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CHEMICAL AND BACTERIOLOGICAL QUALITY OF DRINKING WATER SOURCES IN CALABAR MUNICIPALITY, CROSS RIVER STATE, NIGERIA

BY

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NOVEMBER 2009

CERTIFICATION

I hereby certified that this thesis on chemical and bacteriological quality of sources of drinking water in Calabar Municipality, Cross River State, Nigeria is a record of my research work supervised by Dr. N. S. Olaniran and has not been presented before in any previous publication.

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Supervisor Date:.………………………

DECLARATION

We declare that this thesis on "chemical and bacteriological quality of sources of drinking water in Calabar Municipality, Cross River State, Nigeria" by **KOLAWOLE, ISAAC ANJORIN** with Registration number PUH/MPH/05/002 was carried out under our supervision. The work has been examined and found to have met the regulations of the University of Calabar. We therefore recommended the work for the award of Master Public Health Degree.

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ABSTRACT

This study was carried out on Chemical (Residual Chlorine) and Bacteriological (Total and Fecal coliforms) Quality of drinking water Sources in Calabar Municipality, Cross River State, Nigeria. Apart from the laboratory analyses carried out, 350 copies of questionnaire were distributed to obtain data on; water treatment method, volume of water used, water-diseases suffered within last 1 year, sources of drinking water and basic demographic data. Forty-two water samples were analysed; (8 bottled waters,10 sachet waters, 10 samples of stored borehole waters,4 stream waters, 5 pipe borne waters and 5 Great Kwa river samples). The chemical analysis of these samples showed that 7 (16.7%) had Nitrate-nitrogen concentrations above WHO/SON standard (10mg/l) and the residual chlorine (present only in pipe borne water sample) ranging from 0.4 to 0.9mg/l were above the minimum but below the maximum standard set by WHO (0.2mg/l and 5mg/l) respectively. The bacteriological quality of the water samples showed that only 9 (21.4%) were fit for consumption (all the 5 pipe borne water samples, 2 bottled water and 1 sachet water sample). Only 19.6% of the respondents treated water before drinking by any of the convectional methods. Out of 84 respondents who treated water before drinking, 45 (68.2%) used boiling method. Fifty-six respondents out of 270 who did not normally treat water before drinking claimed they had suffered typhoid within the last 1 year. Null hypothesis between variables tested was rejected using student's t-test. These findings showed that the quality of drinking water sources in Calabar Municipality was not satisfactory. Strict regulation of bore hole water, compulsory treatment of water before drinking and regular sampling and analysis by NAFDAC of the packaged water being sold in the Municipality have been recommended.

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ABBREVIATIONS

IARC - International Agency for Research on Cancer.

USGS - United States Geological Survey.

NAWQA - The National Water Quality Assessment

CDC - Centers for Disease Control and Prevention

WHO - World Health Organization

UNDP - United Nations Development Programme

MDGs - Millennium Development Coals

AIDS - Acquired Immune Deficiency Syndrome

NAFDAC - National Agency for Food and Drugs Administration and Control

NAS - National Academy of Sciences

RDI - Required Daily Intake

GMP - Good Manufacturing Practice

CAWST - Centre for Affordable Water and Sanitation Technology

TU - Turbidity

CCOHS - Canadian Centre for Occupational Health and Safety

SON - Standard Organization of Nigeria

LGA - Local Government Area

DEFINITION OF TERMS

1 **Water quality standard** is the level of pollutants considered by law to be safe. Standards apply and are enforced for public water supplies.

2 **Contaminant:** Any physical, chemical, biological or radiological substance that degrades water quality.

3 **Chemical** refers to nitrates and residual chlorine which the researcher will be testing for in water samples.

4. **Bacteriological** refers to the total and faecal coliforms which was analyzed for in the drinking water sources sampled.

5. **Quality** refers to as how good, potable or hygienic the drinking water is.

6. **Packaged water** refers to as drinking water sealed up in plastic bottles or sachet.

CHAPTER ONE

1.1 INTRODUCTION

Water has acquired added importance in the last decades due to its demand and pollution (Akaninwor et.al. 2007). One of the Millennium Development Goals (MDGs) is the provision of potable water in every home by the year 2015.The United Nations Development Programme (UNDP) 2006 Human Development Report, gave a graphic picture of the water situation in Nigeria. The report was titled, “The Global Water Crisis”. The detailed report revealed that Nigeria may not have adequate access to safe water until 2046. The former Secretary- General of the United Nation, Kofi Annan said at the World Day for Water in 2005 that “We shall not finally defeat AIDS, tuberculosis, malaria, or any other infectious diseases that plague the developing world until we have also won the battle for Safe Drinking Water {http//www.un.org/water for life decade).

A large proportion of the rural population in the developing world takes water from natural sources directly for drinking (WHO, 1983). The water is usually not treated at all or treated insufficiently to ensure acceptability according to International Guidelines (WHO, 1983). Natural water is therefore never pure and water being a universal solvent dissolves many chemical substances and also carries in suspension many impurities (WHO, 1998).

Every year more than one billion people resort to using potentially harmful sources of water. Two in every ten people of the world have no source of safe drinking water and to improve this appalling state of affairs the MDGs include a specific target to cut in half, by 2015 the proportion of people without sustainable access to safe drinking water. (WHO, 2007).

The level of water contamination depends on the source, although water sources share several characteristics, for example, boreholes, spring and wells tend to be more susceptible to changes in the local environment and microbiological contamination. The stability of borehole water source makes it preferable for use as a private water supply. Where pipe borne water is inadequate people go into commercial water supplies like sachet and bottled water generally known as packaged water. The rate of consumption of these sources of drinking water is increasing. In 2002, there were about three registered companies producing packaged water in Calabar Municipality as compared to about thirty as at December 2007 (NAFDAC, 2007).The non-compliance of the producers after certification is creating doubts on the quality of the water produced.

1.2 Statement of the Problem.

Midway to the global deadline set by the United Nations (UN), adequate water supply in Nigeria has remained a mirage (Akosile 2007). The consequences of our collective failure to tackle the problems of 3,900 children dying everyday of drinking contaminated water will thwart the progress towards achieving the Millennium Development Goals (MDGs) and aggravate the condition of billions of people locked in a cycle of poverty and disease (WHO, 2005).

The quality of water we drink is directly linked to health. Infections spread through water supplies (i.e., drinking water) are known as water- borne diseases. Examples are cholera, typhoid, bacillary dysentery and infectious hepatitis. In Nigeria, typhoid fever at present is still a disease of public health importance with estimated of thirty-three million cases and 500,000 deaths per year (Otegbayo,2005). Diarrheal diseases are a major cause of children morbidity and mortality world wide especially in developing countries (Ribeiro,2000). In May 2006,eighty people died in a cholera outbreak in Borno, Borno State and 2,000 others were affected (www.bio-medicine.org).

In Nigeria Adekunle et.al, (2004) carried out bacteriological analysis of sachet water in Ibadan. About 6.4 percent of the samples had bacterial growth which included Streptococcus faecalis and Pseudomonas aeruginosa. Bottled water has been found to cause travelers' diarrhoea (Adekunle, 2004). Alfred et.al, (2005) isolated 7 bacteria from water samples collected from boreholes in Eastern Obolo Local Government Area (LGA) of Akwa Ibom State. Agbu et.al. (1988) in Samaru, Zaria as well as Adesiyun et.al, (1983) in Katsina, found high coliform density above 15/100ml in the water samples tested in the areas.

The fast development in, and attraction of international business into Calabar municipality is an issue that must be put into consideration concerning access to safe and potable water as a requirement for social-economic development.

1.3.0 General Objective

The general objective of this study was to determine the chemical and bacteriological quality of drinking water sources in Calabar Municipality, Cross River State, Nigeria.

1.3.1 Specific Objectives

The specific objectives of this study were:

i) to determine the mean levels of total coliforms bacteria in Great Kwa River, selected pipe borne water, sachet water, bottled water, boreholes, stream and spring in Calabar Municipality,

ii) to determine the mean faecal coliform levels of water sources in (i) above in Calabar Municipality,

iii) to determine the mean residual chlorine in pipe borne and packaged waters in the study area,

iv) to determine the mean Nitrates levels of the drinking water sources in (i) above in the study area,

v) to compare the chemical and bacteriological quality of Great Kwa River used by the water board as raw water and the treated water supplied to the public,

vi) to determine the proportion of residents that treat water by any method before drinking.

1.4 Expected Benefits of the Study

This study has:

1) Provided the current status of drinking water quality in Calabar municipality.

2) Increased the level of awareness on the need to treat drinking water within the study area by publishing the outcome of this research or informing necessary institution.

3) Provided an insight into the attitudes of the residents towards treatment of their drinking water before drinking.

1.5 Hypotheses

i) There is no significant difference between the mean levels of total coliforms in pipe borne water and boreholes.

ii) There is no significant difference between the mean residual chlorine levels in pipe borne water and packaged water.

iii) There is no significant difference between the mean nitrate levels in Great Kwa River and pipe borne water.

iv) There is no significant difference between the mean levels of faecal coliforms in boreholes and sachet water.

1.6 Scope

The study determined chemical quality (residual chlorine and nitrate levels) of sachet, bottled and pipe borne water sources and nitrate levels of spring, streams and Great Kwa River. It also determined the bacteriological water quality of the above drinking water sources in Calabar Municipality, Cross River State, Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW.

People are increasingly concerned about the water they drink. As improvement in analytical methods allow us to detect impurities at very low concentration in water, water supplies once considered to be pure are found to have contaminants. We can not expect pure water but we want safe water. Some health effects of some contaminants in drinking water are not well understood, but the presence of contaminants does not mean that your health will be harmed (Sandra et. al., 1996.)

The levels of contaminants in drinking water are seldom high enough to cause acute health effects. Examples of acute health effects are nausea, skin rash, dizziness, and even death. Contaminants are more likely to cause chronic health effects. Examples are cancer, liver and kidney damage, disorders of the nervous system, damage to immune system and birth defects. Bacteriological water contamination manifest as waterborne, water washed, water based, or water related diseases which is faster acute in nature.

2.1 Bacteriological Water Quality.

Historically, water has played a significant role in the transmission of human diseases. Typhoid fever, cholera, infectious hepatitis, bacillary and amoebic dysenteries and many varieties of gastrointestinal disease can all be transmitted by water. Contamination by sewage or human excrement presents the greatest danger to public health associated with drinking water, and bacteriological testing continues to provide the most sensitive means for the detection of such pollution. Although modern microbiological techniques have made possible the detection of pathogenic bacteria, viruses and protozoa in sewage and sewage effluents, it is not practical to attempt to isolate them as a routine procedure from samples of drinking water. Pathogens present in water are usually greatly outnumbered by normal intestinal bacteria, which are easier to isolate and identify. The presence of such organisms indicates that pathogens could be present; if they are absent, disease-producing organisms are probably also absent. Contamination is often intermittent and may not be revealed by the examination of a single sample. The most a bacteriological report can prove is that, at the time of examination, bacteria indicating faecal pollution did or did not grow under laboratory conditions from a sample of water. Therefore, if a sanitary inspection shows that a well is subject to contamination or that water is inadequately treated or subject to contamination during storage or distribution, then the water should be considered unsafe irrespective of the results of bacteriological examination. Some of the organisms (Bacteria) that can be found in water are: *Legionella, Shigella, Vibrio cholera, Campylobacter, Yersinia, Salmonella, Ps. Aeruginosa, Mycobacterium*, Cyanobacterial toxins etc.

2.2 **Chemical Water Quality**

The total dissolved solids in water consist of salts and dissolved materials. In natural waters, salts are chemical compounds made of carbonates, chlorides, sulfates, and nitrates (primarily in ground water), and potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na). In most natural conditions, these salts are present in amounts that create a balanced solution. If there is a large rain with a lot of runoff, this balance is changed and most likely has a negative effect on the aquatic system.

Because concentrations of the essential macro and micro elements that occur in natural, potable waters vary greatly, depending upon their source, geographic considerations are very important in any studies attempting to relate water quality to health. Some toxic substances in water are not health threatening, at least not to human beings. They may be toxic only to certain species other than *H. sapiens* or, more important to our considerations, toxic to H. sapiens, but ordinarily found at concentrations insufficient to threaten human health.In recent years, pollutants have contaminated a number of urban and rural wells. The pollutants include: nitrate from septic systems, fertilizer and livestock wastes; pesticides from farm fields; industrial chemicals from old landfills; and gasoline from underground storage tanks.

2.3 Occurrences of Contaminants in Drinking Water Relevant to this Study

Many studies have been conducted on the quality of drinking water in various parts of the country and around the world. The reports from these researches varied widely and many fell below W.H.O standard. Alfred et. al. (2005) carried out microbiological and physicochemical analyses of borehole water samples from Eastern Obolo Local Government Area of Akwa Ibom State to ascertain their potability. Seven bacterial species were isolated and identified. These included *Bacillus subtilis, Enterococcus faecalis, Staphylococcus aureus, Clostridium perfringens, Pseudomonas aeruginosa, Micrococcus varians* and *Escherichia coli.* The results revealed the presence of viable bacteria in the range of $5.2x10^4$ to $1.5x10^5$cfu/ml while the Total coliform count ranged from 2 to 51 cfu/100ml. The water samples from boreholes located at Iko Town were the most polluted as all the isolates were encountered. The only coliform organism encountered was *Escherichia coli*. The coliform density ranged from 2 cfu/100ml at Ikonta Town to 51 cfu/100ml at Ayama. The most frequently occurring organism was *Enterococcus faecalis* (22%) followed by *Pseudomonas aeruginosa* (19%) while the least was *Escherichia coli* (7%).

