterAid, 2006). CLTS is focused on igniting a change in sanitation behavior rather than constructing toilets. This is done by a process of social awakening that is stimulated by facilitators from within or outside the community (Sarpong, 2010).

This approach concentrates on the entire community rather than on individual behaviors. The first significant step of CLTS is to end open defecation as an entry point while changing sanitation behavior. It starts by enabling people to do their own sanitation profile through appraisal, observation and analysis of their practices of open defecation and the effects these have (Cole, 2013). Collective benefit from stopping open defecation can encourage a more cooperative approach. People decide together how they will generate a clean and hygienic environment that benefits everyone (UNDP, 2004). It is essential that CLTS involves no individual household hardware subsidy and does not prescribe latrine models.

2.6.3.5.1 Concept of Community-Led Total Sanitation: Community-Led Total Sanitation (CLTS) is an innovative methodology for mobilizing communities with a view to eradicating Open Defecation (OD). Also, it can be said to be a new approach to sanitation promotion which encourages community self-analysis of existing defecation patterns and threats and promotes local solutions to reduce and ultimately eliminate the practice of Open Defecation (Chambers, 2009). This definition entails that (CLTS) processes can precede and lead on to or occur simultaneously with the following.

i. Improvement of latrine designs
ii. Adoption and improvement of hygienic practices
iii. Solid waste management
iv. Waste water disposal
v. Protection and maintenance of drinking water sources, and
vi. Other environmental health and sanitation strategies.

In many cases, CLTS initiates a series of new collective local development actions by OD communities (Kamal & Moore, 2004). Community-Led Total Sanitation is total and involves or affects everyone in the communities. Collective decision-taking and collective local actions are the keys of CLTS, which enhance social solidarity and cooperation in abundance. At the heart of CLTS lies the recognition that merely providing toilets does not guarantee their use, nor result in improved sanitation and hygiene. Rather, people decide together how they will create a clean and hygienic environment that benefits everyone.

2.6.3.5.2 Principles of Community-Led Total Sanitation: In view of sanitation problem in Nigeria, to achieve total sanitation, that is, open defecation-free communities led by a sustainable use of safe, affordable and user-friendly solutions and/or technologies, the following principles are necessary (Venkataramanan and Rowe, 2014);

i. Total sanitation must include provision of sanitation facilities such as latrines, urinals, adequate bathrooms, hand washing equipment, water, soap,

dustbins, etc., in schools, health centers, markets, dormitories and other public places.

ii. In CLTS, communities must oversee the change process and use their capacity to attain their envisioned objectives. Community members themselves must be allowed to play a control role in planning, with special attention to the need of women, children and other vulnerable groups.

iii. Subsidies (in the form of funds, hardware's, etc.) are not to be given straight to households. Community rewards and incentives should be acceptable only where they encourage collective action, total sanitation, and are used to attain sustainable use of sanitation facilities (as opposed to the construction of infrastructures without educating people on how to use and maintain them).

iv. For sustainable CLTS, local communities must be empowered towards more participatory activities.

v. The visibility of community activities must be strengthened.

vi. Local and international links with donor agencies and other stakeholders on sanitation should be strengthened.

vii. There must be improvement upon initiation of community – driven health and sanitation activities such as the one organized by Center for Women, Gender and Development Studies (CWGDS).

viii. There must be capacity building in rural and urban areas through training.

ix. Local and international policies should be made available to communities so that these may contribute to policy debates.

x. There should be routine tests of self-mobilization of communities; CLTS must contribute to research to enhance community knowledge on the operations of land use Decrees and Acts, etc., (Kamal, 2004; Moore and Mckee, 2012).

2.6.3.5.3 Public Health Implication of CLTS: It is a well-known fact that human excreta have been implicated in the transmission of many infectious diseases including cholera, typhoid, infectious hepatitis, polio, cryptosporidiosis and ascariasis. WHO (2004) estimates that about 1.8 million people annually are affected and 90% of the population are children under five, mostly in developing countries. Poor sanitation gives many infections the ideal opportunity to spread. Common sanitation and hygiene related diseases are Lice, Lymphatic filariasis, Ringworm, Scabies, Soil transmitted helminthiasis and Trachoma (Da, Carmen and Christine, 2012). Others are Amoebiasis, Buruli ulcer, Campylobacter, Cholera, Cryptosporidiosis, Cyclosporiasis, Dracunculiasis (guinea-worm disease), Fascioliasis, Giardiasis, Hepatitis, Leptospirosis, Norovirus, Rotavirus, Salmonellosis, Schistosomiasis, Shigellosis, Typhoid fever (WHO, 2004).

Sanitation and hygiene are very important to health, survival and development. A great amount of disease can be prevented and averted through better access to convenient sanitation equipment and better hygiene practices. Improved

sanitation facilities (for example, toilets and latrines) allow people to dispose of their waste appropriately, which helps break the infection cycles of many diseases (Amadi, 2009).

2.6.3.5.4 Strategies of CLTS in Stopping ODF: In order to attain its objectives, CLTS employs several strategies, which include the following; given priority to sanitation and hygiene, mobilizing political will, requiring good approaches to sanitation and hygiene development, building on existing practices, paying attention to gender, harmonizing institutional frameworks for service delivery, enforcing existing sanitation laws, involving NGOs, community-based organizations (CBOs) and private sectors and sourcing for more funds, especially for sanitation and hygiene.

Figure 1: Flow diagram of igniting community-led total sanitation (Kar, 2010).

2.6.3.5.5 Attributes of CLTS in Relation to ODF: CLTS possesses attributes that depict its actions towards stopping open defecation such as;

i. Focused: It focuses on stopping open defecation.

ii. Encompassing: It employs and relies on the collective action of the members of a community to stop open defecation within the community.

iii. Insightful: It recognizes that sanitation is both a public and a private good, and that individual hygiene behavior can affect a whole community.

iv. Provisioning: It does not take the responsibility of building toilets for a community; rather, it mandates households to finance their own toilets.

v. Promotional: It promotes low-cost home – made toilets constructed with local materials (rather than standard toilet designs imposed by outsiders) with provision to climb up the sanitation ladder.

vi. Improving: It seeks general improvement in personal, household and environmental hygiene (including hand washing);

vii. Additional: It increases ownership and sustainability of hygiene and sanitation activities.

2.6.3.5.6 Implementation of CLTS Approach in Relation to ODF: First, the community rapport is established, the program objective clarified and the community members are convinced why they should implement a no subsidy program led on their own. Once the objectives are understood, then facilitator makes them realize and accept how open defecation could create problems that affects their lives (Chambers, 2009). Then participatory rural appraisal (PRA) methods will be used to bring instant change in the understanding and behavior of the people by incorporating consciousness in their minds (Water and Sanitation Program, 2007).

This purpose is community involvement and initiative to build and use latrines as well as bring positive changes in their hygiene and sanitation behavior. This gives the people a new dimension and perspective thought (Kar & Chambers, 2008). The following tools are used to motivate community members to have positive changes in their hygiene and sanitation behavior.

i. Shameful walk: A shameful walk (transect walk), an initiative involving collectively visiting of the places of open defecation by members of the community and representatives of the facilitating organizations.

ii. Feces mapping: Involves map indicating the places of defecation through community participation.

iii. Feces calculation: Once people realize that there is a lot of feces lying around in the area, they should raise the questions such as: How much on an average does an individual defecate in a day?

iv. Feces mobility mapping: Here, community members are made to realize how dangerous open defecation is, hence the five different fecal-oral contamination ways to avoid the transmission of diseases like diarrhea and improve the health and hygiene situation.

This is called the five-*F-channel*. Fecal-oral contamination can happen through: 1. Food, 2. Fingers, 3. Flies (and all kinds of insects), 4. Fields (Agriculture field), 5. Fluids (e.g. water) (*Water and Sanitation Program*, 2007).

After exploring these methods and tools, the facilitator requests the community to end open defecation and indirect ingesting of feces practice. After the community members have expressed their commitment not to defecate in the open, a committee is set to monitor (Peal, Evans, & Van Der Woorden, 2010). This committee should also decide the duration within which to declare the community an "open defecation free" area.

2.6 Waste Management

From the review of some current state of waste management practices in Nigeria using examples from different parts of the country. Commonly practiced waste disposal methods in Nigeria, are burial, open-air burning, and open dumping, these were found to be ineffective and detrimental to public health and the environment. It's been shown that waste management cannot be successfully operated as a social service. Rather, the generator of waste must be held responsible. In Nigeria problems confronting efficient waste management include the proliferation of unplanned settlements, traffic congestion, insecurity, and ignorance (David, Solomon and Ndambuki, 2016).

2.6.1 Solid Waste Management: Waste management is the collection, transport, processing, recycling or disposal, managing and monitoring of waste materials. The term usually relates to materials produced by human activity and is generally undertaken to reduce their effect on health, the environment or aesthetics. Waste management is also carried out to recover resources from it. Waste management can involve solid, liquid, gaseous or radioactive substances, with different methods and fields of expertise for each. Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential and industrial producers. Management for non-hazardous residential and institutional waste in metropolitan areas is usually the responsibility of local government authorities, while management for non-

hazardous commercial and industrial waste is usually the responsibility of the generator (Adedibu, 2006).

2.6.2 Methods of Solid Waste (Refuse) Disposal: The methods of waste disposal include the following:

Open Dump: This is where refuse is dumped on open land within the community premises. Open dump sites receive wastes of all description in a community. Dumping requires little or no planning, maintenance and unskilled personnel if any. As the name denotes open dump is an insanitary practice and should not be encouraged because, the process is uncontrolled. It allows raw garbage to pile up without treatment. At open dump site, emission of offensive odour is a common feature. It also provides food and shelter for disease carrying animals and insects. The heat emanating from the dump site either because of intentional or accidental burning, cook the raw wastes and these consequently provide food for the rodents and other animals (Adam, Bartram, Chartier and Sims, 2009).

The smoke arising from there will undoubtedly pollute the air. Open dump site attracts rag pickers or scavengers who besiege the site to salvage materials such as discarded pots, rubbers, plastics etc., for economic purposes. This practice is fraught with danger because of inhalation of noxious gases by these men at the site. Continuous exposure to hazardous wastes at the site will inevitably affect their health adversely. Flies in open dump site have been implicated in the transmission of diseases like typhoid fever, cholera, dysentery, tuberculosis,

anthrax and intestinal worms while rats and mice transmit plague, murine typhus, leptospirosis, rat bit fever, trichinosis and food poisoning, etc. (WHO, 2008). Mosquitoes which breed rapidly in tires, cans, bottles and other materials that collect and retain water at the dump site are transmitters of malaria fever, yellow fever, dengue fever, encephalitis and elephantiasis (Amadi, 2009; Oreyomi, 2005).

Burying: Burying waste can be a satisfactory solution if there is public land available for this purpose. Precaution must be taken to prevent the leaching out of the waste to forestall the contamination of the underground water. This method must not be used where water table is high (Oreyomi, 2005).

Incineration: Incineration is a disposal method in which solid organic wastes are subjected to combustion to convert them into residue and gaseous products. This method is useful for disposal of residue of both solid waste management and solid residue from wastewater management. This process reduces the volumes of solid waste to 20 to 30 percent of the original volume. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam and ash. Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants.

Malfunctioned incinerator will produce large quantity of smoke and other pollutants which will contaminate or pollute the air. These particulates that are suspended in the air ultimately find their ways into peoples' lungs and settle where they can cause diseases like emphysema (Amadi, 2009; Nwankwo, 1994)

Composting: This is the humus-like material. This is also known as turning waste to wealth because, garbage and other organic wastes are being turned into manure. It is a biological means of waste treatment. The process involves the breakdown of organic matter by bacteria and fungi under aerobic condition. The primary requisite for proper functioning of a compost operation is the removal or separation of such non-combustibles as glass wares, metals and ceramic items (Lucas and Gilles, 2003).

Sanitary Landfill: Sanitary landfill is defined as the method of disposing of solid wastes by spreading them in their layers, compacting them into smallest practical volume and covering them with daily or more frequently in a manner that will minimize environmental pollution. Methodology of controlled tipping and sanitary landfill is the same in the U.S.A (Oreyomi, 2005). The advantage of this method when properly practiced is the elimination of fire hazards. Different types of refuse can be disposed of at a time. Also, it is very simple to operate and very economical. But if it is not properly practiced, it can degenerate into an ordinary open dump.

Recycling: Recycling materials refer to the collection and reuse of waste materials such as empty beverage containers. The materials from which the items

are made can be reprocessed into new products. Material for recycling may be collected separately from general waste using dedicated bins and collection vehicles or sorted directly from mixed waste streams. The most common consumer products recycled include aluminum such as beverage cans, copper such as wire, steel food and aerosol cans, old steel furnishings or equipment, polyethylene and PET bottles, glass bottles and jars, paper board cartons, newspapers, magazines and light paper, and corrugated fiberboard boxes (Adam, Bartram, Chartier and Sims, 2009).

Controlled Tipping: This is a form of sanitary landfill that is been practiced in some part of the countries. It is a planned and supervised procedure which requires trained personnel. The term-controlled tipping originated from Great Britain. With this method, nuisances are at a minimum and rodents are practically non-existent due principally to the fact that the refuse is usually covered with earth after the day's work (Oreyomi, 2005).

Bio-gasification: Bio-gasification is defined as a thermochemical process that utilizes heat and a low-oxygen environment to transform carbonaceous feedstock such as biomass or municipal solid waste through partial oxidation to release other forms of energy (Barkha, Bhavisha, Vaibav, Pooja, Hakimi and Rajeev, 2019). Biogas is originated from bacterial activities in the process of biodegradation of organic matter under anaerobic conditions. The natural generation of biogas is an important part of the biogeochemical cycle. Methane producing bacteria are the last link in the chain of microorganisms, which degrade

organic matter and transfer the materials to the environment. In this process, the biogas is generated which is a source of renewable energy. Biogas is a mixture of methane (40-70%), carbon dioxide (30-60%), and other gases (1-5%). Biogas may be used for producing heat, electricity and light (EPA, 2009).

Pyrolysis: Pyrolysis is defined as the thermal decomposition of lignocellulosic derivatives under inert condition in oxygen deficient environment. The word is resulting from two Greek words: ‘pyro’, which means fire, and ‘lysis’, which means disintegration into integral parts. This process of thermal degradation of waste in the absence of air produces char, pyrolysis oil and syngas, e.g., the conversion of wood to charcoal (Zaman *et al.*, 2017).

2.7 Bacteriological Analysis of Water

Bacteriological analysis of water is a method of analyzing water to estimate the number of bacteria present and if need be, to determine by characterizing the type of bacteria present. This kind of water analysis represents one aspect of water quality. It is a microbiological analytical procedure which uses samples of water and from these samples determines the concentration of bacteria. It is then possible to draw inferences about the suitability of the water for use from these concentrations. This process is used, for example, to routinely confirm that water is safe for human consumption or that bathing and recreational waters are safe to use.

Microbial contamination is by far the most serious public health risk associated with drinking-water supplies. It is impractical to analyze water for every individual pathogen, some of which can cause disease at very low doses. Instead, since most diarrhea-causing pathogens are fecal in origin, it is practically important to analyze water for indicator species that are also present in fecal matter. The use of indicator organisms in the bacteriological analysis of water has remained the mainstay of water bacteriology.