Itah et al. (1996), conducted bacteriological and chemical analysis of some rural water supply in Calabar, Nigeria and discovered that E. coli were found in most of the water samples. This implies that the water samples are faecally contaminated.

Pedro, et. al. (2000) carried out a cross-sectional study on drinking water in four rural communities of northeastern Trinidad to determine the microbial quality of water supply to households and that quality's relationship to source and storage device. Of the 167 household water samples tested, total coliforms were detected in 132 of the samples (79.0%), fecal coliforms in 102 (61.1%), and E. coli in 111 (66.5%). There were significant differences among the towns in the proportion of the samples contaminated with coliforms ($P < 0.001$) and E. coli ($P < 0.001$). Of 253 strains of E. coli studied, 4 (1.6%) were mucoid, 9 (3.6%) were hemolytic, and 37 (14.6%) were nonsorbitol fermenters. Of 69 isolates of E. coli tested, 10 (14.5%) were verocytotoxigenic. Twenty-eight (14.0%) of 200 E. coli isolates tested belonged to enteropathogenic serogroups. Standpipe, the most common water source, was utilized by 57 (34.1%) of the 167 households. Treated water (pipe borne in homes, standpipes, or truckborne) was supplied to 119 households (71.3%),while 48 households (28.7%) used water from untreated sources (rain, river/stream, or well) as their primary water supply. The type of household storage device was associated with coliform contamination. Water stored in drums, barrels, or buckets was more likely to harbor fecal coliforms (74.2% of samples) than was water stored in tanks (53.3% of samples), even after controlling for water source ($P = 0.04$). Compared with water from other sources, water piped into homes was significantly less likely to be contaminated with total coliforms (56.9% versus 88.8%, $P < 0.001$) and fecal coliforms (41.2% versus 69.8%, $P < 0.01$), even when the type of storage device was taken into account. However, fecal contamination was not associated with whether the water came from a treated or untreated source. They concluded that the drinking water in rural communities in Trinidad was grossly unfit for human consumption, due both to contamination of various water sources and during household water storage.

In the an assessment of the health and social economic implications of sachet water in Ibadan Nigeria and its public health challenge, Adekunle et. al. (2004) noted that the physical parameters were within W.H.O limits for drinking water quality guidelines except for pH which ranged from 6.6 - 9.7. Some chemical parameters were also within the W.H.O guideline values. However, aluminum which concentration ranged from 0.00 — 0.34 mg/l, fluoride concentration ranged from 0.01 — 1.87 mg/I and cyanide concentration ranged from 0.000 —0175 were not. Bacteriological analysis showed that five (5) or 6.4% of the samples tested fielded bacterial growth. Bacteria produced included: Klebsiella sp., Streptococcus faecalis and Pseudomonas aeruginosa.

Muege (1956) noted that, in a number of epidemiological studies, positive associations between the ingestion of chlorinated drinking water and mortality rates from cancer, particularly of the bladder, have been reported. The degree of evidence for this association is considered inadequate by IARC. He further revealed that in a study of 46 communities in central Wisconsin where chlorine levels in water ranged from 0.2 to 1mg/litre, serum cholesterol and low-density lipoprotein levels were higher in communities using chlorinated water. Levels of high-density lipoprotein (HDL) and the cholesterol/HDL ratio were significantly elevated in relation to the level of calcium in the drinking water, but only in communities using chlorinated water. The authors speculated that chlorine and calcium in drinking water may interact in some way that affects lipid levels. An increased risk of bladder cancer appeared to be associated with the consumption of chlorinated tap water in a population-based, case-control study of adults consuming chlorinated or non- chlorinated water for half of their lifetimes.

Echebiri et. al. (2003) sampled water from 20 artesian wells, chosen by the multistage sampling procedure from 5 zones in the city of Enugu, Southeast Nigeria, and analyzed by the disulfonic acid method in duplicate for the presence of nitrate (N[O.sub.3]) and nitrite (N[O.sub.2]). The zonal mean values for N[O.sub.3] were 0.45 mmol/l, 0.46 mmol/l, 0.55 mmol/l, 0.59 mmol/l, and 0.65 mmol/l (mean = 0.54 mmol/l), and for NO2 the values were 0.34 mmol/l], 0.32 mmol/l, 0.21 mmol/l, 0.14 mmol/l, and 0.20 mmol/l (mean = 0.24 mmol/l), respectively. The mean values were reciprocally related (r = -.7356, p = 0.0002), indicating fecal contamination of well water. There were no significant differences between the mean values and the sum of the N[O.sub.3] and N[O.sub.2] values of the samples (p > 0.05), indicating uniform nitrogen content in the region. The mean value for N[O.sub.3] (0.54 mmol/l) was below the guideline values set by the W. H. O. but the mean N[O.sub.2] concentration of 0.24

mmol/l was much higher (290%) than what is considered safe for humans.

The National Water Quality Assessment (NAWQA) program of the USGS assessed water quality of aquifer systems that cover the water resources of > 60% of the population in the contiguous United States. On the basis of the NAWQA findings, approximately 15% of shallow groundwater sampled beneath agricultural and urban areas had nitrate-nitrogen levels above the MCL. In comparison, < 10% of samples taken from 100-200 feet deep exceeded the MCL, and no sample was found to exceed the MCL in groundwater that was > 200 feet below the surface (USGS 1999). Other reports using the NAWQA data showed nitrate-nitrogen levels > 3 mg/L (report assumed levels of ≥ 3 mg/L because of contamination) in 28% of samples taken from public and private wells. More private wells sampled (11%) exceeded the MCL than did public wells (2%) (Squillace et al. 2002).

The U.S. EPA National Pesticide Survey (U.S. EPA 1992), which sampled private wells in 38 states and public water systems in 50 states, found 1.2% of public water systems and 2.4% of private wells exceeded the MCL for nitrate (Spalding and Exner 1993). From this survey, the U.S. EPA estimated that > 4 million people, including some 66,000 infants < 1 year of age, could be served by systems that exceed the MCL for nitrate (U.S. EPA 1992). A survey by the Centers for Disease Control and Prevention (CDC) of > 5,500 private wells in nine Midwestern states found nitrate levels above the MCL in 13.4% of wells sampled (CDC 1998). A survey of 3,351 domestic wells found that 9% had nitrate levels exceeding the MCL, compared with 1% of public wells (USGS 1995).

OGAN, (1992), assessed the microbiological quality of four brands of bottled water sold in retail outlets in Nigeria by routine methods in 90 samples. Samples of two brands were acidic in the pH range 3.5–5.9. Faecal coliforms and streptococci were not recovered from any sample. Heterotrophic plate counts (HPC) numbered 50–800 cfu/ml in two brands, A and B, and 100–87000 cfu/ml in C and D. Component colony types among the HPC bacteria in brands C and D produced water-soluble, fluorescent pigments on colony count and other agar media, and occurred in 11 of 16 batches:

Scientists at the University of Wales at Aberystwyth led by Dr Ron Fuge tested 81 bottled waters, selected at random, for their mineral content using a plasma mass spectrometer. Many were found to have levels of potentially harmful minerals which were above the legal regulation levels for tap water. In some cases they were considerably higher. Also in a test of 51 bottled waters taken at random, Chester Public Health Laboratory found only 22 with a bacterial content within the limits set for tap water. Only Purefect 95 and the sparkling waters bottled in glass had levels comparable to tap water. Ten of the other waters had levels of up to 1,000 bacteria per millilitre, eight had between 1,000 and 10,000, while a further eleven were in the 10,000 to 100,000 bacteria class. One bottle was found to contain 188,000 bacteria per milliliter - a massive 1,880 times the limit for tap water. (http://www.frequencyrising.com/water_bottle.)

Bacteriological quality of sachet water produced and sold in Teshie-Nungua suburbs of Accra, Ghana by Addo et.al.(2009) The brands of sachet water were rated based on the mean MPN values of the three samples. Only two brands met the World Health Organization (WHO) criteria which states that not more than 1 out of 10 analytical units should have an MPN value of >2.2 and that sample should have an MPN value not exceeding 9.2 ; four of the brands did not meet the criteria because they had MPN values greater than 2.2. The total coliform count of the various brands was found to be high. The level of coliform bacteria in the sachet water from the various brands sampled did not meet the WHO guidelines for drinking water .This finding compares with a similar study done in Cape Coast, the capital of the Central Region of Ghana which reported that various brands of sachet water produced in the municipality were contaminated with coliforms . A similar study in Osogbo Metropolis of Nigeria which compared the MPN values of sachet water, tap water and well water recorded 0 to 1 coliform/100ml for sachet water. In that study the sachet water was found to be of good quality.

2.4 Public Health Effects of Drinking Water Quality

The health effects of drinking water that is not potable vary. They depend on whether the contaminant is of bacteria, viral, protozoal, 0r chemical origin. When water contains too much contamination by certain micro-organisms or chemical, it is rendered unsafe in its existing state for an intended use. When such contaminated water is drunk, ranges of acute health effects like nausea, skin rash, dizziness, and even death or chronic health effects like cancer, liver and kidney damage, disorders of nervous system, damage to immune system and birth defects can occur.

2.4.1 Public Health Effects of Bacteriological Water Quality.

The health effects of drinking bacteriological contaminated water have been of concern over a long time. Some types of bacteria (small living organisms) are a threat to drinking water quality and are responsible for most waterborne illnesses. There are a number of human pathogens which can potentially be transmitted in faecally contaminated water, those of particular significance and their effects are briefly described bellow:

i) *Campylobacter* and *Yersinia*

Waterborne outbreaks of gastroenteritis involving *Campylobacter jejuni* and *Yersinia enterocolitica* have been recorded with increasing frequencies in the past few years. Since the realization that water can be a potential route of campylobacteriosis and yersiniosis, isolation and enumeration methods have been developed. Rollins and Colwell recently described the presence of viable but non-culturable states of *C. jejuni* in the aquatic environment. They suggested that this non-culturable type could be one reason why *Campylobacter* is not always isolated from water during a waterborne outbreak of campylobacteriosis.

ii) *Legionella pneumophila*

This is the causative agent of legionellosis and Pontiac fever. It has been recovered in low concentrations in the drinking water of a number of Canadian cities. However, it is not a major component of the bacterial populations of the relatively cold surface waters in Canada. Although chlorination appears to effectively control

Legionella, the bacteria can colonize various niches in buildings (e.g., cooling towers, hot water tanks, shower heads, aerators) and contaminate the air and potable water. This situation is particularly troublesome in hospitals, where susceptible human populations can be exposed to aerosols containing hazardous concentrations of *L.pneumophila*. In general, the presence of this organism is not sufficient evidence to warrant remedial action in the absence of disease cases.

iii) Total coliform.

Total coliform bacteria are very common in the environment; they are found in soil, for example. If only total coliform bacteria are detected, fecal contamination is not probable, and the source is more likely to be from contamination from the environment during construction or while repair to a water main was underway. Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.

iii) *Coliforms, E.coli, Clostridia &Faecal Streptococci*

Coliform microorganisms are a group of different bacterial species which share certain biochemical properties with Escherichia coli, an inhabitant of the gut of mammals and birds. Not all coliforms occur in sewage or faeces. Some survive and grow in environments that are free from contamination with sewage or faecal matter. For this reason judging the sanitary significance of any coliform(s) found in a sample of drinking water is far from straightforward. *Escherichia coli* is used as the primary indicator of faecal pollution. The Secondary faecal indicators- Faecal streptococci are less abundant than *E.coli* in human faeces, but may be more numerous in the gut flora of other animals. They are used as a confirmatory test of faecal pollution after the isolation of coliforms or *E.coli* in a routine sample as they can survive longer out of the gut than *E.coli*. *Clostridia perfringens* is also a secondary indicator of faecal pollution but is used less frequently than faecal streptococci. It can form resistant spores which survive longer out of the gut than both other faecal indicators and is usually present in much lower numbers in faeces.Its use is routinely restricted to specialist applications e.g., for new ground water source assessments. The health implication is that they offer the most sensitive test for the detection of faecal and hence potentially serious pollution. Faecal pollution is likely to carry pathogenic organisms with it and this is a serious risk to public health.

iv) *Pseudomonas.*

Pseudomonas aeruginosa is often but not always associated with faecal contamination. It is also able to multiply within the distribution system when suitable nutrients are available to it. These can be derived from unsuitable materials used in the distribution system or from the any organic nitrogen derived after the treatment process itself. Members of the genus Pseudomonas are opportunist pathogens of the young, and immuno-compromised. They are generally undesirable in potable water, and can create problems in particular circumstance where the degree of water purity required should be high.

2.4.2 **Health Effects of Chemical Water Quality.**

The emphasis on harmful substances that may occur in potable waters has almost obscured the fact that important beneficial constituents are commonly present. The chemical substances in water that make positive contributions to human health act mainly in two ways: (i) nutritionally, by supplying essential macro and micro elements that the diet (excluding water) may not provide in adequate amounts (for example, Mg, I and Zn); and (ii) by providing macro and micro elements that inhibit the absorbtion and/or effects of toxic elements such as Hg, Pb and Cd.

2.4.2.1 Positive Health Effects of Chemical Water Qualities.

These elements (Fluorine, Sodium, Magnesium, Calcium, chromium, Zinc, Selenium and Iodine) mainly ingested in the form of inorganic ions, have many biological functions. For example, they contribute to the formation of vitally important metalloenzymes, carriers (e.g., hemoglobin), and selective membrane permeability; and to the physical integrity of structures such as bone, cartilage, and various fibrous materials (e.g., collagen).

The practical significance to health of these elements depends upon :

(i) the amount of the element in question that is often or occasionally found in potable water, which varies greatly with the geographic region;

(ii) whether or not the element, as it occurs in potable water, is in a biologically active form (for example, cobalt, as such, is not biologically active in terms of human nutrition; to be nutritionally effective it must be ingested and absorbed as a preformed complex, cobalamin);

(iii) the extent to which the normal diet often or occasionally fails to meet the individual's needs (this consideration must take into account common physiologic and pathologic events that may require amounts of the element that will exceed the recommended dietary allowance for average humans).

These protective effects are, of course, limited, but may be quite significant. Levander (1977) has reviewed much of the evidence in support of this category. Stated very briefly, protective action against toxicity from *mercury* is provided by selenium; a high zinc intake appears to offer some protection against the toxic effects of *lead*, whereas a deficiency of *calcium* (also iron and copper to a lesser extent) increases susceptibility to lead; selenium (also zinc and iron to a lesser extent) decreases the toxicity of cadmium, whereas a deficiency of calcium (also iron and copper to a lesser extent) aggravates toxicity.

Based upon an average consumption of 2 L of water per day for adults (including the water content of coffee, tea, milk, fruit juice, soft drinks, beer, soup, etc.) some natural potable waters can supply all of the RDI for magnesium, fluorine, sodium, iodine, and selenium, and more than one-third of the RDI of calcium (Feder et al., 1981). As much as 15% of the RDI of zinc can also be supplied; this amount, although a relatively small percentage of the RDI, can be quite significant because of the wide spread deficiency of zinc in some countries, especially in United States. The nutritional significance of chromium in drinking water has not been demonstrated, but the predominant state of chromium in natural potable waters (Cr^{3+} is the biologically active state and, since the minimal requirement for absorbed chromium is approximately 1µ per day (NAS, 1980), it is reasonable to assume that some waters can provide nutritionally significant amounts of this essential element. Chromium deficiency is relatively common in the United States, and several investigators have shown that it results in demonstrable states of diabetes-like altered carbohydrate metabolism (Freund et al., 1979). Iron represents a special case in that natural, nontoxic waters may supply more than the RDI; however, waters containing concentrations of iron in solution > 1 mg 1^{-1} are distasteful and are rejected for aesthetic reasons.

Important consequences from deficiency of these elements may become apparent only after many years and then, perhaps, only when triggered by a *pathologic* event (for example, deficiency of magnesium, when complicated by acute myocardial ischemia, contributes to a lethal arrhythmia), or a physiological stress (for example, deficiency of calcium. in association with the post menopausal state and its associated endocrine disturbances, contributes to osteoporosis). Many natural, potable waters contribute significant amounts of macro and micro nutrients that are essential for human health. Ordinarily, hard waters have greater nutritional benefits than soft waters, but geographic variations are large, depending on the geochemical environment. A major health benefit from drinking hard water is a decreased risk of dying from cardiovascular disease.

2.4.2.2 **Negative Health Effects of Chemical Water Quality.**

i) **Pesticides and herbicides.**

One of America's leading authorities on water contamination, Dr. David Ozonoff of the Boston University of Public Health warns that, "the risk of disease associated with public drinking water has passed from the theoretical to the real."Many illnesses that in the past could not be linked to a probable cause, can now be directly linked to toxins in our drinking water. The use of pesticides and herbicides has become so excessive that they are now commonly found in household tap water with alarming frequency.

A 1994 study of 29 major U.S. cities by the Environmental Working Group found that all 29 cities had traces of at least one weed killer in the drinking water. The report titled "Tap Water Blues" went on to say that "Millions of Americans are routinely exposed to one or more pesticides in a single glass of tap water."

These first ever "tap water testings" found two or more pesticides in the drinking water of 27 of the 29 cities, three or more in 24 cities, four or more in 21 cities, five or more in 18 cities, six or more in 13 cities and seven or more pesticides in the tap water of five cities. In Fort Wayne Indiana nine different pesticides were found in a single glass of tap water.

As a startling side note it was reported that in these 29 cities 45,000 infants drank formula mixed with tap water containing weed killers and that "over half of these infants were swallowing 4 to 9 chemicals in every bottle!" The tragic health effects of consuming these highly toxic chemicals are magnified many times over for small children because their systems are more sensitive and still developing. Small children also consume a much larger volume of fluids per pound of body weight and therefore get a bigger dose.

According to the Center for Disease Control "Death from cancer is increasing more rapidly than is the population." It is now widely accepted that cancer is an environmental disease. The World Health Organization and the National Cancer Institute both suggest that most human cancers, perhaps as many as 90% are caused by chemical carcinogens in the environment. This realization is paramount for change because it means that most cancers could be prevented by minimizing or eliminating our exposure to chemical carcinogens. While the powerful chemical industry argues that the levels of these toxins in the environment are not significant, scientific evidence has shown otherwise.

ii) **Nitrates.**

Nitrate occurs naturally in soil containing nitrogen-fixing bacteria, decaying plants, septic system effluent, and animal manure. Other sources of nitrate include Nitrogenous fertilizers and airborne nitrogen compounds emitted by industries and automobiles. Nitrate penetrates through soil and remains in groundwater for decades. Groundwater is the source for > 50% of drinking water supplies, 96% of private water supplies, and an estimated 39% of public water supplies.

The health implications of exposure to nitrates in drinking water were first reported in the scientific literature by Comly in 1945 after observing cyanosis in infants in Iowa, where well water was used in formula preparation (Comly, 1987). Since then, most studies on the health effects of nitrates in drinking water have focused on infants because they are thought to be the most vulnerable to this exposure. More recent evaluations of the health implications of nitrates in drinking water have examined reproductive and developmental effects (Tabacova and Balabaeva 1993; Tabacova et al. 1997, 1998).

Excessive levels of nitrate in drinking water have caused serious illness and sometimes death. The serious illness in infants is due to the conversion of nitrate to nitrite by the body, which can interfere with the oxygen-carrying capacity of the child’s blood. This can be an acute condition in which health deteriorates rapidly over a period of days. Symptoms include shortness of breath and blueness of the skin. Nitrates have the potential to cause the following effects from a lifetime exposure at levels above the MCL: diuresis, increased starchy deposits and hemorrhaging of the spleen.

Infants who are fed by water or formula made with water that is high in nitrate can develop a condition called methemoglobinemia. The condition is also called "blue baby syndrome" because the skin appears blue-gray or lavender in color. This color change is caused by a lack of oxygen in the blood. All infants under six months of age are at risk of nitrate poisoning. Some babies may be more sensitive than others. Infants suffering from "blue baby syndrome" need immediate medical care because the condition can lead to coma and death if it is not treated promptly. When nursing mothers ingest water that contains nitrates, the amount of nitrates in breast milk may increase. Although no confirmed cases of "blue-baby syndrome" have been associated with nitrates in breast milk, it may be advisable for nursing women to avoid drinking water that contains more than 50 milligrams per liter nitrate-nitrogen.

Some scientific studies have found evidence suggesting that women who drink nitrate-contaminated water during pregnancy are more likely to have babies with birth defects (Fan and Steinberg, 1996). A report on a cluster of spontaneous abortions in LaGrange, Indiana, cited nitrate-contaminated water from private wells as the possible cause (CDC 1996). The cases included a 35-year-old woman who experienced four consecutive miscarriages and a 37-year-old and a 20-year-old who each experienced one miscarriage.

iii) **Chlorine.**

Chlorine is produced in large amounts and widely used both industrially and domestically. In particular, it is widely used in the disinfection of swimming pool and is the most commonly used disinfectant and oxidant in drinking water treatment. Accidental ingestion of commercial sodium hypochlorite bleach (5.25% or 52,500 mg/L) is one of the most common poisoning events in young children. Intentional ingestion has also been reported frequently in adults. Poisonings have resulted in various degrees of toxicity, including mucosal irritation, nausea, vomiting, diarrhoea, corrosive injury to the esophagus and gastrointestinal tract, acidosis, and even death (IPCS, 1997), although these effects appear to be due mainly to additional chemicals present or the extreme alkalinity of the product (Howell, 1991). Even in the case of misuse, chlorine bleach has only slight toxicity and irritation potential, and recovery is often rapid and reversible (Babel et al., 1998).

Typical concentrations of free chlorine in drinking water are generally less than 1 mg/L, but humans have consumed hyper chlorinated water for short periods of time at levels as high as 50 mg/L with no apparent adverse effects (U.S. EPA, 2002b). An early anecdotal report noted that no adverse health effects were observed when 150 military personnel consumed water with chlorine levels of 50 mg/L during a period of water main disinfection (Muegge, 1956). Military personnel have also been reported to drink water containing up to 32 mg chlorine/L for several months with no ill effects (Australia NHMRC, 2004). Muegge (1956) also noted that army personnel drinking water containing chlorine at concentrations greater than 90 mg/L experienced momentary constriction of the throat and irritation of the mouth and throat (U.S. EPA, 1994c). The toxicity of chlorine at levels normally found in drinking water appears to be relatively low (WHO, 1995), and humans appear to tolerate highly chlorinated water (Muegge, 1956).

In a clinical study, physical and biochemical parameters were measured in ten healthy male volunteers after they drank increasing concentrations of chlorine in water, ranging from 0.1 to 24.0 mg/L, for 18 days. No treatment-related health effects or toxicity were observed (Lubbers et al., 1982). A subsequent study in 60 men demonstrated minor but statistically significant changes in selected blood and biochemical parameters; however, owing to the short duration of the study and rising dose tolerance, the changes were not necessarily of clinical importance.

Epidemiological studies have noted an association between the use of chlorine as a drinking water disinfectant and long-term health effects, including increased risks for cancer and other health effects (Arbuckle et al., 2002). However, these studies have examined only the broad exposure to chlorinated water, and generally links have been made between health effects and exposure to Chlorinated Disinfection By-product (CDBPs) rather than exposure to free chlorine residuals. Since chlorine is intentionally added to drinking water and is highly reactive, its effects have been difficult to separate from those of its by-products. There have not been any epidemiological studies that have specifically examined free chlorine concentrations in water and long-term health effects in the human population (CCOHS, 2004c).

iv) **Lead:**

Lead is the most common contaminant found in tap water. Lead in drinking water usually originates between the water main in the street and the household faucet, so treatment from a central point is not logical or practical. Most lead in drinking water comes from lead lined pipes, lead solder and brass plumbing fixtures inside your home. All chrome-plated brass and brass plumbing fixtures contain 8% to 15% lead. (WHO,1993)

It has been determined and recognized by the United State Environmental Protection Agency (US EPA 2002b) that there is no safe level for lead in drinking water and that any level poses some degree of adverse health effects, especially to small children. Even very low levels of lead can cause reduced intelligent quotient

(IQs),learning disabilities and behavioral problems such as hypertension and reduced attention span in children.(FAO/WHO,1986). And often the effects of lead are life long and irreversible.

One study, done in Baltimore MD, showed that children with high blood-lead levels had a significantly higher rate of problem behaviors than children with low blood levels and concluded that "this study lends support to the belief that undue exposure to lead in childhood years may have a pervasive influence on the prevalence of juvenile delinquency in this country." In adults, lead in drinking water causes high blood pressure and reduces hemoglobin production necessary for oxygen transport and it interferes with normal cellular calcium metabolism. Water borne lead affects every one in a very tragic and permanent way. Lead exposure is cumulative and long lasting. This toxic metal is stored by the body, primarily in teeth and bones. (WHO,1993)

Essentially, lead has a very damaging effect on the body‘s electrical system, the nervous system. It causes the critical life giving messages, sent from the brain to every cell and organ in our body, to become distorted. This results in the onset of a chain of adverse health effects. It is estimated by the (U.S. EPA 2002) that lead in drinking water contributes to 480,000 cases of learning disorders in children and 560,000 cases of hypertension in adults, each year in the U.S. alone.

2.4.3 **Secondary Health Effects of Water Quality.**

The United States Environmental Protection Agency has classified drinking water quality standards into two categories: primary and secondary (http/www.epe.gov/safewater/mcl.html). Primary drinking water contaminants cause adverse affects to human health, while secondary contaminants are constituents that cause cosmetic or aesthetic effects such as taste, odor, or color. The presence of unnatural scum or foam or changes in water color, taste, or order can prevent a waterbody from being used as a drinking water source, recreational area, or limit viability as an aquatic habitat. Aesthetic issues do not necessarily impact human health but can still be a concern. People may think water is not safe to drink if they do not like the way it looks, tastes or smells and they may choose to drink water that looks or tastes better but is not safe. Contaminated water can look clear, and taste cool and refreshing but still make you sick! Properly treated water may or may not look as good, but it is safe to drink. Sometimes, even after the contaminants are removed, treated water can have unpleasant colour, smell or taste. Of the aesthetic constituents, iron, chloride, calcium and magnesium (hardness), sodium and zinc are essential elements. (http://www.who.int/water_sanitation_health/dwq/S05.pdf). A few of the constituents are of interest to many Countries and their characteristics are very much subject to social, economic and cultural considerations.