2.7.1 Bacteriological Methods in Water Analysis: The most reliable methods are direct plate count method and membrane filtration method. mEndo Agar/broth is used for the estimation of coliform bacteria in water samples using the membrane filtration technique, while violet, red bile agar (VRBA) is used in the direct plate count method. A media that contains bile salts which promote the growth of gram negative and has inhibitory characteristic to gram-positive although not complete inhibitory. These media contain lactose which is usually fermented by lactose fermenting bacteria producing colonies that can be identified and characterized. Lactose fermenting organisms produce colored colonies while non lactose fermenting organisms produce colorless ones. Because the analysis is always based on a very small sample taken from a very large volume of water, all methods rely on statistical principles (US EPA, 2014)

For many years, total coliforms have been used as indicators in evaluating water quality for several water uses with respect to fecal contamination (Kashefipour,

Lin, Harris and Falconer, 2012; Hughes and Thompson, 2014). Not all coliforms are from fecal source. Hence, fecal coliforms and pathogenic forms such as *Escherichia coli* are now used largely as bacteriological indicators (Thomann and Muller, 2007). The term "total coliforms" refers to a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermo-tolerant (ferment lactose and produce gas at 45.5°C) coliforms and bacteria of fecal origin as well as some bacteria that may be isolated from environmental sources. Thus, the presence of total coliforms may or may not indicate fecal contamination (Bartram and Pedley, 2006).

In extreme cases, a high count for the total coliform group may be associated with a low or even zero count for thermo-tolerant coliforms. Such a result would not necessarily indicate the presence of fecal contamination. It might be caused by entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliforms. In the laboratory total coliforms are grown in or on a medium containing lactose at a temperature range of 35-37°C. They are provisionally identified by the production of acid and gas from the fermentation of lactose (Bartram and Pedley, 2006). Unlike coliforms from environmental sources, coliforms that come from fecal matter can tolerate higher temperatures. These are more closely associated with fecal pollution than total coliforms.

The most specific indicator of fecal contamination is *E. coli*, which unlike some fecal coliforms never multiplies in the aquatic environment (UNICEF, 2008). *E. coli* is now internationally acknowledged as the most appropriate indicator of

fecal pollution. In source water, its level of occurrence is correlated with the inputs of fecal pollution (human or animal) (WHO, 2010). Other organisms used as indicators of fecal pollution of water includes Fecal *Streptococci*, *Enterococci*, *Clostridium perfringens, Pseudomonas aeruginosa*, Hydrogen sulphide (H_2S) – producing bacteria, coliphages and other bacteriophages (UNICEF, 2008; WHO, 2017).

2.7.2 Conventional Methods for Bacteriological Analysis of Water

The testing of waters for pathogens has been undertaken since waterborne diseases were first recognized. In 1884, after discovery of culture media and microscopy, Robert Koch first isolated a pure culture of *Vibrio,* and Georg Gaffky isolated the typhoid bacillus (Beck, 2010), the known major causes of waterborne disease in the nineteenth century: cholera and typhoid, respectively. The analysis of water for the presence of coliform bacteria has for long been carried out using two classic/conventional methods. These are the multiple tube fermentation or most probable number technique (MPN) and the membrane filtration methods. In recent years, two alternatives: the enzyme substrate (defined substrate method) and H_2S methods, have been gaining increasing popularity (Chessbrough, 2006; UNICEF, 2008)

2.7.2.1 Multiple Tube Fermentation (MTF) or Most Probable Number Technique (MPN)

One of the oldest methods is called the multiple tube method (U.S. Environmental Protection Agency (EPA, 2002)). In this method a measured sub-sample (perhaps 10 ml) is diluted with 100 ml of sterile growth medium, and an aliquot of 10 ml is then decanted into each of ten tubes. The remaining 10 ml is then diluted again, and the process repeated. At the end of 5 dilutions this produces 50 tubes covering the dilution range of 1:10 through to 1:10000.

The tubes are then incubated at a pre-set temperature for a specified time and at the end of the process the number of tubes with growth in it is counted for each dilution. Statistical tables are then used to derive the concentration of organisms in the original sample. This method can be enhanced by using indicator medium which changes colour when acid forming species are present and by including a tiny, inverted tube called a Durham tube in each sample tube. The Durham inverted tube catches any gas produced. The production of gas at 37 degrees Celsius is a strong indication of the presence of *Escherichia coli*.

According to Bartram and Pedley (2006), the MPN technique has been used for the analysis of drinking-water for many years with satisfactory results. It is most suitable in the analysis of very turbid water samples or if semisolids such as sediments or sludge are to be analyzed. The procedure followed is fundamental to bacteriological analyses and the test is used in many countries. It is customary to report the results of the multiple fermentation tube tests for coliforms as a most

probable number (MPN) index. This is an index of the number of coliform bacteria that, more probably than any other number, would give the results shown by the test. It is not a count of the actual number of indicator bacteria present in the sample (Edberg, Rice, Karlin and Allen., 2010; Bartram and Pedley, 2006).

Although this test is time consuming and requiring 48 hours for the presumptive results (WHO, 2011). Multiple samples of the water being tested are added to a nutrient broth in sterile tubes and incubated at a particular temperature for a fixed time (usually 24 hours). If the water source is unprotected or contamination is suspected, serial dilutions of the water (usually10, 1, and 0.1 ml) may be made. Three or five tubes per dilution are commonly used, though ten tubes may be used for greater sensitivity. As coliform bacteria grow, they produce acid and gas, changing the broth colour and producing bubbles, which are captured in a small, inverted tube. By counting the number of tubes showing a positive result, and comparing with standard tables, a statistical estimate of the MPN of bacteria can be made, with results reported as MPN per 100 ml. Since some non-coliform bacteria can also ferment lactose, this first test is called a “presumptive” test. Bacteria from a positive tube can be inoculated into a medium that selects more specifically for coliforms, leading to “confirmed” results.

Finally, the test can be “completed” by subjecting positive samples from the confirmed test to a few additional identification steps. Each of the three steps (presumptive, confirmed and completed) requires 1-2 days of incubation. Typically, only the first two steps are performed in coliform and fecal coliform

analysis, while all three phases are done for periodic quality control or for positive identification of *E. coli*. Disadvantages to this method include the large number of tubes needed and the long-time requirement for the full test.

Accordingly, this test is most conveniently applied in a laboratory setting, though the presumptive test is sometimes made with field kits. Another disadvantage of this method (and other MPN methods) is that the result is a statistical approximation with low precision, and as such should only be considered semi-quantitative (UNICEF, 2008).

2.7.2.2 Membrane Filtration Methods: Until the 1950s, practical water bacteriology relied almost exclusively for indicator purposes on the enumeration of coliforms and *E. coli* based on the production of gas from lactose in liquid media and estimation of most probable numbers using the statistical approach initially suggested (McCrady, 2005). In Russia and Germany, workers attempted to culture bacteria on membrane filters and by 1943, Mueller in Germany was using membrane filters in conjunction with Endo-broth for the analysis of potable waters for coliforms (Waite, 2005).

By the 1950s, membrane filtration was a practical alternative to the MPN approach although the inability to demonstrate gas production with membranes was considered a major drawback. The membrane filter technique shows remarkable advantage over the MPN technique in that it could be used to test relatively large numbers of samples and yields results more rapidly than the

multiple fermentation tube technique. However, this method is inappropriate for turbid waters, which can clog the membrane or prevent the growth of target bacteria on the filter (UNICEF, 2008; EPA, 2002). The technique is hence unsuitable for natural waters containing very high levels of suspended material, sludges and sediments, all of which could block the filter before an adequate volume of water has passed through.

When small quantities of sample (for example, of sewage effluent or of grossly polluted surface water) are to be tested, it is necessary to dilute a portion of the sample in sterile diluent to ensure that there is sufficient volume to filter across the entire surface of the membrane. Another concern with this method is that it may not detect stressed or injured coliforms. It was originally designed for use in the laboratory, but portable equipment is now available that permits use of the technique in the field (Bartram and Pedley, 2006). The membrane filter method gives a direct count of total coliforms and fecal coliforms present in each sample of water.

A measured amount of water is filtered through a membrane with a pore size of about 0.45 μm, which traps the bacteria on its surface. The membrane is then placed on selective agar or a thin absorbent pad that has been saturated with a medium designed to grow or permit differentiation of the organisms sought (Pepper and Gerba, 2004). The success of this method depends on using effective differential or selective media that will enable easy identification of colonies.

2.7.2.3 ATP Testing: An ATP test is the process of rapidly measuring active microorganisms in water through detection of adenosine triphosphate (ATP). ATP is a molecule found only in and around living cells, and as such it gives a direct measure of biological concentration and health. ATP is quantified by measuring the light produced through its reaction with the naturally occurring enzyme firefly luciferase using a luminometer. The amount of light produced is directly proportional to the amount of biological energy present in the sample.

Second generation ATP tests are specifically designed for water, wastewater and industrial applications where, for the most part, samples contain a variety of components that can interfere with the ATP assay.

2.7.2.4 Plate count: The plate count method relies on bacteria growing as colony on a nutrient medium so that the colony becomes visible to the naked eye and the number of colonies on a plate can be counted. To be effective, the dilution of the original sample must be arranged so that on average between 30 and 300 colonies of the target bacterium are grown. Fewer than 30 colonies make the interpretation statistically unsound whilst greater than 300 colonies often result in overlapping colonies and imprecision in the count. To ensure that an appropriate number of colonies will be generated several dilutions are normally cultured. This approach is widely utilized for the evaluation of the effectiveness of water treatment by the inactivation of representative microbial contaminants

such as *E. coli* (Hanaor and Sorrell, 2014; Hanaor, Michelazzi, Leonelli and Sorrell, 2011).

The laboratory procedure involves making serial dilutions of the sample (1:10, 1:100, 1:1000, etc.) in sterile water and cultivating these on nutrient agar in a dish that is sealed and incubated. Typical media include plate count agar for a general count or MacConkey agar to count Gram-negative bacteria such as *E. coli*. Typically, one set of plate is incubated at 22 °C and for 24 hours and a second set at 37 °C for 24 hours. The composition of the nutrient usually includes reagents that resist the growth of non-target organisms and make the target organism easily identified, often by a colour change in the medium. Some recent methods include a fluorescent agent so that counting of the colonies can be automated. At the end of the incubation period the colonies are counted by eye, a procedure that takes a few moments and does not require a microscope as the colonies are typically a few millimeters across.

2.7.2.5 Pour plate method: When the analysis is looking for bacterial species that grow poorly in air, the initial analysis is done by mixing serial dilutions of the sample in liquid nutrient agar which is then poured into bottles which are then sealed and laid on their sides to produce a sloping agar surface. Colonies that develop in the body of the medium can be counted by eye after incubation.

The total number of colonies is referred to as the total viable count (TVC). The unit of measurement is cfu/ml (or colony forming units per milliliter) and relates to the original sample. Calculation of this is a multiple of the counted number of colonies multiplied by the dilution used.

2.7.3 Pathogen Analysis

When samples show elevated levels of indicator bacteria, further analysis is often undertaken to look for specific pathogenic bacteria. Species commonly investigated in the temperate zone include *Salmonella typhi* and *Salmonella typhimurium*. Depending on the likely source of contamination, investigation may also extend to organisms such as *Cryptosporidium spp*. In tropical areas analysis of *Vibrio cholerae* is also routinely undertaken.

2.7.4 Types of Nutrient Media Used in the Analysis

Nutrient broth. 500g meat, e.g., ox heart is minced and mixed with 1 litre of distilled water. 10g peptone and 5g sodium chloride are added, pH is adjusted to 7.3. It is used as a basal media for the preparation of other media, and to study soluble products of bacteria (EPA, 2002).

Nutrient Agar (NA): Is used as a general-purpose medium for the cultivation of less fastidious microorganisms, can be enriched with 5-10% blood or other biological fluids.

Composition: Ingredients in grams / litre; Peptone 5.000, Sodium chloride 5.000, HM peptone 1.500, Yeast extract 1.500, Agar 15.000, pH (at 25°C) 7.4±0.2.

Directions: Suspend 28 grams in 1000 ml distilled water. Heat to boiling to dissolve the medium completely. Sterilize by autoclaving at 15 lbs pressure (121°C) for 15 minutes. Cool to 45-50°C. Mix well and pour into sterile Petri plates.

Principle and Interpretation: Nutrient media are basic culture media used for maintaining microorganisms, cultivating fastidious organisms by enriching with serum or blood and are also used for purity checking prior to biochemical or serological testing. Nutrient Agar is ideal for demonstration and teaching purposes where a more prolonged survival of cultures at ambient temperature is often required without risk of overgrowth that can occur with more nutritious substrate. This relatively simple formula has been retained and is still widely used in the microbiological examination of variety of materials and is also recommended by standard methods. It is one of the several non-selective media useful in routine cultivation of microorganisms. It can be used for the cultivation and enumeration of bacteria which are not particularly fastidious. Addition of different biological fluids such as horse or sheep blood, serum, egg yolk etc. makes it suitable for the cultivation of related fastidious organisms. Peptone, HM peptone B and yeast extract provide the necessary nitrogen compounds, carbon, vitamins and some trace ingredients necessary for the of bacteria. Sodium chloride maintains the osmotic equilibrium of the medium growth (Baird, Eaton and Rice, 2015).

Blood Agar: Most used medium. 5-10% defibrinated sheep or horse blood is added to melted agar at 45-50°C. Blood acts as an enrichment material and as an indicator. Certain bacteria when grown in blood agar produce hemolysis around their colonies. Certain bacteria produce no hemolysis. Types of changes: (a) beta (p) hemolysis. The colony is surrounded by a clear zone of complete hemolysis, e.g., Streptococcus pyogenes is a beta hemolytic streptococcus, (b) Alpha (a) hemolysis. The colony is surrounded by a zone of greenish discolorations due to formation of biliverdin, e.g. Viridans streptococci, (c) Gamma (y) hemolysis, or, No hemolysis. There is no change in the medium surrounding the colony (Baird, Eaton and Rice, 2015).

MacConkey Agar: Most used for Enterobacteriaceae. It contains agar, peptone, sodium chloride, bile salt, lactose and neutral red. It is a selective and indicator medium: (1) Selective as bile salt does not inhibit the growth of Enterobacteriaceae but inhibits growth of many other bacteria. (2) Indicator medium as the colonies of bacteria that ferment lactose takes a pink colour due to production of acid. Acid turns the indicator neutral red to pink. These bacteria are called 'lactose fermenter', e.g., Escherichia coli. Colourless colony indicates that lactose is not fermented, i.e., the bacterium is non-lactose fermenter, e.g., Salmonella, Shigella, and Vibrio. Alfred Theodore MacConkey developed it while working as a bacteriologist for the Royal Commission on Sewage Disposal in the United Kingdom (EPA, 2002).

Eosin Methylene Blue Agar (EMBA): Is recommended for the isolation and differentiation of gram-negative enteric bacteria from environmental media. Methylene blue and Eosin-Y inhibit gram positive bacteria. The ratio of eosin and methylene blue is adjusted to 6:1. Sucrose is added to the medium as an alternative carbohydrate source for typically lactose-fermenting, gram -negative bacilli. The coliforms produce purplish black colonies due to taking up of methylene blue-eosin when the pH drops. Non-fermenters raise the pH of the medium by oxidative deamination of protein, which solubilizes the methylene blue-eosin resulting in colorless colonies.

Preparation Instructions-Suspend 36 grams of EMB Agar in 1000 mls of distilled water. Heat to dissolve the medium completely. Dispense and sterilize by autoclaving at 15 lbs. pressure (121 °C) for 15 minutes. Avoid overheating. Cool to 50 °C and shake the medium to oxidize the methylene blue (i.e. to restore its blue color) and to suspend the flocculent precipitate (Howard, 1994).

Salmonella - Shigella Agar (SSA) medium is recommended as differential and selective medium for the isolation of Salmonella and Shigella species from water samples contaminated with fecal matters and suspected foodstuffs. SS Agar is a moderately selective medium in which gram-positive bacteria are inhibited by bile salts, brilliant green and sodium citrate. Peptic digest of animal tissue, beef extract provides essential growth nutrients. Lactose is the fermentable carbohydrate. Brilliant green, bile salts and thiosulphate selectively inhibit gram-positive and coliform organisms. Sodium thiosulphate is reduced by certain

species of enteric organisms to sulphite and H_2S gas and this reductive enzyme process is attributed by thiosulphate reductase. Production of H_2S gas is detected as an insoluble black precipitate of ferrous sulphide, formed upon reaction of H_2S with ferric ions or ferric citrate, indicated in the center of the colonies. On fermentation of lactose by few lactose-fermenting normal intestinal flora, acid is produced which is indicated by change of colour from yellow to red by the pH indicator-neutral red.

Thus, these organisms grow as red pigmented colonies. Lactose non-fermenting organisms grow as translucent colourless colonies with or without black centers. Growth of Salmonella species is uninhibited and appears as colourless colonies with black centers resulting from H_2S production. Shigella species also grow as colourless colonies which do not produce H_2S (Eaton et al., 2005; MacFaddin, 1985).

Sabouraud Dextrose Agar (SDA): Is used for the cultivation of yeasts, moulds and aciduric bacteria from clinical and non-clinical samples. Sabouraud Dextrose Agar is Carlier's modification of Sabouraud Dextrose Agar which is described by Sabouraud for the cultivation of fungi (yeasts, molds), particularly useful for the fungi associated with skin infections. This medium is also employed to determine microbial contamination in food, water, cosmetics, and clinical specimens. Mycological Peptone provides nitrogenous compounds. Dextrose provides an energy source. High dextrose concentration and low pH favors fungal growth and inhibits contaminating bacteria from test samples (Jorgensen *et al*., 2015).

mFC medium is used in membrane filtration and contains selective and differential agents. These include rosolic acid to inhibit bacterial growth in general, except for fecal coliforms, bile salts inhibit non-enteric bacteria and aniline blue indicates the ability of fecal coliforms to ferment lactose to acid that causes a pH change in the medium (U.S. Geological Survey, 2007).

2.8 On-Site Determination of some Physico-Chemical Parameters of Water Samples in the Study Area

The following parameters: PHs, Temperature (OC), Electrical Conductivity ((EC) mS/cm), Total Dissolved Solids ((TDS) mg/l) were determined on-site using a 4-parameter water testing equipment.

2.8.1 pH: According to Vijay S. K, (2016), pH refers to the hydrogen ion concentration or how acidic or basic water is, and pH is defined as –log[H+]. pH value ranges from 0-14; pH 7 is neutral. 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. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen and carbon) and heavy metals (lead, copper, cadmium etc.). In case of heavy metals, the degree to which they are soluble determines

their toxicity. Metals tend to be more toxic at lower pH because they are more soluble. pH is most important in determining the corrosive nature of water. The lower the pH value the higher is the corrosive nature of water. Very high pH (greater than 9.5) or very low pH (lower than 4.5) values are unsuitable for most aquatic organisms. Aquatic organisms are extremely sensitive to pH levels below 5 and may die at these low pH values. High pH levels (9-14) can harm fish since ammonia will turn to toxic ammonia at high pH (>9).

The pH for drinking water generally lies between 6.5 and 8.5 at 25°C (80° F) (WHO, 2010). The pH of water in a stream, river, lake or underground flow will vary depending on a source of the water, type of soil, bedrock, types of contaminants the water encounters in its path etc. The effects of a specific type of water pollution on living plants and animals can vary greatly. No health-based guideline value is proposed for pH by the WHO (WHO, 2010; Gupta, 2006).

Although pH usually has no direct impact on consumers, it is one of the most important water quality parameters. For example, for effective disinfection with chlorine, the pH should preferably be less than 8. The optimum range for chlorine disinfection is between pH 5.5 and 7.5. High pH causes a bitter taste, water pipes and water-using appliances become coated with deposits, and it depresses the effectiveness of the disinfection of chlorine, thereby causing the need for additional chlorine when pH is high. Low pH water will corrode or dissolve metals and other substances (Araoye, 2009).

2.8.1.1 Factors that Affect pH Levels:

i. Acidic rainfall- may have little effect if the region is rich in minerals that result in high alkalinity values i.e., higher concentrations of carbonate, bicarbonate, and hydroxide ions from limestone can provide a natural buffering capacity capable of neutralizing many of the H+ ions from the acid. Other regions may have low concentrations of alkalinity ions to reduce the effects of acids in the rainfall area.

ii. Level of hard- water minerals

iii. Releases from industrial processes- depends on whether acids or bases are released

iv. Release of detergents into water

v. Carbonic acid from decomposition

vi. Oxidation of sulphides in sediments (acidic)

2.8.2 Temperature: Temperature refers to degree of hotness or coldness of a substance and it is measured in degree Celsius (^{o}C). Water temperature needs to be monitored regularly as outside tolerable temperature range, disease and stress will become more prevalent. Among the consequences of temperature changes are photosynthetic activity, diffusion rate or gases, amount of oxygen that can be dissolved etc. (Araoye, 2009). The aesthetic objective for temperature of less than or equal to 15 degrees Celsius is adopted from the 'Guidelines for Canadian

Drinking Water', which has been accepted by the Ministry of Health Services for application in British Columbia (WHO, 2010).

Temperature is important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature. Water, particularly groundwater, with higher temperatures can dissolve more minerals from the rocks. Therefore, it will have a higher electrical conductivity. Temperature exerts a major influence on biological activity and growth. Temperature governs the kinds of organisms that can live in rivers and lakes. From the user's viewpoint, cool drinking water is preferable to warm; a temperature of $10^{O}C$ is usually satisfactory. The figure of $19^{O}C$ often quoted as a "limit'' above which most consumers complain, is based on an empirical relationship derived about 60 years ago (Araoye, 2009; Gupta, 2006). Turbidity and colour are indirectly related to temperature, because temperature affects coagulation. The efficiency of coagulation is strongly temperature dependent and the optimum pH for coagulation decreases as temperature increase. Corrosion rate is also a function of the dissolved oxygen concentration in water. The solubility of oxygen decreases with increasing temperature (10.15 mg/L at $15^{0}C$ to 7.1 mg/L at $35^{0}C$). The change in dissolved oxygen with temperature is small compared with the larger change in corrosion rates. Warm water holds less dissolved oxygen than cool water and may not contain enough dissolved oxygen for the survival of different species of aquatic life. Some compounds are also more toxic to aquatic life at higher temperatures (WHO, 2010).

2.8.2 Factors affecting Water Temperature:

i. Air temperature

ii. Amount of shade

iii. Soil erosion increasing turbidity

iv. Thermal pollution from human activities

v. Unknown chemical reactions, those not previously occurring in the water.

2.8.2.1 Effects of Water Temperature:

i. Solubility of dissolved oxygen– more gas can be dissolved in cold water than warm.

ii. Rate of plant growth– increased water temperature can cause an increase in the photosynthetic rate of aquatic plants and algae, which can lead to increased plant growth and algal blooms and harm the local ecosystem (WHO, 2010; Gupta, 2006).

2.8.3Total Dissolved Solids (**TDS**): is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular suspended form. Generally, the operational definition is that the solids must be small enough to survive filtration through a filter with 2-micrometer (nominal size, or smaller) pores. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers,

and lakes. Although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects), it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants (EPA, 1999).

Primary sources for TDS in receiving waters are agricultural runoff and residential (urban) runoff, clay-rich mountain waters, leaching of soil contamination, and point source water pollution discharge from industrial or sewage treatment plants. The most common chemical constituents are calcium, phosphates, nitrates, sodium, potassium, and chloride, which are found in nutrient runoff, general stormwater runoff and runoff from snowy climates where road de-icing salts are applied. The chemicals may be cations, anions, molecules or agglomerations on the order of one thousand or fewer molecules, so long as a soluble micro-granule formed. More exotic and harmful elements of TDS are pesticides arising from surface runoff. Certain naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils. The United States has established a secondary water quality standard of 500 mg/l to provide for palatability of drinking water. The desirable limit for TDS is 500 mg/l and maximum limit is 1000 mg/l which is prescribed for drinking purpose (Meride and Ayenew, 2016). However, the palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/litre; good, between 300 and

600 mg/litre; fair, between 600 and 900 mg/litre; poor, between 900 and 1200 mg/litre; and unacceptable, greater than 1200 mg/litre (WHO, 2003).

2.8.3.1 Effects of elevated water TDS:

An elevated total dissolved solids concentration does not mean that the water is a health hazard, but it does mean the water may have aesthetic problems or cause nuisance problems. These problems may be associated with staining, taste (bitterness, salty), films or precipitation on fixtures, corrosion of fixtures, and reduced efficiency of water filter and equipment. With respect to trace metals, an elevated total dissolved solid may suggest that toxic metals may be present at an elevated level. It is important to keep in mind that water with a very lower TDS concentration may be corrosive and corrosive waters may leak toxic metals such as copper and lead from the household plumbing. This also means that trace metals could be present at levels that may pose a health risk. Water is not a health hazard, but dealing with hard water in the home can be a nuisance (Oram, 2014). Water can be classified by the level of total dissolved solids (TDS) in the water:

i. Fresh water: TDS = 500 ppm
ii. Brackish water: TDS = 500 - 30,000 ppm
iii. Saline water: TDS = 30,000 - 40,000 ppm
iv. Hyper-saline: TDS greater than 40,000 ppm (EPA, 1999).

2.8.4 Electrical conductivity (EC):

Electrical Conductivity of water is its ability to conduct an electric current. Salts or other chemicals that dissolve in water can break down into positively and negatively charged ions. These free ions in the water conduct electricity, so the water electrical conductivity depends on the concentration of ions. Salinity and total dissolved solids (TDS) are used to calculate the EC of water, which helps to indicate the water's purity. The purer the water the lower the conductivity. Example, distilled water is almost an insulator, but saltwater is a very efficient electrical conductor. Increase in ions concentration enhances the electrical conductivity of water. Generally, the number of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) measures the ionic process of a solution that enables it to transmit current. According to WHO standards, EC value should not exceed 400 mS/cm (Meride and Ayenew, 2016; WHO, 2003).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research Design

This is a descriptive cross-sectional study to assess community's drinking water, sanitation, hygiene and occurrence of water-borne enteric (bacterial) infections in Imo State. The design of this study focused on assessing WASH which includes water supply, accessibility of sanitary facilities, hygiene practices, bacteriological qualities of water and prevalence of water-borne enteric (bacterial) infections in the state. The evaluation was designed to last within the period of June 2019 to June 2020.

3.2 Area of Study

The study area is Imo State, situated in the Southeast Zone of Nigeria. They are Owerri West, Ngor-Okpala, Aboh Mbaise, Obowo, Onuimo, Njaba, Orlu and Ohaji-Egbema LGAs.

3.3 Description of Imo State

Imo State is a state in the south-east geo-political zone of Nigeria, bothered by Anambra State to the North, River Niger and Delta State to the West, Rivers State on the South and Abia State to the East. It takes its name from Imo River which flows along the states' eastern border. The capital is Owerri and its' nick-named Eastern Heartland. Imo lies within Latitude 4 45'N and 7 15'N, and Longitude 6 50'E and 7 25'E, with an area of about 5,100 sq.km. Imo is the 3rd smallest in

area but 14th most populous with estimated population of over 5.4 million as of 2016 Cencius. Major commercial cities are Owerri, Orlu, and Okigwe. They are predominantly Igbo people (95% of population) (Hoiberg & Dale, 2010). Their traditional language is Igbo. English is widely spoken and serves as the official language in governance and business. Imo state has 27 Local Government Areas (Figure 4)

Figure 3: Map of Nigeria showing location of Imo State

Natural Resources: These include Crude oil, Natural gas, Lead, Calcium carbonate, Solar and Wind power, Zinc, etc. Profitable florae include: Iroko, Mahogany, Obeche, Bamboo Rubber tree, and Oil palm. Their primary occupation is Agriculture.

Climate: Rainy season begins April until October with annual rainfall varying from 1,500mm to 2,200mm (60 to 80 inches). An average temperature at two months above 20^0C (68 F) with annual relative humidity of 75% with humidity reaching 90% in rainy season. Dry season experiences two months of Harmattan from December to late February. The hottest months are between January and March

Figure 4: Map of Imo state showing the Local Government Areas. Imo State Blog (2013).

3.4 Population of Study

The population of this study comprised of male and female community residents in the three senatorial zones of Imo state. Going by the figure from the 2011Population projection of the National Population Commission, (Table 4). The Imo population was given as 3,256,600.

Table 4: Population development in Imo State

Name of LGAs in Imo State		Population Census	Population Projection
Year		1991-11-21	2011-03-21
Imo State		2,845,380	3,256,600
Aboh Mbaise		195,652	122,290
Ahiazu Mbaise		170,902	489,200
Ehime Mbano		204,340	193,820
Ezinihitte Mbaise		192,621	220,460
Ideato South		159,879	157,830
Ideato North		183,260	176,350
Njaba		143,485	156,400
Ngor Okpala		159,932	132,530
Obowo		181,894	208,180
Okigwe		245,987	281,540
Orlu		420,600	252,560
Onuimo		99,368	97,710
Ohaji/Egbema		58,139	66,540
Owerri-West		99,265	100,000
Owerri- North		223,134	255,390
Ihitte/Uboma		120,744	159,160
Nkwerre		163,119	186,700
Oguta		195,743	148,985
Ikeduru		159,300	32,444
OruEast		327,555	98,575
OruWest		164,426	132,271
Mbaitoli		194,223	52,214
Isu		198,736	97,800
Orsu		132,237	413,857
Isiala		32,689	86,331
Okigwe		42,987	86,857
Nwangele		127,691	97434
Owerri Municipal		137,876	476852

Explanation: The 2011 population projection assumes the same rate of growth for all LGAs within a state. The undercount of the 1991 census is estimated to be about 25 million (Source: National Population Commission of Nigeria, 2012).

3.5 Sample Size and Sampling Technique

The study sample size was calculated using Taro Yamane method for survey sampling studies (Yamane, 1967:886), which suggest a sample size of 400. Sample size calculation based on Taro Yamane formula is as follows:

$$n = \frac{N}{1 + N(e^2)}$$

Where, n = the require sample size, N = Population size (3256600), e = Margin of allowable error (0.05)

$$n = \frac{3256600}{1 + 3256600(0.05^2)} = \frac{3256600}{8142.5} = 400$$

Considering the large population under study, I multiplied n (the required sample size) by 2 i.e., the final n, which is 400 x 2 = 800. This will provide for larger reach and more participant- involvement for a balanced conclusion.

To account for 10% non-response in the sample size, a sample size of not less than 880 were deemed appropriate for this study. Based on that, sample size of 920 was used in this study.

Multistage sampling was used to select the samples included in the study.

> **First stage:** Imo state is up of three senatorial zones comprising Owerri Zone; Okigwe Zone; and Orlu Zone. A total of 8 Local Government Areas (LGAs) were randomly selected which covered at least 47% of the LGAs. Orlu Zone has 12 LGAs, Owerri Zone has 9 LGAs and Okigwe Senatorial Zone contained 6 LGAs. Hence two LGAs namely Obowo and Onuimo LGAs were randomly selected from Okigwe Senatorial Zone, while three LGAs each were randomly selected from Orlu and Owerri Senatorial zones. The selected LGAs include Owerri–

West, Ngor-Okpala and Aboh Mbaise for Owerri Zone; Obowo and Onuimo for Okigwe Zone, and Njaba, Orlu and Ohaji-Egbema for Orlu Zone.