2.4.3.1 **Aesthetic Effects.**

This is a characteristic of drinking water that does not affect human health. Typically relates to the taste, smell, or look of the water, or a tendency to build up scale, or stain clothing or plumbing fixtures. Colour, Odour and Taste Problems - Problems with the taste, smell or “look” of the water are called aesthetic issues.

i) Odor and Taste are useful indicators of water quality even though odor-free water is not necessarily safe to drink. Odor is also an indicator of the effectiveness of different kinds of treatment. However, present methods of measuring taste and odor are still fairly subjective and the task of identifying an unacceptable level for each chemical in different waters requires more study. Also, some contaminant odors are noticeable even when present in extremely small amounts. It is usually very expensive and often impossible to identify, much less remove, the odor-producing substance. Standards related to odor and taste are Chloride, Copper, Foaming Agents, Iron, Manganese, pH, Sulfate, Threshold Odor Number (TON), Total Dissolved Solids, Zinc.

ii) Color may be indicative of dissolved organic material, inadequate treatment, high disinfectant demand and the potential for the production of excess amounts of disinfectant by-products.

Inorganic contaminants such as metals are also common causes of color. In general, the point of consumer complaint is variable over a range from 5 to 30 color units, though most people find color objectionable over 15 color units. Rapid changes in color levels may provoke more citizen complaints than a relatively high, constant color level. Standards related to color are Aluminum, Copper, Foaming Agents, Iron, Manganese, Total Dissolved Solids.

iii) Foaming is usually caused by detergents and similar substances when water has been agitated or aerated as in many faucets. An off-taste described as oily, fishy, or perfume-like is commonly associated with foaming. However, these tastes and odors may be due to the breakdown of waste products rather than the detergents themselves. Standards related to foaming is Foaming Agents.

2.4.3.2 **Cosmetic Effects**

i) Skin discoloration is a cosmetic effect related to silver ingestion. This effect, called argyria, does not impair body function. Silver is used as an antibacterial agent in many home water treatment devices, and so presents a potential problem which deserves attention. Standard related to this effect is Silver.

ii) Tooth discoloration and/or pitting are caused by excess fluoride exposures during the formative period prior to eruption of the teeth in children. The secondary standard of 2.0 mg/L is intended as a guideline for an upper boundary level in areas which have high levels of naturally occurring fluoride. It is not intended as a substitute for the lower concentrations (0.7 to 1.2 mg/L) which have been recommended for systems which add fluoride to their water. Standard related to this effect is Fluoride.

2.4.3.3 **Technical Effects**

i) Corrosivity and staining related to corrosion, not only affect the aesthetic quality of water, but may also have significant economic implications. Other effects of corrosive water, such as the corrosion of iron and copper, may stain household fixtures, and impart objectionable metallic taste and red or blue-green color to the water supply as well. Corrosion of distribution system pipes can reduce water flow .Standards related to corrosion and staining are Chloride, Copper, Iron, Manganese, pH, Total Dissolved Solids, Zinc.

ii) Scaling and sedimentation are other processes which have economic impacts. Scale is a mineral deposit which builds up on the insides of hot water pipes, boilers, and heat exchangers, restricting or even blocking water flow. Sediments are loose deposits in the distribution system or home plumbing. Standards related to scale and sediments are Iron, pH, Total Dissolved Solids, Aluminum.

2.5. 0 Water Sources

We are really talking about two sources of water when we talk about water supply. They are groundwater and surface water. Both groundwater and surface water may contain many constituents, including microorganisms, gases, inorganic and organic materials. Different water sources have different characteristics which can have a profound bearing on the suitability of the water for intended use. CAWST, (2008). The suitability of water for a given use depends on many factors such as hardness, salinity and pH. Acceptable values for each of these parameters for any given use depend on the use, not on the source of the water. Uses of water include agricultural, industrial, household, recreational and environmental activities. The chemical nature of water continually evolves as it moves through the hydrologic cycle. Properties of any water source depend on the kinds of substances that are dissolved or suspended in the water. Virtually all of these human uses require fresh water. Ninety seven and half percent (97.5%) of water on the Earth is salt water, leaving only 2.5% as fresh water of which over two thirds is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is mainly found as groundwater, with only a small fraction present above ground or in the air.

2.5.1 Ground Water.

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations. It is a little harder to understand than surface water because you can't actually see this water. Any water that is underground is groundwater. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. (Sophocleous,2002). Typically, groundwater is thought of as liquid water flowing through shallow aquifers, but technically it can also include soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults. It is likely that much of the Earth's subsurface contains some water, which may be mixed with other fluids in some instances. Groundwater may not be confined only to the Earth. The formation of some of the landforms observed on Mars may have been influenced by groundwater. (Sophocleous,2002)

The natural quality of groundwater differs from surface water in that:for any given source, its quality, temperature and other parameters are less variable over the course of time and in nature, the range of groundwater parameters encountered is much larger than for surface water, e.g., total dissolved solids can range from 25 mg/L in some places in the Canadian Shield to 300 000 mg/L in some deep saline waters in the Interior Plains. At any given location, groundwater tends to be harder and more saline than surface water, but this is by no means a universal rule. It is also generally the case that groundwater becomes more saline with increasing depth. Zekster et.al. (2005). As groundwater flows through an aquifer it is naturally filtered. This filtering, combined with the long residence time underground, means that groundwater is usually free from disease-causing microorganisms. A source of contamination close to a well, however, can defeat these natural safeguards. Natural filtering also means that groundwater usually contains less suspended material and undissolved solids than surface water.

2.5.2. Surface Water.

According to United State Geological Survey USGS,(2008), surface water is the easiest water to understand because we see it every day. It is any water that travels or is stored on top of the ground. This would be the water that is in rivers, lakes, streams, reservoirs, even the oceans-even though we can't drink salt water. Snow can become surface and groundwater. An example of this is when it snows a few times on a mountain. The snow might not melt in between snows. When it warms up in the spring, there could be too much water for the earth to absorb. This causes the melted snow water to run down the mountains as surface water until it reaches a body of water.

Sometimes surface water sinks into the ground and becomes ground water. Runoff is the water that runs in gutters, off roofs, and out of mall parking lots when it rains. This is surface water, too. Runoff is a problem because it carries things like car oil, road salt, and trash into the water supply. Surface water is treated before it becomes drinking water. This is done because things like leaves, fish, animal droppings, and boat fuel can easily get into lakes, streams, and rivers. The main sources of pollution of surface water include domestic waste water, industrial waste water, agricultural run-off water and other non point sources. Some companies try to use groundwater more than surface water because it is cleaner. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, and sub-surface seepage. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water lost.

Human activities can have a large impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channeling stream flow. The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. WIN, (2008).

Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need. Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed. Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources listed here; however in practice the quantities are negligible. Humans can also cause surface water to be "lost" (i.e. become unusable) through pollution.

2.6 **Indicators of Microbial Water Quality.**

Traditionally, indicator micro-organisms have been used to suggest the presence of pathogens (Berg 1978). Today, however, we understand a myriad of possible reasons for indicator presence and pathogen absence, or vice versa. In short, there is no direct correlation between numbers of any indicator and enteric Pathogens (Grabow 1996). To eliminate the ambiguity in the term ‘microbial indicator’, the following three groups are now recognized:

i) **Process indicator.** A group of organisms that demonstrates the efficacy of a process, such as total heterotrophic bacteria or total coliforms for chlorine disinfection.

ii) **Faecal indicator.** A group of organisms that indicates the presence of faecal contamination, such as the bacterial groups thermo tolerant coliforms or E. coli. Hence, they only infer that pathogens may be present.

iii) **Index and model organisms.** A group/or species indicative of pathogen presence and behaviour respectively, such as E. coli as an index for Salmonella and F-RNA coliphages as models of human enteric viruses. A direct epidemiological approach could be used as an alternative or adjunct to the use of index micro-organisms. Yet epidemiologic methods are generally too insensitive, miss the majority of waterborne disease transmissions (Frost et al. 1996) and are clearly not preventative. Nonetheless, the ideal is to validate appropriate index organisms by way of epidemiological studies. A good example is the emerging use of an enterococci guideline for recreational water quality (WHO, 1998). Often epidemiologic studies fail to show any relationship to microbial indicators, due to poor design and/or due to the widely fluctuating ratio of pathogen(s) to faecal indicators and the varying virulence of the pathogen The validity of any indicator system is also affected by the relative rates of removal and destruction of the indicator versus the target hazard. So differences due to environmental resistance or even ability to multiply in the environment all influence their usefulness. Hence, viral, bacterial, parasitic protozoan and helminthes pathogens are unlikely to all behave in the same way as a single indicator group, and certainly not in all situations. Furthermore, viruses and other pathogens are not part of the normal faecal microbiota, but are only excreted by infected individuals. Therefore, the higher the number of people contributing to sewage or faecal contamination, the more likely the presence of a range of pathogens. The occurrence of specific pathogens varies further according to their seasonal occurrence (Berg and Metcalf 1978).

2.6.1 **Development of Indicators.**

i) The coliforms

The use of bacteria as indicators of the sanitary quality of water probably dates back to 1880 when Von Fritsch described *Klebsiella pneumoniae* and K. rhinoscleromatis as micro-organisms characteristically found in human faeces (Geldreich 1978). In 1885, Percy and Grace Frankland started the first routine bacteriological examination of water in London, using Robert Koch's solid gelatine media to count bacteria (Hutchinson and Ridgway 1977). Also in 1885, Escherich described Bacillus coli (Escherich 1885) (renamed Escherichia coli by Castellani and Chalmers (1919)) from the faeces of breast-fed infants.

In 1891, the Franklands came up with the concept that organisms characteristic of sewage must be identified to provide evidence of potentially dangerous pollution (Hutchinson and Ridgway 1977). By 1893, the 'Wurtz method' of enumerating B. coli by direct plating of water samples on litmus lactose agar was being used by sanitary bacteriologists, using the concept of acid from lactose as a diagnostic feature. This was followed by gas production, with the introduction of the Durham tube (Durham 1893). The concept of 'coliform' bacteria, those bacteria resembling B. coli, was in use in Britain in 1901 (Horrocks, 1901).

Therefore, the sanitary significance of finding various coliforms along with streptococci and C. perfringens was recognised by bacteriologists by the start of the twentieth century (Hutchinson and Ridgway 1977). It was not until 1905, however, that MacConkey

(1905) described his now famous MacConkey's broth, which was diagnostic for lactose-fermenting bacteria tolerant of bile salts. Nonetheless, coliforms were still considered to be a heterogeneous group of organisms, many of which were not of faecal origin.

ii) Coliform identification schemes.

Various classification schemes for coliforms have emerged. The earliest were those of MacConkey (1909) which recognised 128 different coliform types, while Bergey and Deehan (1908) identified 256. By the early 1920s, differentiation of coliforms had come to a series of correlations that suggested indole production, gelatin liquefaction, sucrose fermentation and the Voges– Proskauer reaction were among the more important tests for determining faecal contamination (Hendricks 1978). These developments culminated in the IMViC (Indole, Methyl red, Voges–Proskauer and Citrate) tests for the differentiation of so-called faecal coliforms, soil coliforms and intermediates (Parr, 1938); these tests are still in use today.

a) Most probable number method.

In 1914, the first US Public Health Service Drinking Water Standard adopted a Bacteriological water standard that was applicable to any water supply provided by an interstate common carrier (Wolf, 1972).It specified that not more than one out of five 10ml portion of any sample examined should show the presence of B.coli group by the specified Multi-tube fermentation procedure (now referred to as the Most Probable Number or MPN procedure).

b) Membrane filtration method

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 by McCrady (1915). In Russia and Germany, a worker 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 1985). 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 (Waite 1985).

c) Defined substrate methods.

Media without harsh selective agents but specific enzyme substrates allow significant improvements in recoveries and identification of target bacteria. In the case of coliforms and E. coli, such so-called defined substrate methods were introduced by Edberg et al. (1991). What has evolved into the Colilert® technique has been shown to correlate very well with the traditional membrane filter and MPN methods when used to test both fresh and marine water (Eckner 1998).Furthermore, these enzyme-based methods appear to pick up traditionally non-culturable coliforms (George et al. 2000).These developments have led to further changes in definitions of total coliforms and E. coli. In the UK, for example, total coliforms are members of genera or species within the family Enterobacteriaceae, capable of growth at 37°C, which possess β-galactosidase . In an international calibration of methods, E. coli was enzymatically distinguished by the lack of urease and presence of β-glucuronidase (Gauthier et al. 1991). Furthermore, the International Standards Organization has recently published miniaturized MPN-based methods for coliforms/E. coli and enterococci based on the defined substrate approach.

iii) Faecal streptococci and enterococci.

Parallel to the work on coliforms, a group of Gram-positive coccoid bacteria known as faecal streptococci (FS) were being investigated as important pollution indicator bacteria (Houston 1900; Winslow and Hunnewell (1902). Problems in differentiating faecal from non-faecal streptococci, however, initially impeded their use

(Kenner 1978). Four key points in favour of the faecal streptococci were:

(1) Relatively high numbers in the excreta of humans and other warm blooded animals.

(2) Presence in wastewaters and known polluted waters.

(3) Absence from pure waters, virgin soils and environments having no contact with human and animal life.

(4) Persistence without multiplication in the environment.

It was not until 1957, however, with the availability of the selective medium of Slanetz and Bartley (1957) that enumeration of FS became popular. Since then, several media have been proposed for FS and/or enterococci to improve on the specificity.

iv) Sulphite -reducing clostridia and other anaerobes.