> **Second stage**: of the sampling involved randomly selecting of communities from the sampled LGAs. Three communities were each selected from all the sampled LGAs. They include Ugbelle, Umuaka and Abazu from Njaba LGA; Umuna, Okporo, and Owerre-Ebiri for Orlu; Umuokanne, Ilile, and Umuagwo representing Ohaji-Egbema LGA (Orlu Zone); Alike, Achara and Odenkwume (for Obowo); Umuna, Okwe, and Okwelle (Onuimo) for Okigwe Zone; Obinze, Ihiagwa, and Ohii (Owerri-West); Umuowa, Ohekelem, and Umuhu (Ngor-Okpala); Nguru, Okwuato and Uvuru (Aboh-Mbaise) for Owerri Zone.

> **Third stage:** involves randomly selecting of 3 villages each from the sampled communities which altogether, produced 24 villages. Figure 4 explained the flow for the selection of the participants.

3.6 Instrument for Data Collection

The primary data were collected using questionnaire drawn from a checklist. The questionnaire and checklist contained closed questions and few open questions. The questionnaire instrument was divided into 7 sections (A–G).

Section A --socio-demographic characteristics of the study participants,

Section B -- water supply and utilization

Section C -- sanitation practices.

Section D --personal hygiene practices

Section E-- solid waste management

Section F --open defecation and

Section G-- WASH- related diseases and its associated risk factors.

3.7 Materials for Laboratory Analysis

i. 4-parameter hand-held pH, Temperature, Total dissolved solids (TDS) and Electrical conductivity (EC) meter with a single probe.
ii. Ice packs
iii. Sterilized bottles (250ml)
iv. Gas burner
v. Methylated spirit
vi. Alcohol
vii. Cotton wool
viii. Disposable hand gloves.
ix. Culture media
x. Autoclave

3.8 Data Collection Method

The researcher and four trained assistants distributed the questionnaire in the selected communities after getting an informed consent from village heads and leaders. Some of the questionnaires were filled under the supervision of the researcher to ensure accurate data entry and clarification. A data preform was created for extraction of relevant data from participants

3.9 Description of Sample locations:

Water samples were taken from three communities in each of the selected Local Government Areas in Imo State, Nigeria. The water samples were taken in such a way as to represent the various sources of water available for use within each community. The water sampling points included the following.

i. Stream and River water sources.

ii. Running tap water source.

iii. Underground well water source.

iv. Reservoirs from Rainwater source.

v. Reservoirs from Borehole source.

3.10 Collection of Samples:

Sampling from the tap: The tap nozzle was cleaned with a cotton wool soaked in methylated spirit/or flamed with gas burner to remove any debris or eliminate microbial contaminants present.

The tap was then allowed to run at maximum flow to allow it run to waste for 1-2 minutes.

The sterilized bottle was carefully opened without touching the mouth and the sample was collected while holding the cap with one hand to avoid contamination, and the bottle was filled without splashing water on it.

Some space was left in the bottle and immediately screwed on the cap.

The bottle was then labeled and placed in the cold box for transport to the laboratory.

Sampling from stored water in buckets/basins/drums

The water container was stirred to create artificial current.

The sterilized bottle was opened and held near the bottom.

The sterilized bottle was submerged with the mouth facing towards the current, then filled and recapped.

It was then labeled and placed in the cold box container.

Labeling of samples

The samples were labeled with the following information before being placed in the cold box.

LGAs name where sample was taken

i. Sample number/code

ii. Source of water/ sampling point or location

iii. Date/time sample was taken

3.12 On-site determination of pH level, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Temperature of the water sample

At the collection points, on-site measurements of pH, electrical conductivity, total dissolved solids and temperature were taken from the water sources and recorded. This was carried out using a 4-parameter hand-held digital apparatus (Hanna

instruments: HI9813-6 Portable pH/EC/TDS/Temperature meter), with a single probe.

Procedure:

1. Water sample was collected in a glass beaker for tests.
2. The 4- parameter digital apparatus was switched-on, calibrated by zeroing the reading on the LCD screen.
3. The probe was inserted into the water sample and the readings on the LCD were observed and recorded for the four parameters- pH, Temperature, EC and TDS for each sample.

Figure 6: HI9813-6 Portable pH / EC /TDS/Temperature Meter with "CAL Check"
Source: Hanna Instruments

3.13 Preparation of media and diluents

Nutrient Agar (NA), Eosin Methylene Blue Agar (EMBA), Salmonella - Shigella Agar (SSA), Blood Agar (BA) and MacConkey Agar (MCA) were prepared according to manufacturer's specification. Nutrient agar was used in the isolation

of heterotrophic bacteria. MacConkey agar selects for coliforms (*Escherichia coli*) and fecal coliforms. EMBA is highly selective for *Escherichia coli* and other Enterobacteriaceae, whereas SSA and Blood Agar were used for the cultivation of *Salmonella and Shigella* and hemolytic bacteria respectively.

Physiological saline used as diluent was prepared by dissolving 9.8g of sodium chloride in 1000 ml of distilled water and dispensed in 9 ml portions. Both diluents and media were sterilized in an autoclave at 121^0C for 15 mins (Cheesbrough, 2000).

3.14 Preparation of samples and inoculation

One milliliter (1 ml) of water sample was serially diluted in 9 ml of sterile physiological saline and swirled to mix thoroughly. An aliquot (0.1ml) of appropriate dilution was inoculated into the pre-sterilized and surface dried medium. Inocula were spread evenly to ensure uniform and countable colonies. Plates were incubated at ambient temperature for 24-48 hours.

3.15 Determination of microbial population

Colony counts obtained on the media were counted and expressed as colony forming units per milliliter (CFU/ml) of the total population. Colony count was done with a colony counter (Uniscope).

3.16 Characterization and identification of microbial isolates

Microbial isolates were characterized based on cultural (colonial), microscopic and biochemical methods with reference to standard manuals. The identities of the isolates were cross matched with reference to standard manuals for the identification of bacteria (Buchanan and Gibbon, 2000).

3.16.1 Microscopic Characterization

3.16.1.1 Gram Staining Test: The Gram staining technique was used for the bacterial isolates as described by Cheesbrough (2006). A smear of the isolate was made on grease free glass slide with a drop of water and allowed to dry. The smear was fixed by mild heating, flooded with crystal violet and allowed to stand for 30 seconds. The crystal violet was rinsed off with water; Lugol's iodine was added and allowed to stand for 30 seconds. This was washed off with water and acid alcohol, till discoloration. It was counter stained with Safranin for 10 seconds and rinsed with water. The wet slide was allowed to air dry. A drop of immersion oil was added on the slide and viewed using 100x objective lens of the microscope. Results: Gram-positive organisms appeared purple while Gram-negative organisms appeared pink.

3.16.1.2 Spore Staining Test: The spore stain was used to confirm the presence of spores when indicated in the Gram stain. Isolates were heat fixed on a slide and flooded with 5% malachite green. It was steamed for 3 minutes (without allowing it to boil), dried and cooled. It was then rinsed off and stained with Safranin for 30 seconds. This was rinsed, dried with filter paper and viewed under

the microscope using oil immersion lens. The positive spores showed green colour while the vegetative cells were stained pink colour (Chessbrough, 2006).

3.16.1.3 Motility Test: This test was used to determine the motility of bacteria isolated. The test was carried out on a semi-solid agar medium in which motile bacteria swarm and gave a diffuse spreading growth. The medium was dispensed into test tubes, sterilized and allowed to set in an upright position. It was then inoculated using an inoculation needle by stabbing it into the medium in the test tube. This was incubated at 37°C for 24 hours. Diffuse growth from the straight line of inoculation was recorded as positive result (Cheesbrough, 2006).

3.16.2 Biochemical Characterization of Bacteria Isolates

Microorganisms that were not identified by the colonial and microscopic characteristics were further subjected to few biochemical tests described by Cheesbrough (2006, 2000).

3.16.2.1 Catalase Test: The enzyme catalase is present in most cytochrome containing aerobic and facultative anaerobic bacteria. Catalase has one of the highest turnover numbers of all enzymes such that one molecule of catalase can convert millions of molecules of hydrogen peroxide to water and oxygen in a second. Catalase activity can be detected by adding the substrate H_2O_2 to an appropriately incubated (18-24 hours) tryptic soy agar slant culture. Organisms which produce the enzyme breakdown the hydrogen and the resulting O_2 production produces bubbles in the reagent drop indicating a positive test.

Organisms lacking the cytochrome system also lack the catalase enzyme and are unable to breakdown peroxide into O_2 and water and are catalase negative (Chessbrough, 2006).

3.16.2.2 Coagulase Test: Coagulase is enzymes that clot blood plasma by a mechanism that is like normal clotting. The coagulase test identifies whether an organism produces exoenzyme. This enzyme clots the plasma component of blood. The only significant disease-causing bacteria of humans that produce coagulase are *Staphylococcus aureus.* Thus, this enzyme is a good indicator of *S. aureus.* In the test, the sample is added to rabbit plasma and held at 37ºC for a specified period. Formation of clot within four hours is indicated as positive result and indicative of a virulent *Staphylococcus aureus* strain. The absence of coagulation after 24 hours of incubation is a negative result indicative of an avirulent strain (Chessbrough, 2000).

3.16.2.3 Oxidase Test: Oxidase test is an important differential procedure that should be performed on all gram-negative bacteria for their rapid identification. The test depends on the ability of certain bacteria to produce indophenol blue from the oxidation of dimethyl-p-phenylenediamine and ∞-naphthol. This method uses N, N-dimethyl-p-phenylenediamine oxalate in which all *Staphylococci* are oxidase negative. In the presence of the enzyme cytochrome oxidase (gram negative bacteria) the N, N-dimethyl-p-phenylenediamine oxalate and ∞-naphthol react to indophenol blue. *Pseudomonas aeruginosa* is an oxidase positive organism (Chessbrough, 2006).

3.16.3 Sugar Fermentation/Oxidation: This test is used to differentiate between bacteria groups that oxidize carbohydrate such as members of Enterobacteriaceae. One milliliter (1ml) of 10% glucose, maltose, lactose, fructose, mannitol, and sucrose were separately under aseptic conditions transferred into duplicate tubes containing 9ml of sterile Hugh and Leifson's medium to obtain a final concentration of 1% of each of sugar. The tubes were stab-inoculated in duplicates while two uninoculated tubes served as control. Vaseline was used to cover one set of the duplicate tubes, one control to discourage oxidative utilization of sugar. All tubes were incubated at 37^{o}c for 48h. After the incubation, they were observed for acid production in the culture. Yellow coloration indicates acid production in the open tubes only suggesting oxidative utilization of the sugar while acid production in the sealed tubes suggests a fermentative reaction (Chessbrough, 2000).

3.16.3.1 Hydrogen Sulphide Production (H_2S) Test: The test isolates were aseptically inoculated into a tube containing triple sugar iron agar started by stabbing the agar to the bottom and streaking the surface of the slant. The inoculated tube was incubated at 37^{o}c for 72h and was examined daily. Black precipitation and yellow colouration was checked for. Black precipitate indicates H_2S production and yellow colouration for sucrose, lactose and glucose fermentation (Chessbrough, 2006).

3.16.3.2 Urease Test: Urease Agar slant in McCartney bottle was inoculated with the bacteria isolate at 30^{o}C for 4 hours and then overnight. A pink colour in the medium indicated a positive result (Chessbrough, 2006).

3.16.3.3 IMViCTest: This test consists of four different tests; they are Indole production, Methyl-Red test, Voges Proskauer test and Citrate utilization test. This test is specifically designed to determine the physiological properties of microorganism. They are especially useful in the differentiation of Gram-negative intestinal bacilli, particularly *Escherichia coli* and the *Enterobacter-Klebsiella* group (Chessbrough, 2006).

3.16.3.4 Indole Test: This test demonstrates the ability of certain bacteria to decompose the amino acid-Tryptophan to Indole. The bacteria isolates were inoculated into the medium and incubated at 37°C for 48 hours. At the end of incubation period, 3 drops of Kovac's reagents were added and then shaken. A red colour ring at the interface of the medium denotes a positive result.

Methyl red and Voges-Proskauer test must be considered together since they are physiologically related. Opposite test is usually obtained from the MR and VP test, that is, MR+, VP-, or MR-, VP+.

Methyl red test was preformed to demonstrate the capacity of different organisms to produce acid from the fermentation of sugar (dextrose). Methyl-red positive organisms produce a red coloration when five drops of methyl-red indicator are added into 48h old MR-VP broth culture.

The Voges-Proskauer test demonstrates the ability of organisms to produce acetoin from glucose metabolism. Some organisms metabolize glucose to produce pyruvic acid which is further broken down to yield Butane-diol and acetyl-methyl carbinol as an intermediate product.

Into one milliliter of the culture add one milliliter of six per cent alcoholic solution of alpha-naphthol and one milliliter of 16% KOH and stand for 15-20 minutes. Development of red to pink colour is a positive test.

3.16.3.5 Citrate Utilization Test: This is one of the several techniques used to assist in the identification of Enterobacteria. Principle of the test is based on the ability of an organism to use citrate as its only source of carbon. The test was carried out using Simmon's citrate agar.

The slopes of the media were prepared in bijou bottles as recommended by the manufacturers. A sterile straight wire was used to the slope with a saline suspension of the test organisms before stabbing the butt. The bottles were incubated at 35^{o}C for 48 h. Bright blue colours in the medium means positive test while no change in colour of medium indicates negative citrate test (Cheesbrough, 2000).

3.17 Method of Data Analysis

Data analysis was performed on IBM-SPSS version 23 (IBM-SPSS Inc, Chicago, USA). Preliminary data analysis involved the analysis of mean and standard deviation. Frequency distributions were constructed for the data and were all expressed as the percentage of the distribution. Statistical chart such as pie chart was used to represent some of the variables in the data. Chi-square test was used to test for association in the data at 5% level of significance. However, at situations where the chi-square rule was not fulfilled, Fishers exact test was used for a 2 by 2 table while likelihood ratio Chi-square ($LR\chi^2$) was used for more than a 2 by 2 cross tabulation.

CHAPTER FOUR

4.0 RESULTS

4.1 Socio-demographic Characteristics of the study participants

There was a total of 920 subjects that participated in the study. Table 5 contained the demographic characteristics of the study participants. The largest age group used was the 31- 40 years old at 310 (33.7%), followed by the 41 – 50 years at 214 (23.3%). Those who were less than 20 years old were 102 (11.1%). The marital status of the respondents was such that 584 (63.5%) were married, 298 (32.4%) were singles and 30 (3.3%) were divorced. The study participants were predominantly Christians (93.9%) with a few Muslims (0.9%) and traditional worship practices (5.2%).

In terms of education level of the group studied, more than half (600 or 65.2%) attained up to tertiary level of education and almost 24% had secondary education, while those with primary and non-formal educational level were 6.5% and 4.3% respectively. Large number of the study group (408 or 44.3%) were civil servants, followed by artisans at 166 (18%) and 126 (13.7%) whose occupation is teaching and 118 (12.8%) who are engaged in trading activities. Only 114 (12.4%) earn above one hundred thousand naira (₦100, 000) per month. Up to 338 (36.7%) earn between ₦21,000 to ₦50,000 per month while about a quarter of the respondents each earn less than ₦21, 000 (25.7%) or between ₦ 51,000 – 100,000 (Table 5).