Until bifidobacteria were suggested as faecal indicators C.perfringens was the only obligately anaerobic, enteric micro-organism seriously considered as a possible indicator of the sanitary quality of water (Cabelli ,1978) C. perfringens is the species of clostridia most often associated with the faeces of warm-blooded animals (Rosebury 1962), but is only present in 13–35% of human faeces The main criticism of the use of C. perfringens as a faecal indicator is its long persistence in the environment, which is considered to be significantly longer than enteric pathogens (Cabelli,1978). Bonde (1963) suggested that all SRC in receiving waters are not indicators of faecal pollution, hence C. perfringens is the appropriate indicator.

v) Bacteriophages.

These are viruses which infect bacteria, also known as phages. The evolving role for phages to coliforms, known as coliphages however, has been model human enteric viruses. Studies on the incidence of phages in water environments have been reported unfortunately the data are not consistent. One reason for this is that there are many variables that affect the incidence, survival and behaviour of phages in different water environments, including the densities of host bacteria and phages, temperature, pH and so on. Another important reason is the inconsistency in techniques used for the recovery of phages from water environments, and eventual detection and enumeration of the phages.

vi) Faecal sterol biomarkers

The presence of faecal indicator bacteria gives no indication of the source, yet it is widely accepted that human faecal matter is more likely to contain human pathogens than animal faeces. The detection of human enteric viruses is specific, however, the methods are difficult and expensive, and not readily quantifiable. Vivian (1986), in his review of sewage tracers, suggested that using more than one method of determining the degree of sewage pollution would be prudent and advantageous. The use of alternative indicators, in this case faecal sterols as biomarkers, in conjunction with existing microbiological indicators, offers a new way to distinguish sources of faecal contamination and monitor river 'health' (Leeming et al. 1998).

2.6.2 **Emerging Microbiological Methods**

i) Fast detections using chromogenic substances .

The time required to perform tests for indicator organisms has stimulated research into more reliable and faster methods. One result is the use of chromogenic compounds, which may be added to the conventional or newly devised media used for the isolation of the indicator bacteria. These chromogenic substances are modified either by enzymes (which are typical for the respective bacteria) or by specific bacterial metabolites. After modification the chromogenic substance changes its colour or its fluorescence, thus enabling easy detection of those colonies displaying the metabolic capacity. In this way these substances can be used to avoid the need for isolation of pure cultures and confirmatory tests. The time required for the determination of different indicator bacteria can be cut down to between 14 to 18 hours.

ii) Application of monoclonal and polyclonal antibodies.

Monoclonal antibodies have been successfully used for the detection of indicator bacteria in water samples (Obst et al. 1994). In these studies the water sample was subjected to a precultivation in a selective medium. In this way the complication of detecting dead cells was avoided. Another option for the detection of 'viable' indicators is the combination of immunofluorescence with a respiratory activity compound. This approach has been described for the detection of E. coli O157:H7, *S. typhimurium* and *K. pneumoniae* in water (Pyle et al. 1995). Detection of Legionella from water samples has also been achieved with antibodies (Obst et al. 1994). In general, immunological methods can easily be automated in order to handle high sample numbers.

iii) Immunomagnetic Separation and other rapid culture-based methods

Immunomagnetic separation offers an alternative approach to rapid identification of culturable and non-culturable micro-organisms (Safarik et al.1995). The principles and application of the method are simple, but rely on suitable antibody specificity under the conditions of use. Purified antigens are typically biotinylated and bound to streptoavidin-coated paramagnetic particles(e.g. Dynal TM beads). The raw sample is gently mixed with the immuno-magnetic beads, then a specific magnet is used to hold the target organisms against the wall of the recovery vial, and non-bound material is poured off. Target organisms can then be cultured or identified by direct means. The IMS approach may be applied to recovery of indicator bacteria from water, but is possibly more suited to replace labour-intensive methods for specific pathogens. An example is the recovery of E. coli O157 from water (Anon 1996a). Furthermore, E. coli O157 detection following IMS can be improved by electrochemiluminescence detection (Yu and Bruno 1996).

iv) Gene sequence-based methods.

Advances in molecular biology in the past 20 years have resulted in a number of new detection methods, which depend on the recognition of specific gene sequences. Such methods are usually rapid and can be tailored to detect specific strains of organisms on the one hand or groups of organisms on the other. The methods have a substantial potential for future application in the field of drinking water hygiene (Havelaar 1993). The new methods will influence epidemiology and outbreak investigations more than the routine testing of finished drinking water. Polymerase Chain Reaction (PCR) and Fluorescence in-situ Hybridization (FISH) methods are based on gene sequenced-based principle. One problem with PCR is that the assay volume is in the order of some micro-litres, whereas the water sample volume is in the range of 100–1000 ml. Bej et al. (1991) have published a filtration method to concentrate the sample,but another problem is that natural water samples often contain inhibitory substances (such as humic acids and iron) that concentrate with the nucleic acids. Hence, it is critical to have positive (and negative) controls with each environmental sample PCR to check for inhibition and specificity. It may also be critical to find out whether the signal obtained from the PCR is due to naked nucleic acids or living or dead micro-organisms (Toze 1999).One solution has been established by using a three-hour pre-incubation period in a selective medium so that only growing organisms are detected (Frahm et al.1998). Other options under development include targeting short-lived nucleic acids such as messenger or ribosomal RNA. A most important advantage of PCR is that the target organism(s) do not need to be culturable. A good example is the specific detection of human Bacteroides spp. to differentiate human faecal pollution from that of other animals

(Kreader 1995).Future development of methods on micro assays and biosensors are possible for the detection of indicators.

2.6.2. The Current Applicability of Faecal Indicators.

Many members of the total coliform group and some so-called faecal coliforms (e.g. species of Klebsiella and Enterobacter) are not specific to faeces, and even E. coli has been shown to grow in some natural aquatic environments. Hence, the primary targets representing faecal contamination in temperate waters are now considered to be E. coli and enterococci. For tropical waters/soils, where E. coli and enterococci may grow, alternative indicators such as Clostridium perfringens may be preferable. Numerous epidemiological studies of waterborne illness in developed countries indicate that the common aetiological agents are more likely to be viruses and parasitic protozoa than bacteria (Levy et al. 1998). Given the often lower persistence of vegetative cells of the faecal bacteria compared to the former agents, it is not surprising that poor correlations have been reported between waterborne human viruses or protozoa and thermotolerant coliforms (Kramer et al. 1996). Such a situation is critical to understand, as evident from recent drinking water outbreaks where coliforms standards were met (Craun et al. 1997). A further confusion over the use of indicator organisms arises from the fact that some indicator strains are also pathogens. This is perhaps best illustrated by the toxigenic E. coli strains (Ohno et al. 1997). E. coli O157:H7 has been responsible for illness to recreational swimmers (Ackman et al. 1997) and several deaths have been documented through food- and waterborne outbreaks (Jones and Roworth 1996). Such toxigenic E. coli are also problematic to detect, as they may form viable but non-culturable cells in water (Kogure and Ikemoto 1997).

2.7 Water Quality Analysis In Emergency Situations

Water quality analysis is required in emergency situations to determine whether water is safe to drink. People who are traumatized by an emergency event and in poor health are particularly vulnerable to water related diseases including those which are spread through the drinking of poor quality water.

In the initial phases of an emergency it should be assumed that all water sources are contaminated microbiologically and when water is supplied to people in camp situations, chlorination and the testing of chlorine residual should always be undertaken. For water with a low turbidity, chlorination is reasonably simple, but for water with a high turbidity, a pre-treatment process will be required to reduce the turbidity levels to <5TU prior to chlorination. After the initial phase of the emergency is over, investigation can then be undertaken into the microbiological, and where appropriate, the chemical constituents of the water.

2.7.1 **The Purpose of Water Quality Analysis**.

Pathogens such as bacteria, virus, ova and cysts, can be ingested through drinking water. Water which looks clear may still be microbiologically contaminated or have chemical contaminants which are dangerous to health, such as arsenic or high levels of nitrates or nitrites. The biggest risk to life in an emergency situation is microbiological contamination as diarrhoeal diseases can spread rapidly in environments where large numbers of people are living in poor conditions and in close proximity. In the initial stages of an emergency, focus should be on providing an adequate quantity of water and then on good quality water microbiologically. It should also be assumed that all water is contaminated and will require chlorination, particularly for piped supplies. After the initial stage is over, it is then appropriate to test the water microbiologically and also to look at other parameters of health significance or which could cause problems due to adverse colour, taste, or staining, if it is felt that they may be a significant problem.

WHO (2004, p109) notes that 'Many chemicals in drinking-water are of concern only after extended periods of exposure. Thus, to reduce the risk of outbreaks of waterborne and water-washed e.g. trachoma, scabies, skin infections) disease, it is preferable to supply water in an emergency, even if it significantly exceeds the guideline values for some chemical parameters, rather than restrict access to water, provided water can be treated to kill pathogens and can be supplied rapidly to the affected population'.

2.7.2 Parameters to Be Tested In an Emergency Situation.

Chemical parameters, such as arsenic, fluoride, chloride, TDS/conductivity, iron, manganese, nitrate, nitrite, aluminium or zinc, would usually only be tested after the initial phase of an emergency and then only when a specific problem is suspected through local knowledge, catchment mapping, or sanitary survey. Sanitary survey which identifies the contamination risks should be one of the key tools for determining if water quality analysis is required during the intermediary periods.

1) Faecal coliforms-The test is carried out whenever there is a diarrhoea outbreak at the initial phase of the emergency. All water is assumed to be contaminated and chlorination is therefore necessary.

2) Turbidity (TU).-If chlorination is done, it must be ensured that turbidity is less than 5TU.

3) PH-This is also tested for and must be less than 8.0 otherwise the retention time is increased before supply.

4) Chlorine Residual

CHAPTER THREE

MATERIALS AND METHODS

3.1 **Study Area**.

The study area was Calabar Municipality, Cross River State. It has a land mass of 141.33 square kilometers. It is bounded in the North by Odukpani LGA, in the West by Calabar River, in the South by Calabar South LGA and in the East by Akpabuyo LGA and Great Kwa River. It is politically divided into 10 wards. It has a population of one hundred and seventy nine thousand three hundred and ninety two (179,392) (NPC, 2006). According to 1991 population census, the number of house hold was thirty two thousand and sixty four (32,064) households. Using population projection rate of 2.9% annual growth, the number of household units would be 50,660 as at year 2007.

The Municipality has industries and establishments. e.g. Seaport, Airport, Export Processing Zone (EPZ), Naval and Army Base, Tinapa, Free Trade Zone, NNPC Depot ,Cement factory (UNICEM) etc. Most dwellers are civil and public servants, some are factory workers. Their sources of drinking water include and not limited to boreholes, dug wells, pipe borne water, streams, rivers and packaged waters (sachet and bottled).

3.2 **Study Design**

A descriptive and analytical design was used. It involved laboratory analysis for bacteriological (Total and Fecal coliforms) and chemical (residual chlorine and nitrate-nitrogen) water quality. Inventory of sources of drinking-water in Calabar Municipality was taken.

3.3 Target Population.

The target population was all the residents of Calabar Municipality.

3.4 Instrument for Data Collection.

Structured questionnaire was administered to adults/heads of households. There were two major headings with a total of 17 items in the questionnaire: Demographic data (age, sex, size of household, marital status, level of educational, occupation and religion); water quality and sources of drinking water (water treatment methods and water consumption).

3.5 Sample Size Determination

In order to determine the number of households or adults to which questionnaire were to be administered, statistical method defined by Lutz (1982) was employed with the formula:

$$n = \frac{z^2pq}{d^2}$$

Where;

n= minimum sample size

z= confidence limit (95% or 1.96)

p= estimated population (30% or o.3)

q= 1-p i.e. (1-0.3) = 0.7

d= precision (0.05 or 0.01).

Substituting into the formula 323 was obtained but 350 was used to make up for questionnaires that might not be correctly filled or returned.

3.5.1 **Sampling Technique.**

Thirty-five copies of questionnaires were administered per ward. The inventory of the names of streets per ward was obtained. Three streets were randomly selected per ward. The second and the third streets were to be used incase the questionnaires were not exhausted in the first street per ward. But the 35 copies of questionnaires were exhaustively distributed to adults or heads of households in the first randomly selected street only and there was no need using the second or third randomly selected street. The following are the wards and streets where the questionnaires were administered:

Ward 1(Barracks Road), Ward 2 (Abong Aseng Street), Ward 3(Ediba Street), Ward 4 (Atekon Street), Ward 5 (Diamond Hill), Ward 6 (Nsemo Street), Ward 7 (Ikot Anwatim), Ward 8 (Mammy Market), Ward 9 (Itaken Street) and Ward 10 (Ikot Nkebre).

3.6 **Water Quality Analyses (Chemical and Bacteriological)**

Six different water sources were collected and examined for bacteriological (Total and Fecal coliforms) and chemical (Residual chlorine and Nitrates-nitrogen levels) water quality.

3.6.1 **Number of Samples.**

i) **Bottled water:** There were 15 brands of bottled water in the study area as at December 2007. Namely; Eva, Pure life, Gossy, Swam, Tropical, Blue Rose, Cannonball, Ragolis, Caspri, Reena, Sparwasser, Laura, Mariam, Faro and Aquasan Eight (i.e.,Eva, Pure life, Sparwasser, Blue Rose, , Ragolis, Mariam, Faro and Aquasan) of these were randomly selected, sampled and analyzed for all the above parameters.

ii) **Sachet water:** There were 20 brands of sachet water as at December 2007. Namely: Nsodo, Boikab, Hila, Ndumex, Tropical, Emaraj, Blue Rose, Vanik, Mariam, Yettco, Cannon Ball, Nwanse, Planet, So-Good, Asiaval, Mabis, Laura, Delity, Dukon and Inem. The following 10 brands (Tropical, Blue Rose, Mariam, Nwanse, Planet, So-Good, Asiaval, Mabis, Laura, and Inem.) were randomly selected, sampled and analyzed for all the above parameters.

iii) **Boreholes:** There was no available record of the number of boreholes in the study area as at December 2007. Through convenience sampling, one borehole from each of the ten wards (totaling 10 samples) were selected, sampled and analyzed for all the above parameters.

iv) **Springs:** One spring is available at Ward 5 near UNICEM cement factory in the study area and was sampled and analyzed for only Total and Fecal coliforms and nitrate-nitrogen.

v) **Pipe-borne water:** Five samples were collected through convenience sampling from 5 utility points and analyzed for all the above parameters.

vi) **Streams:** Two streams commonly used by the residents of wards 9 and 10 in the study area were sampled and analyzed for all the above parameters.

3.6.2 Sample Collection.

Sampling was done using WHO/APHA Guidelines, WHO (1983). A sterilized 4 liters polypropylene container was used for sampling of spring, boreholes, streams and pipe-borne water sources.

Sterility was ensured by keeping the security cap intact immediately prior to sampling. For boreholes and pipe-borne water sources, the taps were disinfected using sodium hypochlorite solution and allowed to run for 2-5 minutes before sampling to avoid any contamination through the taps. For sachet water, a sterilized syringe was used to take sample from each sachet for chemical analysis. For bottle water the caps were cleaned using sodium hypochlorite solution and hands washed before taking 100ml for bacteriological analysis.

3.6.3 **Sample Preservation**:

Bacteriological examination of the water samples commenced promptly after sampling apart from the sachet and bottled water. All samples were analyzed within one hour after collection to preserve the freshness of each sample.

3.7 **Materials and Analytical Procedures**

i) **Bacteriological Analysis.**

The following materials were used for bacteriological analysis of the water samples; Petri dishes, media (endo and m-fc agar), incubator (bicasa model), autoclave, filtration unit (stainless), forceps, Erlenmeyer flask vacuum pump, alcohol, membrane filter (0.45um pore size),100ml measuring cylinder, conical flask and colony counter.

3.7.1 **Sterilization of Materials.**

Before usage, all the glass wares were sterilized in an autoclave at 121^o for 15 minutes after which they were brought out and allowed to cool before being used. The media used (see appendix for their preparation) were prepared based on manufacturer's instruction and sterilized in an autoclave at 121^{o}c for 15 minutes. They were poured into sterile Petri dishes (20ml) and allowed to set before inoculation.

3.7.2 **Analytical Procedures.**

A sterile filtration unit was mounted on the Erlenmeyer flask and covered properly to avoid local contamination. The working bench was sterilized with absolute alcohol. All the Petri dishes containing the media were labeled accordingly. A membrane filter was carefully picked with a sterile forceps and placed on the filtration unit. About 100ml of the sample was measured with a sterile measuring cylinder (100ml) and poured into the filtration unit. By turning on the vacuum pump, the water was filtered out through the membrane filter while trapping the bacterial cells on its surface. This was repeated for all the samples for both Total and Fecal Coliforms. The Petri dishes were incubated upside down for 24 hours at 37^{o}c for Total Coliforms and 44^{o}c for Fecal Coliforms.

3.7.3 **Colony Count.**

The colonies were counted with the aid of a colony counter (Stuart Scientific) and the counts approximately noted.

ii) **Chemical Analysis**:

Colorimetric and Spectrophotometric methods were used to analyze the water samples for Residual Chlorine and Nitrate-Nitrogen levels respectively.

For residual chlorine, 2.5ml of the water samples (packaged and Pipe borne water only) were measured into a sample bottle. Residual chlorine test pillow was added to the water sample in the sample bottle. If there were colour change from colourless to pink, this indicated that chlorine was present. The specific amount of residual chlorine in the sample was then measured using colourimeter.

For Nitrates, one level spoonful of reagent No_3^-A and 5ml of reagent No_3-B were added into a test tube. This was shaken vigorously for homogeneity. About 1.5ml of the water sample was added to the mixture. This was allowed to stay for 8 minutes for colour development. Colour change indicated the presence of nitrates which was measured using spectrophotometer at 520nm wavelength.

3.7 **Data Analysis.**

Data were analyzed using percentages, means, range, and standard deviation. Test of significance was carried out using Student's t-test.

CHAPTER FOUR

RESULTS

4.1 Demographic Data

Three hundred and fifty copies of questionnaire were distributed to cover the 10 wards in the study area. The response rate was 96% (336) while 4% (14) were not returned. Out of the 336 respondents interviewed, 130(38.7%) were heads of households of which 77(50.2%) were males and 53(40.8%) were females. The adults in the households were 206 (61.3%) of which 76(36.9%) were males and 130 (63.1%) were females. The religions of the respondents were Christianity 333(99.1%) and Islam 3(0.9%). None of the respondents belonged to traditional religion.

Table 1 shows the distribution of respondents by age group and sex. One hundred and ninety-two (57.1%) respondents were in age group 21-30 and only 6 (1.8%) respondents were in the age group 70 above. One hundred and eighty-three (54.5%) were females and 153 (45.5%) were males. **Table 2** shows the distribution of respondents by marital status and size of households in the study area.

Table 1 Distribution of Respondents by Age Group and Sex.

(n=336)

	Sex		
Age Group (yrs)	Males (%)	Female (%)	Total (%)
21-30	87 (45.3)	105(54.7)	192(57.1)
31-40	40 (46.0)	47(54.0)	87(25.9)
41-50	10 (40.0)	15(60.0)	25 (7.4)
51-60	10 (52.6)	9 (47.4)	19 (5.7)
61-70	5 (71.4)	2 (28.6)	7 (2.1)
> 70	1 (20.0)	5 (80.0)	6 (1.8)
Total	153 (45.5)	183 (54.5)	336 (100)

TABLE 2: Distribution of Respondents by Marital Status and Size of Households in Calabar Municipality (n=336)

SIZE OF HOUSE HOLDS	RESPONDENTS	MARRIED (%)	SINGLE (%)	SEPARATED (%)	DIVORCED (%)	WIDOW (%)	WIDOWER (%)	TOTAL (%)
56	2	22 (39.3)	32 (57.1)	1 (1.8)	NIL (0)	1 (1.8)	NIL (0)	**56 (16.7)**
47	3	29 (61.7)	17 (36.2)	1 (2.1)	NIL (0)	NIL (0)	NIL (0)	**47 (14.0)**
49	4	30 (61.7)	17 (34.7)	1 (2.0)	1 (2.0)	NIL (0)	NIL (0)	**49 (14.6)**
53	5	29 (54.7)	23 (42.4)	NIL (0)	NIL (0)	1 (1.9)	NIL (0)	**53 (15.7)**
47	6	22 (46.8)	22 (42.4)	2 (4.3)	NIL (0)	1 (2.1)	NIL (0)	**47 (14.0)**
84	>6	47 (55.9)	35 (41.7)	NIL (0)	NIL (0)	1 (1.2)	1 (1.2)	**84 (25.0)**
TOTAL **336**		**179 (53.3)**	**146(43.4)**	**5 (1.5)**	**1 (0.3)**	**4 (1.2)**	**1 (0.3)**	**336(100)**

Eighty-four (25%) of the respondents had more than 6 household members while 56 (16.7%) of the respondents had only 2 household members. One hundred and seventy nine (53.3%) of the respondents were married, 146 (43.4%) were single and 1 (0.3%) was divorced. One hundred and eighteen (35.1%) of the respondents had tertiary education out of which 29 (24.6%) were civil servants and 6 (5.1%) were unemployed. Thirty-nine (11.6%) of the respondents had no formal education 4 of whom were civil servants (10.3%) and 2 (5.1%) were unemployed **(See Table 3**).

4.2 Drinking Water Sources, Treatment Methods, Volume Used and Water- related Diseases.

Data were collected through a structured questionnaire on source of drinking water, treatment method(s), volume of water used daily and water-related diseases the respondents had contracted within the last year. **Table 4** shows the use of different drinking water sources in the study area. Majority of the respondents used more than one source of drinking water. Sixteen (4.8%) used borehole water only, 66 (19.6%) used borehole and pipe-borne water. The proportion of the respondents using various water treatment methods is shown in **Table 5.** .

Table 3 Distribution of Respondents by Level of Education and Occupation (n=336)

	Occupation (%)										
Level of education	Civil servant	Business or Trade (%)	Craftsman (%)	Farmer (%)	Fishermen (%)	Factory worker (%)	Student (%)	Fulltime housewife	Unemployment (%)	Others (%)	Total (%)
No formal education	4 (10.3)	16 (41.0)	4 (10.3)	4 (10.3)	Nil (0)	Nil (0)	Nil (0)	7 (17.9)	2 (5.1)	2 (5.1)	39 (11.6)
Primary	4. (9.5)	20 (47.6)	4 (9.5)	2 (4.8)	Nil (0)	2 (4.8)	Nil (0)	1 (2.4)	4 (9.5)	5 (11.9)	42 (12.51)
Secondary	9 (6.6)	56 (40.9)	Nil (0)	2 (1.5)	Nil (0)	11 (8.0)	28 (20.4)	6 (4.4)	11 (8.0)	14 (10.2)	137 (40.8)
Tertiary	29 (24.6)	19 (16.2)	Nil (0)	3 (2.5)	Nil (0)	1 (0.8)	47 (39.8)	2 (1.7)	6 (5.1)	11 (9.3)	118 (35.1)
Total	46	111	8	11	Nil (0)	14	75	16	23	32	336 (100)

Table 4 Use of Different Drinking Water Sources (n=336)

Drinking Water Source	No of Respondents (%)
Borehole only	16(4.8)
Borehole and Pipe-borne	66(19.6)
Borehole and Rain	32(9.5)
Borehole and Packaged Water	40(11.9)
Pipe-borne and Packaged Water	28(8.3)
Pipe-borne and Hand dug Well	22(6.5)
Spring and Rain	17(5.0)
Stream and Rain	11(3.3)
Stream, Borehole and Rain	20(6.0)
Borehole, Spring and Rain	15(4.5)
Borehole, Packaged Water and	10(3.0)
Pipe-borne	59(17.6)
Borehole, Pipe-borne and Rain	
Total	336(100)

Table 5 Distribution of Respondents by Water Treatment Methods

(n=66)

Water Treatment Methods	No of Respondents (%)
Filtration with Cloth	8 (12.1)
Filtration with Sand	Nil (0)
Addition of Alum	4 (6.1)
Addition of Milton/Chlorine	9 (13.6)
Covered Earthenware Pots	Nil (0)
Boiling	45 (68.2)
Total	66 (100)

Sixty-six (19.6%) of the 336 respondents treated water by any of the conventional methods before drinking. Out of the 66, 45 (68.2%) boiled water before use but filtration with sand and storage in earthenware pots were never used in the study area. The water- related diseases identified by the respondents included typhoid, diarrhoea, skin-rashes and cholera. None of the 66 respondents who usually treated their drinking water reported any diseases within the last year (i.e. 2008). Out of the 270 respondents who did not normally treat their drinking water, 84 claimed they had suffered from water-related diseases. Majority of the respondents, 56 (66.7%) respondents indicated typhoid while 6(7.1%) chose Cholera (**See Table 6).** Twenty four (28.6%) of the respondents claimed they suffered from water-related diseases once a year and 9(10.7%) suffered from water-related diseases twice a year. **See table 7**

Table 8 shows the distribution of respondents by the Number of Packaged Water (Bottled and Sachet) Drunk Daily. Sixty respondents (17.9%) had never taken or drunk sachet water because they doubt the quality while 209(62.2%) had never drunk bottled water because they could not afford it. Seventy- eight respondents (23.2%) drank 1 sachet water daily while 22 respondents (6.5%) drank 6 and above sachet water daily. Ninety-three respondents (27.7%) drank 1 bottled (150cl) of water while no respondents drank more than 3 bottled water.

Table 6 Distribution Respondents by Water-Related Diseases in the Study Area (n=84)

Diseases	No of Respondents (%)
Typhoid	56(66.7)
Diarrhoea	19(22.6)
Skin Rashes	3(3.6)
Cholera	6 (7.1)
Total	84(100)

Table 7 Distribution of Respondents by Frequency of Diseases in Calabar Municipality (n=84)

Frequencies of Water-Related Diseases	No of Respondents
Weekly	Nil (0)
Monthly	27 (32.14)
Quarterly	18 (21.43)
Twice Yearly	15 (17.86)
Yearly	24 (28.57)
Total	84 (100)

Table 8 Distribution of Respondents by the Number of Packaged Water (Bottled and Sachet) Drunk Daily (n=336)

No of Sachet Water Drunk per Day (50cl)	No of Respondents (%)	No of Bottled Water Drunk per Day (150cl)	No of Respondents (%)
1	78(28.3)	1	77(60.6)
2	85(30.8)	2	25(19.7)
3	47(17.0)	3	15(11.8)
4	19(6.9)	4	10(7.9)
5	25(9.1)	5	Nil(0)
6	22(7.9)	Total	127(100)
Total	276(100)		

the distribution of respondents by volume of water used daily by each household. Thirty-six (10.7%) used 200 litres of water per day and 55 (16.4%) used 20 liters of water daily. **Table 9** shows the distribution of respondents by volume of water used daily by each household. Thirty-six (10.7%) used 200 litres of water per day and 55 (16.4%) used 20 liters of water daily.