Table 5: Socio Demographic Characteristics of the study participants

Socio-Demographics	Frequency (n=920)	Percent (%)
Age (years)		
Less than 20	102	11.1
20 -30	130	14.1
31 – 40	310	33.6
41 – 50	214	23.2
50+	164	17.6
Total	920	100.0
Marital Status		
Single	298	32.4
Married	584	63.4
Divorced	30	3.3
Widowed	8	0.9
Total	920	100.0
Religion		
Christianity	864	93.9
Islam	8	0.9
Traditionalist	48	5.2
Total	920	100.0
Education Level		
Non formal	40	4.3
Primary	60	6.5
Secondary	220	23.9
Tertiary	600	65.3
Total	920	1000
Occupation		
Farming	86	9.3
Trading	118	12.8
Civil servant	408	44.3
Teaching	126	13.7
Artisans	166	18.0
Others	16	1.7
Total	920	100.0
Income Level		
Less than 21000	236	25.7
21000 – 50000	338	36.7
51,000 – 100,000	232	25.2
Above 100,000	114	12.4

4.2 Water supply and Use

The responses indicate that there are many drinking water sources in the study area. Most common ones include spring water source (38.1%), borehole (36.1%), and lake/ stream (10.4%). Up to 240 (26.1%) responded that the distance of the source of water from household is ≤ 100 meters, 130 (14.1%) responded for 101 -250 meters and 138 (13%) stated that it is within 251 – 450 meters. There were 132 (14.3%) who responded that the distance of the source of water from their household is greater than 1 km. (Table 6). On what the respondents think that makes water good for use in the community, their perception was such that 63.9% responded that their water which should be good for use in the community should appear 'very clear', 24.3% responded that it is the taste of the water while 6.5% stated for the colour of the water.

The household water fetcher comprised mainly of male and female children under 15 years (490 or 53.3%), followed by adult female 202 (22%) and adult male 116 (12.6%). Majority of the households (580 (63.1%)) do not treat their water before use, while only 326 (35.4%) do treat their water before use. Among those that do treat the water before use, 254 (77.9), that is clear majority use boiling method while 30 (9.2%) indicated that they add alum and filter it through cloth while 12 (3.7%) use chlorination. The respondents that do store water in the households were 812 (88.3), out of which 420 (51.7%) use plastic bucket/drum and 180 (22.3%) use Gee-pee tank and 140 (17.2%) use earth-pot.

In terms of awareness that potable water promotes good health 862 (93.7%) stated (“yes) while 32 (3.4%) stated “no”. More than half of those that showed awareness 426 (53.4%) indicated that they were able to know it through schools, followed by radio 196 (24.6%) and television 100 (12.5%). The least was through posters 8 (1.0%).

Table 6: Water supply and Utilization

Water supply and Utilization	Frequency (n=920)	Percent
Community main source of drinking water		
Piped water	24	2.6
Borehole	332	36.1
Covered well	16	1.7
Open well	30	3.3
Spring	356	38.7
Rainwater catchment	26	2.8
Lake/ stream	96	10.4
Bottled water	40	4.3
Distance of source of water from household		
≤ 100 meters	240	26.1
101 -250 meters	130	14.1
251 – 450 meters	120	13.0
451 – 1km	114	12.4
Greater than 1km	132	14.3
Don't know	184	20.0
Perception on what makes water good for use in the community		
Colour	60	6.5
Taste	224	24.3
Odour	14	1.5
very clear	588	63.9
Combined reasons	26	2.9
Other	8	0.9
Household water fetcher		
Adult male	116	12.6
Adult female	202	22.0
male and female children under 15 years	490	53.3
male children only	42	4.6
female children only	24	2.6
Combine options selected	42	4.6
Nonresponse	4	0.43
Treatment of water before use		
Yes	326	35.4
No	580	63.1
Non-response	14	1.5
If yes on above question what type of water treatment is practiced?		
Boiling	254	77.9
Chlorination	12	3.7
Add alum and filter through cloth	30	9.2
let it stand and settle	8	2.5
Other	22	6.7
Do you store water in your household?		
Yes	812	88.3
No	84	9.1
Nonresponse	24	2.6

If yes, what type of storage container do you use for water drinking		
Earth-pot	140	17.2
Iron bucket/drum	66	8.1
plastic bucket/drum	420	51.7
Gee-pee tank	180	22.3
Others	6	0.7
Are you aware that potable water promotes good health?		
Yes	862	93.7
No	32	3.4
Nonresponse	26	2.8
If yes, how did you know?		
Radio	196	24.6
Television	100	12.5
Friends	46	5.8
Schools	426	53.4
Churches	22	2.8
Posters	8	1.0

4.3 Awareness of WASH Practices and programs

The practice of WASH programs includes several programs such as community led total sanitation, school sanitation, and others that could lead to reduction in economic loss, morbidity, mortality and promotion in longevity. Figure 7 represents the output of the level of awareness of the study participants concerning the practice and implementation of WASH programs. A bit more than half of the respondents (52.2%) showed awareness. The awareness level was slightly higher with 480 (52.2%) compared to those who were not aware 440 (47.8%).

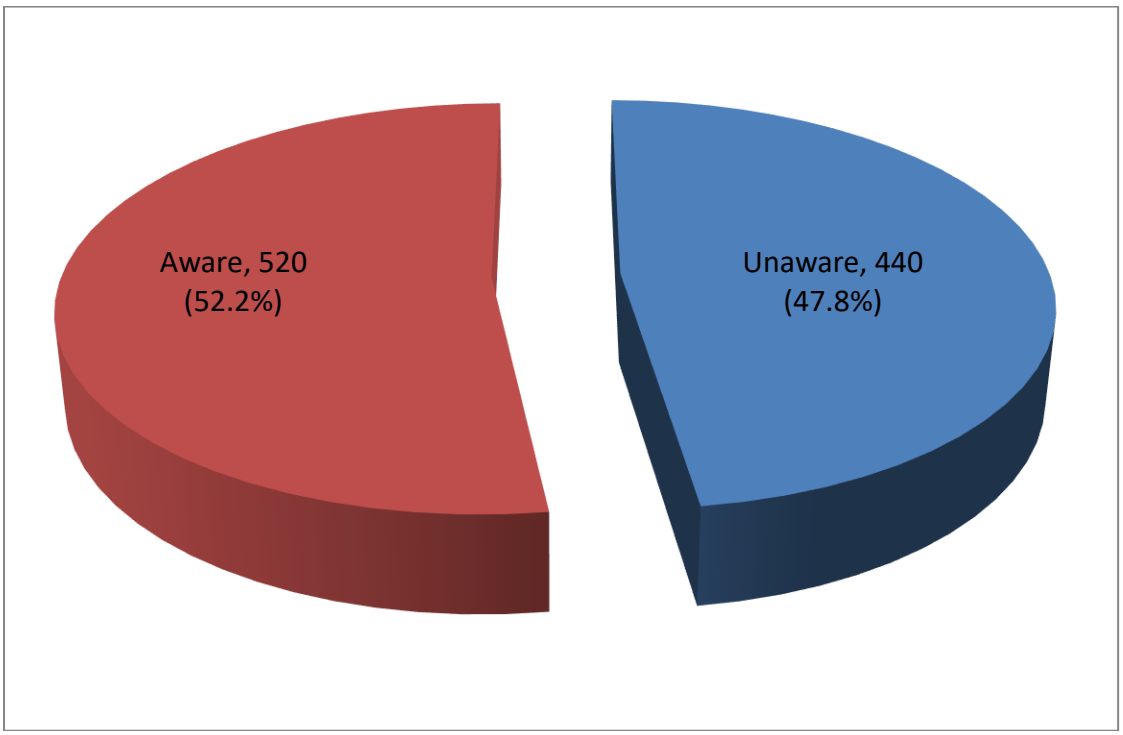

Figure 7: **Awareness of WASH Practices and Programs**

4.4 Association between Awareness of Practice of WASH

On Table 7, among those who showed awareness of practice and implementations of WASH programs, 83.8% reported that they have suffered from WASH related infections while a total of 16.3% reported that they have not suffered from WASH related infections. On the other hand, among those that showed unaware, 94.5% reported that they have suffered WASH related infections. Clearly the result indicates that those who suffered from WASH related infections were reported higher among the unaware group compared to that of the aware group. The difference between the two groups were found to be statistically significant at 5% level ($p < 0.001$, $\chi^2 = 13.570$).

Table 7: Association between Awareness of Practice and Implementations of WASH programs and suffering from WASH related infections among the study group

Awareness of Practice and Implementations of WASH programs	Suffered WASH related infections					p value	Chi-square (χ^2)
	Total	No		Yes			
Aware	480	78	16.3%	402	83.8%		
Unaware	440	24	5.5%	416	94.5%		
Total	920	102	11.1%	818	88.9%	0.001	13.570

4.5 Sanitation Practices among the Study Participants

Over half of the study respondents indicated that they have water cistern (WC) toilet 492 (53.5%), followed by pit latrine at 216 (23.5%) and pour flush latrine at 126 (13.7%). On the materials they use for anal cleaning, 392 (42.6%) responded for tissue paper, 97% responded for tissue paper and water, 158 (17.2%) responded for paper and 94 (10.2%) responded for tissue paper with water and soap.

Those who indicated that they do wash hand after toilet was 874 (95%), while 22 (2.4%) responded “No”.

Reasonable number 620 (71.6%) use water and soap to wash hand after toilet use while 246 (28.4%) use only water. Those who have functional toilet were 536 (58.3%) while in terms of the provision of the functional toilets, 216 (23.5%) were provided by the age grades, 150(16.3%) by individuals and 78 (8.5%) by the government.

When asked if they believe that proper excreta disposal improves status of their community, 812 (88.3%) responded “yes” and 70 (7.7%) responded “no”. up to 356 (38.7%) responded that they clean or disinfect their toilets weekly, 316 (34.3%) responded that their toilets are cleaned on daily basis and 122 (13.3%) stated that theirs are cleaned or disinfected on monthly basis.

Table 8: Sanitation practices among the Study Participants

Sanitation practices	Frequency (n=920)	Percent
Latrine type they have		
Bucket latrine	14	1.5
Silt-mounted latrine	56	6.1
pit latrine	216	23.5
Ventilated improved pit -latrine (VIP)	8	0.9
Pour flush latrine	126	13.7
Water cistern (WC)	492	53.5
combined options	8	0.9
Material used for anal cleansing		
Small wooden stick	16	1.7
Corncob	8	0.9
Paper	158	17.2
Tissue paper	392	42.6
Water only	58	6.3
Tissue paper and water	194	21.1
Tissue paper with water and soap	94	10.2
combined options selected	14	1.5
Do you wash hands after using toilet		
Yes	874	95.0
No	22	2.4
Nonresponse	16	1.7
what they used in washing hand after toilet use		
water only	246	28.4
water and soap	620	71.6
Presence of functional toilet in the community		
Yes	536	58.3
No	368	40.0
Functional toilet provider in the community		
Government	78	8.5
Age grade	216	23.5
Individuals	150	16.3
Donor agency	124	13.5
Others	16	1.7
Believe that proper excreta disposal improves status of their community		
Yes	812	88.3
No	70	7.7
Frequency of cleaning or disinfecting toilet		
Daily	316	34.3
Weekly	356	38.7
Monthly	122	13.3
Three Months	40	4.3
Others	30	3.3

4.6 Personal Hygiene

Based on the result obtained (Table 9), there seems to be high awareness of hygiene. Apparently, the respondents have heard about hygiene apart from 38 (4.1%) who indicated that they haven't heard about hygiene. Very reasonable number of the participants 694 (75.4%) indicated that they use water and soap for hands cleaning, 188 (20.4%) use water only, 16 (1.7%) used detergents, whereas 8 (about 1%) used both water and ash and others. Only 6 (0.7%) utilized all the methods and none of the participants used clay soil only.

On when they normally wash their hands, 232 (25.2%) of the participants washed their hands before cooking food, 228 (24.8%) washed their hands when it is dirty, 202 (22.0%) did wash their hands after eating food. However, 134 (14.6%) combined the various methods while, 68 (7.4%) did wash hands before eating and after handling food. 32 (3.5%) did not respond to when they normally wash their hands. 16 (1.7%) participants said to wash hands before and after feeding babies and 8 (0.9%) did wash hands after cleaning babies' bottom.

According to the result obtained, majority of the participants 714 (77.6%) had their bath twice daily, 190 (20.7%) had theirs once daily, while 16 (1.7%) had their bath twice weekly. Greater number of the participants 876 (95.2%) said "yes" that hygiene practices reduced water-borne infections while, 38 (4.1%) said "no", with only 6 (0.7%) non respondents.

Table 9: Personal Hygiene

Personal Hygiene practices	Frequency	Percent
Heard about hygiene		
Yes	882	95.9
No	38	4.1
Total	920	100.0
What they use for hand washing		
water only	188	20.4
water and soap	694	75.4
Water and ash	8	.9
Clay soil only	-	-
Detergent	16	1.7
all the above	6	.7
Other	8	.9
When they normally wash hands		
before cooking food	232	25.2
Before eating and handling food	68	7.4
After eating food	202	22.0
Before and after feeding babies	16	1.7
after cleaning babies' bottom	8	.9
when hands are dirty	228	24.8
Combined Answers	134	14.6
Nonresponse	32	3.5
Bath Frequency		
Once daily	190	20.7
Twice daily	714	77.6
Twice weekly	16	1.7
Aware that hygiene practices reduce water borne infections		
Yes	876	95.2
No	38	4.1
Nonresponse	6	0.7

4.7 Bacterial Count and Microbial Qualities of Water in the Study Area

4.7.1: Total Bacteria Counts (CFU/ml) of water Samples from Different locations of the Study Area

Table 10 represents the result for the total bacteria Counts (CFU/ml/g) of water samples from different locations of the study area. The mean overall count was as follow: NA = $7.7x\ 10^6$, EMBA = 7.9×10^4. SSA = $3.4x\ 10^3$, BA = $5.0x\ 10^5$, MCA = 1.6×10^7. The mean total bacteria count is lowest in NA ($3.4x\ 10^3$). At Okigwe Zone, we have NA = 7.6×10^6, EMBA = 7.8×10^4. SSA = $3.4x\ 10^3$, BA = 5.3×10^5, MCA = 1.6×10^7. At Orlu Zone, it was relatively lower especially on NA ($4.4x\ 10^6$), EMBA (1.2×10^5) and SSA (4.2×10^3). At Owerri Zone, total bacteria count on the water samples was zero for SSA, while it recorded 1.7×10^7 and 1.1×10^5respectively for NA and EMBA

Table 10: Total Bacteria Counts (CFU/ml) of water Samples from Different locations of the Study Area

Sample	Total counts on NA	Total counts on EMBA	Total counts on SSA	Total counts on BA	Total counts on MCA
Okigwe Zone					
Mean	7.6×10^6	7.8×10^4	3.4×10^3	5.3×10^5	1.6×10^7
Standard deviation	1.6×10^7	2.4×10^5	1.8×10^4	1.9×10^6	8.5×10^7
Orlu Zone					
Mean	4.4×10^6	1.2×10^5	4.2×10^3	1.1×10^8	8.4×10^7
Standard deviation	9.2×10^6	5.8×10^5	2.0×10^4	7.0×10^8	5.8×10^7
Owerri Zone					
Mean	1.7×10^7	1.1×10^5	0	6.4×10^5	9.5×10^5
Standard deviation	2.2×10^7	5.0×10^5	0	1.4×10^6	1.8×10^6
Total					
Mean	7.7×10^6	7.9×10^4	3.4×10^3	5.0×10^5	1.6×10^7
Standard deviation	1.7×10^7	1.2×10^7	1.8×10^4	1.4×10^6	8.6×10^7

4.7.2 Microbial qualities of the water consumed in study area of Imo State

Tables 11 and 12 were the outputs representing microbial qualities of water consumed in Imo State. The results in both tables were summarized in figure 8. Clearly the largest bacteria isolate found was *Enterococcus faecalis* at 15%, followed by *Klebsiella pneumoniae* 9%. Others *include Staphylococcus aureus, Bacillus cereus, Pseudomonas aeruginosa* and *Micrococcus roseus* at 8% each. The least bacterial isolates were the *Streptococcus pyogenes, Escherichia coli and Aeromonas sp.* at 3% each (Figure 8).

Table 11: Colonial and Microscopic Characteristics of Bacteria isolated from water samples

Colonial Characteristics	Motility Test	Spore Formation	Capsule Formation	Gram morphology/reaction	Probable Identity
Circular moist and shiny golden yellow colonies on Nutrient Agar and light yellow on Mannitol Salt Agar	-	-	-	Gram positive cocci predominantly in clusters, few in tetrads and pairs	*Staphylococcus* sp
Large slimy mucoid colonies on Eosin Methylene Blue Agar	+	-	+	Gram negative short thick rods in chains	*Klebsiella* sp
Small circular moist and shiny low convex cream colonies on Nutrient Agar	-	-	-	Gram positive cocci predominantly in chains and pairs	*Enterococcus* sp
Light pink mucoid moist and shiny colonies on Salmonella Shigella Agar	+	+	-	Gram negative single and short rods	*Shigella* sp
Serrated dull and dry flat cream colonies on Nutrient Agar				Large gram-positive rods with central spores	*Bacillus* sp
Greenish metallic sheen on Eosin Methylene Blue Agar	+	-	-	Gram negative rods predominantly in single and pairs	*Escherichia coli*
Cream moist and slimy cream colonies on Nutrient Agar	+	+	-	Large gram-positive rods with central spores in chains	*Bacillus* sp
Bluish green moist colonies on Nutrient Agar	+	-	-	Gram negative slightly curves rods	*Pseudomonas sp.*
Small smooth moist and shiny low convex yellow colonies	-	-	-	Cocci predominantly in tetrads and few in pairs and irregular	*Micrococcus* sp
Orange moist and shiny colonies	-	-	-	Cocci predominantly in tetrads and few in pairs and irregular	*Micrococcus* sp
Mucoid pink colonies on Eosin Methylene Blue Agar	-	-	-	Gram negative rods in pairs and short chains	*Enterobacter* sp
Moist and shiny purple colonies on Nutrient agar	-	-	-	Gram positive Cocci predominantly in singles, few in pairs	*Aeromonas* sp
Dull and dry umbonate cream colonies	-	-	-	Gram positive Pleomorphic rod	*Corynebacterium* sp
Smooth black fisheye colonies on SSA				Gram negative rods in singles and short chains	*Salmonella* sp
Complete (beta) hemolysis on blood agar with zone of clearance around colonies	-	-	-	Gram positive cocci predominantly in chains	*Streptococcus sp.*

Table 12: Biochemical Characteristics and Carbohydrate Fermentation of Bacteria Isolated from water samples

Cat	Oxi	Coag	IN	VP	Cit	NO_3	Ure	G	S	L	M	Mn	Xyl	Ara	MR	Identity of Isolates
+	-	+	-	+	-	+	+	+	+	+	+	+	-	-	-	*Staphylococcus aureus*
+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	*Klebsiella* sp
-	-	-	-	-	+	+	-	+	+	+	-	+	-	+	-	*Enterococcus faecalis*
-	-	-	-	-	+	+	-	-	-	-	+	-	-	+	+	*Shigella* sp
+	-	-	-	+	+	+	-	+	-	-	-	-	-	-	-	*Bacillus cereus*
+	-	-	+	-	-	+	-	+	+	+	+	+	+	+	-	*Escherichia coli*
+	-	-	-	+	+	+	-	+	-	-	-	+	+	+	-	*Bacillus subtilis*
+	+	-	-	-	+	+	+	+	-	-	-	+	+	+	+	*Pseudomonas aeruginosa*
+	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+	*Micrococcus luteus*
+	-	-	-	-	+	+	-	+	+	-	-	-	-	-	+	*Micrococcus roseus*
+	-	-	-	+	-	+	-	+	-	+	-	-	+	-	+	*Enterobacter coli*
+	-	-	-	-	-	+	-	+	+	-	-	-	+	+	+	*Aeromonas* sp
+	-	-	-	-	+	-	+	+	+	+	-	+	+	+	+	*Corynebacterium diphtheriae*
-	-	-	-	+	+	+	-	+	-	-	-	+	-	-	-	*Streptococcus pyogenes*
+	-	-	-	-	+	-	+	+	+	-	-	+	+	-	+	*Salmonella typhi*

Cat- Catalase; Oxi- Oxidase; Coag- Coagulase; In- Indole; VP- Voges Proskauer; MR- Methyl Red; Cit-Citrate; NO_3- Nitrate reduction; Ure- Urease; G- Glucose; S-Sucrose; L-Lactose; M- Maltose; Mn, Mannitol; Ara- Arabinose; Xyl- Xylose

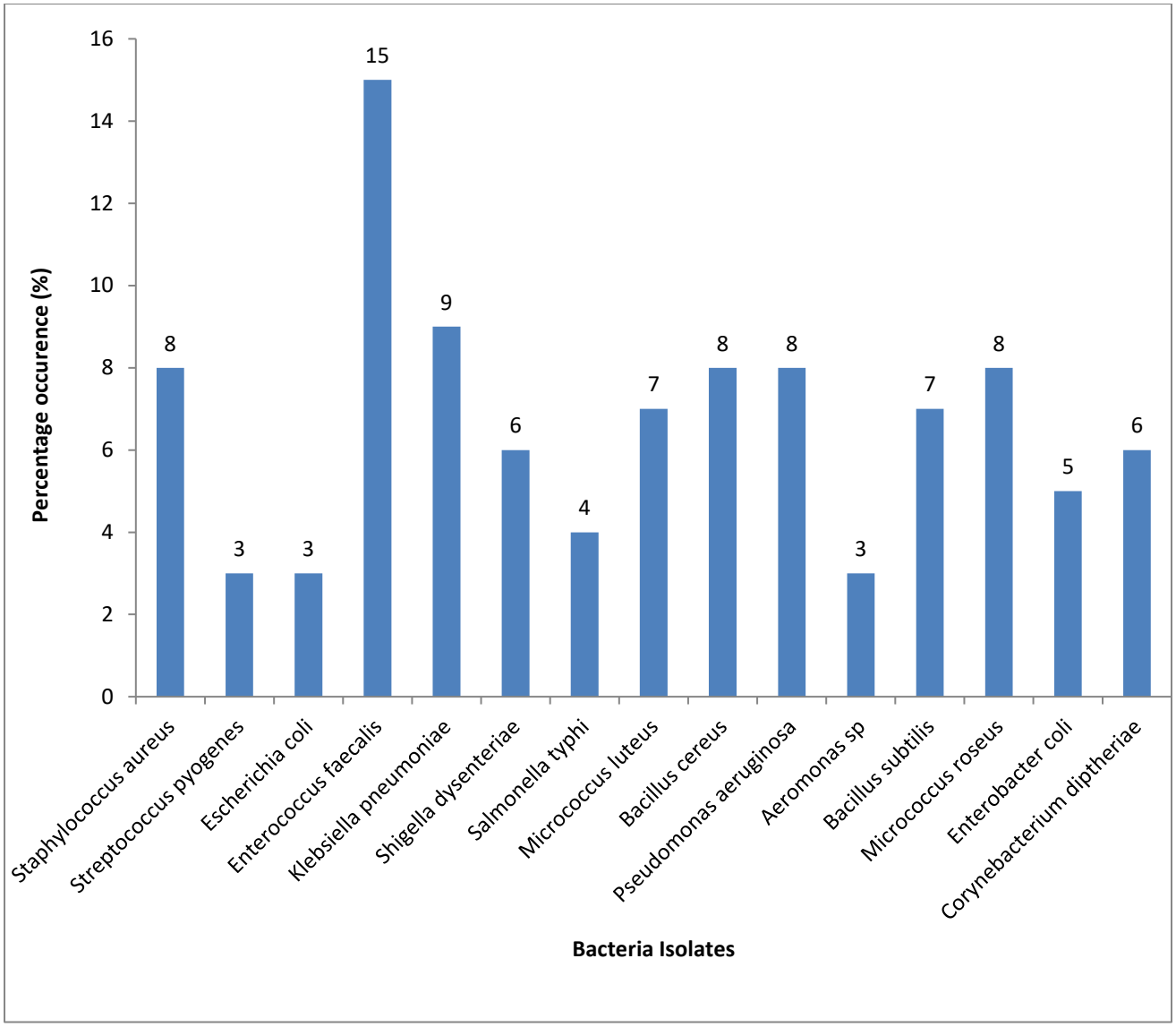

Figure 8: Bar chart of bacterial isolates in water samples in Imo State

4.7.3 On-site physico-chemical analysis of Water Samples obtained from Different Locations of the Study communities

Based on the on-site physico-chemical analysis of water samples obtained from different locations of the study area. The mean pH was found to be 5.1 (Standard deviation= 0.79). This is a clear indication that the water used in Imo is acidic. The lowest and highest pH values obtained in the study area were 3.6 and 7.2 respectively. Across the zones in Imo state, the mean pH was found to be 5.12 ±0.95 in Okigwe zone, 5.45± 0.74 in Orlu zone and 4.49± 0.55 in Owerri zone. On average, the water samples in Owerri zone were more acidic compared to the samples from Okigwe zone and Orlu zone.

Other physico-chemical properties studied include electrical conductivity (EC), total dissolved solids (TDS) and temperature. The average (mean) EC found in the study was quite low (0.04 µs/cm) at a corresponding standard deviation of 0.08 µs/cm (Okigwe zone = 0.03µs/cm, Orlu zone = 0.03µs/cm, Owerri zone = 0.09µs/cm). The TDS for the water samples was 36.4 ppm (Okigwe zone = 24.6ppm, Orlu zone = 26.0ppm, Owerri zone = 71.0ppm), while the average total temperature of 28.18 ^{0}C was higher than the range required for drinking water, comprising of. 28.7^{0}C for Okigwe zone, 27.20C for Orlu zone and 27.4^{0}C for Owerri zone.

Table 13: Summary of On-site Physico-Chemical Analysis of Water Samples from Different locations of the Study Area

Zone	WHO Standard	Okigwe Zone		Orlu Zone		Owerri Zone		Total	
	Mean	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
pH	6.5 -8.5	5.12	0.950	5.45	0.737	4.49	0.550	5.1	0.79
EC (µs/cm)	≤ 400	0.03	0.053	0.03	0.030	0.09	0.140	0.04	0.08
TDS (ppm)	500	24.58	39.858	25.97	24.527	70.97	99.087	36.4	60.68
Temperature (^{0}C)	≤ 15	28.66	4.521	27.16	0.820	27.44	2.260	28.18	2.65

4.8 Open Defecation

The defecation pattern among the respondents was such that 332 (36.1%) defecated with pit toilet, 80 (8.7%) defecated in the stream and trench. Those who use bucket were 76 (8.3%) while 68 (7.4%) and 40 (4.3%) respectively defecate in the bush and with polythene bags. When asked on the distance from where they defecate to the source of community water supply, 348 (37.9%) responded for more than 150 meters, followed by 162 (17.6%) for less than 50 meters and 120 (13%) for 51 – 100 meters (Table 14).

As large as 818 (88.9%) responded that they are aware that open defecation can lead to diseases like cholera, while 46 (5%) stated that they have no idea whatsoever on whether open defecation can lead to diseases like cholera. In terms of whether they have any led group or committee set up to stop people from defecating openly in your community, 346 (37.6%) responded “yes”, 462 responded “no” and 112 (12.2%) stated that they do not know. Among those that responded “yes”, 154 (48.7%) responded that the group head is LGA and the community.

Table 14: Open Defecation Habit

Habit of Open Defecation	Frequency	Percent
Where do you defecate?		
Bush	68	7.4
Bucket	76	8.3
Pit toilet	332	36.1
Polythene bags	40	4.3
Stream and trench	80	8.7
Others	182	19.8
What is the distance from where you defecate to your source of community water supply?		
≤ 50 meters	162	17.6
51 -100 meters	120	13.0
101 -150 meters	112	12.2
more than 150 meters	348	37.9
Are you aware that open defecation can lead to diseases like cholera		
Yes	818	88.9
No	6	0.7
No idea	46	5.0
Total	870	94.6
Do you have any led group or committee set up to stop people from defecating openly in your community?		
Yes	346	37.6
No	462	50.2
don't know	112	12.2
If yes where is the head from		
LGA	154	48.7
Community	154	48.7
Others	8	2.5

4.9 WASH Related Diseases

The WASH related diseases identified among the respondents in the study area include cholera, diarrhea, typhoid, skin infection and malaria. There were 818 (88.9%) who indicated that they have recently suffered from any WASH related diseases against 102 (11.1%) that responded that they have not suffered from any of such diseases recently (Figure 9).

The most suffered WASH related disease in the study area is malaria (Table 15) Half of the respondents 460 (50%) indicated that they have suffered malaria, and that was followed by typhoid 186 (20.2%), diarrhea 96 (10.4%) and cholera 54 (5.9%). When asked for how long since they have suffered malaria, 288 (31.3%) stated three months ago 278 (30.2%) was for last month and 188 (20.4) stated for more than one year while 164 (17.8%) responded for last six months. When the respondents were asked if they use of clean water for washing, drinking and bathing was an appropriate way to prevent water related diseases among community people, clear majority (870 or 94.6%) responded “yes”. The respondents who agree that adequate well maintained and clean toilet facilities are prerequisite for good health of the community were 44 (47.8%) while 480 (52.2%) could not agree.