4.3 Bacteriological and Chemical Water Quality.

Drinking water samples in the study area were analyzed for Total and Fecal Coliform (Bacteriological), Residual Chlorine and Nitrate-Nitrogen (NO_3-N) (Chemical). **Table 10** shows Nitrate-nitrogen concentrations (mg/l), Residual Chlorine levels (mg/l), Total and Fecal Coliform counts per 100ml of water in bottled and pipe-borne water samples. Nitrate-nitrogen concentrations of bottled water samples ranged from 1.3mg/l to 6.6mg/l and were much less than WHO standard (10mg/l). The highest Nitrate-nitrogen concentration for pipe-borne water samples was 2.0mg/l and the lowest was 1.0mg/l. No residual chlorine was detected in any of the bottled water samples however residual chlorine levels in pipe-borne water samples ranged from 0.4mg/l to 0.9mg/l.These residual chlorine levels were above the minimum WHO standard (0.2mg/l) but do not exceed the maximum

WHO standard of 5mg/l. None of the pipe-borne water samples had either Fecal or Total Coliform count. Only 3 out of the 8 bottled water

Table 9 Distribution of Respondents by Volume (Liters) of Water Used Daily by each Household.

Volume Of Water Used (Litres)	Number Respondents (%)
200	36(10.7)
160	18(5.4)
120	53(15.8)
80	74(21.9)
40	100(29.8)
20	55(16.4)
Total	336(100)

Table 10. Nitrate-Nitrogen, Residual Chlorine, Total and Fecal Coliform Counts in Bottled (n=8) and Pipe Borne (n=5) Water.

PARAMETER	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	$\overline{X}$±SD	P_1	P_2	P_3	P_4	P_5	$\overline{X}$±SD	WHO standard
Nitrate-Nitrogen (mg/l)	2.5	2.8	6.6	6.3	1.9	3.3	1.3	3.7	3.6±1.8	2.0	1.5	1.7	1.0	0.9	1.42±0.42	10
Residual Chlorine (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	0.6	0.8	0.7	0.9	0.68±0.17	minimum 0.2
Total Coliform (cfu/100ml)	0	151	2	3	0	3	4	0	20.4±49.4	0	0	0	0	0	0±0	0
Fecal Coliform (cfu/100ml)	0	0	0	0	0	0	0	0	0±0	0	0	0	0	0	0±0	0

Bottled Water Samples

NB: B_1=Nestle
B_2=Sparwasser
B_3=Blue Rose
B_4= Marian
B_5= Aquazan
B_6=Faro
B_7=Ragolis
B_8=Eva

Pipe-borne Water Samples

NB: p_1=Ward 10
p_2 = Ward 8
p_3 =Ward 7
B_4=Ward 6
B_5 =Ward 9

samples analyzed had zero Fecal and Total Coliforms counts. **Table 11** shows Nitrate-nitrogen concentrations (mg/l), Residual Chlorine (mg/l), Total and Fecal coliform counts per 100ml of water in sachet water samples. Eight samples out of 10 had zero Fecal Coliforms counts per 100ml of water and only 1 had zero Total Coliform count. The results of laboratory analyses of borehole water samples in the study area are shown in **Table 12**. The highest Nitrate-nitrogen concentration was 11.0mg/l; this is above WHO standard. All the water samples had high levels of Total and Fecal coliforms counts per 100ml. The values for Total and Fecal Coliforms ranged from 691cfu/100ml to 810 cfu/100ml and 112 cfu/100ml to 200 cfu/100ml, respectively. The analyses of the Springs, Streams and Great Kwa River water samples showed that the Nitrate-nitrogen concentrations ranged from 4.8 mg/l to 5.1mg/l, 2.0 mg/l to 6.2 mg/l and 21mg/l to 24mg/l, respectively. The highest levels of Total and Fecal coliforms in Great Kwa River water samples were 1885cfu/l and 1662cfu/l, respectively (**See Table 13). Plate 1** shows Fecal Coliform growth (white circle) at the middle of the plate surrounded by black circle while Total Coliform growth is shown in pink circle surrounded by an orange circle.

Table 11 Nitrate-Nitrogen, Residual Chlorine, Total and Fecal Coliforms in Sachet Water Samples in Calabar Municipality. (n =10)

Parameter	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	$\bar{X}$±SD	WHO Std
Nitrate- Nitrogen (mg/l)	2.2	5.2	1.2	17.3	4.3	5.7	5.9	2.7	4.5	3.1	5.21±4.3	10
Residual Chlorine(mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**ND**	0.2
Total Coliform (cfu/100ml)	136	0	7	180	18	51	14	300	20	17	74.3±94.6	0
Fecal Coliform (cfu/100ml)	0	0	0	41	0	0	0	26	0	0	6.7±14.56	0

Sachet Water Samples

NB.S_1= Blue Rose S_6= So-Good **NB.** ND= Not Detected.

S_2= Uwanse S_7= Inem

S_3= Asieval S_8= Tropical

S_4= Mabis S_9= Mar S_5= Laura S_{10}= Planet

TABLE 12 Nitrate-Nitrogen, Total and Fecal Coliforms Counts in Bore Hole Water Samples in Calabar Municipality. (n =10)

parameter	**BH$_1$**	**B$_2$**	**BH$_3$**	**B$_4$**	**B$_5$**	**B$_6$**	**B$_7$**	**BH$_8$**	**BH$_9$**	**B$_{10}$**	$\bar{X}$±SD	**WHO std**
Nitrate-Nitrogen (mg/l)	**4.4**	**6.0**	**6.0**	**3.2**	**5.3**	**5.8**	**6.3**	**11.0**	**7.0**	**8.5**	**6.4**±2.1	**10**
Total Coliform (cfu/100ml)	**800**	**798**	**790**	**810**	**691**	**800**	**772**	**760**	**780**	**720**	**772.1**±36.7	**10**
Fecal Coliform (cfu/100ml)	**120**	**184**	**155**	**181**	**160**	**180**	**200**	**112**	**128**	**166**	**158.6**±28.3	**10**

Bore Hole Water Samples Collection Sites.

NB. BH$_1$- Barracks Road

BH$_2$- Edim Otop

BH$_3$- Ediba

BH$_4$-Oma Street

BH$_5$-Wapi Road

BH$_6$- Nsemo Street

BH$_7$- Village 1 Ikorinim

BH$_8$- Federal Housing

BH$_9$ -Water Intake road

BH$_{10}$- Old Odukpani Road (Eight Miles).

TABLE 13 Nitrate-Nitrogen, Total and Fecal Coliform Counts in Spring, Stream and Great Kwa River (Raw Water Samples) in Calabar Municipality.

Parameter	Sp_1	Sp_2	X±SD	R_1	R_2	R_3	R_4	R_5	$\overline{X}$±SD	St_1	St_2	$\overline{X}$±SD	WHO STD
Nitrate-Nitrogen (mg/l)	**5.1**	**4.8**	5.0±0.15	**24**	**21**	**22**	**24**	**22**	22.6±1.2	**6.2**	**2.0**	4.1±2.1	**10**
Total Coliform (cfu / 100ml)	**1480**	**1500**	1490±10	**1800**	**1885**	**1564**	**1654**	**1750**	1.73x10^3±111.9	**1200**	**1240**	1.2x10^3±20	**10**
Fecal Coliform (cfu / 100ml)	510	600	555±45	500	1335	1662	1445	1200	1.23x10^3±394.4	800	818	809±9.0	**10**

Spring Water: Sp1-Sp_2 =spring water samples from Unicem Site (n=2).

River: R_1-R_5 = Great Kwa river (n=5).

Stream: St_1-St_2=Stream water samples from Wards 10 and 9 (n=2)

Plate 1 Fecal Coliforms (White Circle) at the Middle of the Plate surrounded by a Black Circle while Total Coliforms (Pink Circle) Surrounded by an Orange Circle.

4.4 Mean Levels of Residual Chlorine, Nitrate-Nitrogen, Total and Fecal Coliform Counts in Drinking Water Samples in the Study Area.

The mean levels of Nitrate-Nitrogen, Total and Fecal coliform counts, and Residual Chlorine in sources of drinking water in the study area are shown in **Table 14.** Pipe-borne water samples had the lowest mean nitrate-nitrogen level (1.42mg/l) while Great Kwa River had the highest (22.6mg/l),which is above WHO standard .The lowest mean value for Total coliform counts (0 cfu/100ml) and the highest (1.85 X 10^3 cfu/100ml) were obtained from Pipe-borne and Great Kwa River samples respectfully. Pipe-borne and Bottled water samples had zero mean level while Great Kwa River sample had the highest (1.23x10^3cfu/100ml).

4.5 Hypotheses Testing.

Appendix VII-X shows the results of the Hypotheses. Hypotheses were tested using Student's t-test at probability level of $p < 0.05$.

All were significant as follows:

i) There was a significant difference between the mean Total Coliform levels in pipe-borne water and borehole water samples.

ii) There was a significant difference between the mean Residual Chlorine levels in pipe-borne water and Bottled water samples.

Table14. Mean Levels of Residual Chlorine, Nitrate-Nitrogen, Total and Fecal Coliform Counts in Drinking Water Samples in the Study Area.

Parameter/unit	Pipe borne (n=5)	Sachet (n=10)	Bottled (n=8)	Borehole (n=10)	Spring (n=2)	Stream (n=2)	River (n=5)
Nitrate (mg/l)	1.42	5.21	3.6	6.4	5.0	4.1	22.6
Total Coliform cfu/100ml	0	74.3	20.4	772.1	1490	$1.2\text{x}10^3$	$1.73\text{x}10^3$
Fecal Coliform cfu/100ml	0	6.7	0	158.6	555	809	$1.23\text{x}10^3$
Residual Chlorine mg/l	0.68	0	0	N/A	N/A	N/A	N/A

iii) There was a significant difference between the mean Nitrate-Nitrogen concentrations in Great Kwa River and pipe-borne water samples.

iv) There was a significant difference between the mean Fecal Coliform levels in pipe-borne water and sachet water samples.

CHAPTER FIVE

DISCUSSION, SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Discussion.

The result of bacteriological analysis of 10 brands of sachet water samples commonly sold in Calabar municipality using Membrane Filtration Method, revealed the unsanitary condition of 9 of the 10 samples. The results of this study support an earlier observation made by Ademoroti, 1996; Agada, (1998) that the sachet water being produced is of questionable quality. Out of 10 brands randomly selected 9 had Fecal and Total Coliforms despite all having NAFDAC approved number. NAFDAC standard says that total and fecal coliforms levels must be zerocfu/100ml. Total Coliforms in the remaining 9 samples ranged from 14 to 180cfu/100ml but 6 of these had no Fecal Coliforms. This means that the contaminants might not be of fecal origin. As useful as sachet water is to the society, the results of the analyses raised doubts as to its quality Adekunle et.al. (2004). There was no Residual Chlorine detected in any of the samples which shows that chlorination was not employed in their water treatment method. The Nitrate-nitrogen concentrations of these samples ranged from 1.2 to 17.3mg/l. The results agree with the observation of Adekunle et.al. (2004), in assessment of the health and social economic implications of sachet water in Ibadan, Nigeria where most samples analysed had nitrate-nitrogen levels below WHO standard . Only 1 sample had Nitrate-nitrogen concentration of 17.3mg/l which is above WHO standard (10mg/l).

The public health effects of drinking water containing high level of Nitrates are of great concern especially in children. The health implications of exposure to nitrates in drinking water were first reported in the scientific literature by Comly in 1945 after observing cyanosis in infants in Iowa, where well water was used in formula preparation. Infants who are fed by water or formula made with water that is high in nitrate can develop a condition called methemoglobinemia. Nitrates have the potential to cause the following effects from a lifetime exposure at levels above recommended limit: diuresis, increased starchy deposits and hemorrhaging of the spleen.

Eight different brands of bottled drinking water randomly selected and bought from different retail shops were analyzed for chemical (Residual Chlorine and Nitrate-nitrogen) and bacteriological (Fecal and Total Coliforms) to compare their qualities with the recommended limits of the World Heath Organization (WHO). No Residual Chlorine was detected in any of the samples as observed in sachet water samples. The Nitrate-nitrogen concentrations of these samples ranged from to 1.3 to 6.6mg/l below the WHO limit (10mg/l). All the samples had zero Fecal Coliform level which indicates that contamination might be due to the environment (production machine, staff or the container). The Total Coliform levels were between 2 and 151cfu/100ml. Only two brands had zero Fecal and Total Coliforms. The result of 4 brands of bottled water analyzed in retail outlet in Nigeria by Ogan, (1992) showed that there was no fecal Coliforms but Heterotrophic plate counts (HPC) numbered 50–800 cfu/ml in two brands and 100–87000 cfu/ml in other 2 brands in agreement with the above results. Zamberlan,et.al. (2008), detected at least 1 Coliform and at least 1 pathogenic bacterium in bottled water analyzed in Brazil.

Consumption of bottled water is increasing rapidly in developing countries especially among the middle and high income earners as it is generally perceived to be pure, clean and of good quality. This has led to the sales of different brands of bottled water in the study area. Although disease outbreaks due to contaminated bottled water are rare, bottled water has been found to cause travelers' diarrhoea (Adekunle, 2004). The bacteriological quality of bottled water sold on the Ghanaian market carried out by Addo, et.al (2009), indicated that there was no bacteriological contamination (Total coliform, Faecal coliform or E. *coli*) in the selected brands of bottled water per every 100 ml analyzed.

The results of bacteriological analysis of Borehole water samples showed that 1 out of 10 samples had Nitrate-nitrogen concentration (11.0mg/l) above WHO standard (10mg/l). None of the samples was potable for drinking with the levels of Fecal and Total Coliforms which ranged from 112cfu/ml to 200 cfu/ml and 619 to 810cfu/ml respectively. This is pathetic because borehole water is the most accessible source of drinking water in the study area. More than 92% of households in Calabar Municipality still rely on borehole as an important source for drinking water. The presence of Fecal coliforms suggests fecal contamination and the possible presence of pathogenic bacteria like Salmonella typhi. Itah, et.al. (2005).The results agree with the earlier reports by Itah et.al. (1996) in the study of bacteriological characteristics of rural water supply in Calabar and that of Agbu et.al.(1998) in Samaru, Zaria as well as Adesiyun in katsina in terms of high density Coliforms obtained.

Out of 336 respondents interviewed, 270 did not normally treat their water. Out of this 270, 84 claimed they had suffered from water-related disease of which 56 (66.7%) indicated they had suffered typhoid within the last year (2007).

The Fecal and Total Coliforms levels of Spring water, Stream and Great Kwa River water samples were very high above standard set for untreated water samples (10cfu/100ml). Spring water is supposed to be naturally fit for consumption which was not so in this study. This is probably due to contamination as the water flows from the source down to the fetching point and the various activities (washing and bathing) being carried out by residents at the fetching point.

The Residual Chlorine levels in pipe borne water samples ranging from 0.4 to 0.9mg/l. were above WHO minimum standard (0.2mg/l) but below the maximum standard of (5mg/l). Chlorine, the most commonly used disinfectant and oxidant in drinking water treatment may have adverse health implication and aesthetic effects (odour and colour) if the level is not controlled or is above WHO limit. Although, humans appear to tolerate highly chlorinated water (Muegge, 1956), however, high consumption by humans can cause significant changes in selected blood and biochemical parameters Lubers et.al. (1982). Arbuckle et al. (2002) noted an association between the use of chlorine as a drinking water disinfectant and long-term health effects, including increased risks for cancer and other health effects. However, health effect could be due to exposure to chlorine by-product. The mean value of Residual Chlorine of the pipe borne water samples is 0.68mg/l.This value is lower than the value obtained (0.78mg/l) by Eddy and Ekop, (2006) in the assessment of the quality of pipe borne water distributed by the Akwa Ibom State Water Company.

Sixty-six (19.6%) of the 336 respondents treated their drinking water by any of the convectional methods, but boiling was mostly used for water treatment by the respondents i.e. 45 (68.2%) out of the 66 respondents that usually treated water before drinking, and this is just 13.4% of the total respondents (336). In a survey carried out in one of the communities of Ipu West, in Owaza town of Abia State, Nigeria, by Ijeoma, (2007) revealed that only 30% of the residents treated their drinking water before use.

5.2 Summary.

The primary objective of monitoring sources of drinking water is to protect the health of the community by preventing the spread of water-borne diseases and a reassurance of the current quality. Bottled water doesn't deserve the nutritional halo that most people give it for being pure.

The peculiar situation of sachet water is that most of the producers do not obey the rules of GMP once they are registered by NAFDAC. Sachet water as a source of drinking water once contaminated and get into the market, the consequences could be fatal. It is obvious from the study that some of the sachet water being sold in the study area and in the other suburbs of the city is not safe as far as bacteriological quality is concerned. Regrettably the consumers have no way of knowing which product is safe and which one is not. It therefore behooves the regulatory authorities to employ adequate measures to protect the consumer because packaged water has come to stay and the producers are increasing by the day. Water borne diseases could be contacted and spread through drinking of such contaminated water. Providing safe, reliable, piped borne water to every household is an essential goal, yielding optimal health gains while contributing to the Millennium Development Goal (MDG) targets for poverty reduction, nutrition, childhood survival, school attendance, gender equity and environmental sustainability.

5.3 Conclusion

Safe drinking water is an essential element of public health and primary health care. More than 92% of households in Calabar Municipality still rely on borehole as an important source for drinking water although in addition to other sources. The major problem with bottled water is that we just don't know what is in it. Tap-water regulations make it mandatory that the public water supply is tested daily and that findings are freely available for scrutiny. While most bottled waters are safe, their bacterial contents mean that they are not as safe as tap water. Studies have found that drinking tap water in any part of the USA is usually safer than drinking bottled water. (http://www.frequencyrising.com/water_bottle.) The boreholes in the study area are not regulated or monitor by any regulatory body, based on my findings. In the study area, people have access to sufficient quantities but unsafe water. It has been known from this research that the quality of drinking water sources in Calabar Municipality is poor and that majority of the residents do not treat water. Effective household water treatment should therefore be encouraged and interventions to treat and maintain the microbial quality of water at the household level are highly needed.

5.4 Recommendations.

(i) The Cross River State Water Board (CRSWB) Management should ensure periodic check on their pipe line to avoid leakages and prevent future contamination of this source of drinking water being the best in this study.

(ii) They should also carry out proper enumeration, registration and regulation of boreholes in the study area to enable periodic examination of this source of drinking water.

(iii) CRSWB should make pipe borne water available and affordable for all the residents of Calabar Municipality.

(iv) Due to poor quality of packaged drinking water NAFDAC should;

(a) Undergo periodic and regular visit to the packaged water factories for re-assessment of their GMP not less than 4 times yearly,

(b) Undergo periodic re-testing by randomly sampling and analyzing packaged water being produced to ascertain if the quality still meet pre-registration quality,

(v) Water treatment by individual or household should be encouraged by government through intensive campaign by workshops and seminar on the importance of water treatment before use.

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APPENDIX 1

QUESTIONNAIRE

CHEMICAL AND BACTERIOLOGICAL QUALITY OF SOURCES OF DRINKING WATER IN CALABAR MUNICIPALITY, CROSS RIVER STATE, NIGERIA

Questionnaire instructions

Please respond to the following questions as correctly as possible by giving short answers or ticking the appropriate box provided. (There may be more than one answer to a question). All information given will be kept in the strictest confidence.

Thank you.

A. **DEMOGRAPHIC DATA**

1 Person interviewed

1.1 Head of household ☐

1.2 Adult in household ☐

2. Size of household

2.1 2 ☐

2.2 3 ☐

2.3 4 ☐

2.4 5 ☐

2.6 6 ☐

2.7 >6 ☐

3. Sex 3.1 Male ☐

3.2 Female ☐

4. Age 4.1 21 – 30 ☐

4.2 31 – 40 ☐

4.3 41 – 50 ☐

4.4 51 – 60 ☐

4.5 61 – 70 ☐

4.6 >70 ☐

5. Marital Status

5.1 Married ☐

5.2 Single ☐

5.3 Separated ☐

5.4 Divorced ☐

5.5 Widow ☐

5.6 Widower ☐

6. Religion

6.1 Christianity ☐

6.2 Islam ☐

6.3 African Traditional Religion ☐

6.4 Others (specify)…………………………………………...

7. Level of Education.

7.1 No formal education ☐

7.2 Primary education ☐

7.3 Secondary education ☐

7.4 Tertiary education (University, Polytechnic education, teacher training college) ☐

7.5 Others (specify)……………………………………………….

8. Occupation.

8.1 Civil Servant ☐

8.2 Business / Trader ☐

8.3 Craftsman ☐

8.4 Farmer ☐

8.5 Fisherman ☐

8.6 Factory worker ☐

8.7 Student ☐

8.8 Full time house wife ☐

8.9 Unemployed ☐

8.10 Others (specify) ……………………………………….

B. WATER QUALITY AND SOURCES

9. What is your main source of water supply?

9.1 River ☐

9.2 Stream ☐

9.3 Hand dug well ☐

9.4 Rain water ☐

9.5 Borehole ☐

9.6 Pipe-borne water ☐

9.7 Spring ☐

9.8 Packaged water ☐

9.9 Others (specify)…………………………………………

10. Do you usually treat water before use?

☐ 1 Yes

☐ 2 No

11. If yes, what type of treatment do you apply?

11.1 Filtration with cloth ☐

11.2 Filtration with sand ☐

11.3 Addition of Alum ☐

11.4 Addition of Chlorine/Milton ☐

11.5 Boiling ☐

11.6 Storage in covered earth ware (pots) ☐

12. Have you at anytime attributed any sickness or disease to the quality of water used in your household?

12.1 Yes ☐

12.2 No ☐

13. If yes to question 12, name such illness(es) or disease(s).

1) ……………………………………………………

2) ……………………………………………………..

3) ……………………………………………………

4) ……………………………………………………..

5) ………………………………………………………

14. Indicate the frequency of illness or disease.

1) Weekly ☐

2) Monthly ☐

3) Quarterly ☐

4) Once a year ☐

5) Twice a year ☐

15. Indicate the amount (Volume) of water used in your house daily.

    15.1 One 20litres Jerry can ☐

    15.2 Two 20litres Jerry can ☐

    15.3 Four 20litres Jerry can ☐

    15.4 Six 20litres Jerry can ☐

    15.5 Eight 20litres Jerry can ☐

    15.6 Ten 20litres Jerry can ☐

16. Indicate the amount (Sachet) of water used in your house daily.

    16.1 One sachet ☐

    16.2 Two Sachets ☐

    16.3Three Sachets ☐

    16.4 Four Sachets ☐

    16.5 Five Sachets ☐

    16.6 > Six Sachets ☐

17. Indicate the amount (bottle) of water used in your house daily

    17.1 One bottle 75cl or150cl ☐

    17.2 Two bottles 75cl or150cl ☐

    17.3 Three bottles 75cl or 150cl ☐

    17.4 If more than any of the above, (specify)………………………

Appendix ii

W.H.O GUIDELINES FOR WATER QUALITY

Microbiological Quality	**WHO**	**European Communities**		**The Netherlands**	
	Guideline	**Guide Level**	**MAC***	**Guide Level**	**MAC***
Piped water supplies					
Treated water					
• Feacal coliforms number/100 ml	0		<1	<1**	
• Coliform organisms number/100 ml	0		<1	<1**	
• Feacal streptococci number/100 ml			<1	<	
• Sulphite-reducing Clostridia number/20 ml			<1	<1***	
• Total bacteria 37°C number/ml		10			
• Counts 22°C number/ml	no value set	100			
• Enterovirus					
Untreated water					
• Feacal coliforms number/100 ml	0				
• Coliform organisms number/100 ml	0				
• Coliform organisms number/100 ml	3				

* Maximum Admissible Concentration
** Per 300 ml
*** Per 100 ml
**** In 95% of samples examined throughout the year
***** In occasional sample but not in consecutive samples.

Microbiological Quality	**WHO**	**European Communities**		**The Netherlands**	
	Guideline	**Guide Level**	**MAC**	**Guide Level**	**MAC**
Water in the distribution systems					
Treated water					
• Feacal coliforms number/100 ml	0			<1	
• Coliform organisms number/100 ml ***	0			<1	
• Coliform organisms number/100 ml *****	3				
• Total bacteria 37 oC number/ml				10	
• Counts 22 oC number/ml				100	
Untreated water					
• Feacal coliforms number/100 ml	0				
• Coliform organisms number/100 ml *****	10				

Microbiological Quality	**WHO**	**European Communities**		**The Netherlands**	
	Guideline	**Guide Level**	**MAC**	**Guide Level**	**MAC**
Protozoa (pathogenic)	No guideline Value set				
Helminths (pathogenic)	No guideline Value set				
Free living organisms (algae, others)	No guideline Value set				

Appendix vi HYPOTHESES TESTING.

Hypotheses were tested using Student t-test at probability level of $p < 0.05$.

Hypothesis I

There is no Significant Difference between the Mean Levels of Total Coliform in Pipe borne and Borehole Water.

Drinking water Samples	Total Coliform (mean ± SD)
Pipe Borne	0.0 ±0.0
Boreholes	772.1± 36.7

At $P < 0.05$, df =13, calculated t-ratio (43.33) > table t-ratio (2.160). H_o (null) hypothesis rejected hence there is a significant difference between the Total Coliform Levels in Pipe borne and Borehole Water.

Hypothesis II

There is no Significant Difference between the Mean Residual chlorine levels in Pipe borne and Bottled Water.

Drinking water Samples	Residual Chlorine (Mean ± SD)
Pipe Borne	0.68±0.19
Bottled Water	0.0±0

At $P < 0.05$, df =11, calculated t-ratio (9.2) > table t-ratio (2.201). H_o (null) hypothesis rejected hence there is a significant difference between the Residual chlorine levels in Pipe borne and Bottled Water.

Hypothesis III

There is no Significant Difference between the Mean Nitrate levels in Great Kwa River and Pipe borne Water.

Drinking water Samples	Nitrate (Mean ± SD)
Pipe Borne	1.42 ± 0.6
Great Kwa River	22.6 ± 1.2

At $P < 0.05$, df =8, calculated t-ratio (29.01) > table t-ratio (2.306). H_o (null) hypothesis rejected hence there is a significant difference between the Nitrate levels in Great Kwa River and Pipe borne Water. (See Appendix IX for student t-test calculation).

Hypothesis IV

There is no Significant Difference between the Mean Fecal Coliform Levels in Pipe borne and Sachet Water.

Drinking water Samples	Fecal Coliform (Mean ± SD)
Borehole	158.6± 29.79
Sachet	6.7 ± 14.56

At $P < 0.05$, df =18, calculated t-ratio (13.74) > table t-ratio (2.101). H_o (null) hypothesis rejected hence there is a significant difference between the Nitrate levels in Pipe borne and Great Kwa River.