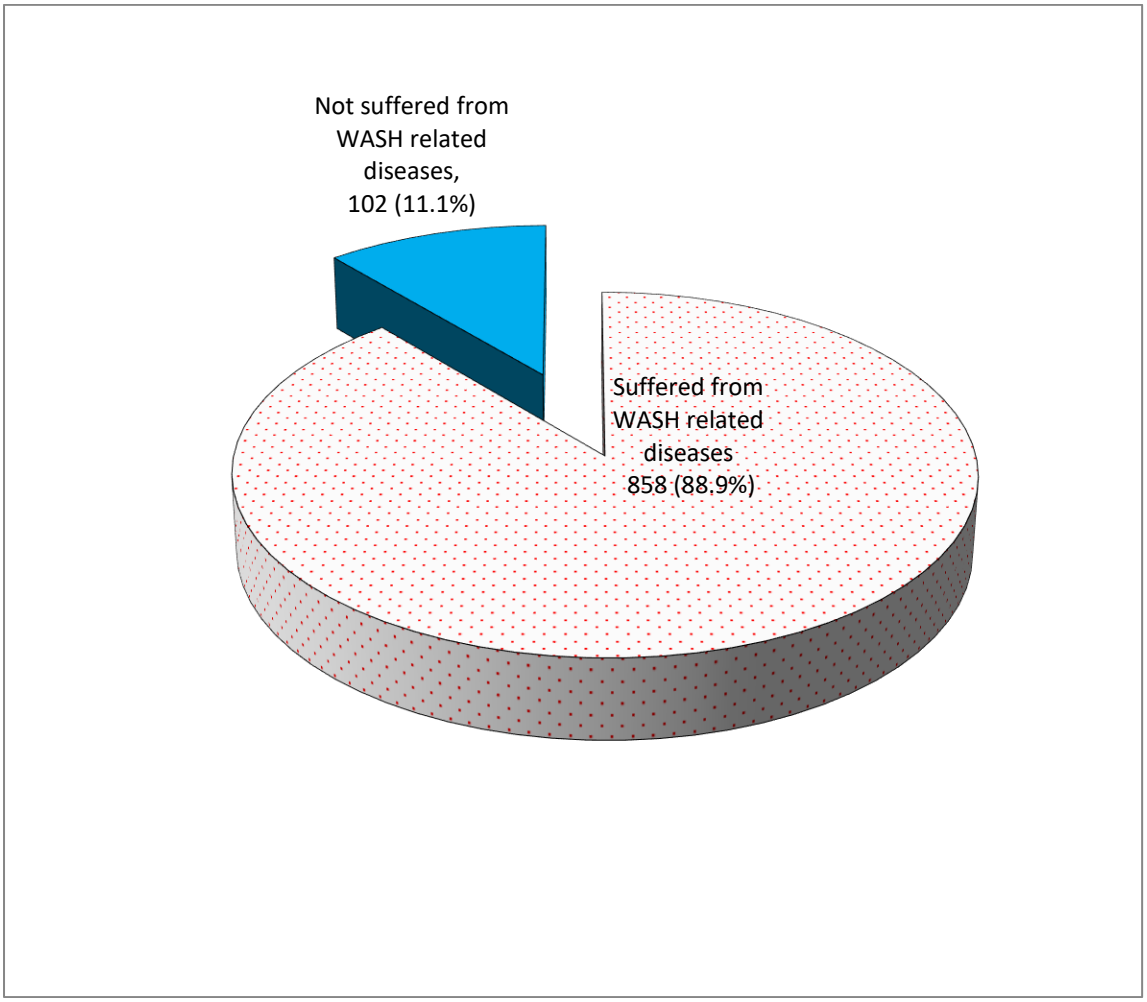

Figure 9: Proportion of those that have either suffered any WASH related disease recently or not

Table 15: WASH Related Diseases

WASH and related diseases	Frequency (n=920)	Percent (%)
Have you suffered any WASH related disease?		
None	102	11.1
Cholera	54	5.9
Diarrhea	96	10.4
Typhoid	186	20.2
Skin infection	122	2.4
Malaria	460	50.0
For how long now		
last month	278	30.2
last three months ago	288	31.3
last six months ago	164	17.8
More than one year	188	20.4
Does the use of clean water for washing, drinking and bathing an appropriate way to prevent water related diseases among community people?		
Yes	870	94.6
No	50	5.4
Agree that adequate well maintained and clean toilet facilities are prerequisite for good health of the community		
Yes	440	47.8
No	480	52.2

4.10 Relationship between Water supply and Utilization with WASH related Diseases

Significant factors of water supply and utilization with WASH related diseases include Community main source of drinking water (p=0.001, LRχ^2=34.713), distance of source of water from household (p=0.001, χ^2=27.041), perception on what makes water good for use in the community (p=0.001, LRχ^2 =20.993), type of storage container used for water drinking (p=0.001, LRχ^2 =12.648) and source of awareness that potable water promotes good health (p=0.001, LRχ^2 =27.740) (Table 4. 12).

Bottled water and Lake/ River/ stream sources were more protective of WASH related diseases than piped water. Those whose source of water distance from household were 101 -250 meters and less than 100meters suffer less of WASH related diseases than those at distance of more than 1 km. the respondents whose perception of the odor of the water is a way of identifying what makes water good for use in the community were the less to suffer from WASH related diseases than others.

Though school is the most sources of awareness aware that potable water promotes good health, but it wasn't quite protective as television. Many whose source of information on aware that potable water promotes good health were radio and school still suffer from water borne related diseases than those who rely on television. This is not a surprise because most people tend to learn more from what they can see visually than the normal talking and listening.

Table 16: Relationship between Water supply and Utilization with WASH related Diseases

Water supply and Utilization		Suffered WASH related diseases					
	Total	**No**	**%**	**Yes**	**%**	**LRχ^2**	**p value**
Community main source of drinking water						34.713	0.001
Piped water	24	0	0.0	24	100.0		
Borehole	332	100	15.1	282	84.9		
Covered well	16	0	0.0	16	100.0		
Open well	30	32	53.3	14	46.7		
Spring	356	36	5.1	338	94.9		
Rainwater catchment	26	0	0.0	26	100.0		
Lake/ stream	96	24	12.5	84	87.5		
Bottled water	40	12	15.0	34	85.0		
Distance of source of water from household						27.041	0.001
≤ 100 meters	240	40	8.3	220	91.7		
101 -250 meters	130	56	21.5	102	78.5		
251 – 450 meters	120	16	6.7	112	93.3		
451 – 1km	114	16	7.0	106	93.0		
Greater than 1km	132	0	0.0	132	100.0		
Don't know	184	76	20.7	146	79.3		
Perception on what makes water good for use in the community						20.993	0.001
Colour	60	0	0.0	60	100.0		
Taste	224	40	8.9	204	91.1		
Odour	14	16	57.1	6	42.9		
very clear	588	148	12.6	514	87.4		
Combined reasons	26	0	0.0	26	100.0		
Other	8	0	0.0	8	100.0		
Household water fetcher						8.824	0.184
Adult male	116	28	12.1	102	87.9		
Adult female	202	52	12.9	176	87.1		
male and female children under 15 years	490	112	11.4	434	88.6		
male children only	42	0	0.0	42	100.0		
female children only	24	0	0.0	24	100.0		
Combine options selected	42	12	14.3	36	85.7		
Nonresponse	4	0	0.0	4	100.0		

Table16: Continued

Water supply and utilization	Suffered WASH related diseases						
	Total	**No**	**%**	**Yes**	**%**	**LRχ^2**	**p value**
Treatment of water before use						0.989	0.610
Yes	326	38	11.7	288	88.3		
No	580	66	11.0	514	89.0		
Non-response	14	6	42.9	8	57.1		
If yes on above question what type of water treatment is practiced?						5.352	0.253
Boiling	254	30	11.0	228	89.0		
Chlorination	12	0	0.0	12	100.0		
Add alum and filter through cloth	30	0	0.0	30	100.0		
let it stand and settle	8	2	33.3	6	66.7		
Do you store water in your household?							0.454ɔ
Yes	812	96	11.8	712	88.2		
No	84	6	7.1	78	92.9		
If yes, what type of storage container do you use for water drinking						12.648	0.013
Earth-pot	140	16	11.4	124	88.6		
Iron bucket/drum	66	14	21.2	52	78.8		
plastic bucket/drum	420	60	14.3	360	85.7		
Gee-pee tank	180	6	3.3	174	96.7		
Others	6	0	0.0	6	100		
Are you aware that potable water promotes good health?							0.236ɔ
Yes	862	187.4	51	23.6	380		
No	32	6.8	0	0.0	16		
If yes, how did you know?						27.74	0.0001
Radio	196	2	7.1	182	92.9		
Television	100	22	22	78	78.0		
Friends	46	8	17.4	38	82.6		
Schools	426	42	9.9	384	90.1		
Churches	22	0	0.0	22	100		
Posters	8	8	100	0	0.0		

Asterisk (*) indicates significance at 5%, LRχ^2 = Likelihood Ratio Chi-square, The symbol ŧ indicates that Person Chi-square was used and ɔ indicated that Fishers exact test was used

4.11 Relationship Between Sanitation Practices and WASH related Diseases

On Table 17, Sanitation practices and WASH related diseases were found to be significantly associated on Latrine type they have (p=0.015, LRχ2=15.735), material used for anal cleansing

(p=0.001, LRχ2=28.33), washing hands after toilet use (p=0.01, LRχ2=4.61), having functional toilet provider in the community (p=0.001, LRχ2=27.77), Believe that proper excreta disposal improves status of their community (p=0.037) and frequency of cleaning or disinfecting toilets (p=0.012, LRχ2=12.821). Those that use pour flush latrine and water cistern (WC) slightly suffer less of WASH related diseases than those that use bucket and Silt-mounted latrine.

The participants that use tissue paper and water as well as those that use water only suffered less of the WASH related diseases than those that used small wooden stick and corncob. Similarly, those that do wash hands after toilet use suffer less of the diseases than those that do not, while those who asserted that they believe that proper excreta disposal improves status of their community also suffered less of the WASH associated diseases than others. The respondents who clean or disinfect their toilets daily suffer less of the WASH related diseases compared to all others that do not clean the toilets daily.

Table 17: Sanitation practices and Suffered WASH related diseases among the Study Participants

Sanitation practices	Suffered WASH related diseases						
	Total	No	%	Yes	%	LRχ^2	p value
Latrine type they have						15.735	0.015*
Bucket latrine	14	0	0.0	14	100.0		
Silt-mounted latrine	56	0	0.0	56	100.0		
pit latrine	216	16	7.4	200	92.6		
Ventilated improved pit -latrine (VIP)	8	0	0.0	8	100.0		
Pour flush latrine	126	24	19.0	102	81.0		
Water cistern (WC)	492	62	12.6	430	87.4		
Combined options	8	0	0.0	8	100.0		
Material used for anal cleansing						28.33	0.001*
Small wooden stick	16	0	0.0	16	100.0		
Corncob	8	0	0.0	8	100.0		
Paper	158	16	10.1	142	89.9		
Tissue paper	392	20	5.1	372	94.9		
Water only	58	8	13.8	50	86.2		
Tissue paper and water	194	50	25.8	144	74.2		
Tissue paper with water and soap	94	8	8.5	86	91.5		
Do you wash hands after using toilet						4.61	0.001*
Yes	874	102	11.7	772	88.3		
No	22	0	0.0	22	100.0		
Nonresponse	16	0	0.0	16	100.0		
what they used in washing hand after toilet use							0.263
water only	246	24	9.8	222	90.2		
water and soap	620	78	12.6	542	87.4		
Presence of functional toilet in the community							
Yes	536	38	7.1	498	92.9		
No	368	64	17.4	304	82.6		

Table 17: Continued

Sanitation practices	Suffered WASH related diseases						
	Total	No	%	Yes	%	LRχ^2	p value
Functional toilet provider in the community						27.77	0.001*
Government	78	8	10.3	70	89.7		
Age grade	216	0	0.0	216	100.0		
Individuals	150	14	9.3	136	90.7		
Donor agency	124	16	12.9	108	87.1		

Others	16	0	0.0	16	100.0		
Believe that proper excreta disposal improves status of their community							0.037ɔ
Yes	812	86	10.6	726	89.4		
No	70	0	0.0	70	100.0		
Frequency of cleaning or disinfecting toilet						12.821	0.012
Daily	316	50	15.8	266	84.2		
Weekly	356	30	8.4	326	91.6		
Monthly	122	14	11.5	108	88.5		
Three Months	40	0	0.0	40	100.0		
Others	30	0	0.0	30	100.0		

Asterisk (*) indicates significance at 5%, LRχ^2= Likelihood Ratio Chi-square, the symbol ɬ indicates that Person Chi-square was used and ɔ indicated that Fishers exact test was used

4.12 Relationship between Personal Hygiene Practices and Wash related Diseases

When the respondents normally wash hand was found as a significant factor of WASH related diseases in this study ($p=0.018$, $LR\chi^2 = 16.908$) Though the proportion for WASH related diseases was found high among different respondents, it was slightly lower on those who responded that the normally wash hands before cooking food, after eating food and whenever the hands are dirty (Table 4.14).

Though all other items assessed on personal hygiene were not found significant ($p > 0.05$), those who have heard about hygiene suffered less of the WASH related diseases than those that responded that they have not heard of it. Those who wash hands with water and soap also suffered less of the diseases than those that wash with other items. Being aware that hygiene practices reduce water borne infections showed more protection against WASH related diseases than mot being aware as all those who were not aware suffered from the diseases compared to 88.4% for the aware group.

Table 18: Personal Hygiene practices and WASH related disease

Personal Hygiene practices	Suffered WASH related diseases						
	Total	**No**	**%**	**Yes**	**%**	**LRχ^2**	**p value**
Heard about hygiene							2.50ɔ
Yes	882	102	11.6	780	88.4		
No	38	0	0.0	38	100.0		
What they use for hand washing						8.727	0.334
water only	188	16	8.5	172	91.5		
water and soap	694	86	12.4	608	87.6		
Water and ash	8	0	0.0	8	100.0		
Clay soil only		0	0.0	0	0.0		
Detergent	16	0	0.0	16	100.0		
all al the above	6	0	0.0	6	100.0		
Other	8	0	0.0	8	100.0		
When they normally wash hands						16.908	0.018
Before cooking food	232	36	15.5	196	84.5		
Before eating and handling food	68	0	0.0	68	100.0		
After eating food	202	24	11.9	178	88.1		
Before and after feeding kids	16	0	0.0	16	100.0		
after cleaning kids bottom	8	0	0.0	8	100.0		
when hands are dirty	228	28	12.3	200	87.7		
Combined Answers	134	14	10.4	120	89.6		
Nonresponse	32	0	0.0	32	100.0		
Bath Frequency						2.11	0.238
Once	190	24	12.6	166	87.4		
Twice daily	714	78	10.9	636	89.1		
Twice weekly	16	0	0.0	16	100.0		
Aware that hygiene practices reduce water borne infections						5.306†	0.070
Yes	876	102	11.6	774	88.4		
No	38	0	0.0	38	100.0		
nonresponse	6	0	0.0	6	100.0		

Asterisk (*) indicates significance at 5%, LRχ^2= Likelihood Ratio Chi-square, the symbol † indicates that Person Chi-square was used and ɔ indicated that Fishers exact test was used

CHAPTER FIVE

5.0 DISCUSSION

5.1 Discussion

The highest load of bacterial isolate *was Enterococcus faecalis*, followed by *Klebsiella pneumoniae*. Others include *Staphylococcus aureus, Bacillus cereus, Pseudomonas aeruginosa, Micrococcus roseus, Streptococcus pyogenes, Salmonella typhi, Bacillus subtilis, Shigella dysenteriae, Escherichia coli, Aeromonas sp.,* and *Enterobacter coli.* Similar isolates were identified on Ibe and Okplenye (2005) and in Onyango, *et al*, (2018). Based on the on-site physico-chemical analysis of water samples obtained from different locations of the study area, it is a clear indication that the water used in Imo State is acidic. This is not a surprise as Imo State is an oil producing state in Nigeria and most water sources in Niger delta region is acidic (Nduka and Oram, 2008)

Majority of the study group indicated that they have recently suffered from any WASH related diseases. The WASH related diseases identified among the respondents in the study area include cholera, diarrhea, typhoid, skin infection and malaria. The most suffered WASH related disease in the study area is malaria, typhoid and diarrhea. It has been reported that malaria is a major public health problem in Nigeria where it accounts for more cases and deaths than any other country in the world. (US Embassy of Nigeria, 2019).

Awareness of practice and implementations of WASH programs was also found as a significant factor to reported having suffered from WASH related diseases. In Assefa and Kumie (2014), it was established that awareness and the probability of having WASH related diseases are associated. More than half of those that showed awareness that potable water promotes good health, of which many indicated that they were able to know it through schools.

Similarly, more than half of the group studied have been aware that the practice and implementation of WASH programs include several programs that could lead to reduction in economic loss, morbidity, mortality and promotion in longevity. The respondents who indicated that they were aware of the practice and implementations of WASH programs were quite higher compared to those who were not aware. This result was not a surprise since many of the study respondents were educated. Education is an important factor of awareness in health studies (Yuan, *et al.,* 2015)

Some of the water supply and utilization factors found to be significantly related to WASH related diseases in this study include community main source of drinking water, distance of source of water from household, perception on what makes water good for use in the community, type of storage container used for drinking water and source of awareness that potable water promotes good health.

Bottled water and Lake/ River/ stream sources were more protective of WASH related diseases than piped water and those whose household were over 1 km from the source of water suffer more in WASH related diseases than others.

While schools are the most source of awareness that potable water promotes good health, it wasn't quite protective as television. Probably television is more educative, and most people tend to learn more from what they can see visually than normal talking and listening.

Sanitation practices and WASH related diseases were found to be significantly associated with latrine type they have, material used for anal cleansing, washing hands after toilet use, having functional toilet provider in the community, believe that proper excreta disposal improves status of their community and frequency of cleaning or disinfecting toilets. Those that use pour flush latrine and water cistern (WC) slightly suffer less of WASH related diseases than those that use bucket and Silt-mounted latrine.

The participants that use tissue paper and water as well as those that use water only suffered less of the WASH related diseases than those that used small wooden stick and corncob. Similarly, those that do wash hands after toilet use suffer less of the diseases that those that do not, while those who asserted that they believe that proper excreta disposal improves status of their community also suffered less of the WASH associated diseases than others.

The respondents who clean or disinfect their toilets daily suffer less of the WASH related diseases compared to all other that do not clean the toiles daily.

While many defecate with pit toilet, some also defecate in the river/ stream trench and use of bucket. However, many defecate at a distance not very far from the source of community water supply. The implication is that such open defecation is likely to increase the risk of diseases such as diarrhea and cholera (Saleem, Burdett and Heaslip, 2019). Large number of them are aware that open defecation can lead to diseases like cholera and others. But in many places, they have no led group or committee set up to stop people from defecating openly in their community, which have been asserted as an effective method of controlling open defecation (UNICEF, 2014).

Though the proportion for WASH related diseases was found high among different respondents, it was slightly lower on those who normally wash whenever the hands are dirty, and those who practice hand washing with water and soap suffered less of the WASH related diseases than those that wash with other items.

5.2 Conclusion

Community water used in Imo State is not free from bacteria. The level of community water, sanitation and hygiene practices is quite permissible for the occurrence of water-borne enteric infections. There is need to create more awareness and to improve on water, sanitation and hygiene for heathier Imo community.

5.3 RECOMMENDATIONS

Based on the findings from this study, the following recommendations and suggestions for future research were made:

i. Community water used in Imo State is not free from bacteria. The level of community water, sanitation and hygiene practices is quite permissible for the occurrence of water-borne enteric infections. Therefore, there is need to create more awareness and to improve on water, sanitation and hygiene for healthier Imo community.

ii. There is also a need to increase improved sources of drinking water in Imo State.

iii. Boreholes water sources should be regularly tested and treated adequately by qualified Public Health Practitioners before use, as most of the borehole water is acidic in Imo community.

iv. Health education on sources for drinking water, containers used for storage, means of getting water from the containers will significantly help to reduce the occurrence of water-borne enteric infections in Imo State.

v. Also, health education on the need for proper handwashing before preparing food, after using the toilet, after cleaning babies' bottom and after eating will help in militating against the occurrence of water-borne enteric infections like diarrhea, typhoid and cholera in Imo community.

vi. Proper channeling of toilet wastewater, the use of cleaning materials for handwashing especially after using the latrine will greatly reduce the occurrence of water-borne enteric infections in Imo State.

vi. There is the necessity of involving religious leaders in WASH education, awareness creation, supervision and communication to have an all-inclusive job done

vii. Schools, markets, and religious institutions should not be sited by or close to community water sources as is the case in some study communities

viii. Strict adherence to global standards should be enforced and adhered to.

Appropriate and independent body/agency to collaborate with national, state and local health authorities on global WASH issues to meet advocacy for action target and development goals. Funds budgeted for WASH related issues should not be diverted or misappropriated, for its about public health especially low and middle- income population

5.4 Contributions to knowledge

Based on the results obtained from this research, the following contributions to knowledge are drawn:

i. The poor hygiene and sanitation conditions in the state have increased the prevalence of water-borne enteric infections. The implication is that hygiene and sanitation awareness must be scaled up to reduce the prevalence of water-borne enteric infections in Imo State.

ii. Given the high bacterial loads and the acidic nature of water (borehole) in Imo community as observed in this research, there should be concerted effort towards a greater community awareness combined with regular curing of the water to achieve greater impact in the overall health of Imo community.

iii. Political ward leaders, community leaders (including youth reps, Imams, Priests, Development leaders, etc.), should be committed for greater grassroot economic recovery and community's health care sustenance.

iv. NGOs, Churches, LGA's authority etc. should periodically organize awards and honors to deserving individuals and villages in respect to provision of sanitation facilities and adherence to sanitation and hygiene protocols

5.5 Suggestions for future research

There is need for this research to be carried out in other oil producing states due to the acidic nature of water sources in Imo State.

Again, there is need to expand this research to ascertain if there is an association between water, sanitation and hygiene practices and communicable and non-communicable diseases prevalent in Imo State and beyond.

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APPENDICES

Appendix One: Definition of Terms and Abbreviations

Enteric infections: These are infections caused by intestinal microbes- bacteria, viruses, fungi, protozoa and helminths*;* that typically enter the body through the mouth. They are acquired through contaminated food and water, by contact with animals or their environments, by contact with the feces of an infected person and they are characterized by diarrhea, abdominal discomfort, nausea and vomiting, and anorexia.

Hygiene factors: These factors include both household and personal hygiene behavior.

Hygiene promotion: This is the correct use and maintenance of water and sanitation facilities to ensure a thorough sustained hygiene promotion. Water and sanitation facilities are used as resources for hygiene education.

Insanitary: An unhygienic condition that is likely to cause infection or ill health.

Practice: Those externally demonstrated behavior of an individual which in some way or the other influences his health.

Prevent: To anticipate beforehand and stop from happening occurrence of disease, hazard, accident, injury or death.

Sanitation: Maintenance of hygienic conditions through services, such as excreta disposal.

Toilet/Latrine: A place set apart for defecation and urination.

Water facilities and access to water: Sufficient water-collection points and water use facilities are available, allowing convenient access to, and use of water for drinking and personal hygiene, and for food preparation, cleaning and laundry.

Water quality: Water for drinking, cooking, personal hygiene, cleaning and laundry is safe for the purpose intended.

Water Quantity: Sufficient water is always available for drinking and personal hygiene, and for food preparation, cleaning and laundry when applicable.

CLTS: Community-Led Total Sanitation

ODF: Open Defecation-Free

RTTC: Re-invent The Toilet Challenge

UNDP: United Nations Development Program

UNICEF: United Nations Children's Fund

WASH: Water, Sanitation and Hygiene

WHO: World Health Organization

Appendix Two:

The Questionnaire for this Study

Dear Respondent,

This questionnaire was designed to help the researcher in receiving information on water, sanitation and hygiene and occurrence of water-borne enteric infections in Abia State, Nigeria. kindly respond to the questions, as your answers will be treated confidential and will be used for academic purposes only.

INSTRUCTION:

Please tick (√) *the appropriate option and fill in the blank spaces available.*

Section A: Socio-Demographic Characteristics

1. Age of the respondents: Less than 20 years [ ] 20-30 years [ ] 31- 40 years [ ] 41-50 years [ ] 50 years and above [ ]
2. Marital status of the respondents: Single [ ] Married [ ] Divorced [ ] Widowed [ ]
3. Religion of the respondents: Christianity [ ] Islam [ ] Traditionalist [ ], Others (specify)
4. Educational level of the respondents: Non formal education [ ] Primary education [ ] Secondary education [ ] Tertiary education [ ]
5. What type of work do you do to earn a living? Farming [ ]Artisans [ ] Trading [ ] Civil servant [ ] Teaching [ ] Other (specify)----------
6. Income Level: Less than N20,000 [ ] N21,000-N50,000 [ ] N51,000-100,000 [ ] Above N100,000 [ ]

Section B: Assessment of Water Supply and Utilization

7. What is your main source (s) of drinking water in your community? Piped water [ ] Borehole [ ] Covered well [ ] Open well [ ] Spring [ ] Rainwater catchment [ ] Cart/Tanker-truck [ ] Lake/River/Stream [ ] Bottled water [ ]
8. What is the distance of the source of water from your household? <100meters [ ] 101 – 250meters [ ] 251- 450meters [ ] 451- 1kilometer [ ] > 1kilometer [ ] Don't know [ ]
9. What do you think that makes the water good for use in your community? Colour[ ] Taste [ ] Odour [ ] Very clear [ ]

10. Who normally goes to fetch water for your household? Adult male [ ] Adult female [ ] Male and female children under 15years [ ] Male children only [ ] Female children only [ ]
12. Do you normally treat your water before drinking or use? Yes [ ] No [ ]
13. If yes, what type of water treatment do you practice? Boiling [ ] Chlorination [ ] Add alum and filter through cloth [ ] Let it stand and settle [ ] Solar disinfection [ ] Others (specify)
14. Do you store water in your household? Yes [ ] No [ ]
15. If yes, what type of storage container do you use for drinking water? Earth-pot [ ] Iron bucket/drum [ ] Plastic bucket/drum [ ] Gee-pee tank [ ] Others (specify)
16. Are you aware that potable water promotes good health? Yes [ ] No [ ]
17. If yes, how did you know? Through Radio [ ] Television [ ] Friends [ ] Schools [ ] Churches [ ] Mosques [ ] Posters [ ]

Section C: Assessment of Sanitation Practices

18. What type of latrine do you have? Bucket latrine [ ] Stilt-mounted latrine [ ] Pit latrine [ ] Ventilated improved pit latrine (VIP) [ ] Pour flush latrine [ ] Water Cistern (WC) [ ] Others (specify)
19. What type of material(s) do you use for anal cleansing? Small wooden stick [ ] Corn-cob [ ] Paper [ ] Tissue paper [ ] Water only [ ] Tissue paper and water [ ] Tissue paper with water and soap [ ] Others (specify)
20. Do you wash your hands after using the toilet? Yes [ ] No [ ]
21. If yes, what do you use in washing your hands? Water only [ ] Water and soap [ ] Water and ash [ ] Clay soil only [ ] Other agents (specify)
22. Are there any functional public toilets/latrines in your community? Yes [ ] No [ ]
23. If yes, who constructed/provided the toilet/latrine facilities? Government (State, LGA) [ ] Age grade [ ] Individual [ ] Donor agency [ ] Others (specify)
24. Do you believe that proper excreta disposal improves the aesthetic status of your community? Yes [ ] No [ ]
25. How often do you clean and disinfect the toilet? Daily [ ] Weekly [ ] Monthly [ ] Three months [ ] Others (specify)

Section D: Personal Hygiene Practices

26. Have you heard about hygiene? Yes [ ] No [ ]

27. What do you use for hand washing? Water only [ ] Water and soap [ ] Water and ash [ ] Clay soil only [ ] Detergent [ ]
28. When do you normally wash your hands? After using toilet [ ] Before cooking food [ ] Before eating and handling of food [ ] After eating food [ ] Before and after feeding kids [ ] After cleaning kids bottom [ ] When hands are dirty [ ]
29. How often do you normally take your bath? Once a day [ ] Twice daily [ ] Twice weekly [ ] Four times in a month [ ] Bath only when water is available [ ]
30. Are you aware that hygiene practices reduce water borne infections? Yes [ ] No [ ]

Section E: Solid Waste Management

31. What type of solid waste do you generate? Vegetable stock [ ] Wood [ ] Paper [ ] Cellophane [ ] Metals [ ] Iron [ ] Bottles [ ] Others (specify)
32. Can you estimate the quantity of solid waste generated within your community? Less than 2.5kg [ ] 2.6 – 3.5kg [ ] 3.6 – 4.5kg [ ] 4.6 – 5.5kg [ ] Greater than 5.6kg [ ]
33. What method of waste collection do you practice in your community?
    Door to door collection [ ] Wheel-barrow [ ] Cart [ ] None [ ] Others (specify)
34. How do you store the waste generated? Galvanized bucket with tight-fitting cover [ ] Polythene bags [ ] Any container [ ] Others (specify)
35. How do you dispose the waste generated from your community? Open burning [ ] Com-posting [ ] River/stream [ ] Incineration [ ] Landfill [ ] Municipal waste dumpsite [ ]

Section F: Practice of Open Defecation (ODF)

36. Where do you defecate? Bush [ ] Bucket [ ] Pit toilet [ ] Polythene bags [ ] River/stream [ ]
    Trench [ ] Others (specify)
37. What is the distance from where you defecate to your source of community water supply? 50meters [ ] 51 – 100meters [ ] 101 – 150meters [ ] more than 150meters [ ]
38. Are you aware that open defecation can lead to diseases like cholera, diarrhoea, typhoid fever, worms? Yes [ ] No [ ] No idea [ ]
39. Do you have any led group or committee set up to stop people from defecating openly in your community? Yes [ ] No [ ]
40. If yes, where is the head from? LGA [ ] Community [ ] Others (specify)

Section G: Prevalence of WASH-related Diseases and its Associated Risk Factors

40. Have you suffered any WASH-related diseases? Cholera [ ]Diarrhea [ ] Typhoid [ ] Nausea [ ] Anorexia [ ] Skin infection [ ] Sleeping sickness [ ] Malaria [ ]
41. For how long now? Last month [ ] Three months ago [ ] Six months ago [ ] More than one year [ ]
42. Does use of clean water for washing, drinking and bathing an important way to prevent water related diseases among community people? Yes [ ] No [ ]
43. Adequate, well maintained and clean toilet facilities are prerequisite for good health of the Community people? Yes [ ] No [ ]
44. Does adequate practice and implementation of WASH programs such as community-led total sanitation, school sanitation; reduce economic loss, morbidity, mortality and promote longevity of the community people? Yes [ ] No [ ] Don't know [ ]

Thank you for participating.

Appendix Three:

Percentage occurrence of Bacteria isolated from water samples

Bacterial isolates	Percentage occurrence (%)
Staphylococcus aureus	8
Streptococcus pyogenes	3
Escherichia coli	3
Enterococcus faecalis	15
Klebsiella pneumoniae	9
Shigella dysenteriae	6
Salmonella typhi	4
Micrococcus luteus	7
Bacillus cereus	8
Pseudomonas aeruginosa	8
Aeromonas sp	3
Bacillus subtilis	7
Micrococcus roseus	8
Enterobacter coli	5
Corynebacterium diptheriae	6

Appendix Four:

MEDIA COMPOSITION

Nutrient Agar (NA) (Biomark Laboratories)

Ingredients	g/l
Peptic digest of animal tissue	5.0
Beef extract	1.5
Yeast extract	1.5
Sodium chlorine	5.0
Agar	15.0
pH at 25^0c	7.4+0.2

MacConkey Agar (MCA) (Tm Media)

Ingredients	g/l
Peptone	20.0
Agar	12.0
Lactose	10.0
Bile salts	5.0
Neutral Red	0.075
pH at 25^0c	7.4+0.2

Salmonella Shigella Agar (SSA) (Tm Media)

Ingredients	g/l
Peptic digest of animal tissue	15.0
Proteose peptone	5.0
Dextrose	1.0
Lead acetete	0.2
Sodium thiosulphate	0.08
Agar	15.0
pH at 25^0c	7.0+0.2

Blood Agar (BA) Himedia Lab

Ingredients	g/l
Peptone	10.0
Tryptose	10.0
Sodium chlorine	5.0
Agar	15.0
pH at 25^0c	7.3+0.2

Eosin Methylene Blue Agar (EMBA) (Oxoid)

Ingredients	g/l
Peptone	10.0
Lactose	10.0
Dipotassium Phosphate	2.0
Methylene Blue	0.065
Eosin-Y	0.4
Agar	15.0
pH at 25^0c	7.2+0.2

Sabouraud Dextrose Agar (SDA) (Tm Media)

Ingredients	g/l
Dextrose (Glucose)	40.0
Mycological Peptone	10.0
Agar	15.0
pH at 25^0c	5.6+0.2